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GOVERNMENT OF ASSAM

ONE MAN ENQUIRY COMMITTEE

(ORDER No. FRW.6/2020/1 Dt. 12th June, 2020)

REPORT
ON
DAMAGES TO
ENVIRONMENT, BIODIVERSITY, WILDLIFE,
FORESTS & ECOLOGY

ON ACCOUNT OF

BLOW OUT AND EXPLOSION AT OIL WELL No. BGN-5

BAGHJAN, TINSUKIA

ASSAM (INDIA)

BY

MAHENDRA KUMAR YADAVA I.F.S.

ADDITIONAL PRINCIPAL CHIEF CONSERVATOR OF FORESTS (WILDLIFE)
&
CHIEF WILDLIFE WARDEN, ASSAM

10th February, 2021

VOLUME : I





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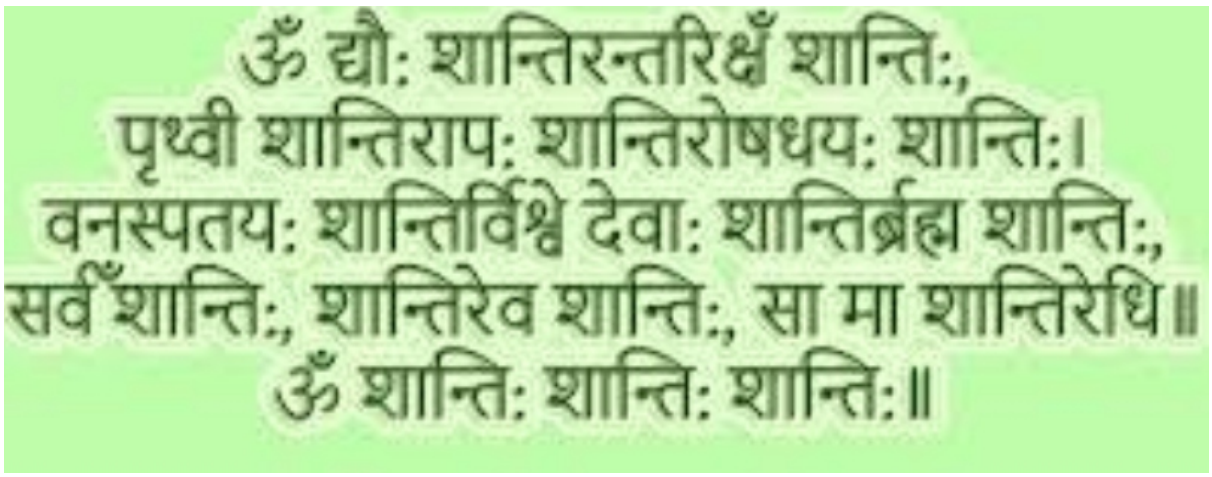
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(Yajur Veda, Shukla, 36:17)

Let Harmony be in Sky
Let Harmony be in Space
Let Harmony be in Earth
Let Harmony be in Waters
Let Harmony be in Herbs
Let Harmony be in Plants & Trees
Let Harmony be in all Gods
Let Harmony be in Bramhan
Let Harmony be All Pervading
Let Harmony be in Harmony
Let Harmony never be Breached
Harmony! Harmony!! Harmony!!!



The Mushroom of Baghjan at OIL Well BGN-5 on 9th June, 2020 at 1.30 PM



The Baghjan Flame with a Clear and Visible Lift-Off



GOVERNMENT OF ASSAM

OFFICE OF THE ONE MAN ENQUIRY COMMITTEE

(ORDER NO- FRW.6/2020/1 DATED.12/06/2020)

ROOM NO.08, CIRCUIT HOUSE,
TINSUKIA, ASSAM,
PIN-786126.

Email ID:
onemancommitteemky@gmail.com

No. OMEC/MKY/BGN-5/2020/L01/49 **Dt. 10th February, 2021**

From: M.K. Yadava, IFS,
Addl. PCCF (WL) & CWLW and
One Man Enquiry Committee

To
The Principal Secretary to the Govt. of Assam,
Department of Environment & Forests, Dispur,
Guwahati-781 006, Assam

Sub:- Submission of Enquiry Report of the One Man Enquiry Committee
Ref:- Govt. Of Assam Letter No. RW.6/2020/1 Dt.12th June, 2020 &
Letter No. FRW.6/2020/83 Dt. 4th July, 2020
OMEC Letter No. OMEC/MKY/BGN-5/2020/L01/48 Dt. 12th November, 2020

Sir,

With reference to the subject cited above, I am submitting herewith the final Report of the One Man Enquiry Committee to assess damages that occurred due to the blowout, explosion and subsequent fire at the Baghjan Oil Well in Tinsukia District.

The Report is in three Volumes, First Volume being the Report per se, the Second Volume being compilation of all subsidiary reports received from the various members of the Expert Committee, viz. Dr. Narayan Sharma of Cotton University and his team, the Wildlife Institute of India, Bombay Natural History Society, College of Fisheries, Raha, Assam Agricultural University, Jorhat, and other noted research scholars and experts such as Dr. Deborshee Gogoi & Dr. Ranjita Bania and other institutions. The Third Volume is compilation of the communications from the OMEC, secondary documentary records, petitions and material received from the members of public and the correspondences of the Committee. All the three volumes are being submitted.

As requested earlier, and also mentioned in the Report, it is hereby requested that the One Man Enquiry Committee headed by the undersigned may be wound up with this Report in three Volumes. However, it is requested that the Expert Committee under the Chairmanship of the undersigned may be allowed to continue for regular assessment of the ecosystem at an interval of six months. One review assessment is already due.

I must admit that the Baghjan blowout has been quite a tragedy and an ecological disaster. Every attempt was made to keep the scientific temper high, and prepare an objective report that could stand scrutiny of time. The Report is based on wide spectrum of published research findings in peer reviewed journals and publications. The first cut draft report was prepared on 12th November, 2020, and was circulated in a limited edition for peer review and comments. Several comments were received. Additionally, the work of compilation of Volume II and III continued, including a collection of photographs for the Report. The Report was edited all over again and certain chapters were revisited as the fire was extinguished on 15th November, 2020. The Report in three Volumes has been prepared in hardbound limited copy edition and in soft copy PDF mode. The Report is also expected to be made available online for wide circulation.

I wish to take this opportunity to thank the Government of Assam for appointing me to head the Committee as one man, and thus, to serve the cause of environmental protection. I sincerely hope the Report finds some utility and is able to serve the cause for which it was commissioned.

Thanking you**,**

Yours faithfully,

(Mahendra Kumar Yadava IFS)

Copy:
1. The Chief Secretary, Assam
2. The Additional Chief Secretary to the Hon'ble Chief Minister, Assam
3. Justice B. P. Katakey, Judge (Retired), Hon'ble Gauhati High Court
3. The PCCF & HoFF, Assam
4. The PCCF (Wildlfe) & Chief Wildlife Warden, Assam
5. Members of the Expert Committee
6. The Director, Wildlife Institute of India
7. The Deputy Commissioner, Tinsukia
8. The PS to the Hon'ble Minister, Environment & Forests, Govt. of Assam
9. The CMD, Oil India Ltd, Duliajan

ACKNOWLEDGMENT

I would like to place on record my thankfulness and gratitude to Sri Sarbananda Sonowal, the Hon'ble Chief Minister of Assam for giving me an opportunity to lead the enquiry into this rare and one of a kind blowout and assess its impact on the environment, ecology and biodiversity of the Dibru-Saikhowa National Park, Maguri Motapung Beel and the surrounding areas. Thanks are also due to Sri Parimal Suklabaidya, Hon'ble Minister of Environment & Forests, Govt. of Assam who took a keen interest into the enquiry and constantly encouraged the undersigned.

I would like also to place on record the appreciation and acknowledge the support provided by Sri Kumar Sanjay Krishna IAS (Retd.), the previous Chief Secretary, Assam. I express my thankfulness to Sri Jishnu Barua IAS, Chief Secretary, Assam who has been a constant source of inspiration and has been very endearing and encouraging all along. I wish to thank Sri Paban Kr. Barthakur IAS, Additional Chief Secretary to the Hon'ble Chief Minister, Assam who showed keen interest in the Report after taking over charge from Sri Sanjay Lohia IAS, former principal Secretary to the Hon'ble Chief Minister. Thanks are also specially due to Sri Lohia during whose tenure this enquiry was instituted. Thanks are due to Sri Avinash P. Joshi, IAS Principal Secretary to the Government of Assam, Environment & Forest Department, Dispur who has been facilitating the enquiry on behalf of the Government.

Thanks are due to Sri A. M. Singh IFS, PCCF & HoFF, Assam who proactively constituted the Expert Committee on the 2nd June, 2020 within a week of the blow out and I was given the privilege to chair the Committee. Thanks are also due to Sri Amit Sahai IFS, PCCF (Wildlife), Assam who always encouraged me to come up with a quality report. Special thanks are due to Sri Y. Suryanarayana IFS, Chairman, Pollution Control Board, Assam who provided a great support from the PCBA and made the exercise of assessment a lot more meaningful. Thanks are due to my colleagues in the Wildlife Wing at Aranya Bhawan namely Sri D. D. Gogoi IFS (Retd.), former CCF (Wildlife) who did an excellent job of coordinating with the various members of the Expert Committee from the day the EC was notified. Thanks are also due to Sri Bankim Sharma IFS, CF (Wildlife) who provided an excellent office support at the Aranya Bhawan and coordinated with various Government agencies.

Thanks are also due to Sri S. P. Vashisth IFS, APCCF (UAZ), Guwahati who provided all the field support required in Upper Assam from Jorhat to Tinsukia. Special thanks are also due to Sri Narayan Mahanta IFS, CF (EAC), Jorhat who provided a very active support on the ground. He also personally assisted me in the initial days of the Committee by doing all the writing work for the media and press in Assamese including issuance of all the notices in the print media.

Thanks are due to Sri Bhaskar Pegu ACS, the then Deputy Commissioner, Tinsukia who provided tremendous support to the One Man Enquiry Committee and was always accommodating. We had spent considerable time together with the local people to break the ice in the initial days of the Baghjan fire. Special thanks to Sri Siladitya Chetia IPS, S.P. Tinsukia who provided tremendous support on the ground. I deeply acknowledge and thank the officials of the Indian Army and Assam Rifles who provided support during the initial period of working at the site.

Very special thanks to Sri Rajendra Singh Bharti IFS, DFO, Tinsukia Wildlife Division, and Sri Pradipta Baruah, DCF, DFO, Dibrugarh Division who organized almost all the facilities and logistic support required for the Expert Committee. Thanks are also due to Sri Atikur Rahman, the then Digboi DFO, Sri Dilip Deka, the then DFO, Doomdooma, Sri Sunil Nath ACF, Makum, Sri Jaganath Agrawalla, RO, Guijan, Sri Jadab Chandra Dutta, RO, Saikhowa Range, Sri Manjit Sonowal, RO Tinsukia for providing all local support and cooperation without which assessment exercises would not have seen the light of the day. Thanks are also due to Sri Tejas Mariswamy IFS, DFO Zoo for logistic support.

It is time now to thank the great team who made it all happen, a very challenging task in view of the lockdown and COVID19 pandemic threats. Very many thanks to Dr. Narayan Sharma, Department of Environmental Biology & Wildlife Sciences, Cotton University, Guwahati and his dedicated team comprising of Sri Rajib Rudra Tariang, Department of Zoology, Digboi College, Shamim Rahman, Dept of Zoology, DCB Girls' College, Jorhat and the entire team of dedicated researchers. Special thanks to Sri Tariang for continuing the work and providing the inputs till a few days back. Special thanks to Dr. Qamar Qureshi, Dr. Vishnupriya Kolipakam, Dr. Abdul Wakid and the entire team of the Wildlife Institute of India for their great contributions in this assessment. Thanks are due to Dr. Girish Jathar, Asstt. Director, BNHS, Sri Biswjit Chakdar of Bombay Natural History Society for the avian survey and some rare insights into the Baghjan blowout after effects. A very special thanks to Dr. Deborshee Gogoi, Asstt Professor, Deptt. Of Commerce, Digboi College, Dr. Ranjita Bania, Head of Aquaculture, Wetland & Livelihood Division, Jeeva Suraksha, Sibsagar, Dr. Imtiaz Ahmed, Asstt. Professor, Fisheries Resource Management, College of Fisheries, AAU, Raha, Dr. Kishore Kumar Sharma, Professor, Deptt of Plant Breeding and Genetics, AAU, Jorhat and Dr. Samiron Dutta, Professor, Department of Soil Science, AAU, Jorhat.

Thanks are also due to the members of the Expert Committee, especially Dr. Aswini Kr. Baruwa, Dr. Apurba Chakraborty who could not join the field visit due to COVID19 restrictions, but guided from home. Thanks are also due to the PCBA Dibrugarh team led by Sri. Hemanta Kumar Sharma AEE and Sri Bikash Gogoi AE. Special thanks to Sri Kausik Barua, Hon. Wildlife Warden, Guwahati, Padmashree Dr. K. K. Sharma, Dr. Munmun Sharma of College of Veterinary Science, Khanapara. Thanks are also due to Dr. Khanin Changmai, Mobile Veterinary Unit, Upper Assam, WTI at Tinsukia.

Special thanks to team from AMTRON comprising of Sri Monoj Barua, Addl Manager, Sri Anupam Sharma, Sri Naba Goswami, Sri Pranab Kalita, Sri Bhaskar Pran Bora, Sri Raktim Bora and Sri Jitu Moni Deka. Thanks is also due to Sri Mrinal Gogoi and Himangshu Goswami of AMTRON who have been managing the OMEC Office at Room No. 8, Tinsukia Circuit House from the 16th June, 2020. Thanks also to the drone team of Pentaprism, Sri Sanjay Kr. Das, Sri Manas Das and Sri Chandan Bhuyan.

A special mention and great many thanks to Justice Sri B. P. Katakey, Retired Judge of the Gauhati High Court and Chairman of the 8 Member Committee formed by the Hon'ble National Green Tribunal in the OA No. 43/2020 & OA No. 44/2020 who have been guiding and encouraging the undersigned. He also invited the undersigned to some of the meetings of the Committee. Special thanks to Sri A. K. Johari IFS (Retd.), former SPCCF (Biodiversity & Climate Change), now an esteemed member of the Justice B. P. Katakey Committee who always encouraged me.

A special thanks to some of the research scholars in India and abroad who extended help. Most names have been acknowledged at appropriate places. Special mention is made of Dr. Ranjan Kr. Das, Deptt. Of Geography, Tinsukia College, Dr. Jayanta Pathak of AEC, Sri Shantanoo Bhattacharyya of PWD (NH), Dr. O.S. Ismail of Ibutan University, Nigeria. Thanks are to several of the learned people who agreed to peer review various parts of the write up. Thanks is also due to the local wildlife lovers and admirers of Dibru-Saikhowa NP and Maguri Motapung Beel, local communities, NGO groups and local activists, students and cultural bodies, members of Baghjan Milanjyoti Yuba Sangha, active youth like Sri Niranta Gohain, Sri Jainal Abedin, Sri Jeevan Dutta and Sri Binanda Hatikakati.

Thanks are also to Sri Sushil Ch. Mishra, Chairman & Managing Director, M/s Oil India Ltd, Sri Dilip Kumar Das, Resident Chief Executive, Duliajan and Sri Sanjay Kr. Rai, Executive Director (Field Headquarter Affairs). OIL. Thanks are also due to Sri Rupam Jyoti Sutradhar, CE(S&E), Sri R. B. Thakare, Dy. General Manager (S&E), M/s OIL for providing constant updates on the flame, and providing all the inputs.

My heartfelt thanks to my family for their cooperation, understanding, support and sharing with me the travails and tribulations of writing this Report which began its journey on the 27th June, 2020 at 13:48:51 Hrs at Tinsukia Forest IB.

I have mentioned only a few names here. The entire team of researchers is given citation at the beginning of Chapter 11. I wish to thank all who have supported me morally, spiritually and intellectually in carrying out this arduous task which would not have been possible without the blessings of the elders, teachers and well wishers.

Mahendra Kumar Yadava IFS
Dt. Guwahati, 10th February, 2021



The Baghjan Flame and its Surrounding Areas



NDRF Jawans Salvaing the Dead Bodies of the 2 Firemen who Died in the Blast

EXECUTIVE SUMMARY

On the 27th May, 2020 at 10.30 AM, while workover was going on at the Oil Well No. BGN#5 belonging to M/s Oil India Ltd, a Navaratna company of the Govt. Of India, the well kicked and there was a massive blowout. Natural gas and condensate gushed forth from the well, and soon, it was a rain of crude oil all over. The local residents rushed for cover, and had to be evacuated. While trying to control the blowout, the well accidentally caught fire on the 9th June, 2020 and exploded at 1.30 PM. Two firemen of M/s Oil India Ltd. died in the incident, but others could escape and were saved. The surrounding areas caught fire and the inferno raged until next day when the fire was contained and confined to the well. However, since it was a massive flame fuelled by a huge uninterrupted supply of natural gas and condensate gushing at more than 4000 psi at the well head, its ramifications started to dawn slowly. It induced ground shaking and houses in the vicinity started vibrating. The noise from the flame was deafening and unbearable. More people deserted their homes and moved to relief camps set up for the affected families, and it is to be noted that it was the onset of COVID19 as well and lockdown was already clamped all over the country.

The Hon'ble Chief Minister in the evening of the 11th June, 2020 announced two One Man Enquiry Committees. This One Man Enquiry Committee was headed by the undersigned. The Committee was duly notified vide Govt. Of Assam, Department of Environment and Forests, Dispur Order No. FRW.6/2020/1 Dt. 12th June, 2020 to assess the damages to Environment, Biodiversity, Wildlife, Forests and Ecology on account of Blowout and Explosion at Oil Well No. BGN-5 at Baghjan, Tinsukia. Meanwhile, the PCCF & HoFF, Assam had already constituted an Expert Committee on the 2nd June, 2020 under the Chairmanship of the undersigned. Merging the two roles into one, the undersigned proceeded with the enquiry and assessment on the ground along with the members of the Expert Committee and other expert organizations such as Wildlife Institute of India, BNHS, College of Fisheries, Raha, Assam Agricultural University, local researchers and experts were roped in.

The Report has been divided into three Volumes. Volume I being this Report, and other volumes being compilation of all the secondary material upon which this Report has relied. Additionally, it relied on ahost of measurements by several agencies such as data on heat and noise and other sensor base measurements, drone based orthophotography by AMTRON have been used in this Report. The Volume II consists of

all subsidiary reports received from the members of the Expert Committee, Wildlife Institute of India, Bombay Natural History Society, Dr. Narayan Sharma of Cotton University and his team, College of Fisheries, Raha, Assam Agricultural University, Jorhat, and other noted research scholars and experts such as Dr. Deborshee Gogoi and Dr. Ranjita Bania. Environmental tests reports by the PCBA, and reports on environmental parameters made by agencies employed by M/S OIL also go to the Volume II. The Third Volume contains secondary documents, records, petitions and material received from the members of public, as well as the details of the public hearings conducted, the correspondences of the Committee and relpies by M/s OIL.

Organization of the Report:

The Volume I of the Report has been divided into two parts. Part I contains Chapter 1 to 5, and Part II contains Chapters 6 to 17. These are described briefly here:-

The **Chapter 1** is entitled "***The Baghjan Blow Out Unfolding***" and has been written as a memoir of the author. The **Chapter 2** is entitled "***Situation Analysis: Socio-Economic***" and is a brief on geography, land use, demography and livelihoods of the area, along with a brief description of the existing social infrastructure. The **Chapter 3**, entitled "***Situation Analysis: Ecology & Ecosystems***", contains a brief description of the ecological entities and ecosystems of the area, especially the Dibru-Saikhowa National Park, Maguri Motapung Beel, Dibru river etc. The **Chapter 4**, entitled "***Situation Analysis: Oil, Oil Spills and Blow outs***", give a brief on M/s OIL India Ltd, an overview of the oil production in the country and Assam, and dwells upon energy and climate change, blowouts and blow out risks, mentions some onshore blowouts in the past and lastly gives a brief chronology of events of the Baghjan blowout. The **Chapter 5**, entitled "***Matters of Law and Policy***" dwells upon various legal aspects relevant to the matter of enquiry at hand, especially the laws on environment and wildlife. It also throws in an international perspective with reference to blowouts.

The **Chapter 6** entitled "***Understanding the Baghjan Blow Out-I***" investigates at basic level the physical and chemical and other properties of the blow out, explosion and the flame. The explosion yield estimate gets finalized. The **Chapter 7** entitled "***Understanding the Baghjan Blow Out – II***" enquires into the properties of the flame such as flame temperature, flame height, flame power, acoustic power, flame plume, chemical composition of the natural gas and condensate and their chemical properties of combustion are determined. The **Chapter 8** entitled "***Atmospheric Pollution***"

estimates the emissions from the blowout into the atmosphere, such as CO_2, CO, NO, NO_2 etc. The **Chapter 9** entitled "***Noise Pollution and Vibrations***" dwells on details on the levels of noise pollution, noise spectra and ground vibrations. The **Chapter 10** entitled "***Thermal Pollution***" dwells upon the heat aspect of the flame and its impact on the ecosystems, especially the plant community w.r.t. to their productivity. The **Chapter 11** entitled "***Soil and Water Pollution***" estimates the damage to water quality and soil. Drone based photography is used here to arrive at the extent of damages. The **Chapter 12** entitled "***Assessment of Biodiversity Loss***" examines the damage to biodiversity, ecology and ecosystems by looking at indicator communities such as earthworms, mollusca, butterflies & moths, odonates, herpetofauna, beetles, benthos and fish fauna. The **Chapter 13** entitled "***Assessment of Impact on Avifauna***" dwells on the impact of the Baghjan blowout on avifauna. The **Chapter 14** entitled "***Impact Assessment of Gangetic River Dolphins & Other Mammals***" dwells on the impact of the blowout on the Gangetic River Dolphins and other mammals. It also dwells on the possible underwater impacts of the flame noise. The **Chapter 15** entitled "***Looking at Man & Biosphere***" dwells very briefly on the impact of the blowout on the local population, their livestock, orchards, crops and other properties. The **Chapter 16** entitled "***Baghjan Blowout Balance Sheet***" looks at the tangible and intangible losses in terms of the damages that can be counted and estimated and those that cannot be quantified. It lists out a summary of uncountable damages, and prepares a balance sheet with environmental damages and losses (only those which could be converted into money values) on one hand, and the ability of the owners to pay the liabilities. The concept of carbon prices is also introduced, and final liability worked out in money terms. The **Chapter 17**, being the last chapter is entitled "***Iti Vartah***". It contains all the conclusions drawn in the previous Chapters, and puts forth key issues that may be looked at by the Hon'ble Judiciary and the Government, and places a few recommendations and finally draws a budget for a period of 10 years.

Key Findings:

The region of Dibru-Saikhowa National Park, Maguri Motapung Beel, Dibru river and the surrounding areas is very rich in biodiversity, ecology and contains fragile ecosystems that harbour some of the most endangered, rare, vulnerable, threatened and near threatened wildlife. M/s OIL is a central PSU with Rs. 2500 cr of profits, and their owner companies together earn more than Rs. 33,000 cr of profits annually, and the MoPNG has an annual budget of more than Rs. 27,000 cr and IEBR spending of more than Rs. 100,000 cr annually. Even though all parameters from other blowouts in the world are

not available, it can be said that Baghjan could be the largest onshore blowout, given its longest duration, a very high Heat Release Rate and the fact that the well blow out did not diminish a bit in quantum of the fluid flow. Further, the Baghjan blowout was a "catastrophic" and "worst case" blowout.

Physical & Chemical Properties of the Blowout, Explosion and the Flame: The explosion that rocked Baghjan on the 9th June, 2020 at 1.30 PM has been estimated to have a yield of 0.833 kT of TNT or more. The flame temperature was estimated and measured to be more than 1200^0C. Due to device limitation, higher temperature, if any, could not be ascertained. The flame was supersonic with average flame height of 108 m and mean mass flow rate of 343.50 kg/s of natural gas and condensate in a single-phase flow at oil-head pressure of more than 5100 psi. The flame was 12m wide on average at its middle point. The Mach Number estimated for the supersonic flame was estimated to vary from 3.1 to 8.5. The radiative flux was estimated to be 43 kW m^{-2} at 100 m from the flame. The flame plume carried enough heat up in the atmosphere at 1000 m height to heat the surrounding cool air upto 34^0C when the normal temperature at that height was expected to be 8^0C. The thermo-acoustic efficiency of the flame was estimated at $4x10^{-4}$, and the acoustic power to be 10,000 W (160 dB). The natural gas chemical composition was estimated to be $C_{1.1144}H_{4.2026}$. The condensate chemical formula was estimated to be $C_{8.2808}H_{18.5582}$. The emission from 1 m^3 burning of the gas was estimated to be CO_2: 1.54 Kg, CO: 0.34 Kg, NO: 0.92 Kg and NO_2: 1.42 Kg.

Breaches of Prescribed Standards of Air & Water Quality: The highest NO_2 level recorded 97 µg/m^3. The various other emission levels recorded during the blowout- CO levels 9.05 mg/m^3, PM_{10} levels 78 µg/m^3, $PM_{2.5}$ levels 67.8 µg/m^3. Noise levels were found higher than 75 dBA within 700 m, 55 dBA within 5 km, and more than 40 dBA within 40 km range of the blowout. The water temperature was found to be more than 5^0C higher than the normal temperature. Water DO levels dipped to dangerously low levels upto 0.94 mg/L. The pH was found below 6.5 at as many as 250 spots. There was breach in respect of Pb and Cu content as measured by the PCBA. The Oil and Grease in water far exceeded the prescribed limits.

Other Breaches and Damages: The 10,000 W flame was found capable enough to cause ground vibrations varying from 0.013g to 0.13g levels. The explosion on 9th June, 2020 at 1.30 PM was estimated to be of 3.9 magnitude on the Richter scale. The flame

and the associated turbulence was capable of causing random seismic quakes of value 1.3 magnitude or higher. Heat Island Effect was noticed. The flame released more than 140 PJ of heat into the surroundings. The hot gushes of air blast emanating from the site were capable of raising human body temperature from normal to 111.2^0 F. The temperature of the surrounding areas rose higher than normal by 5-10^0C.

It was estimated that about 64,000 kg of condensate oil containing heavier hydrocarbons might have fallen around 3 km radius of the blowout on the south side of the blowout site over an estimated area of 589 Ha. About 24 Ha area around the flame was severely burnt, and about 102 Ha partially burnt. Polycyclic Aromatic Hydrocarbons (PAH), many of which are carcinogenic, and organic substances were found in high levels. PAH was found as high as 691.31 µg/l and 395.8 µg/kg in the water and sediment samples tested from the Lohit river by WII. Oil and grease in soil samples were found to be ranging from 1.11 to 17.15 gm/kg by PCBA.

Damages to Ecosystem, Wildlife and Biodiversity: It was estimated that damaged wetland area was 1632 Ha, grassland area damaged stood at 523 Ha, river and stream covering 176 Ha and forests 213 Ha, the degree of damage varying based on the proximity of the ecosystem to the blowout site. This, leaving aside the overall sound and light pollution and impacts of heat radiation. Sound impacted the whole of the National Park and the Bherjan and Podumoni parts of the BBP WLS. The Maguri Motapung Beel was directly the most impacted and devastated of all the ecosystems. Almost 70% of the earthworms in the Maguri grasslands and condensate affected areas were estimated to be dead.

Open Bill Stork population may be at risk due to high molluscs death in the areas. Moths and butterflies have suffered heavily in the area due to constant deaths because of the flame. Moths and butterflies have been seen largely as singletons. Of Odonates, damsel flies have suffered the worst. Lack of odontes can adversely impact butterfly populations. PAH concentrations and low DO levels would adversely affect populations of fish fingerlings, tadpoles and other aquatic insects which are prey/ food of odonates. The Herpetofauna have been adversely impacted by the disaster, and continue to be impacted due to heat and sound levels [*until 15th November when the flame got extinguished*]. The Baghjan fire has been a death trap within 1 to 1.5 km of its radius for many animals. Fish populations have been impacted by PAH, oil spill, low DO and low pH levels. There has been a sizeable decline in the fish catch. Furthermore, several of

the rare and ornamental fish populations of Maguri are at risk. A detailed assessment is required. Most bird species have been seen in single counts only, other than 15-20 most common birds. 53% of the bird species showed up only as singleton. Maguri Motapung beel and the Dibru-Saikhowa NP are unique bird habitats, Bird richness of the grasslands declined by 59%, and that of the wetlands by 85%. Since there are many threatened, endangered, critically endangered and rare birds inhabiting these parts, a systematic study is immediately required to evaluate and work on long term. Birds give oil spill sites a miss for more than 10 years after the incident. A study is also needed immediately after the fire gets extinguished to evaluate the impact.

Post blowout, the Gangetic River Dolphin population has taken a hit. From an estimated population of 28-34 dolphins earlier, the current estimates point to not more than 4 dolphins. The underwater sound pollution is possibly impacting the dolphins adversely. The lone dead Dolphin died because of organic chemicals (*It is now confirmed*). The Hoolock Gibbons at Barekuri were adversely impacted by the oil spill. They refused to eat for atleast two days. One mother gave birth to a still born baby, and herself died after a gap of 25 days. Most large mammals have moved out of the area, and a few that got trapped could have ingested organic chemicals while grazing and drinking water.

Death of Species: As counted/ evaluated on ground by various methods, in all it was found that the blowout, explosion and fire directly impacted 40 listed scheduled animals in the Wildlife (Protection) Act, 1972 belonging to different classes/ orders, genera, families and species. Habitat of these animals was disturbed, destroyed, the young ones, larvae, eggs and nests damaged. This is a clear cut case of “hunting” under the Act. The actual visual count of dead animals listed in the Schedules of the Wildlife (Protection) Act, 1972 was found to be 91 which included 1 Gangetic River Dolphin and 2 Hoolock gibbons (mother and baby, baby being a case of still birth). These are all cases of “hunting” under the Wildlife (Protection) Act, 1972. In addition to these deaths, there were counted deaths of 25,825 wild animals belonging to 41 genera/ families. ***Further, the assessment showed that there was an estimated loss of biodiversity upto 55%***.

Damages to life and property: In this accident, so far two firemen and one young engineer from M/s OIL have lost their lives, 3 foreign experts at the site received minor burn injuries in an accident when the fire tilted suddenly. As regards the local human population, hundreds of people living in the vicinity were directly exposed to various risks. The population could be facing some health hazards as well. The livestock also

seem to be showing impact of PAH contamination, which is evident from large number of still births in all domestic animals. The Oil spill seems to have affected the plants, agricultural and horticultural crops adversely. It has been observed that flowers and fruits are falling off from the plant prematurely.

Monetary Valuation of the Ecological Damages:
The damages estimated amounted to ~Rs. 25,000 crore. Estimated carbon earnings were valued at Rs. 18234 crore (during restoration), and this resulted in net liability of Rs. 6800 crore over a period of 10 years.

Conclusions and Recommendations:
Statutory Omissions and Commissions: The Environmental Clearance (EC) issued by the Ministry of Environment, Forests & Climate Change, New Delhi Dt. 1st November, 2011 was found to be faulty as it mentioned that there were no National Parks and Wildlife Sanctuaries located within 10 km of the project site, whereas the Dibru-Saikhowa National Park and Bherjan Borajan Podumoni WLS are within 1 to 5 km range of the drilling sites. The two EIA Reports submitted by M/s Oil India Ltd. were found wanting in quality and content, and did not stand up to the mark required for proper ecological handling of such a sensitive project next to a National Park and a Biodiversity Hotspot. It appears that the EIA reports were not evaluated properly and the findings/ data supplied were not examined critically. There was also no prior approval under the Forest Conservation Act, 1980 for the PML lease granted whereas the lease area covered by the EC Dt. 1st November, 2011 covered partly the Dibru-Saikhowa national Park and the Bherjan Borajan Podumoni WLS. Further, three wells namely BGN#25, 26 and 27 were found falling outside the area covered by the EC Dt. 1st November, 2011, and were under production without any prior approval of the MoEF&CC.

Other Observations: The PLI Act, 1991 and the Environment Relief Fund (ERF) need to undergo a rethinking in respect of large ecological disasters, as both were severely found wanting to meet even the basic requirements in the Baghjan blowout ecological disaster. It was also found that M/s Oil India Ltd and so many others associated with the disaster were only “fire fighting”, and little attention was given to the understanding of the fire, the underlying forces, their impacts on the ecosystems and biodiversity, and extent of damages. It seemed to be a lost opportunity where a lot of learning for handling of future ecological disasters were given a miss. This reflected our lack of capacities, equipment and technology to handle such events with full scientific temper.

Recommendations: Some of the main recommendations are: Creation of a special fund to meet such ecological disasters, setting up of Institute of Wildlife Health & Research, Creation of river patrol and other infrastructure for Dibru-Saikhowa NP, Rejuvenation plan for Maguri Motapung beel, Centre of Excellence for Resource Studies and Simulations (IT compute infrastructure to support simulation, resource mapping and AR/VR), people centric infrastructure (educational, healthcare, veterinary, agricultural, sports etc.), life, health and property insurance based on hazard risk zonation, hazard zone of 500 m around all wells, carbon sink plantation of about 12-20 cr seedlings and afforestation of 500-750 sq km, and modernization of the Makum Timber Treatment Plant.

Budgetary Proposals: To spend over a period of 10 years, Rs. 1000 cr on State level Fund Ecological Disasters, Rs. 350 cr for Institute of Wildlife Health & Research, Rs. 300 cr for Centre of Excellence, Rs. 350 cr to Corpus of Wildlife for manpower logistics and research, Rs. 100.00 cr for consolidation of Dibru-Saikhowa National Park, Rs. 200 cr for Maguri Motapung rejuvenation plan, Rs. 2000.00 cr for carbon capture and storage (plantations), Rs. 1000.00 cr for peoples' infrastructure support, Rs. 300.00 cr for restoration of agriculture, homesteads, fisheries, livestock, livelihoods etc,, Rs. 850.00 cr for Special Package, and Rs. 100.00 cr being cost of design, planning, execution, management, and monitoring of the ecosystem rejuvenation. **Total: Rs. 6800 cr**.

ABBREVIATIONS & ACRONYMS

AAGSU	All Assam Gurkha Students' Union
AAMYCP	All Assam Matak Yuba Chatra Parisad
AASU	All Assam Students' Union
AAU	Assam Agricultural University
ACF	Assistant Conservator of Forests
ACS	Additional Chief Secretary / Assam Civil Service
ADP	Adenosine Diphosphate
AE, AEE	Assistant Engineer, Assistant Executive Engineer
AFT	Adiabatic Flame Temperature
AJYCP	Asom Jatiyatabadi Yuva Chatra Parishad
ALOHA	Ariel Locations of Hazardous Atmosphere
AMSU	All Moran Students' Union
AMTRON	Assam Electronics Development Corporation Limited
AN	Ammonium Nitrate
AOC	Assam Oil Company
AOV / AoV	Angle of View
AR	Assessment Report/ Augmented Reality
ATP	Adenosine Triphosphate
ATTSA	Assam Tea Tribes Students' Association
BAU	Business As Usual
BBP	Bherjan Borajan Podumoni
BBP-WLS	Borjan Berjan Podumoni Wildlife Sanctuary
BCM	Billion Cubic Meter
BDL	Below Detectable Limit
BECC	Bioenergy with Carbon Capture and Storage
BGN	Baghjan
BIS	Bureau Of Indian Standards
BMC	Biodiversity Management Committee
BNHS	The Bombay Natural History Society
BOD	Biological Oxygen Demand

BOP	Blow Out Preventer
BPCL	Bharat Petroleum Corporation Ltd.
BR	Biosphere Reserve
BT	Brightness Temperature
BTU	British Thermal Unit
CAG	Comptroller and Auditor General of India
CAM	Crassulacean Acid Metabolism
CCF	Chief Conservator of Forests
CCS	Carbon Capture and Storage
CDR	Carbon Dioxide Removal
CF	Conservator of Forests
CFD	Computational Fluid Dynamic
CHO, CHON	Carbon Hydrogen Oxygen, Carbon Hydrogen Oxygen Nitrogen
CO	Carbon Monoxide
COD	Chemical Oxygen Demand
CPAH	Carcinogenic PAH
CPCB	Central Pollution Control Board
CPSU	Central Public Sector Undertaking
CR	Critically Endangered
CS	Chief Secretary / Cross Section
CSIR	The Council of Scientific & Industrial Research
CTE	Consent To Establish
CTO	Consent To Operate
CWC	Central Water Commission
CWLW	Chief Wildlife Warden
DC	Deputy Commissioner
DCB	Demand Collection & Balance / Devi Charan Baruah
DCF	Deputy Conservator of Forests
DFO	Divisional Forest Officer
DGH / DGHC	Director General, Hydrocarbons
DGM	Director, Geology & Mining
DO	Dissolved Oxygen

DOD	Department of Defence, USA
DONER	Ministry of Development of North Eastern Region
DSBR	Dibru-Saikhowa Biosphere Reserve
DSF	Discovered Small & Marginal Fields
DSL	Dead Storage Level
DSLR	Digital Self Lens Reflex
DSNP	Dibru-Saikhowa National Park
DSS	Digital Sampling System / Decision Support System
DWH	Deepwater Horizon
EAC	Expert Appraisal Committee
EC	Expert Committee / Environmental Clearance
ED	Executive Director
EIA	Environmental Impact Assessment
EMP	Environmental Management Plan
EN	Endangered
EPA	Environmental Protection Agency
EPA	Environment (Protection) Act, 1986
EPS	Early Production Setup
ER	Elephant Reserve
ERD	Extended Reach Drilling
ERP	Emergency Response Plan
ESZ	Eco-Sensitive Zone
EUB	Energy & Utilities Board
FC	Forest Clearance
FCA	Forest (Conservation) Act, 1980
FEMA	Federal Emergency Management Agency, USA
FPI	Foreign Portfolio Investment
FSL	Full Storage Level
FV	Forest Village
GDP	Gross Domestic Product
GHGs	Green House Gases
GIS	Geographic Information System

GoA, GoI	Government of Assam, Government of India
GOM	Gulf of Mexico
GOMOS	Global Ozone Monitoring by Occultation of Stars
GOR	Gas Oil Ratio
GPS	Global Positioning System
GWP	Global Warming Potential
H-VIS	High Viscous fluid
HEM	Hexane Extractable Materials
HOFF	Head of Forest Force
HPCL	Hindustan Petroleum Corporation Ltd.
HRR	Heat Release Rate
HVLR	High Volume Long Range
IA	Interlocutory Application
IAQ	Indoor Air Quality
IASST	Institute of Advanced Study in Science and Technology
IB	Inspection Bungalow
IBA	Important Bird Area
ICICI	ICICI Prudential Life Insurance Ltd.
IEBR	Internal & External Budgetary Resources
IFS	Indian Forest Service
IIT	Indian Institute of Technology
IITG	Indian Institute of Technology, Guwahati
IMC	Indian Major Carps (Fishes)
IMO	International Maritime Organization
InSAR	Interferometric Synthetic Aperture
IOCL	Indian Oil Corporation Ltd.
IOGS	Integrated Oil and Gas Services
IOPG	International Association of Oil and Gas Producers
IPC	Indian Penal Code
IPS	Indian Police Service
IRV	Indian Rhino Vision
IT	Information Technology

IUCN	International Union For Conversation Of Nature
klpd / KLPD	Kilo Litres Per Day
KNP / KTR	Kaziranga National Park / Kaziranga Tiger Reserve
LF	Low Frequency
LIC	Life Insurance Corporation of India Ltd.
LNG	Liquefied Natural Gas
LST	Land Surface Temperature
MAB	Man and the Biosphere
MCR	Mineral Concession Rules, 1960
MMB	Maguri Motapung Beel
MMBTU	Million British Thermal Units
MMSCM / MSCUM	Million Metric Standard Cubic Meters
MMT	Million Metric Tons
MMTOE	Million Metric Tonne of Oil Equivalent
MODIS	Moderate Resolution Imaging Spectroradiometer
MoPNG	Ministry of Petroleum and Natural Gas
NAAQS	National Ambient Air Quality Standards
NABL	National Accreditation Board For Testing And Calibration Laboratories
NADP, NADPH	Nicotinamide Adenine Dinucleotide Phosphate
NBWL	National Board for Wildlife
NEIST	North East Institute Of Science And Technology
NELP	New Exploration Licensing Policy
NGT	National Green Tribunal
NMEC	National Media Exploitation Center
NMHC	Non Methane Hydrocarbons
NO	Nitric Oxide
NP	National Park
NPV	Net Present Value
NT	Near Threatened
NRL	Numaligarh Refinery Ltd.
NWMP	National Water Monitoring Programme

OALP	Open Acreage Licensing Policy
OCS	Outer Continental Shelf
OCSLA	Outer Continental Shelf Lands Act, 1953
O/G	Oil and Grease
OIL	Oil India Limited
OMEC	One Man Enquiry Committee
ONGC	Oil And Natural Gas Corporation
ORD	Oil Fields (Regulation & Development) Act, 1948
OTT	OTT Hydromet (www.ott.com) / Over The Top
PA	Protected Area
PAH	Polycyclic Aromatic Hydrocarbons
PAM	Passive Acoustic Monitoring
PBR	Peoples' Biodiversity Register
PCBA	Pollution Control Board, Assam
PCCF	Principal Chief Conservator Of Forest
PEL	Petroleum Exploratory Lease
PEP	Phospho-Enol-Pyruvate
PGA	Peak Ground Acceleration
PLI	Public Liability Insurance Act, 1991
PML	Petroleum Mining Lease
PNG	Petroleum & natural Gas Rules, 1959
PoC, POC	Place of Occurrence/ Proof of Concept
PPE	Photo Pyro Electric
PPV	Peak Particle Velocity
PSD	Power Spectral Density
PSU	Public Sector Undertaking
PTM	Pig-tailed Macaque
RCC	Reinforced Cement Concrete
Rf	Reserved Forest
RFP	Radiating Fire Power
RO	Range Officer
RSPM	Respirable Suspended Particulate Matter

RuBisCo	Ribulose-1,5-bisphosphate carboxylase/oxygenase
SBWL	State Board for Wildlife
SCUM	Standard Cubic Meter
SEIAA	State EIA Authority
SMA	Strong Motion Accelerograph
SOFC	Solid Oxide Fuel Cell
SOP	Standard Operating Procedure
SP	Superintendent of Police
TAE	Thermo-Acoustic Efficiency
TERI	The Energy and Research Institute
THC	Total Hydrocarbons
TMPK	Takam Mising Porin Kebang
TNT	Tri Nitro Toluene
TOA	Top of Atmospheric
TPH	Total Petroleum Hydrocarbon
TSPM	Total Suspended Particulate Matter
TVOC	Total Volatile Organic Carbon
UDRF	Upper Dihing RF
UHI	Urban Heat Island
UNESCO	The United Nations Educational, Scientific And Cultural Organization
US EPA	United States Environmental Protection Agency
USGS	United States Geological Survey
UV	Ultraviolet
VC	Video Conference
VIIRs	Visible Infrared Imaging Radiometer Suite
VOC	Volatile Organic Carbon
VUL	Vulnerable
WII	Wildlife Institute of India, Dehradun
WLS	Wildlife Sanctuary / West Lose Subtract
WPA	Wildlife (Protection) Act, 1972
WPC	Writ Petition (Civil)

SYMBOLS	NAME OF THE SYMBOLS
α	Thermal Diffusivity
ΔS	Entropy Change (JK^{-1})
A_H	Acceleration - horizontal component
A_V	Acceleration velocity
c	Velocity of sound in air
C_P	Heat Capacity at constant pressure
C_{specie}	Concentration of the specie
C_V	Heat capacity at constant volume
D	Flame Diameter, Burner Diameter, Orifice Diameter
D_E	Ecosystem water vapor Deficit
D_H	Displacement -horizontal component
D_{MA}	Margalef's Index
D_{ME}	Menhinick's Index
D_V	Velocity Displacement
e	Subscript for exit of gas (at the orifice or hypothetical nozzle), Thermal Effusivity
E_I	Emission from i^{th} specie
E_R	Encounter rate
γ	Ratio of heat capacities
H_A	Long wavelength Heat flux
H_c	Sensible heat due to convection (Heat flux)
H_D	Heat exchanged with deep water (Heat flux)
H_E	Latent heat due to evaporation (Heat flux)
H_f	Flame height
H_I	Heat exchanged through inflows and outflows (Heat flux)
H_{NET}	The net Heat flux
H_p	Heat flux due to precipitation (Heat flux)
H_S	Short wavelength incoming solar radiation (Heat flux)
h_T	Height of the Mach front
H_W	Long wavelength radiated from water (Heat flux)
K	Kelvin (Unit of temperature), Stiffness constant
kT	Kilo Tonnes of TNT
λ	Wavelength, Thermal Conductivity
L_A	Weighted sound pressure level
L_{eq}	Weighted sound pressure level
L_I	Sound Intensity Level in Decibels
L_N	Sound Power Level in Decibels
L_P	Sound Pressure Level
L_T	Time period
L_W	Sound Power Level
L_W	Positive pressure wavelength
m_b	Seismic magnitude
M	Mass
M_e	Mach Number (at exit)

m_f	No. of moles of specie i
M_i	Molecular mass of specie i
M_N	Seismic magnitude
M_{specie}	Molecular weight of the specie
M_{TNT}	Yield of explosion in Megtons of TNT
N_{EE}	Ecosystem respiration rate
N_{ee}	Ecosystem respiration rate
N_{EE}	Ecosystem respiration rate
N_F	No. of moles
N_i	No. of moles
NO_x	NO & NO_2
NO_2	Nitric Oxide
n_{TA}	Thermal to Acoustic Efficiency
ν	Frequency
P_A	Instantaneous sound pressure
P_r	Total duration of the wave
P_{ref}	Reference sound pressure
P_{SO}	Pressure of the incoming wave
P_V	Proportion of vegetation
Q_C , $\dot{Q}$	Rate of Heat Transfer
Q_K	Power of the Flame
R_E	Reynold's Number (exit)
R_G	Ground distance
R_H	Reynold's Number
ρ	Density
S_u	Maximum Laminar Burning Velocity
t_A	time of arrival of the shock wave
T_{ad}	Adiabatic Temperature
T_{AG}	Arrival time for direct ground
T_{MAX}	Temperatures (maximum) at which photosynthesis totally stops
T_{MIN}	Temperatures (minimum) at which photosynthesis totally stops
T_{OPTE}	Ecosystem optimal temperature for growth
T_{opte}	Ecosystem optimal temperature for growth
T_{surr}	Temperature of the surroundings
T_{SYS}	Temperature of the system
T_W	Water temperature
V_e	Kinematic Viscosity
V_H	Velocity horizontal component
V_V	Vertical velocity
Y_{MAX}	Maximum Noise Value of the Class (dBA) from sampled data
Y_{MAX}	Maximum Noise Value of the Class from sampled data
Y_{MIN}	Minimum Noise Value of the Class (dBA) from sampled data
Y_{MIN}	Minimum Noise Value of the Class from sampled data
Z_G	Scaled ground distance

UNITS, CONVERSIONS & CONSTANTS

Units	
BTU	Unit of heat (British Thermal Unit)
Gt	Giga tonnes
Hz	Unit of frequency (Hertz)
J kg^{-1} $^0C^{-1}$	Heat Capacity
J kg^{-1} K^{-1}	Specific heat capacity
J m^{-3} K^{-1}	Volumetric heat capacity
kg m^{-3}	Density
kg s^{-1}	Mass flow rate
klpd	Mass flow rate (1000 litre / day)
kW m^{-2}	Heat flux
kW m^{-2}	Heat flux
kWH	Unit of energy
l	Unit of volume (Litre)
m^2 s^{-1}	Unit of viscosity, Thermal diffusivity
m^3 d^{-1}	Mass flow rate (Cubic meter / day)
MJ Kg^{-1}	Calorific value
mole	Unit of measurement for amount of substance containing 1 Avogadro Number
N	Unit of force (Newton)
Pa	Unit of pressure (Pascal)
pcf	Unit of material density (Pound Force / Cubic feet)
SCUM	Standard Cubic Meter
W	Unit of power (Watt)
W m^{-1} K^{-1}	Thermal conductivity
W m^{-2}	Sound intensity, Unit of irradiance
W m^{-1} K^{-1}	Thermal Conductivity
W $m^{-2}K^{-4}$	Unit of Stefan-Boltzmann constant
W $s^{1/2}$ m^{-2} K^{-1}	Thermal effusivity

Units of volume	**Units of Acceleration**	**Units of time**
l	ms^{-2}	s
m^3 (=1000 l)	ft s^{-2}	min (=60 s)
CuM		
	Units of pressure	**Units of speed or velocity**
Units of Concentration	psi	Kg/s
µg/m^3	Pa	cm/s
mg/m^3	gm/m^2	m s^{-1}
mg/l	atm	KMPH
µg/l	mmHG	
µg/kg		
kg/m^3		

	Units of temperature	
gm/kg	^0C	**Units of density**
mg/kg	^0F	gm/cc
Kg/Kg	K (=^0C+273)	Kg m^{-3}
ng/m^3		Kg/1000 m^3
	Units of Area	
Units of length	m^2	
m	Ha (=10000 m^2)	**Units of energy**
Ft (=0.3048 m)	Km^2 (=100 Ha)	J (=0.2390057361 cal)
		MMTOE (= $4.1868 \cdot 10^{+16}$ J)
Units of sound	**Units of Mass**	KWh (= 3.6 MJ)
dB	G (=10^{-3} kg)	kcal/SCUM
dBA	MMT (=10^6 kg)	MJ/SCUM
Unit of Vibration Level	Tonne (= 1000 kg)	kT
VdB	Lb (=0.453592 kg)	kcal (=4.184 kJ)

Prefixes & Conversion Factors			**Constants**	
n	nano	10^{-9}	pi (π)	3.1416
ppb	Parts per billion	10^{-9}	Speed of sound in air	343 ms^{-1}
μ	micro	10^{-6}	G or g	9.81 ms^{-2}
			Avogadro's Number	$6.022x10^{23}$
ppm	Parts per million	10^{-6}	Stefan-Boltzmann constant (σ)	$5.6703x10^{-8} Wm^2k^{-4}$
m	milli	10^{-3}	Gas constant (R)	8.3144 J mol^{-1} K^{-1}
k	kilo	10^3	e	2.7182
Lakh		10^5	**Conversions**	
Crore	Cr	10^7	$\log_e$ to $\log_{10}$	2.3025
Million	Mega	10^6	1 Pa	$9.86923x10^{-6}$ atm
G	Giga	10^9	1 atm	101325 Pa
Billion		10^9	Psi to Pa	6894.76
T	Tera	10^{12}	1 kg TNT	4.184 MJ
P	Peta	10^{15}	1 kg AN Eqv.	0.4 kg TNT



The Hot Gaseous Clouds above the Baghjan Flame

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ॐ अग्निमीले पुरोहितं यज्ञस्य देवमृत्विजम्। होतारं रत्नधातमम्।

(**Rigveda 1:1:1**)

Om Aghnimīḷe purohitaṃ yajñasya devaṃ ṛtvījam |
hotāraṃ ratnadhātamam ||

"I pray unto thee, O Agni, the prime element of the Almighty, by performing this sacred act. Thou were there before there was anything, with thee, the creation started. Thou are the giver of all. I pray unto thee in all days, in all seasons. Thou sustaineth all creations and wilt consume all at the end. It is by thy Grace, O Agni, that we get all the beautiful things of life. Thou art the source of all goodness"



GOVERNMENT OF ASSAM

ONE MAN ENQUIRY COMMITTEE

(ORDER No. FRW.6/2020/1 Dt. 12th June, 2020)

REPORT PART-I

ON

DAMAGES TO

ENVIRONMENT, BIODIVERSITY, WILDLIFE, FORESTS

&

ECOLOGY

ON ACCOUNT OF

BLOW OUT AND EXPLOSION AT OIL WELL No. BGN-5

BAGHJAN, TINSUKIA
ASSAM (INDIA)

BY

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VOLUME-I

CHAPTER – 1

1 THE BAGHJAN BLOWOUT UNFOLDING

1.1 My First Information

I got woken up by an early morning call on the 28th May, 2020; and I am used to such odd hour calls being the Chief Wildlife Warden of a State where wildlife emergencies are common, and the caller said he was from Maguri and just wanted to inform me that there was a massive leakage of gas at one of the wells near the Maguri Beel, and all the fishes were dying and all the birds were in danger too! Then, I quickly reached out to the DFO Tinsukia Wildlife Division, Sri Rajendra Bharti IFS, a 2012 Batch Officer. He told me that there was a major gas leak and he is going there shortly. Because of its close vicinity to Dibru-Saikhowa and Maguri Beel. The blowout became an environmental disaster, and occupied much space in the news and social media. On 29th May morning, I got the news that a Dolphin was found dead in the Maguri Beel, and there was a Press Conference of the Hon'ble Forest Minister, Sri Parimal Suklabaidya at the Assam Administrative Staff College at 11.00 AM, on the coal mining at Tikok and Dehing Patkai Wildlife Sanctuary. I also expected some fierce questions on the blow out, the dead dolphin and accordingly had prepared a few slides on Baghjan too, including the photo of the dead dolphin. I had also briefed the Hon'ble Minister on the subject. However, to my surprise, the media was so much preoccupied with the Dihing Patkai and the coal mining, that not a single question was asked on the blowout that had suddenly unfolded at 10.30 AM of 27th May, 2020 at the Baghjan Oil Well No. 5 (coded as BGN-5), being one of the many oil wells owned and operated by M/S Oil India Limited, a Navaratna company of the Government of India.

1.2 My First Actions

While being constantly in touch with the field at Maguri, I kept getting updates and also assisted the DFO in sorting out many challenges, including getting deputed Dr. Abdul Wakid, Project Scientist at the Wildlife Institute of India, Dehradun, who was conducting studies with base camp at Jakhlabandha in Kaliabor Sub Division of Nagaon District with a team of 3-4 researchers to the site. He along with his team was first to reach for any kind of assessment, from the side of the Forest Department within two days of the occurrence of the incident. Of course, I must admit, he was definitely not the first to reach at the site, as many local enthusiasts, wildlife and bird lovers and researchers were there, and did whatever was within their capacities- they started rescuing a lot of

wildlife in the Maguri Motapung beel. In contrast to the local efforts and zeal to save Maguri, the apathy and indifference of the national level institutions was so contrasting that actually none volunteered (may be COVID19 was a factor!); but the conspicuous silence of the national level institutions 'to rise to the occasion' of occurrence of a disaster of such proportions as the Baghjan Blow Out, is not at all a healthy sign for "*scientific temper*" in the country.

Therefore, I could not sit quiet and decided to bring an action strategy to work after a brief and very preliminary discussions with Padmashri Dr. K.K. Sharma of the College of Veterinary Science and Sri Dibya Dhar Gogoi IFS (Retd.) to explore possibilities of getting a small "Local Team of Experts" to assess as to what was happening at Baghjan in terms of the ecological damages in the surrounding areas including the Dibru-Saikhowa National Park famous for the feral horses and as abode of the White Winged (Wood) Duck. Accordingly, I sent an email on the morning of the 1st June, 2020 to the PCCF & HoFF, Assam, Dr. A.M. Singh IFS, who promptly agreed, and a notification of an Expert Committee was issued on the 2nd June itself. The latest that we all could meet (given the COVID19 situation and the restrictions imposed thereof, in person and on video conference was on the 6th of June, 2020. The meeting was also joined later by Sri Kausik Barua, Hon. Wildlife Warden, Guwahati, and the Expert Committee members much benefitted from the discourse that followed.

It must also be mentioned here that the weather was inclement, especially in Upper Assam where it was raining incessantly since 25th May, 2020; and while I had two drones stationed at Makum for ortho-photography of the Tikok coalmine areas in the Saleki PRF, the fear of an accident and eventual fire from any small spark that may occur in case of a drone flying near the site of blow out (and OIL authorities also rejected my verbal proposal), I could not get any effective ground feedback for the fear of an accidental blast and fire. Nevertheless, the Expert Committee decided to visit the site on the 9th itself, as atleast one "working day" was needed to assemble things and procure essentials for sample collection at the site, and the visit could not have been made earlier than that. The Expert Committee also felt and recorded that while it was raining, the situation from ecological point would be quite under control, but things may turn ugly if the rain were to stop [*and as you would see, the apprehensions of the Committee were not unfounded*]. Dr. Narayan Sharma of Cotton University, Guwahati, volunteered first, and the rest followed; and thus, the Committee members moved on the 9th June morning to Baghjan. I requested Sri D D Gogoi to accompany me, and he agreed.

1.3 My First Trip To Baghjan Blow Out Site

As was my wont, I stopped for a while at Kohora and had a brief meeting with the Director, Kaziranga National Park, Sri P. Sivakumar IFS on certain issues, and had reached Negherting (famous for Ahom time Shiva Temple of great significance), when I got the first news, while already speaking with the DFO Tinsukia over phone, that there was something wrong at the Well, and smoke was bellowing uncontrollably. Immediately after the call from the Tinsukia DFO, I talked to Sri Sanjai Rai, ED of OIL who said that something was terribly wrong at the site, and he would get back. Meanwhile I received the first few photographs of the explosion (taken from Guijan and Dibru river side) of the blast from the DFO. What the Expert Committee had dreaded, came to be true and the well had caught fire. The news too spread like wildfire. The explosion happened at 1.30 PM. The Hon'ble Forest Minister had to rush to some news channel discussion, and I had to brief him immediately on phone. The PCCF & HoFF enquired repeatedly as to how soon I would reach the site, and I kept replying 'a couple of hours only'. As an Expert Committee Chairman, I was completely at a loss and full of regret that we acted too slow; and I felt it was a complete disaster, as all our original plans now would fail, and a fresh strategy required to be worked out. I felt sad at such a sudden and large explosion at the very beginning of the venture itself. While most people watched the tragedy unfold on TV screens, I concentrated on reaching as fast as I could, and thinking of options as to how to tackle the new unforeseen situation, now that everything had changed at the site. The initial feedback and thinking was that it could be a controlled fire by the OIL (as flaring is often resorted to in gushing wells), but these thoughts were dispelled soon after, when Sri Sanjai Rai confirmed that it was an accident.

Many phone calls and anxieties later, including deep concerns from my family, as to how much should I venture and how much should I not (the age old "*To be or not to be*…" issues), I was very close to reaching Guijan. Meanwhile, the law and order situation worsened at the site, as reported by the DFO. The Maguri bridge approach from Nutangaon was blocked, and there were massive protests. I also heard that Army was called in, and there was flag march in the area, and still the situation remained out of control. I reached Guijan road on the Tinsukia bypass at 5.00 PM, and was met by the DFO; and I had already told him to take me to the site directly, but as all the approaches were closed, the only option left open was the river route.

We quickly reached Guijan Ghat, and straightway onboarded the Department's speedboat on a sprawling sheet of water of River Dibru that had swelled to almost 1 km

width and daunting, and the river (often also called by the name Dangori or even Lohit) was in full spate, just about to topple over the banks. As we reached nearer the site, the monstrous flame started getting "revealed" in its full form. From the riverside, I could approach almost as close as 700-800m, and it was quite an experience- the heat, the sound, the blaze and its shine, all very extraordinary and pervading. I could also see the fire spreading to other areas radially, and houses burning and bamboo grooves and trees on fire. It was kind of a line of fire, but all was not visible from the river side alone. I could feel the heat from the fire very much even from the boat. As we were on a "fossil-fuel" mounted device, I decided not to venture closer, as the heat on the river side was direct and scorching. However, in between, a gush of the cold winds on the sheet of water took over the heat. It was kind of a "heat and cold" treatment that one does in metallurgy, such was the evening 6.00 PM scenario at 700 m from the flame on the River Dibru. The scene of fire all around and the sheet of water next to it, presented an eerie feeling of a war-ravaged terrain or a leaf straight out of the Trojan War. I directed DFO to evacuate all nearby camps, as there was a threat of fire spreading to new areas.

Returned to Guijan range Office by 7.30 PM, and after some waiting, all other members also arrived. We had a brief discussion, and the trip by boat gave me good insight to approach the site in the morning on boat from the riverside alone, as we were not sure of things at the mainland side. I, along with Sri DD Gogoi, decided to stay at Guijan itself and have a first hand feel of the fire at night. At 10.00 PM, I decided that we must visit the site from where the first photographs of the explosion were sent by the DFO, and accordingly, we walked almost two and half kilometers to reach the point. There was a water body in between us and the fire. We could feel the enormous thundering and the heat and after sometime returned back to the Range Office.

1.4 My First Encounter With The Flame

The flame quite occupied my mind and imagination when I saw it first time in the evening of the 9th June, 2020. Therefore, I decided to devote one or two chapters in the Report to the flame itself. But for now, the team of Experts assembled at Guijan at 7.30 AM on the 10th June, 2020. The team members gathered, besides myself, DFO Sri Bharti IFS, and Sri DD Gogoi IFS (Retd), were: Dr. Narayan Sharma, Prof. Dr. Kishore Kr. Sharma, AAU, Jorhat, Dr. Samiran Dutta, AAU, Jorhat, Dr. Shamim Rahman, DCB Girls' College, Jorhat, Sri Rajib Rudra Tairang, Digboi College, Sri Bikash Gogoi, AE, PCBA, Sri Hemanta Kr. Sarma, AEE, PCBA. I had also requested Dr. Kuleswar Singha, my old aide in GIS in the Forest Department for almost a decade, and now Asstt. Professor at Abhayapuri

College, who happened to be at the site with his friends Dr. Ujjal Deka Baruah, Asstt. Professor, Gauhati University. They also came with their drone and OTT Hydromet DSS sensor set.

As we approached the site from one of the inner channels of Dibru river which grazes along the Maguri grassland on the northwestern side of the Blow out, we could see thin films of oil on the river waters all over. Since it was a thin film, it was not easily discernible unless large quantities had gathered at any one place. Finally the boat was steered to the point of closest approach, and we got down with equipment to start the work. In the near distance in the from was the blazing flame with deafening noise, and on the left was flowing the river, and on the right, in the distance, one could see thinly the road from the Maguri bridge where there were a few vehicles. Sri Bharti and I ventured quite close to the fire through the bamboo grooves and an abandoned house and unburnt tea garden bushes. A few small pool fires were still burning here and there. We returned after one round of reconnaissance, when we saw a group of OIL Fire Service personnel approaching us. They said that two of their colleagues went missing after the yesterday's explosion, and the team were searching for them. They sought our support by way of binoculars, DSLR cameras and Drone in locating them. Myself with Gogoi, Bharti, local Range Officer, Kuleshwar and Deka Barua went through the pump house area to the nearest possible point on that day on the edges of the small pool of water which was about 70-75m away from the flame. Intense heat and very loud noise made almost difficult to do any work. After a lot of ifs and buts, the drone was flown almost close to the water water surface, and as much as it could go. Though the total flight time was just 3.2 minutes, it appeared to be so long and full of anxiety, and we all feared that the drone might catch fire in the extreme heat. After one quick hovering over the stretch of water around, the drone was quickly withdrawn. Now, in so much of heat and light, there was no way to see the captured video from the drone. Then, I quickly pulled my *Bodo Gamucha*, over the heads of three of us- myself, Deka Barua and one of the OIL firemen. And we could spot one body in the water at the other end close to the fire. We all felt miserable and very sorry for the firemen. We guessed that the other body could be underneath the first body. Our eyes were moist. I consoled the OIL firemen who were with us and then left the site with heavy heart and a new realization. At the exit road, met members of Press who were eagerly waiting for the outcome of the search operation. I gave a small briefing to the Press gathered there, and also met the NDRF team that had, by then, just arrived. Briefed them too, and then joined back the rest of the survey party.

While it was a *good turn*, though very tragic, done at the flame site, and I had also not planned to visit so close to the flame, my focus had entirely been on biodiversity damage assessment. The first close range encounter with the imposing flame left quite an impression on my mind and a whole lot of questions emerged thereon. It was a phenomenon in itself, and appeared as if it could tell so many tales. The brilliance of the flame was amazing, the sound was like that of many jumbo jets taking off at the same time, or flying past over your head with Mach speeds. The flame was surely supersonic, I concluded. This was my first conclusion. I got deeply interested in the flame and its properties, and since then made it a point not to miss an opportunity to visit it and understand it. I visited the flame site as many as five times, but utter lack of equipment worthy of the flame pinched me very hard. I knew we were losing quite an amount of data and information in not being able to study the flame! I did try to manage some measurements of the flame temperature by getting equipment through AMTRON (M/s Assam Electronics Corporation Ltd). However, during lock-down procurement and transport of equipment was almost like another uphill project. Thanks to AMTRON, I managed a few equipment. All throughout I felt handicapped as I lacked proper equipment to study the flame.

1.5 My Night Experience With The Flame

I had deliberately decided to camp at Guijan to be as close to the flame as possible. The first day i.e. the 9th June was very long and tiring, and I slept like a log. However, I got awakened in the night twice as if earthquake had come, and it was a great deal of sound in the room. I got up just to realize that it must have been the flame and the wind directions playing game in the quiet of the night. While the day's work had been very tiring on the 10th June, and we had a small meeting and debriefing session too at about 8.00 PM, and then myself, DFO and Sri Gogoi had a long discussion after dinner, and then we retired for the day. It would be a quiet night, but whenever the wind blew in this direction of Guijan, then, it was like fighter jets flying past the building in times of the war. The sound impression got so much embedded in my mind in the two nights that whenever and wherever I heard a similar sound, the flame stood dancing before my eyes. It strengthened my conclusion that the flame was, somehow, supersonic in nature. I would have to prove it mathematically, and decided to take the job more seriously, even though no one may be interested in knowing what the Baghjan flame was all about!

1.6 My Second Visit To Baghjan

All the team members again met in the morning on the 11th June. After we briefly discussed and confirmed the detailed pathways for the next few days, I left for Guwahati at about 9.30 AM. Had lunch at the Forest IB at Jorhat, and again a brief stop over at Kaziranga with a meeting on the land transfer issues. On the way to Guwahati in the night, I got the information that the Hon'ble Chief Minister, Assam had ordered an enquiry into the Baghjan blow out incident, and I was nominated as Head of the one of the two One Man Enquiry Committees (OMEC) to be instituted by the Government of Assam.

Another thing that I had decided, now that there was no fear of any accidental fire, to press the Drone team to survey the National Park and surrounding areas. The team arrived on the 11th night itself at Guijan; and that very night I sent the team lead Sri Sanjay Kumar Das along with the DFO to the Guijan's nearest point to photograph the flame at night, and see if he was getting any vibrations on the ground. He reported that vibrations could be easily felt.

The next day morning I had just started the day with a VC of the Hon'ble Union DONER Minister on IT, that Sri Sanjay Lohia, the then Principal Secretary to the Hon'ble Chief Minister, called up, and requested me to return to Baghjan at once. Despite my best efforts, I could not start my journey before 5 PM. However, with a brief stop over at Jorhat Forest IB at 10.30 PM, I reached once again Baghjan, now as One Member Enquiry Committee, on the early morning of 13th June, 2020 at 6.00 AM.

1.7 My First Interactions With The Affected Communities

While the whole day of the 13th June, 2020 went into reworking the strategies now that there was a mandate from the Hon'ble Chief Minister himself, learnt the news that the Hon'ble Chief Minister would be visiting Baghjan the day after.

On the 14th June, 2020, the Honble Chief Minister arrived at Baghjan Helipad along with the Hon'ble Union MoPNG Minister. After visiting the ground zero, and talking to the communities at the Rehabilitation camps, the first meeting at about 3.30 PM was held with the members of the Baghjan Gaon Milanjyoti Yuba Sangha. Got a first hand opportunity to learn of the woes of the communities and the anguish and pain in their hearts. The Hon'ble Chief Minister not only promised that maximum possible compensation would be worked out for the affected communities, and then also introduced me at that point of time to them saying that I would be working out all the details, and they need not worry. These words of the Hon'ble Chief Minister had a

profound impact on the communities as well as on myself. There was another meeting at 4.30 PM which the Hon'ble Chief Minister chaired with the various local organizations, and once again echoed similar thoughts.

These two meetings in themselves helped me to come closer to the communities. The next day at 5.30 PM, the Deputy Commissioner, Tinsukia, Sri Bhaskar Pegu ACS, had called a meeting of all the District level officials associated with the Baghjan issue. Sri Lalit Gogoi, IAS from the Revenue Department was also present along with the SP, Tinsukia, Sri Siladitya Chetia IPS. The OIL officials including the ED, HR were also present. After listening to all the Departments and OIL, I had little option but to say that the whole issue was being approached in a conventional manner, and even the approach of OIL was also very unscientific and run of the mill. It was very much clear to me that "conventional" Business As Usual (BAU) approach would not work. Its like whether you are fully prepared for a "once in a 50 year" kind of a rainfall or else, you are a game to get washed away with the shower anytime by planning for a normal rainfall – a 'happy go lucky approach'.

On the 16th June, 2020, a long meeting with the members of the Baghjan Milanjyoti Yuba Sangha was held in the DC Office Conference Room. Besides the Deputy Commissioner, Tinsukia, Sri Bhaskar Pegu ACS, Sri Lalit Gogoi, IAS, Revenue Department and SP, Tinsukia, Sri Siladitya Chetia IPS were also present. While the Deputy Commissioner, Tinsukia reiterated the promise of the Hon'ble Chief Minister about providing maximum possible compensation, I added that maximum awards of compensation would be possible only if we look at the disaster from mostly environmental angle, and whether, the OIL had fulfilled all its obligations as required under the existing laws of the land. I also stressed that without proper scientific assessment of damages, conjecturing might not be of any use in this case. After a long discussion over the demands of the group, which included among others insurance cover, livelihood cover, appropriate compensation for damages of agriculture, tea gardens, plants and trees, and houses, and trauma caused by the fire, sound and the tremors, the meeting ended with a plea that every family must get compensation of Rs. 1.00 crore at the least. It cannot be denied that this accident of blow out had brought more than thousand families to the streets, and about 300-400 families lost whatever they owned in terms of physical possession near the site of blow out. It was traumatic, and no amount of compensation could buy them what they lost.

1.8 My Understanding Of The Issues

My 2nd trip to Baghjan concluded on the 17th morning at 7.30 AM when I started my return to Guwahati via Kaziranga. Thereafter, the 3rd trip was undertaken on the 22nd June, 2020 morning. I reached Tinsukia in the late evening hours after attending a function of the Hon'ble Chief Minister, Assam at 11.00 AM at the Burapahar Range of KNP. I stayed at Tinsukia till 29th June, and on the early morning at 4.30 AM of June 30th I started back for Guwahati again.

During this period I met many people, including representatives of the affected communities, several scientists working in the field, members of various organizations, visited the devastated site many times. Visited Maguri Beel, and also the Maguri grasslands, and walked there often. I went from one end to the other of the Dibru-Saikhowa National Park on boat and on foot. [*The last trip was awarded with a serious injury on my left leg when I slipped from the boat in the Lohit River across Saikhowa on the other end*]. I saw the fire from so many points, at much of distances, and heard its sound from the near and far, and traced them with thermal scanners and used all possible methods, on the flame, that I could think of and lay my hands on every possible equipment that I could get during the COVID19 lockdown.

A few questions always played in my mind:-

1. What if there was no "Amphan", and no rains, and then what would have been the scenario post blow out and explosion?
2. What if, the wind directions were towards the National Park?
3. What if, it were not May-June, but February-March?
4. What if the explosion would have happened just 30 minutes before it actually happened?

Therefore, the issue is not that there was a blow out, and it was raining, and very little damage to the ecosystems and/ or properties were caused, or even the issue is not that whether no rains would have made things easier for OIL and ONGC to handle the blow out in a better way. To me the issue is that ***the giants Oil PSUs and Navaratna companies of the Government of India are not even the least in the know of the things for soliciting answers to such questions as any of the "what ifs" above? I found a complete lack of "What if" scenario planning.***

If the Baghjan Oil Well Blow Out is just seen as another "oil well accident", we shall fail to learn the right lessons; and bigger disaster may follow in the times of so many

frequent earthquakes in the region, climatic instabilities, extremes of weather, and increasing impingement of unknown "viruses"- 'human errors' may actually multiply. Given the climate uncertainties, these vulnerabilities would only increase in the future.

1.9 My Approach To The Baghjan Blow Out Environmental Damage Assessment

The onerous task entrusted by the Government of Assam to the One Man Enquiry Committee (OMEC) for assessment of damages to ecology, environment, forests, wildlife and biodiversity came with such a wide mandate that I felt in no way qualified enough to meet even part of the challenge put in front of me. This was a multi-mode, multi-discipline and multi-member job. However, by the circumstances already narrated in the previous paragraphs, I had, fortunately, the full advantage of so many experts already working on the ground with me, and a large "go getter" Force of the Assam Forest at my command. I only had to "glean" my "teaming brain" and call in my faculties for the arduous task at hand. This Report is a reflection of efforts by all the team members who have been giving selfless service to the cause of the ecological damage assessment of the Maguri Motapung Beel, Dibru River and the Dibru-Saikhowa National Park.

In addition to just being an assessment, the One Man Enquiry Committee, in my thinking, should reflect a bit on fixing responsibility on those who were guilty of "omissions and commissions" (breaches) of forest and environmental laws of the land such as the Forest (Conservation) Act, 1980, Environmental (Protection) Act, 1986, the Environmental (Protection) Rules, 1986, the Environmental Clearance Notification of the MoEF&CC of 2006, the ESZ notifications of the National Parks and Wildlife sanctuaries around the area in question and the Biological Diversity Act, 2002. The question also would need to be examined whether the matter was referred to the State Board for Wildlife or the Standing Committee of the National Board for Wildlife.

However, the causes of the "leak and blow out" are beyond the scope of this Committee. Having said that, we still need to look for the "*primum suspicari*" or the "causa" prime that could account for the large scale environmental and ecosystem damages caused including loss of life, and loss of property, and trauma caused to humans and wildlife alike. The key, as I always felt while reflecting upon the imposing flame, would be held by the nature of the blow out and would be governed by such factors as the physical, chemical, acoustic, vibrational and thermal properties of the flame like chemical compositions, densities and calorific values of the substances being emitted in the blow out, the rate at which the fuels are being emitted, the amount of reserves below the

surface of the earth at distances 3000-4000m deep, the pressures acting there, and external environmental conditions like temperature, pressure, rain, humidity, wind direction, and verily the nature of objects in the surroundings, their flash points and inflammability hazard properties to mention a few. Therefore, some of these properties, if not delved into some depth, would render this enquiry a futile exercise. [*This aspect has been examined in as much detail as was possible based on collected data. The Part II is mostly about these parameters. See Chapters 6 to 11*]

Most importantly, a systematic set of robust methodologies was the need of the hour; and I soon realized that a 'classical' chapter on methodology would not work, and I had to abandon this approach after working for about two months on the flame, as I realized soon that every subject matter needed a separate treatment. Thus, each the investigative Chapters of Part II (Chapter 6-15) have their own 'Methodology' section. The Expert Committee and other assessment reports also have their own set of methodologies, and these have been incorporated in the Report appropriately. The One Man Enquiry Committee followed the usual path of publishing notices in newspapers, local media for inviting public response, held public hearings, interacted with various Departments of the Government of Assam, asked for various reports from OIL authorities, met several local NGOs working on the environment.

The Report now stands in three volumes. This being the Vol. I, and all the primary findings and reports of the Expert Committee etc. are put together in Vol. II. All the secondary reports, findings and replies received from various experts, laboratories, authorities, agencies and members of the public are put together in Vol. III of the Report.

It also needs to be mentioned that the One Man Enquiry Committee is fully aware of the fact that no assessment can be done in just 15-30 days, and moreover, the impacts of the blow out could be long ranging, and just cannot be pin pointed in a few months or a few years time. The impact on plants and animals could be long ranging, and could only be seen once the effect of the pollutants is fully immersed in the food-web of the ecosystem. Even health impacts on people and cattle would not be immediately visible.

Lastly, many people asked whether this Committee would cover damages caused to the human populations; to which my reply is that man is a part of the Biosphere, and the ecosystem, and cannot be separated from it. Even if we may desire it politically by creating artificial boundaries, ecosystems do not recognize such principles. Hence, assessing damages to properties is surely a part of it, but is only limited in scope and time.

1.10 My After Thoughts

Having compiled the Report well within six months of the constitution of the One man Enquiry Committee, and having given the Report for peer review and initial comments, the most imposing question I got was - '*Could this Report not have been done without so many formulae and calculations which seemingly have no direct link with biodiversity and ecological assessment?*' According to many, I was unnecessarily indulging into undesirable mathematical expressions and calculations, whereas the last few chapters were actually good enough for the assignment. Furthermore, I also got the comments that most people would actually not even go through those arduously and clumsily written chapters on so many properties of the Baghjan flame. Moreover, would it matter if the flame was little colder or hotter or little less or more oil flew from the orifice?

While writing, I had somewhere an inkling that this Report would surely gather dust in some corner of this whole wide world. Let me say that even then due to lack of time and resources I could do only this much, and I had to drop so many other vital aspects. When I look back now, this Report is akin to a 'crime scene' investigation; and I needed all the vital clues of the 'crime', else I would not have been able to pin point anything. Whether earthworms and butterflies are 'important' for this 'part of the world' where oil flows so much in abandon that a fire like Baghjan raging for five months could not even deplete the reserves by any significant bit, and how many of them would need to be killed to call Baghjan an ecological disaster? 'Disaster' means damage to human life and property, damage to ecology can wait. Therefore, we do not have ecological disasters either defined or laws for their prevention. The prime focus, therefore, was to ascertain the scale of the 'accident' objectively and whether such scale of events were foreseen by the Ministry of Petroleum and Natural Gas (MoPNG) and the oil PSUs owned by it.

Assessing the various parameters was, by no means, easy and I had every liberty not to labor on them. However, I chose the other path to establish most parameters that were needed to understand the fire and its impact on the surroundings. These findings, make the claim of damages on ecology very realistic and at least provide a scientific basis of what actually happened or could have happened. While fossil fuel extraction is an important economic activity vital for the nation, its possible consequences on ecology and environment appear to have been always undermined. On the face of rising crude oil and gas imports, an ecologist is bound to ask the question- where to draw the line?

It is for the reader, in general, and the authorities, in particular, to speak on the merit of the Report. M/S OIL and MoPNG would probably be duty bound to reject this Report outright by hiring best of lawyers and 'brains'. Nevertheless, let the debate begin. ***Ecology shall prevail over economy***!



The Pristine Maguri Beel before the Blowout

[Photo Credit: Sanjib Baruah]



The Well Fire at Baghjan in Full Bloom roaring from 9th June to 13th September, 2020

CHAPTER-2

2 SITUATION ANALYSIS: SOCIO-ECONOMIC

2.1 Location

The Baghjan Well No. 5, code named BGN-5 by M/S Oil India Ltd falls in the Baghjan (literally meaning *Tiger Stream*) village under the Baghjan Gaon Panchayat in Hapjan (literally meaning *Snake Stream*) Development Block, Police Station Baghjan in Tinsukia District of Assam. Tinsukia district is the main hub of mineral oil and coal mines in the State of Assam. It boasts of the oldest Oil Refinery at Digboi in the whole of Asia established in 1891, and still under operation. Oil was first discovered here in 1867. The BGN-5 OIL well is located at GPS longitude & latitude 95° 22' 51.066" E 27° 35' 46.566" N. Location map of the Well site may be seen at **Fig. No. 2.1.**

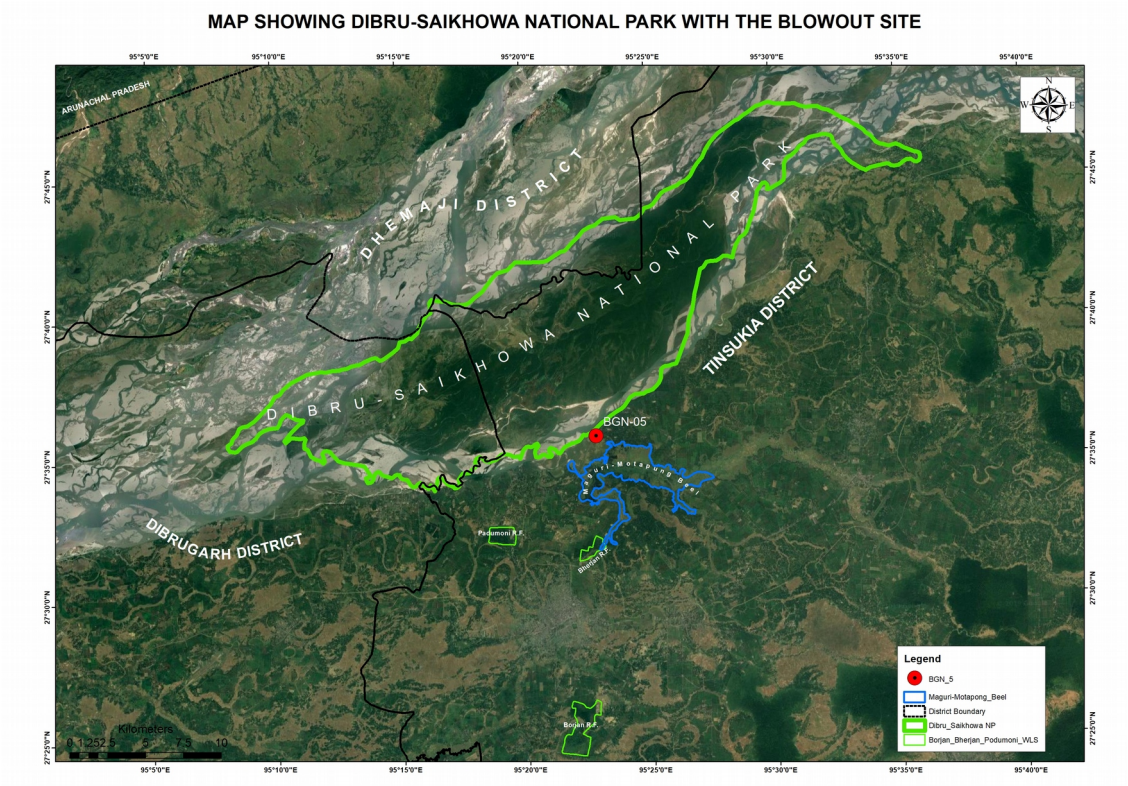


Fig. No. 2.1: Map of Dibru-Saikhowa NP & Other Conservation Areas & Blow Out Site

2.2 Approach To The Site

The Baghjan Oil well site, BGN-5, is almost a pentagonal site of about 47 Ha on the edges of the Maguri Beel and the grassland together with closely inhabited hamlets and tea gardens. The site at BGN-5 can be approached from all the four directions. The shortest route from Tinsukia is via Gelapukhuri and the Plastic Park Road. This road

comes right onto the stream which is supposed to be a stream of Dibru River over which there is a beautiful steel truss bridge near Natungaon. After the bridge the road opens into the Maguri Grasslands on the left and the Maguri Beel on the right. Before the bridge, the Plastic Park road is also joined by a road from Guijan, which is further west of the Plastic Park, and which in turn is about 2 km from the Tinsukia bypass. This road goes to Natungaon via the Balijan TE, and meets the Plastic Park Road just before the steel bridge. There is another road from Doomdooma side vial the Dighaltarrang village which runs almost close to the Dibru river and parallel to it for about 1.5 km. The Baghjan site can be approached by road from Tinsukia, Doomdooma and Makum

2.3 Surrounding Villages

There are about 7-10 villages in the immediate vicinity of the BGN-5 well site. Notable among them are Baghjan, Natungaon, Dighaltarrang, Guijangaon, Daisajan, Bandarkhati, Gotongaon, Barekuri, Kordoiguri and Doidam. People belong mostly to Moran, Muttock, Tea tribes, Sonowal, Ahom and Nepali communities.

2.4 Nearest Townships And Other Landmarks

The nearest town is Doomdooma which is also known world over for some of the largest tea gardens. The town boasts of one of the largest cosmetics factories in India owned by M/S Hindustan Lever Ltd. It also hosts the Divisional Forest Office of the Doomdooma Division. Doomdooma town is located on the banks of the Doomdooma river, and is the gateway to the newly constructed Dhola Sadiya Bridge, which is the longest road bridge over any river in India.

Makum is another small oil town from where one can access the road network to Baghjan. Makum is directly connected to Doomdooma by road and rail. Makum is also a railway junction, from where a branch line goes to Doomdooma and Dangori. Dangori is a small town on the banks of the Dangori river close to Dhola Ghat, a few kilometers prior to reaching the river Lohit, over which the Dhola Sadiya Bridge is built. The river Lohit is one of the main tributaries that join together, along with Dibang and Dihang after which, the confluence of the rivers is known as the mighty river Brahmaputra.

Sadiya is one of the Civil Sub Divisions of Tinsukia District, and lies immediately across the Lohit river and can be now crossed via the Dhola Sadiya bridge. Its an old town with significance from the Mahabharata age. Sadiya acts as one of the gateways to Arunachal Pradesh. From there one can approach Roing, Anini and Tezu. At about three hours driveway from Sadiya, and just about 20 km from Tezu, is also one of the most sacred Hindu pilgrimage sites called the Parasuram Kunda in Arunachal Pradesh.

Tinsukia is the largest city, which is an industrial hub of the upper Assam most famous for coal, mineral oil, natural gas and rain forests. Once, it was the national hub for plywood and veneer industry (prior to the ban of the Hon'ble Supreme Court in 1996 on felling of timber in the WPC 202/1995). Tinsukia is well connected by way of road, rail and airways. The nearest airport is at Mohanbari near Chabua.

2.5 Tea Gardens Around The Blow Out Site

The Baghjan site is rich in tea industry, and a lot of large tea gardens are located in the vicinity of the site itself. Some of the large gardens adjacent to the site are Baghjan TE, Dighalturrung TE, Daisajan TE, Balijan TE, Rangagora TE, Guijan TE to mention a few. In addition, there are a host of small tea growers in the area.

2.6 Land Use Pattern, Agriculture And Allied Activities

The people are largely small and marginal farmers or share-croppers. Paddy is the main crop, and people have in their *Bari land* plants of betel nut, climbers of Paan, vegetable garden and kitchen garden. Tea plants are now very commonly found in almost every household. While most area within 2-3 km radius is occupied by either the water bodies, rivers or grassland on one hand, and tea garden on the other hand. The farmlands are very few. Most people have occupied the non-cadastral Govt and and doing agriculture on those land parcels. The land use pattern in a radius of 30 km of the Baghjan site is given below:-

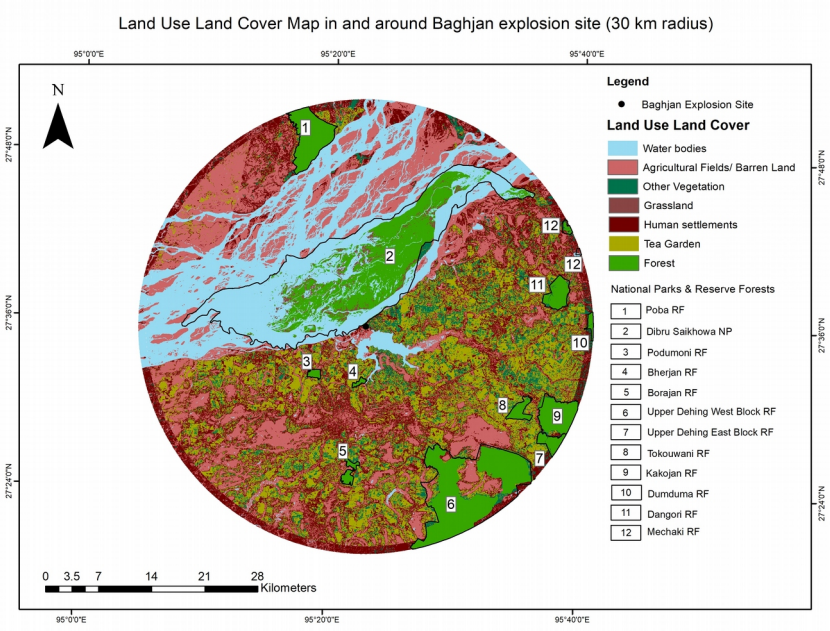


Fig. No. 2.2: Land Use Cover Map in 30 Km Radius of the Blow Out Site

The land use map can be seen at **Fig. No. 2.2** The area statement of land use within 30 km radius is given below:-

Table No. 2.1: Land Use Class Area in 30 Km Radius of the Blow Out Site

Class	Area (in sq. km)
Human settlements/ modified areas	587.159
Water bodies	493.286
Forest	301.030
Other vegetation	113.941
Barren lands	758.235
Tea garden	556.141
Grassland	18.725

2.7 Demography

While Baghjan and Dighaltarrang TE are the two largest villages, in that order, there are a large number of small villages, settlements and colonies (among the tea gardens). Average household size was found to be 5.21. The average sex ratio was found to be 955, which is lower than the State average (958) but higher than the national average (943). The highest sex ratio was found in Baghjangaon (1000), and lowest in Dighaltarrang (899). There is a large population of tea community, as well as pockets of Gurkha communities, in addition to major communities such as Sonowal Kacharis, Mising, Moran-Motok etc. The literacy rate was observed to be low. People are largely agriculture dependent, wage earners, farmers, artisans, tea labourers and skilled workers.

2.8 Housing

The housing in the area is seen to be largely rural, with exception of industrial infrastructure in the form of tea estate factories, tea estate bungalows, warehouses and the other industrial buildings, with labour lines that are well organized. The typical rural houses are semi pucca with tin roof. Kuccha houses, thatched huts, RCC buildings can also be seen.

2.9 Agriculture & Allied Sectors

Agriculture is the mainstay of livelihood. However, areas in the immediate vicinity of the blow out are surrounded by tea gardens. People also rear cattle, keep poultry, duckery and piggery for livelihoods. People also rear fish in ponds. Especially the population on the banks of the Maguri Motapung beel subsist on fishing. Fishing in the rivers and water bodies is also a source of income for them.

2.10 Public Institutions, Schools And Hospitals

2.10.1 Educational facilities

Primary schools (LP-Lower Primary) are present in almost all villages, while M.E. schools are not in every village. Baghjangaon has an ME School. Some villages have High schools too, such as Banderkhati, Kordoiguri and Guijan. There are a few private institutions such as St. Joseph's High School and Dibru English Academy.

2.10.2 Health Services

There are several Primary Health Centres and Community Health Centres. However, major healthcare facilities are available at Doomdooma, Tinsukia and Dibrugarh.

2.10.3 Other Infrastructure

The area is industrial with more than 30 oil rigs. However, the available social and community infrastructure, leaving aside what has been built earlier by the tea garden management and religious institutions, is very much lacking. There are a couple of large play grounds, but undeveloped. One of them was used as helipad during the disaster. There is also a dilapidated veterinary hospital building with no doctor posted. The surroundings are totally rural with oil rigs scattered around.

2.11 Immediate Vicinity Of The Blowout Site

The BGN#5 site is a densely packed site on the north, east and the south. The western and south western parts are dominated by the Maguri grasslands and the beel. To the north, there were a number of houses with a lot of tea bushes planted up, and cattle. The east and south east sides are dominated by tea gardens and villages. An exclusive landuse of the area within 3 km of the blowout site is given below in Fig. No. 2.3.

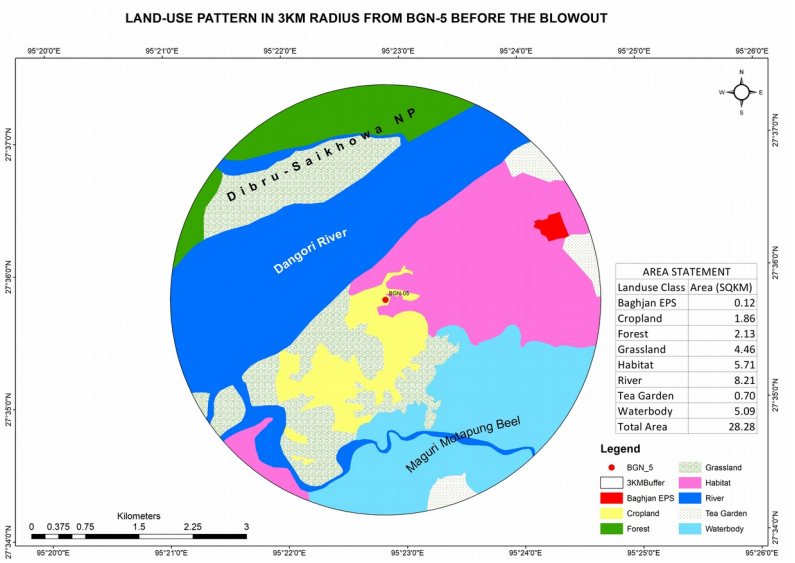


Fig. No. 2.3: Land Use Cover Map in 3 km Radius of the Blowout Site





Ruddy Shell Ducks @ Maguri Beel

CHAPTER-3

3 SITUATION ANALYSIS: ECOLOGY & ECOSYSTEMS

3.1 Ecology Of The Surrounding Area

The nearest areas of biodiversity and environment concern is the Motapung Maguri Beel, which is an Important Bird Area (IBA) recognized by the BirdLife International. The water bodies and the impinging grasslands are home to several flora and fauna including wild buffalo, barking deer, and a variety of avifauna. This area is about 100-200 m distance from the blow out location in the south and south east directions. The next nearest biodiversity hot spot is the Dibru-Saikhowa National Park and Biosphere Reserve spread over 350 to 650 sq km to the north, northeast and northwest of the blow out. The nearest point of the Park lies within 900 m of the blow out ground zero. In between the Park and the blow out area lies the Lohit branch of the mighty Brahmaputra that has a confluence with Dangori river and later Dibru river, largely known as Dibru or even Dangori River. The river starting from Sadia Dhola bridge on the upper reaches to the Bogibeel on the downstream forms a rich habitat of the Gangetic River Dolphins. These three unique ecosystems put together account for 36 mammalian species, 500 avifauna including migratory birds, 11 species of turtles, 9 species of lizards including two species of monitor lizards, 18 species of amphibia, 104 species of fish and 23 species of snakes, 104 species of butterflies, and 26 species of molluscs besides supporting astonishingly rich flora including 28 tree species, 26 species of shrubs, 2 species of parasitic plants, 17 species of grasses, 16 species of aquatic plants, 3 species of marshy plants, 4 species of climbers and scandens, 5 species of canes, 13 species of orchids, and 6 threatened medicinal plant species. The Hapjan Biodiversity Management Committee (BMC) has recorded 69 varieties of rice among other flora and fauna. The Dibru-Saikhowa National Park is also world famous for the feral horses.

The next important conservation regime is the Bherjan Borajan and Podumoni Wildlife Sanctuary. While Bherjan, being closest, is at a distance of 6 km from the ground zero and lies to the south of the Motapung Maguri beel, Podumoni is at a distance of 8 km to the west of the blowout site. These areas are rich habitats of butterflies and there were resident troops of Hoolock Gibbon (the only ape found in India) in the past. The gibbons also have now a broken habitat, and a few found outside the sanctuary areas (other

than Borajan[1]). While Borajan[2] still supports Hoolock Gibbon populations, one such known location outside the protected area, but very close to the blowout site, where troops of Hoolock Gibbons, numbering 19 individuals, have been residing for long is Barekuri[3] Gaon Panchayat falling within 2-3 km south of the blowout site. The map of the area is given below:-

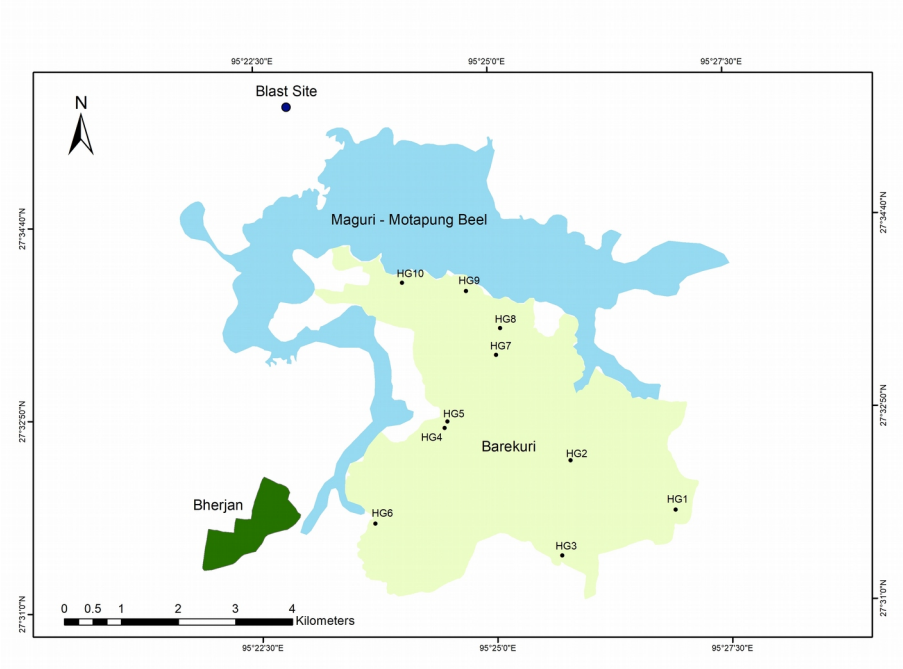


Fig. No. 3.1: Distribution of Hoolock Gibbons around the Blowout Site

As regards the ESZ, the only notified ESZ is that of Dibru-Saikhowa NP, and the Well No. BGN-5 falls outside the ESZ and is seen to be located within 860m of the ESZ. The only notified Elephant Reserve is Dihing Patkai Elephant Reserve which is situated at more than 30 km distance from the blowout site.

3.2 Dibru-Saikhowa National Park

Dibru-Saikhowa represents one of the most pristine riverine ecosystem landscapes spread over an area of almost 650 sq. km. Its conservation journey started in 1890 when the Dibru-Reserved Forest was notified in 1890 with 249.82 sq km area. Subsequently, Saikhowa RF was notified to the east of Dibru RF in 1920 comprising of an area of 68.09 sq km. Both the areas together were declared a Wildlife Sanctuary in 1995, a Biosphere

1 Hoolock Gibbons went extinct in Pudumoni RF in 1970s. [*Choudhury , A., 1996, Primates in Bherjan, Borajan and Podumoni, Reserved Forests of Assam, India. Asian Primates, 5, 10–11*]; and in 2005 Bherjan [*Sharma N et al, 2012, Fauna & Flora International, Oryx, 46(2), 308–311, doi:10.1017/S0030605311001402*]

2 As per the latest survey by Deka B, Goswani A. A., Gogoi N, Sharma N, (2020) unpublished survey of primates in the BBPWLS carried out for the Wildlife Wing of the Assam Forest Department, there are ***only 4 Hoolock Gibbon individuals in Borajan***.

3 As per Deka B et al (2020)

Reserve (supported under the UNESCO Man And Biosphere Programme) in 1997 and a National Park in 1999. The National Park area is 340 sq km. There is a buffer to the National Park area comprising of 422 sq km (which is actually buffer under the Biosphere Reserve).

The Dibru-Saikhowa National Park and Biosphere Reserve is located in Tinsukia and Dibrugarh Districts of Assam, India. The area lies in the **Indo-Burma Global Biodiversity Hotspot** and the **Assam Plains Endemic Bird Area**. The terrain of the Park is flat and it is situated in the floodplains of various rivers and the initial tributaries of the river Brahmaputra viz the Dibru, Dangori, Lohit and others. The elevation of the Park varies from 110-126 metres above mean sea level. The whole area is a reservoir of rich deposits of crude oil and natural gas below the sub surface of the highly diverse and unique ecosystems and river beds. [*This is the irony of Dibru-Saikhowa and the biggest challenge today: rich biodiversity and rich mineral fuel resources rest one on top of the other without any conflicts; but when we exploit the sub surface, the top surface gets highly disturbed*.]

3.2.1 Brief Conservation History

Initially by amalgamating the then Dibru RF and Saikhowa RF, the Dibru-Saikhowa Wildlife Sanctuary was declared in 1986 encompassing 650 sq. km. area. However, while finalizing the boundary of the Sanctuary in 1995, its area was reduced to 340 sq. km. In 1999, its status was upgraded to that of a National Park. However, the Dibru-Saikhowa Biosphere Reserve which was declared during 1997 covers the erstwhile total area of the Proposed Wildlife Sanctuary as well as surrounding river and fringe villages. The core of the Biosphere Reserve is 340 sq km which covers the entire, now, notified National Park of 340 sq. km. area. The buffer of the Biosphere Reserve encircles the entire core from all sides, spreading over an area of 425 sq. km taking the total area of the Biosphere Reserve to 765 sq. km.

3.2.2 Vegetation and Biodiversity of DSNP

The original natural vegetation was Tropical Wet Evergreen Forest (Rain Forest) with grassland and reed beds in the riverine tracts and depressions. During the great earthquake of 1950, large parts of the then Reserve Forest sunk by a few meters, resulting in the regular flooding of the area. This was followed by the emergence of a

new type of vegetation. 'Salix swamps' and deciduous forest now dominate the PA. Evergreen Forest is restricted to a few patches of the PA only as of now.

About one third of the National Park is covered with *Salix tetrasperma* and *Bischofia javanica*—the most abundant tree species. *Dipterocarpus-macrocarpus* trees, which were common before 1950, are now a rare. Grassland and reed beds cover another third of the Park. The main reed and grass species are *Arundo donax*, *Phragmites karka*, *Imperata cylindrica*, *Saccharum* spp., etc. Annual floods with periodic high-level flooding, and soil erosion by water channels are major natural threats to the area. Soil erosion of the Brahmaputra and Lohit Rivers has already taken away large chunk of grassland and woodland of the PA.

3.2.3 Significance And Assessment Of Conservation Values

Dibru-Saikhowa National Park / Dibru-Saikhowa Biosphere Reserve is the **third largest National Park of Assam**, managed on a core-buffer strategy. The core area of DSNP/ DSBR is a mosaic of many habitat types, the diversity of which is reflecting in the faunal diversity that it supports. The Core Zone is characterized by Littoral and Swamp Forests, Semi-evergreen Forests, Deciduous Forests and patches of Wet Evergreen Forests. This diversity is reflecting in the **36 species of Mammals, 500 species of Birds, 105 species of Butterflies, 104 species of Fish, 11 species of Turtle, 18 species of Lizard and 23 species of Snakes**. Core Zone DSNP/DSBR is home of **38 species of Orchids** which augment floral diversity. DSNP/DSBR is rich with the extra ordinary avian biodiversity. Bombay Natural History Society along with Birdlife International (India) has declared the Dibru-Saikhowa Complex including Maguri-Motapung Beel (Wetland) as an Important Bird Area (IBA). Dibru-Saikhowa is also designated as Assam Plains Endemic Bird Area. The core of DSNP / DSBR is home to highly range-restricted avifauna, such as the Marsh prinia, Black breasted Parrotbill and the Jerdon's Babbler. While the area lies in the Indo-Burma global biodiversity hotspot, it is unique in the fact that **this area lies in proximity to the transition zone of the Eastern Himalaya and Indo-Burma biodiversity hot spots**. With the core literally forming an ecotone at the junction of two

major biodiversity hubs, it is needless to highlight the biodiversity facets it represents. This area is recognized as **a potential rhinoceros translocation site** under the Indian Rhino Vision 2020 (IRV 2020). Grassland of core area and the complex of tall wet grasslands and swamps make this ecosystem highly productive, diverse and conducive as a habitat for the rhinoceros.

3.2.4 THE CORE OF DIBRU-SAIKHOWA BIOSPHERE RESERVE

Core is being traversed by numerous rivulets and nullahs and Buffer is covered by River water of Brahmaputra, Luhit, Dibang, Siang, Dangori, Dibru and others. The **Gangetic Dolphin** (*Platanista gangetica*) is a major attraction of the River water of DSNP/DSBR which presents a unique value of the protected area. The Park is also known worldwide for the feral horses which were abandoned since the World War II. The Park hosts unique habitat of White Winged Duck, which is an endangered bird and is endemic to Assam. The core of the Biosphere Reserve is also a potential translocation site for the Eastern Swamp Deer (Barasingha) which is known to exist only in Kaziranga National Park (and now translocated to Manas National Park). This deer species, *Cervus duvauceli ranjitsinhi* is morphologically different from its north Indian *Cervus duvauceli duvauceli* and central Indian *Cervus duvauceli branderi.*

3.2.5 THE BUFFER OF DIBRU-SAIKHOWA BIOSPHERE RESERVE

The Buffer of DSNP/DSBR consists of **27 fringe villages** in addition to the areas originally notified as Wildlife Sanctuary in 1986. Most of the people are poor and below the poverty line and their problems are compounded by recurring floods in the region, which sometimes make agriculture a failure. The buffer along with the core forms an integral constituent of **the Dihing–Dibru-Saikhowa and Dibru-Deomali Elephant Corridor**, which has been cited as an important movement pathway for elephants. Elephants from Deomali Forest Division in Tirap District of Arunachal Pradesh are known to move around in the buffer of DSNP and Digboi area of Tinsukia district. It may well be concluded that the buffer forms a vital component of elephant migration route in the area, and with the elephant being a Scheduled I animal, the value of managing

the buffer assumes greater importance. The buffer along with the core is also significant in the fact that it forms an overlap for two major avian migratory flyways- the **East Asian** and **Central Asian Flyways**. The Maguri-Motapung wetland complex near the buffer in Guijan, in fact, is a haven for migratory birds.

3.3 Maguri Motapung Beel

Maguri-Motapung wetland[4] is an important International Bird Area (IBA). It is located in the buffer zone of Dibru-Saikhowa Biosphere Reserve and deserves special attention under Man and Biosphere Programme (MAB) of UNESCO. About 95% of the total human population of ~12,000 that inhabits within the bounds of the 10 adjoining villages is directly dependent on different bioresources of the wetland. Further, a large population with their livestock is residing in the periphery of the wetland and their livelihood is dependent on the finite resources of the wetland. The Maguri-Motapung Beel is located to the south of the Dibru-Saikhowa National Park (DSNP) between the geographical limits 27° 34’ 49.92”N to 27° 34’ 34.98”N and 95° 21’ 37.68”E to 95° 24’11.39”E in the upper Brahmaputra basin of Tinsukia district. It is a wetland complex which includes the Maguri *Beel* connected to the Motapung *Beel* and various drainage channels of rivers, Doomdooma river flowing in from the south east, and Dibru river flowing to the north west, that feed these water bodies seasonally. It is a cluster of several wetlands and feeder channels connecting them to nearby rivers that stretch up to Doomdooma from Guijan Ghat. It is an ‘open’ *beel* or wetland which is connected to the river Dibru. In the past, this wetland system was hydrologically connected to the Lohit River through its tributary called Dangori River as well as Dibru River. During 1990s the Dibru River started flowing through the Maguri Beel carrying water from the Dangori-Lohit combination due to avulsion of Lohit River. As a result, Maguri Motapung Wetland now acts as both lentic and lotic[5] system throughout the year. It shows characteristics of both a wetland and a river especially during the summer. In fact, the wetland is located in a region which is hydrogeomorphologically extremely dynamic region experiencing

4 ICIMOD, 2017, Maguri-Motapung Wetland Management Plan, 2017-2021, DC, Tinsukia
5 Lentic: Still water ecosystem; Lotic: Flowing water ecosystem

frequent changes in river channels and thus, an ever changing landscape. The wetland is rich in biodiversity, particularly in fishes, macrophytes and birds. The wetland fills up area of ~167.40 Ha at Full Storage Level (FSL) and ~117.18 Ha at Dead Storage Level (DSL). Maximum depth of Maguri was recorded as 4.3 m and depth at dead storage level is ~0.95 m. The length of the wetland ranges from 1850 to 2800 m and its breadth ranges from 640 to 800 m. This wetland system is separated from the Dibru-Saikhowa Nation Park by the Dibru River and sand bars during winter.

The Maguri-Motapung Beel is a 10 sq. km water body. Adjacent to the wetland there is also the Maguri and Koliapani grasslands spread across an area of ~10 sq. km. which are secure refuge for grassland birds. Maguri-Motapung Beel area is an important birding destination for tourists from across the world. The wetland complex is part of the Dibru-Saikhowa Important Bird Area (IBA IN-AS-13) and is located on the southern bank of the Dibru River, which is a tributary of the Brahmaputra. The Beel is connected to the Dibru River by a system of channels, and is very rich in aquatic life. The grasslands adjacent to the northern, and western, parts of the beel are an essential habitat for important grassland species. The main grass species here include: *Andropogan* species, *Arundinella bengalensis, Arundinella nepalensis, Narenga porphyrocoma, Saccharum reynaudiana, Saccharum arundinaceum, Saccharum procerum Saccharum spotaneum (Kohua), Arundo donax (Nal), Cynodon dactylon (Dubori), Imperata cylindrica (Ulukher), Erianthus ravennae* (Ikora), *Phragmites karka* (Khagori), *Themeda villosa, T. arundinacea, and Vetiveria zizaniodes* (Birina). Almost all the wetland bird species found in Dibru-Saikhowa National Park are reported to have been sighted here. Around 220+ species of birds have been recorded from the wetlands and grasslands of Maguri- Motapung. These include 3 nos. of Critically Endangered (CR) species such as Slender-billed Vulture, White–rumped Vulture and Baer's Pochard; 1 no. of Endangered (EN) species such as Yellow-breasted Bunting; 7 nos of Vulnerable (VUL) species such as Marsh Babbler, Swamp Prinia, Black-breasted Parrotbill, Swamp Francolin, Jerdon's Babbler, Lesser White-fronted Goose, Lesser Adjutant, and 12 nos of Near Threatened (NT) species such as Darter, Falcated Duck, Ferruginous Pochard, River Tern, Red-necked

Falcon, River Lapwing, Eurasian Curlew, Spotted Redshank, Black–tailed Godwit, Himalayan Griffon, Spot-billed Pelican and Black headed Ibis, White-browed Crake, Slaty-breasted Rail, Water Rail, Red Knot, Spot-winged Grosbeak, etc. as per recent sighting records.

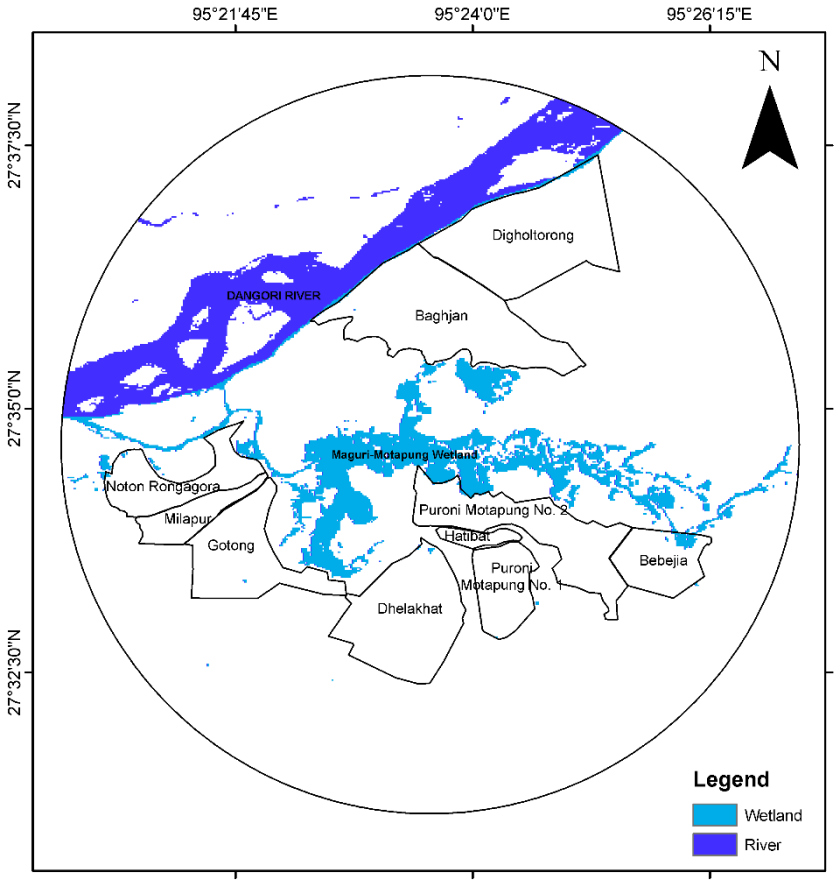


Fig. No. 3.2: Location of Maguri-Motapung Beel and the Ten Adjoining Villages

There are 21 villages within 6 km radius of the wetland centering the mid-point of the wetland on Dibru River near Puroni Motapung No. 2 village. Of these 21 villages, 10 villages (Baghjan, Dighaltarrang, Natungaon Rangagora, Milapur, Gotong, Dhelakhat, Purani Motapung No. 1 & 2, Habibat, Bebejia & Dhelakhat) were defined as fringe villages which are located within 3 km distance from the river/wetland bank. These fringe villages directly influence the health of the wetland as well as are affected by the wetland. These 10 villages fall under 4 Gaon Panchayats, 2 Blocks and 2 Revenue Circles.

3.3.1 Floral Diversity

Terrestrial Plant Diversity: A total of 122 plant species were listed from the terrestrial habitats adjoining to Maguri Motapung wetland. This includes 83 herbs, 17 shrubs, 18 trees, 2 climbers, 1 epiphyte and 1 bamboo species belonging to 58 families. *Poaceae* was the dominant family represented by 13 species followed by *Asteraceae* (10 species) and Cyperaceae (9 species). The rest of the 55 families were represented by species ranging from 1 to 6. Overall, the species composition comprised of 50 annuals and 72 perennials.

Aquatic Macrophytes: The Maguri-Motapung Beel supports a rich and diverse group of macrophytes which are used by the local inhabitants as food, for preparation of medicine and also as fodder. A total of 57 species of macrophytes belonging to 31 families and 43 genera were recorded. The wetland is dominated by the family *Polygonaceae* with 5 species, followed by *Poaceae* and *Hydrocharitaceae* each having 4 species.

Agricultural Crop Diversity: The villagers cultivate a large variety of agricultural, horticultural, vegetable and spice crops. At least 13 varieties of paddy are under cultivation .However, the area under paddy cultivation is decreasing over the years. The area under small tea gardens is gradually increasing by replacing orange cultivation due to commercial considerations. A large number of chilli varieties are also grown in the area. As per the Peoples' Biodiversity Register (PBR)[6] of the Hapjan Anchalik Panchayat Biodiversity Management Committee (BMC), the area boasts of 69 varieties/cultivars of rice, 12 species of oil seeds and spices, 6 species and cultivars of tuber crops, 18 species/ varieties of lentil & pulses, 103 species & varieties of vegetables, 32 species of fruiting plants, 13 nos of fodder species in addition to tea cultivation. The area also has recorded 13 species of weeds and 27 pest species (fauna). In all there are 81 types of fruits and almost 175 species of medicinal plants.

6 PBR of Hapjan Achalik Panchayat BMC, 2016, Assam State Biodiversity Board

3.3.2 FAUNAL DIVERSITY

Fish Diversity: Previous studies have reported a total of 84 fish species from Maguri-Motapung Beel, comprising of 48 genera and 23 families. Overall, *Cyprinidae* is the dominant family followed by *Bagridae, Channidae* and *Cobitidae*. Seven species of murrels are recorded from the area. Among the riverine fauna in the wetlands, Indian Major Carps (IMC), giant Catfishes and Featherbacks are frequently encountered while residential forms including air-breathing forms and ornamental species like *Botia, Barilius, Chanda, Danio, Glossogobius,* and *Tetraodon* are also found almost throughout the year. Most of the recorded fishes of Maguri-Motapung Beel, about 40%, fall under lower risk category from conservation point of view. Near Threatened category and Endangered category have 6 and 4 species respectively. Species such as *Amblypharyngodon mola, Aspidoparia jaya, Cirrhinus reba, Devario devario, Puntius sophore, Wallago attu, Chanda nama, Heteropneutes fossilis, Channa punctata, Mastacembelus* spp. and *Xenentodon cancila* were recorded throughout the year. On the other hand, *Catla catla, Cirrhinus mrigala, Labeo rohita, Puntius sarana sarana, Notopterus chitala, Gudusia chapra, Bengala elanga, Nandus nandus, Badis badis, Channa barca, Devario dangila, Botia dario, Ompok* spp. were occasional while genera such as *Anguilla bengalensis, Labeo calbasu, Ailia coila, Chaca chaca, Sisor rabdophorus* are rarely encountered. The fish *Clarias batracus*, locally known as M*agur* is alarmingly decreasing from the wetland, which was earlier abundant in the area.

Mollusc Diversity: A total of 26 molluscan species have been reported from the Maguri-Motapung Beel. Among these, *Sphaerium austeni* has been listed as Near-Threatened in the IUCN Red List, while majority of the species have been listed under Least Concerned category.

Bird Diversity: Maguri-Motapung Beel is known world over for its bird diversity. At least 220[7] bird species have been reported from the beel area earlier[8]. The avian diversity has

7 Gogoi D, Pkukan P J, Panging D K, Saikia A J, 2015, Birds of maguri Motapung, Parrotbill Publication, ISBN No. 978-81-937702-4-5.

8 www.cloudbirders.com/tripreport/repository/BARUAH_India_12_2010.pdf

already been described in the preceding paragraphs. The Maguri-Motapung Beel has been well established as the birders' paradise. Some of the rare sightings are mentioned here: Lesser White-fronted Goose in 2008, Baikal Bush Warbler in 2013 (this being the fist sighting in the Indian subcontinent), Eurasian Curlew and Common Crane in 2013, Dunlin, Ruff and Little Stint, Black-breasted Parrotbill, Great Bittern in 2014, White-bellied Heron in 2015, White-browed Crake (a new sighting for the whole of South Asia) in 2016, followed by sightings of Slaty-breasted Rail, Red Knot and Spot-winged Grosbeak.

Wetland Diversity: The Maguri-Motapung Beel contains several economically and culturally important plant and animal species. The villagers have high dependency on these resources. While fish and molluscs are consumed at household level by most of the families, most of the households depend on these aquatic resources for their livelihood. The plant species are used for various purposes such as handicrafts, building materials, food, fodder *etc.* A diverse group of macrophytes exist in Maguri-Motapung beel. The free floating forms are found to be more than any other growth forms affecting productivity. A good number of macrophytes have medicinal values whereas some others are used extensively as food and fodder, so that, these macrophytes play an important role in livelihood of local residents. Sustainable utilization of these hydrophytes and commercial cultivation of some of them will be beneficial for all concerned.

3.4 Bherjan Borajan Podumoni WLS

The Bherjan Borajan Padumoni Wildlife Sanctuary (BBPWLS) include three distinct and geographically disjoint Reserved Forest patches Bherjan RF (declared RF on 29th August, 1916), Borajan RF (declared RF on 29th August,1916) and Padumoni RF (declared RF on 20th March, 1916) situated in Tinsukia District in the State of Assam having an area of 1.06 sq. km, 4.39 sq. km. and 1.76 sq. km. respectively. The three Reserved Forests declared in the year 1916, totalling to 7.21 sq. km, were declared collectively a protected area on 13th October, 1999 vide Government of Assam Notification No. FRW-

47/99/66, Dt. 13-10-1999, as a single wildlife sanctuary unit. The sanctuary, in its three different and geographically separated patches, attracts primate populations especially Hoolock Gibbons and important primates like Slow Loris, Pig tailed Macaque, Assamese Macaque and other animals like Shrew, Chinese Pangolin, Jackal, Leopard Cat, Leopard including about 83 species of Forest dwelling birds. The sanctuary area has some very significant patches of remnants Assam Valley Tropical Wet Evergreen Forest (can be said as Rain Forest) interspersed with Eastern Seasonal Swamp Forest and Assam Alluvial Plains Semi Evergreen forests. This sanctuary area has the principal categories of fauna which inter alia include 24 species of mammals like Short-tailed Mole, Shrew, Capped Langur, Leopard, Barking Deer, Porcupine, also includes 83 species of birds such as Pond Heron, Cattle Egret, Great Hornbill, Woodpeckers, Asian Barred Owlet, Bronzed Drongo, Daurian Redstart to mention a few. The BBPWLS is known for the primates. We shall dwell a while more on the subject.

The six diurnal primate species (Assamese Macaque, Rhesus Macaque, Pig-tailed Macaque, Stump-tailed Macaque, Hoolock Gibbon and Capped Langur) in Bherjan Borajan Padumoni WLS appear to exhibit variable responses to fragmentation over time[9]. The Joolock Gibbon, a highly arboreal species, was lost more than 40 years ago in Podumoni as per Choudhury (1996)[10] and since 2005 in Bherjan. Capped Langurs, which were present in all the fragments of Upper Brahmaputra Valley 30 years ago, went extinct in all small fragments. However subsequent recolonization had been recorded in both Bherjan (three males) and Podumoni (a troop of eight) as per Sharma et. al (2012)[11]. During the last 16 years overall primate abundance declined by 56% and 89% in Bherjan and Borajan, respectively, whilst in Podumoni the Assamese and Pig-tailed Macaques went extinct. Except the Pig-tailed and Rhesus Macaques all the other

9 Sharma, N., Madhusudan, M.D. and Sinha, A., 2014. Local and landscape correlates of primate distribution and persistence in the remnant lowland rain forests of the upper Brahmaputra Valley, Northeastern India. *Conservation Biology*, *28*(1), pp.95-106.

10 Choudhury, A., 1996. Primates in Bherjan, Borajan and Podumoni Reserved Forests of Assam, India. *Asian Primates*, 5, 10–11.

11 Sharma, N., Madhusudan, M.D., Sarkar, P., Bawri, M. and Sinha, A., 2012. Trends in extinction and persistence of diurnal primates in the fragmented lowland rainforests of the Upper Brahmaputra Valley, North-eastern India. *Oryx*, *46*(2), pp.308-311

primate species might become locally extinct from the area if the biotic pressures continue as the other species are restricted to forest interiors as per Roonwal & Mohnot (1977)[12]. Fragmentation of the forest patches have already divided the original populations of these primates into several sub-populations which has resulted from the loss of larger proportion of food and roosting trees in these fragments in addition to a greater disruption of canopy contiguity. Due to decrease in habitat area and increase in isolation from source populations they are exposed to direct and indirect threats which are likely to have serious effect on the demography of the remaining primate populations in these fragments (*N. Sharma unpublished data*).

Apart from these, the three patches are also an Important Bird Area (IBA) harbouring 84 species of birds along with three threatened species, the Lesser Adjutant Stork and two species of Gyps Vultures as per Choudhury (1995)[13]. The Upper Brahmaputra Valley is an important area for the vulture species. As these species are scavengers and if they feed upon the dead organisms, the hydrocarbons might enter into their food chain.

3.5 Dibru-Saikhowa National Park Wildlife Management

The Tinsukia Wildlife Division, which started functioning from 7th June, 1989, with its headquarters at Tinsukia, is the authority under the Wildlife Wing of the Assam Forest Department vested with powers to look after the management of the Dibru-Saikhowa National Park and Biosphere Reserve, and the Bherjan Borajan Padumoni WLS. It is headed by an officer of the rank of Deputy Conservator of Forests, aided by an ACF and two Range Officers, one each at Guijan Range and Saikhowa Range. The areas outside the Protected areas are looked after by the DFO, Dibrugarh Forest Division under which the Tinsukia Forest Range looks after areas such as Maguri-Motapung Beel etc.

12 Roonwal, M. L., and Mohnot, S. M., 1977. Primates of south Asia: ecology, sociobiology, and behavior. Harvard University Press, Cambridge, Massachusetts

13 Choudhury, A. U., 1995. Wildlife Survey in Bherjan, Borajan and Podumoni Reserved Forests of Tinsukia District, Assam, with a proposal for a Wildlife Sanctuary. The Rhino Foundation for Nature in NE India, Guwahati, India

3.5.1 ANTI POACHING CAMPS

The two ranges under the Tinsukia Wildlife Division have a number of Anti Poaching Camps (APC) under them. The APC position is given below:-

Guijan Range: The Guijan Range is the main range of Tinsukia Wildlife Division for entering into the Dibru-Saikhowa National Park. It is located on a low-lying plot of land adjacent to the Dibru river (may also be now called Lohit) near Guijan Ghat. The range office is located in a low lying area next to the Ghat and is very prone to flooding. Flood waters often flood the range and disrupt normal functioning. The anti poaching camps under the Guijan Range are:

1. Kothalbam Anti Poaching Camp
2. Kundaghat Anti Poaching Camp
3. Kolomi Anti Poaching Camp
4. Baluchar Anti Poaching Camp (Damaged/ repairable).
5. Lonka Anti Poaching Camp
6. Horali Floating Anti Poaching Camp
7. Ulumora Floating Anti Poaching Camp

The Guijan Range also looks after the Bherjan Borajan Padumoni WLS. To manage the sanctuary, there are, as of now, two anti poaching camp, namely, Podumoni APC and Bajaltoli APC in Podumoni, Borajan and Jutulibari Camps in Borajan, and Bherjan and Chandmari APC in Bherjan part of the Sanctuary.

Saikhowa Range: The Saikhowa Range is housed a few kilometers west of the Saikhowa Ghat, which is also the eastern most end point of the NH37 - considered to be the lifeline of the Upper Assam. The Park boundary, which is an old embankment, is adjacent to the Range office. The, now famous and newly built, Dhola Sadiya bridge is about 3-4 km east of Saikhowa. The anti poaching camps under the Saikhowa Range are:-

1. Kolia Anti Poaching Camp
2. Paglum Anti Poaching Camp
3. Holockbari Anti poaching Camp
4. Dolphin Floating Anti Poaching Camp
5. Deohanh Floating Camp

The Deohansh APC is a mechanized boat which is damaged and unserviceable.

3.5.2 CAMPS, OTHER INFRASTRUCTURE AND STAFF

The DSNP has 8 stationary camps and 4 floating camps, 2 doogdoogi and 8 small boats. The Park is facing huge shortfall of boats and camps. Most of the camps are not in good

condition and in monsoon season the conditions becomes inhospitable and much worse for the staff. The Park requires immediate attention towards betterment of the existing condition of camps and floating camps. Staff inside the Park is not only facing lack of amenities but also the threat of being washing away during monsoons. As almost all the area of DSNP submerges in flood waters, adequate numbers of boats are necessary for round the year patrolling. Even after receding of the water, foot patrolling is very difficult as the sediment on the ground remains wet and slushy. In this scenario, the non availability of boat is a huge challenge for management of the Park. Anti poaching operations are severely impacted throughout the year, and this leaves a big question mark on the protection of the Park from poachers and illegal timber smugglers. The number of anti poaching camps also needs to be intensified manifold. The present number of anti poaching camps is highly inadequate for proper protection.

Staff Position: Currently, the Tinsukia Wildlife Division has 11 Foresters Level-1, 28 Forest Guards, 4 Game-watchers (2 on deputation) and 7 Fixed Pay (2 on deputation). The poor strength of frontline staff is a very serious concern in DSNP. Being an important National Park of the State, adequate staff should be there for patrolling and protection duties. Additional staff, at least three times the existing number needs to be deployed for the protection of the Park.

Laika Dadhia: Two Forest villages namely Laika FV and Dadhia FV were established in 1951-52 and 1956-57 within Dibru Reserved Forest and Saikhowa Reserved Forest under Dibrugarh & Doomdooma Forest Divisions respectively. The **sanctioned area of Laika FV is 238 ha and that of Dodhia FV is 135 ha** as per notification of Dibru-Saikhowa Wildlife Sanctuary. In 1986, by amalgamating both the Reserve Forests, a Wildlife Sanctuary was constituted namely Dibru-Saikhowa Wildlife Sanctuary with an area of 340 sq km by keeping the two Forest Villages inside the Sanctuary. During 1999, the entire area of 340 sq km was declared as Dibru–Saikhowa National Park. The population of these FVs according to 2019 census is 6865 (1480 Nos. of households). The DSNP is a highly dynamic ecosystem. During this monsoon season (year 2020) the Siang River sifted its course in the range of 0.88 -1.44 km in the surveyed forest village areas. The Siang River is now falling directly into Kolomi River. This has caused large destruction in Laika Forest Village. Houses have been damaged and many villagers have shifted to the

nearby areas in the core area of DSNP. A proposal has been submitted to Govt of Assam for relocation of these Forest Villages. The Government is very serious in settling the two villages outside the Park, and it is hoped that the issue of Laika and Dadhia FV would be would be fully resolved in a very short period of time, thanks to the very positive set of actions taken by the Government of Assam, the District Administration and the Forest Department. Thereafter, once the villagers leave the Park fully, the Park needs to be consolidated with additional areas, and should be restored to its original area of 650 sq km at the least. The Park ecosystem is totally riverine and would need a large area to ensure survival of large mammals during the floods. It may also require shifting of a few hundred households on the periphery of the Park, especially the Erasuti village which is on the Park side, north of Dibru river and the inhabitants have been facing serious issues of erosion and inundation. Similarly a few households fall on the eastern side of the Park boundary occupying the originally surveyed areas where even the boundary pillars were found during the boundary survey of the Park at the time of Baghjan ecological assessment. Some of the starting boundary pillars appear to be under encroachment. However, a detailed consolidation survey needs to be conducted, as the landmarks and position of certain streams and locations have changed considerably beyond recognition since 1986 and 1999. Thereafter, the national Park may be renotified.

3.6 Baseline Biodiversity Assessment By EIA

M/s Oil India Ltd. carried out two Environmental Impact Assessment (EIA) studies, one in 2009 by experts from the Gauhati University, and the secondly in 2019 by a private expert consulting group for obtaining Environment Clearance (EC) of the drilling projects sites around Baghjan. It was conventional drilling of more than 25 drill sites (which included the blowout site) in 2009 and 7 Extended Reach Drilling (ERD) below the sub surface of the Dibru-Saikhowa National Park in 2019. The two EIA reports have been quoted extensively in thie Report and referred to as EIA-GU (2009) and EIA-ERM (2019). Under these EIA studies, the expert teams carried out sampling and baseline studies in the area. It is to be noted that the EIA-GU (2009) was spread over a wider area covering

49 oil wells, and the EIA-ERM (2019) covered only 7 wells around Baghjan. A brief snapshot is presented from both the studies in respect of biodiversity assessment. Common information lifted from the Forest Working Plans and Wildlife Management Plans and incorporated in these EIA reports are not mentioned here.

3.6.1 BIODIVERSITY ASSESSMENT BY EIA-GU (2009)

The study recorded various plant and animals species distribution. These are being selectively shown here.

Wasteland Vegetation: The wasteland vegetation was found to be devoid of tree species but mainly dominated by herbs, shrubs, creepers and climbers. The common species found were: *Cynodon dactylon, Leucas plukenetii, L. aspera, Leonurus sibiricus, Cuscuta reflexa, Ipomea sp.,Cassia tora, Cassia sophera, Mimosa pudica, Cynodon dactylon, Croton bonplanadium, Parthenium sp, Spilanthes paniculata, Scoparia dulcis, Alocasia indica, Phyllanthus niruri, Solanum nigrum, Solanum indicum, Solanum torvum, Xanthium strumarium, Polygonum chinense, Polygonum sp., Physalis minima, Solanum khasianum, Eupatorium odoratum (Chromolaena odorada)* etc.

Epiphytic Plants: Other than common epiphytic orchids, the area was found to be rich in pteridophytes, mosses and lichens. Foliose and crustose types of lichens were observed most commonly. The species encountered were: *Parmelia* spp, *Lecanora* spp, *Dirinaria* spp, *Graphis* spp and *Cryptothecia* spp.

Cryptogamic Species: Pteridophytes, bryophytes, algae and fungi represent this group. Pteridophytes, bryophytes and algae normally prefer moist or aquatic habitats. Common terrestrial pteridophytes found were *Azolla pinnata, Dryopteris spp., Adiantum spp., Pyrrosia spp., Pteris cretica, Pteridium aquilinum, Lygodium spp. and Selaginella spp*. Bryophytes and fungi are less frequently observed in comparison to pteridophytes. Only two species of bryophytes, viz., *Marchantia* and *Polytrichium*, were available during the study period, while fungi observed belonged to the genera of *Polyporus, Polystictus, Agaricus, Lycoperdon* and *Peziza*. Powdery mildew (*Oidium* sp.) and microfungi causing leaf spot disease were occasionally observed on leaves of certain plants. *Spirogyra, Anabaena* and *Spirulina* were the common algae recorded from stagnant water bodies. Red algae (Cephaleuros sp) was occasionally recorded on tea leaf.

Rare Plants and Medicinal Herbs: Some of the rare plants and trees observed were *Cedrela toona, Mesua ferrea, Duabanga sonneratoides, Sapium baccatum, Litsea glutinosa, Bischofia javanica*. Rare medicinal plants observed: *Abrus precatorius, Abuliton indicum,*

Clerodendrum indicum, Hibiscus abelmochus, Bryophyllum pinnatum, Costus speciosus, Oroxylum indicum, Terminalia arjuna, Antidesma bunius, Persicaria hydropiper, Alternanthera phyloxeroides, Alisma plantago, Enhydra fluctuans, Ipomea aquatica, Lasia spinosa, Ludwigia adscendens, Jussiaea repens, Rare ornamental plants included: *Sansevieria roxburghiana, Gladiolus illyricus, Jasminum sambac, Acalypha hispida, Murraya exotica, Gardenia jasminiodes, Kaempfera rotunda, Amorphophallus paeoniifolius, Annona squamosa, Garcinia xanthochymus, Baccaurea sapida,. Aquilaria agallocha* was once endemic and endangered plant in the wild, now widely cultivated.

Bamboos & Canes*: The bamboo species found were: Bambusa arundinacea, Bambusa vulgaris, Bambusa tulda, Bambusa balcooa, Bambusa nana.* The canes are*: Calamus viminalis, Calamus flagellum, Calamus rotang.*

Orchids*: Rhynchostylis retusa, Vanda roxburghii, Aerides rosea, Dendrobium fimbriatum, Vanda teres, Cymbidium spp, Dendrobium spp.*

Mammals*:* Two populations of elephants, one from north bank and one from south bank are reported based on secondary literature. Population estimate is not available. Gaur in UDRF (West Block) is reported with population estimate of less than 100. Population of wild buffaloes was estimated at 400. These are all based on secondary literature. Presence of tigers, leopards, clouded leopard also reported from the Park and adjoining areas. Leopards are reported from other areas too. Other carnivores include Leopard Cat, Jungle Cat, Fishing Cat, Asiatic Jackal, Small Indian Civet, Common Palm Civet, Large Indian Civet, Small Asian Mongoose, Indian Grey Mongoose, Common Otter and Smooth-coated Otter.

Among the primates, the Bherjan Borajan Podumoni WLS is a rich habitat where atleast 6 species of primates are present. Slow Loris, Pig-tailed Macaque, Rhesus Macaque, Assamese Macaque, Capped Langur and Western Hoolock Gibbon are found in vatrious parts of the BBP WLS. These primate species are also found in the DSNP. In Dihing Patkai WLS, (and UDRF West Block), Stump-tailed Macaque is also found.

Special mention must be made of the Gangetic River Dolphin about which the EIA Report is totally silent.

Avifauna: The EIA survey team in 2009 found 126 species of birds. The DSNP is a rich habitat of White Winged Duck. In the IUCN critically Endangered list are White-rumped Vulture, Slender-billed Vulture and Bengal Florican. Some of the IUCN Endangered category birds are the Greater Adjutant Stork, Lesser Adjutant Stork, Swamp Francolin, Palla's Fishing Eagle and Great Horned Owl. The Oriental Darter, Grey-headed Fish

Eagle, Sparrow Hawk, Blyth's Kingfisher are nearly threatened. A detailed list of avifauna of the area has already been discussed, and the same is not repeated here.

Herpetofauna: The EIA-GU (2009) provides a checklist of 10 amphibia and 35 species of reptiles, including 17 snake species, 8 lizard species, 10 species of turtles and tortoises. Of these, the Asiatic Rock Python, the Red-necked Keelback and Monitor Lizard are of conservation concern in the area. Similarly 6-10 Chelonians are also of conservation concern.

Fish: Catch based surveys were carried out in the lotic water bodies of Dibru river, Tengrai river and Brahmaputra river. The study found 8 species of threatened category fish fauna in the study area. These include the Indian Longfin Eel, Olive Barb, Bengal Barb, Gangetic S*cissortail rasbora*, Assamese King Fish, Gangetic Gonch, Gonch and Barca Snakehead. Of the checklist, 59 species were found nearly threatened, and 40 species were found to be in vulnerable category from conservation point of view.

Butterflies: The only invertebrates to be studied were the butterflies during the faunal survey. A total of 63 species were recorded. Of these 10 species were found rare, among them being White Dragontail, Green Dragontail, Yellow Helen, Common Peacock, Sixbar Swordtail, Green Windmill, Rose Windmill, Lesser Jay, Metallic Caerulean and Great Duffer.

3.6.2 Assessment of Biodiversity by EIA-ERM (2019)

The consultants carried out baseline and primary survey by way of sampling to identify floral and faunal species in terrestrial and aquatic habitats. The habitats covered for sampling were tea plantations, homestead plantations and riparian vegetation. They carried out sampling with 10x10m plot for tree species, 5mx5m for shrubs, 1mx1m for herbs and grasses. They also worked out Shannon Weiner Index, Species Richness and Important value Index for plant species.

Other than what is contained already in management plans and working plans for these areas, and the EIA-GU (2009), the additional inputs made available in the EIA-ERM (2019) are presented below:-

Roadside Plantations: Some of the species found in roadside plantations are: *Alstonia scholaris, Aegle marmelos, Melia azedarach, Artocarpus heterophyllus, Bombax ceiba, Ficus religiosa, Lagerstroemia speciosa*.

Homestead Plantations: Some of the important tree species in homestead were found to be: *Mangifera indica, Melia azedarach, Aegle marmelos, Delonix regia, Ficus religiosa,*

Syzigium cumini, Gmelina arborea, etc. [In addition, the homestead gardens have betel leaf, coconut, areca palm, *Piper longum, Piper nigrum*, and a variety of herbs and shrubs, Banana plants, Bamboos, Narasingha, Jetuka etc. are also widely planted and cultivated. Further, several homesteads in these areas have been found to have homestead tea gardens in the small tea grower category.]

Tea Gardens: In tea gardens, there are several shade trees especially *Albizia sp. Cassia siamea, Gmelina arborea, Shonka arvenis, Artocarpus heterophyllus*.

Riparian Vegetation: The vegetation along river banks was found to be: *Anthocephalus sinensis, Alstonia scholaris, Bombax ceiba, Ficus hispida, Syzygium cumini* etc.

Floral Diversity: In all, 274 number of plant species were identified and reported including 152 tree species, 53 shrubs and herbs, 12 species of climbers, 19 species of grasses, 38 species of epiphytes.

Species Richness and Diversity Index: The species richness, Shannon Weiner Index were calculated for the sampled areas. These are given in Table No. 3.1.

Table No. 3.1: Biodiversity Indices by EIA-ERM (2019)

S No.	Habitat Type	Total no. of Plots Studied	Species Richness	Shannon Weiner Index (H')
1	Tea Plantation	8	21	1.02
2	Homestead Plantation	10	44	3.00
3	Riparian Vegetation	5	21	1.71
4	Bamboo Brake	1	3	0.01

Aquatic Ecosystem: Other than the main river systems such as the Lohit, Dibru, Dangori, Siang and Brahmaputra rivers, the other river channels are: Kolomi, Salbeel, Dadhia, Chabrujan, Laikajan, Antanala, Dimoruhola and Nayanadi within the Dibru-Saikhowa National Park. On the southern part lies the Maguri Motapung wetland in which also drains the Doomdooma river. A detailed study of macrophytes and Planktons were done. The findings are briefly presented below:-

Macrophytes: The most dominant macrophytes encountered during the survey are *Eichhornia crassipes, Polygonum hydropiper, Ranunculus sceleratus, Azolla pinnata, Cleome hassleriana, Pistia stratiotes, Ipomoea fistulosa, Trapa natans, Salvinia perpusilla, Phragmites karka*,. A total of 10 species of aquatic macrophytes were recorded from these aquatic ecosystems.

Planktons: The phytoplanktons recorded: *Navicula spp., Nitzschia spp, Coelastrum, spp., Coscinodiscus sp. Chlorella spp., Phacus spp., Spirulina sp., Scenedesmus sp., Spirodella sp., Spriogyra spp., Anabaena spp.* The Zoo planktons recorded: *Brachionus quadridentatus, Keratella cochlearis, Lecane luna, Lepadella patella, Filinia longiseta, Alona quadrangularis, Moina micrura, Mesocyclops leuckarti, Asplanchna priodonta, Brachionus angularis, Euchlanis dilatata, Lecane bulla, Hexarthra mira, Bosmina longirostris, Ceriodaphnia cornuta, Macrothrix spinosa, Diaphanosoma sarsi, Tropocyclops prasinus, Heliodiaptomus viduus*.

3.7 Environmental Management Plan (EMP)

The Environmental Management Plan under the aegis of the EIA-ERM (2019) starts from Page No. 175 and ends somewhere unceremoniously on or before Page 212. The EMP under the EIA-GU (2009), under Chapter V, is slightly better structured though it runs a little shorter than that of EIA-ERM (2019), from page 197 to 209. So much care well taken of the emergencies that may arise, and the environmental concerns that may need addressing. In a nut shell, the Environment Management Plan are very poorly planned in both the documents and do not have any contextual validity. None of the EIA reports talk of any possible ecological disaster/ major accident that the drilling activities may cause accidentally. There is no What-if scenario analysis on environmental risks that the projects would pose in event of a major accident. None of the EIA reports foresee any major environmental fall out of the drilling projects under consideration.

3.8 Emergency Response Plan (ERP)

The Emergency Response Plan and the Environment Management Plan presented in EIA-ERM (2019) are just wrapped up in a few pages 198-212 with a budget of Rs. 11.22 lakh per well, totalling to Rs. 78.54 lakh for the 7 proposed wells under the ERD scheme. It is not understood what aims and objects the EIA consultants, M/S OIL and the Regulating authorities are trying to achieve with such an ERP and EMP. It was found that EMP & ERPs are unprofessionally designed and serve little or no purpose, whatsoever. It should be a matter of research by the oil drilling companies and Ministry of Petroleum & Natural Gases (MoPNG) as to how much they actually benefited from the EIA documents, EMPs and ERPs at the time of this great crisis of the Baghjan blowout. Surely, these documents might not have even been referred to by the OIL authorities and their owners during the instant crisis. It can also be said that very few among the regulators and the OIL companies/ Ministries concerned would have anything to derive from these documents to relay to the ground. [*This enquiry found that*

these documents even do not serve even the purpose of a baseline document fully]. Therefore, these are documents prepared at huge costs just as a mandatory requirement for the EC from the MoEF&CC without any practical use of them thereafter. Neither the users nor the Regulators have any use of these documents afterwords [*after the consultants have prepared it and the EC been granted*]. None of the EIA reports mention any impact on the environment, flora and fauna, biodiversity and ecosystems and ecosystem services that may arise from any possible accidents happening at the project sites.

3.9 Conclusions

1. The Dibru-Saikhowa National Park and adjoining ecosystems of Maguri Motapung Beel, Dibru river etc. which comprise of grasslands, wetlands, river systems and wet evergreen forest formations are very rich in biodiversity and form a network of unique ecosystems.
2. Many Scheduled I species listed under the Wildlife (Protection) Act, 1972 and as per IUCN criteria such as Critically Endangered, Endangered, Vulnerable, Threatened, Nearly Threatened are found in these habitats including mammals, avifauna, fishes, herpetofauna, butterflies etc.
3. These ecosystems are home to some very rare and endangered fauna such as White Winged Duck, Capped Langur, Feral Horses, rare fish, birds and reptiles.
4. The Laika and Dadhia villages should be relocated. The Dibru-Saikhowa National Park should be re-consolidated with additional areas.
5. The EIA reports prepared for M/S OIL India Ltd for the two projects were found to be highly deficient in Emergency Response Management and Environmental Management Plans. These deficiencies render the EIA document of little consequence in wake of a major accident or ecological disaster. The overall quality of the EIA Reports was found to be very poor and wanting in many respects. There is an urgent need to change all these “run of the mill” processes which do not serve any real purpose.

CHAPTER-4

4 SITUATION ANALYSIS: OIL, OIL SPILLS & BLOWOUTS

4.1 Outline Of The Chapter

The Chapters 4 and 5 are the two chapters that dwell upon the "Pollutor" and the laws governing "Pollution". While Chapter 4 is an introduction on M/s OIL, the PSU, behind the Baghjan blowout, Chapter 5 is on the legal provisions possibly applicable to the Baghjan disaster and the accompanied situation.

The Chapter 4 shall, very briefly dwell upon the oil company that owns the Baghjan well BGN#5 i.e. M/S Oil India Ltd. (OIL in short), its owners. It also dwells briefly upon their financial conditions. Thereafter, it dwells upon oil imports and production, usage of energy and the associated issue of climate change. Then, it moves on to oil wells and blow outs, blowout frequencies and historical data. At the end, chronology of major incidents associated with the Baghjan blowout has been provided.

4.2 A Brief Account Of M/S Oil India Ltd. (OIL)

M/S Oil India Ltd was born on 16th February, 1959 at Duliajan as a joint venture company between Burma Oil Company Ltd (also the parent of the then Assam Oil company, AOC that ran the first refinery of Asia at Digboi) with two third stake and Government of India with one third stake. The company went public in 1961 and in 1981 was nationalized with 100% Government of India stake. M/s Oil India Ltd (OIL) has a very chequered and interesting journey all the way from 1959 to 2020, just about 61 years and 9 months old, and is a Navaratna company of the Government of India.

Today the Company is engaged in the business of exploration, development and production of crude oil and natural gas, transportation of crude oil and production of LPG. M/s OIL also provides various oil and natural gas exploration and production related services and holds 26% equity in Numaligarh Refinery Ltd. (NRL). The Authorized share capital of the Company is Rs. 2000 Crores. The Issued, Subscribed and Paid share capital of the company is Rs. 1084.41 Crore. At present, the Government of India, the Promoter of the Company is holding 56.66% of the total Issued & Paid-up Capital of the Company. The balance 43.34% of the Equity capital is held by Public and others including Bodies Corporate, Mutual Funds, Banks, FPIs, Resident Individuals etc. M/s OIL has over 1 lakh sq km of PEL/ML areas for its exploration and production

activities, most of it in the North East India, which accounts for its entire crude oil production and majority of gas production. Rajasthan is the other producing area of OIL, contributing 10 per cent of its total gas production. Additionally, OIL's exploration activities are spread over onshore areas of Ganga Valley and Mahanadi. M/s OIL also has participating interest in New Exploration Licensing Policy (NELP) exploration blocks in Mahanadi Offshore, Mumbai Deepwater, Krishna Godavari Deepwater, etc. as well as various overseas projects in Libya, Gabon, USA, Nigeria, Sudan. Venezuela, Russia, Israel, Mozambique etc. not only oil fields but also oil pipelines. It holds about 56,900 sq km of mining lease areas in India.

4.2.1 SHAREHOLDING OF OIL

As per the Annual Report of M/S OIL for 2018-19, the shareholding pattern is as follows:-

Table No. 4.1: Shareholding of M/S OIL

Key shareholders	% Shareholding
Government of India	66.13
Life Insurance Corporation of India	10.88
Indian Oil Corporation Ltd.	4.71
Bharat Petroleum Corporation Ltd.	2.36
Hindustan Petroleum Corporation Ltd.	2.36
ICICI Prudential Life Ins. Co. Ltd.	1.15
TOTAL	**87.59**

The rest of the shareholding 12.41% is in other hands and sundry shareholders.

4.2.2 FINANCIAL STANDING OF THE SHAREHOLDERS

The basic financial strengths of the stakeholders is proposed to be seen in terms of the annual budget size for the Govt. of India in the MoPNG, and revenues/ income/ Profit before tax and profit after tax for the companies holding shares in M/S Oil India Ltd. All figures taken from Annual Reports of the companies available in public domain. All figures are for 2018-19 and 2017-18 financial years. All figures are in Crore Rupees.

MoPNG: The Ministry of Petroleum and Natural Gas (MoPNG) is one of the largest ministries that handles the mineral oil and natural gas resources of the country. It has under its umbrella some of the largest and highest profit making Public Sector Undertakings of the country who now have been able to develop strong stakes even overseas in oil exploration, pipelines and refining. The Ministry owns twelve such entities, in addition to almost 10 entities dedicated to non production and non manufacturing services such a quality control, training and capacity building, safety, energy conservation etc. The Ministry also runs some of the largest Direct Benefit Transfer schemes in the country such as subsidies to the rural and urban poor on LPG cylinders etc. The Budgetary estimates of the Ministry, other than transfers to the States, can be divided in two category: firstly, the budgetary estimates (profits) of the oil companies owned by the Ministry, and secondly, the budgetary estimates for running its various schemes and ways and means expenditure.

The Central Ministry Budget of MoPNG for 2018-19 was Rs. 27,216.04 Cr, and the Internal & External Budgetary Resources (IEBR) for the Central Oil PSUs stood at Rs. 89,335.09 Cr for 2018-19. The actual expenditure on account of the IEBR stood at Rs. 100,309 Cr. for 2018-19. The IEBR for the CPSUs was Rs. 93,639 Cr for 2019-20.

LIC: Life Insurance Corporation of India (LIC) holds 10.88% share into the Oil India Ltd. It was set up as a **Statutory Corporation established by an Act of Parliament- LIC Act 1956.** LIC continues to be a market leader in the insurance sector with 66.24% of total market share in Total First year Policies and 74.71% in New Policies. The company is profit-making and its profit statements for 2018-19 and 2017-18 are given below:-

Table No. 4.2: Profits of M/S LIC

Profits	**2018-19**	**2017-18**
Before Tax	2703.48	2459.42
After tax	2688.50	2446.41
Assets	3,665,743.00	3,313,049.00

IOCL: Indian Oil Corporation Ltd. (IOCL) holds 4.71% of stake in Oil India Ltd. it is a Govt. of India undertaking with currently 52.1% shareholding. It ranks 117th in the Fortune Global 550 List. IOCL owns 11 of the 23 oil refineries in India. Now it also owns the Assam Oil Company (AOC) at Digboi, the oldest refinery of Asia. The company is profit-making and its profit statements for 2018-19 and 2017-18 are given below:-

Table No. 4.3: Profits of M/S IOCL

Profits	2018-19	2017-18
Before Tax	25127.00	32564.00
After tax	16894.00	21346.00
Gross Revenue	605,924.00	506,428.00
Assets	313,873.00	279,449.00

BPCL: Bharat Petroleum Corporation Ltd. (BPCL) owns 2.36% of the stake of M/S Oil India Ltd. BPCL is a Govt. of India company with 52.98% shares (while its roots go back to Scotland in 1886). It is India's second largest oil company and ranks 275th in the Fortune Global 500 list of companies of the world. The company is profit-making and its profit statements for 2018-19 and 2017-18 are given below:-

Table No. 4.4: Profits of M/S BPCL

Profits	2018-19	2017-18
Before Tax	10,439.62	11,285.97
After tax	7132.02	7976.30
Gross Revenue	340,879.15	279,437.99
Assets	136,714.00	97,601.00

HPCL: Hindustan Petroleum Corporation Ltd. (HPCL) owns 2.36% share of M/S Oil India Ltd. HPCL was incorporated in 1974 and after a long journey, now, ONGC holds 51.11% stake in HPCL. It is also listed at 367th rank in the Fortune Global 500 list. The company is profit-making and its profit statements for 2018-19 and 2017-18 are given below:-

Table No. 4.5: Profits of M/S HPCL

Profits	2018-19	2017-18
Before Tax	13077.21	12521.39
After tax	6028.66	6357.07
Gross Revenue	295,712.56	243,226.66
Assets	62579.27	51508.29

ICICI: ICICI Prudential Life Life Insurance Ltd. (ICICI) owns 1.15% of shareholding in Oil India Ltd. ICICI is held with 52.87% stake by ICICI Bank Ltd. The company is profit-making and its profit statements for 2018-19 and 2017-18 are given below:-

Table No. 4.6: Profits of M/S ICICI Prudential

Profits	2018-19	2017-18
Before Tax	1727.89	1833.60
After tax	1140.65	1719.56
Gross Revenue	1729.89	1833.60
Assets	3335.94	2714.02

4.2.3 Financials and Profitability of OIL

The Company had an income flow of Rs. 13,700 cr in 2018-19, and a profit of Rs. 2590 cr. The profit before and after tax of the Company for last 5 years from 2018-19 is given below:-

Table No. 4.7: Profits of M/S OIL

Profit	2018-19	2017-18	2016-17	2015-16	2014-15
Before Tax	3962.22	3709.80	2146.32	3440.50	3728.70
After Tax	2590.14	2667.93	1548.68	2301.67	2510.20
Networth	22967.31	22745.31	23201.75	22802.26	21497.59
Assets	47465.30	44034.18	45339.55	39149.20	36227.12
Revenue	15170.00	12440.64	11191.07	11158.63	11019.86

4.3 Oil Well Drilling And Production

As per the 2018-19 Annual Reports of the Company, which is available in public domain, OIL produces more than 3 million metric tons (MMT) of crude oil and more than 2800 million metric standard cubic meters (MMSCM) of natural gas. During 2017-18, it produced more than 2900 MMSCM of natural gas. M/s OIL owns in the domestic market 44 blocks under various lease categories (such as PML / PEL/ NELP / DSF/ OALP[14]) with a total area of 22,647 sq km. They also own internationally 13 oil & natural gas blocks with a total area of 44,675 sq km. m/S OIL has know how and experience end to end in the oil and natural gas exploration and production. They own also pipelines about 5000 km in length and hold almost 1.90 lakh Kilo Litre of crude oil storage capacity.

14 PEL: Petroleum Exploratory Lease; PML: Petroleum Mining Lease, NELP: New Exploration Licensing Policy; DSF: Discovered Small & Marginal Fields; OLAP: Open Acreage Licensing Policy

4.3.1 Mining Lease Assets of OIL In India

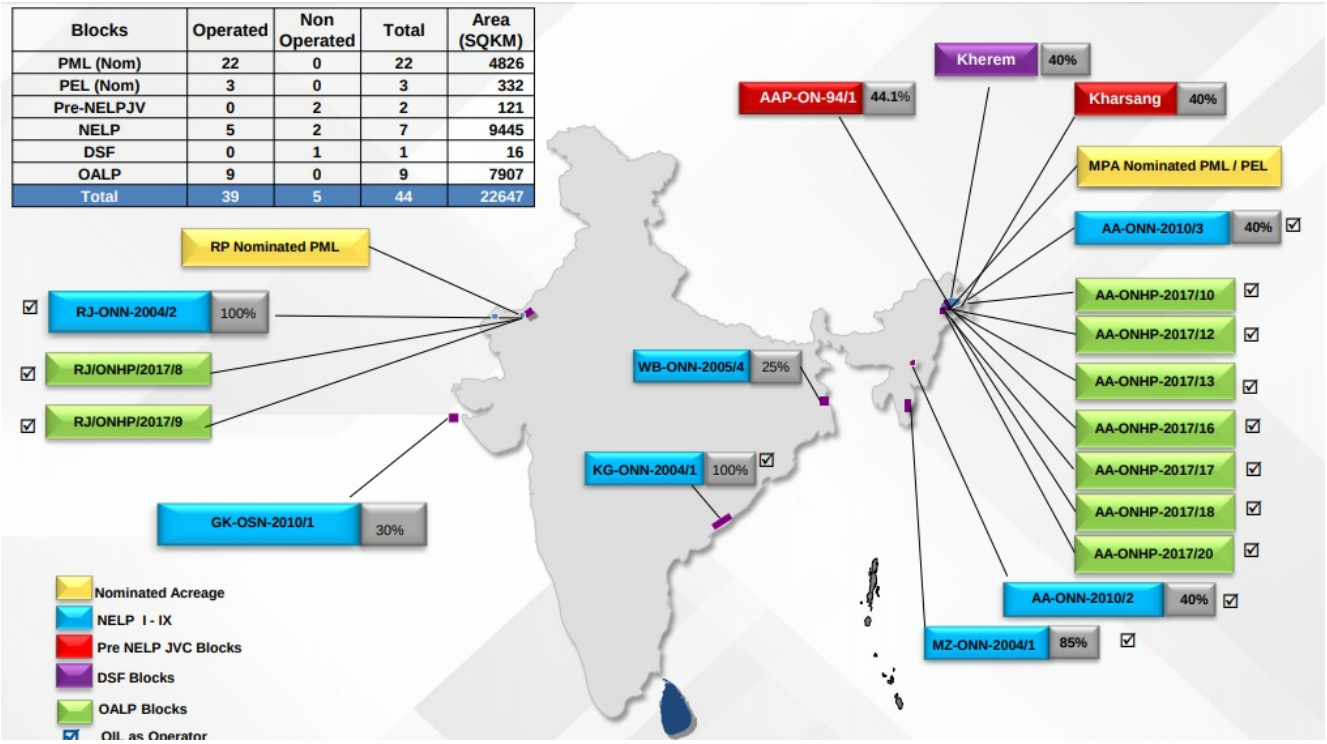


Fig No. 4.1: Assets of M/S OIL inIndia (2018-19)

4.3.2 OIL Assets Overseas

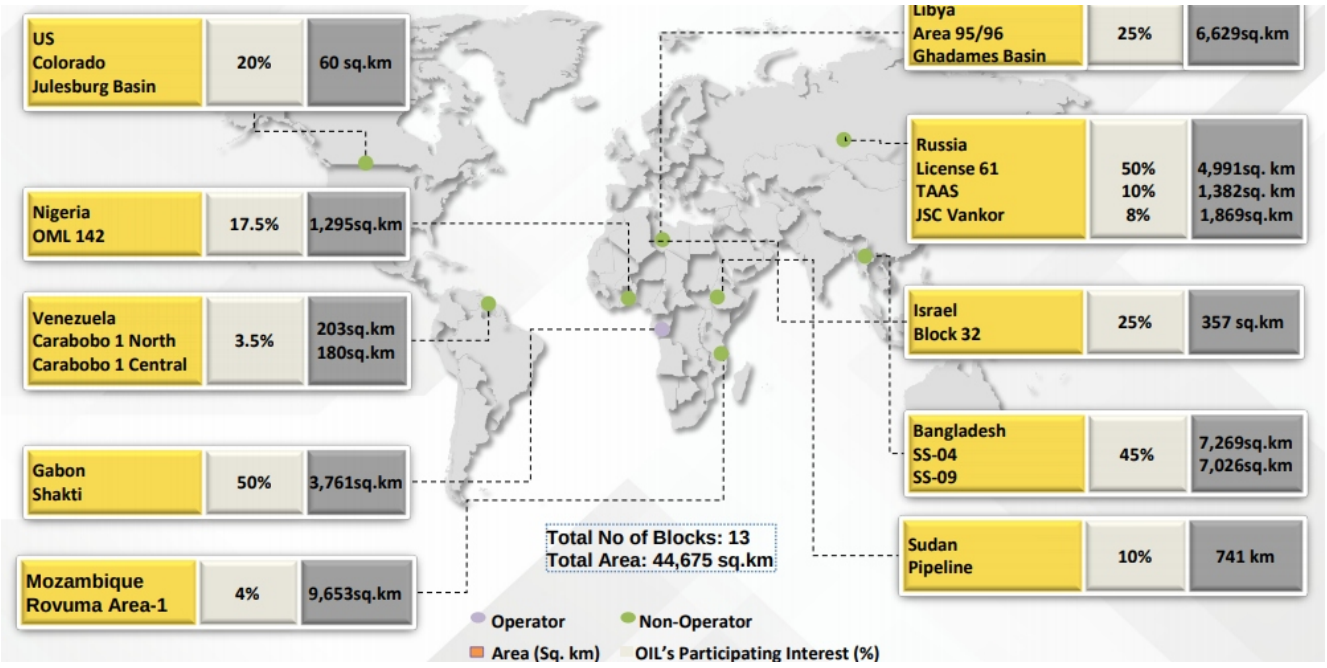


Fig. No. 4.2: Assets of M/S OIL Overseas (2018-19)

4.3.3 OIL Assets in Upper Assam

OIL currently owns and operates 13 drilling rigs and 14 work-over rigs, besides chartered hiring drilling rigs based on operational requirement. Oil India Ltd (OIL) has drilled more than 1,000 wells covering over 3.5 million metres, varying in depth from 1000–5000 m, have been drilled in various surface and sub-surface environments, including high underground pressures and temperature conditions. Wells are first exploratory and if exploitable crude oil or natural gas is discovered, then those are converted to development wells. OIL's conversion rate from exploratory to development is more than 80%. The balance reserve as of 2018-19 of crude oil is 105 MMT and natural gas 165 MMTOE.

The main Petroleum Mining Lease (PML) and Petroleum Exploratory Lease (PEL) areas are Naharkatiya, Naharkatiya Extension, Baghjan, Barekuri, Barhapjan, Hugrijan, Makum blocks, Deohal-Bogapani-Nagajan block, Karbi Anglong (New Block), Khagarijan, Khakarijan East, Doomdooma, Meshaki blocks etc. Some of the areas still have not got forest clearance, and due to non declaration of ESZs, some blocks are held up for long.

There are more than 220 exploratory and development wells in this region surrounding Baghjan and neighbouring areas. Within the area of North Hapjan-Tinsukia-Dhola, there were 49 exploratory drilling sites of which many are under production phase now. Recently M/S OIL has been granted permission for drilling of 7 sub-surface sites in Dibru-Saikhowa National Park from three pads using Extended Reach Drilling (ERD) technology. The FC clearance is underway. These are under North West Baghjan PML. The location details are given below:-

Table No. 4.8: Location Details of ERD Sites of M/S OIL in North West Baghjan PML

Locations	Coordinates (Lat Long)	Area
ERD Subsurface Locations		
Location A	27°36'11.8757"N;95°21'58.7298"E	DSNP, Tinsukia
Location B	27°36'20.5540"N; 95°22'28.3568"E	DSNP, Tinsukia
Location C	27°36'46.6790"N; 95°22'25.9099"E	DSNP, Tinsukia
Location D	27°36'48.5098"N; 95°22'59.1363"E	DSNP, Tinsukia
Location E	27°37'7.9496"N; 95°23'7.0839"E	DSNP, Tinsukia
Location F	27°37'5.1939"N; 95°23'30.0919"E	DSNP, Tinsukia
Location G	27°37'17.9866"N; 95°24'6.0105"E	DSNP, Tinsukia
ERD Surface Locations		
PAD 1	27°36'46.06"N; 95°24'53.47"E	Baghjan Village, Doomdooma Tehsil, Tinsukia
PAD 2	27°35'59.73"N; 95°24'16.04"E	Baghjan Village, Doomdooma Tehsil, Tinsukia
PAD 3	27°35'37.57"N; 95°23'4.14"E	Dighaltarang Village, Doomdooma, Tehsil, Tinsukia

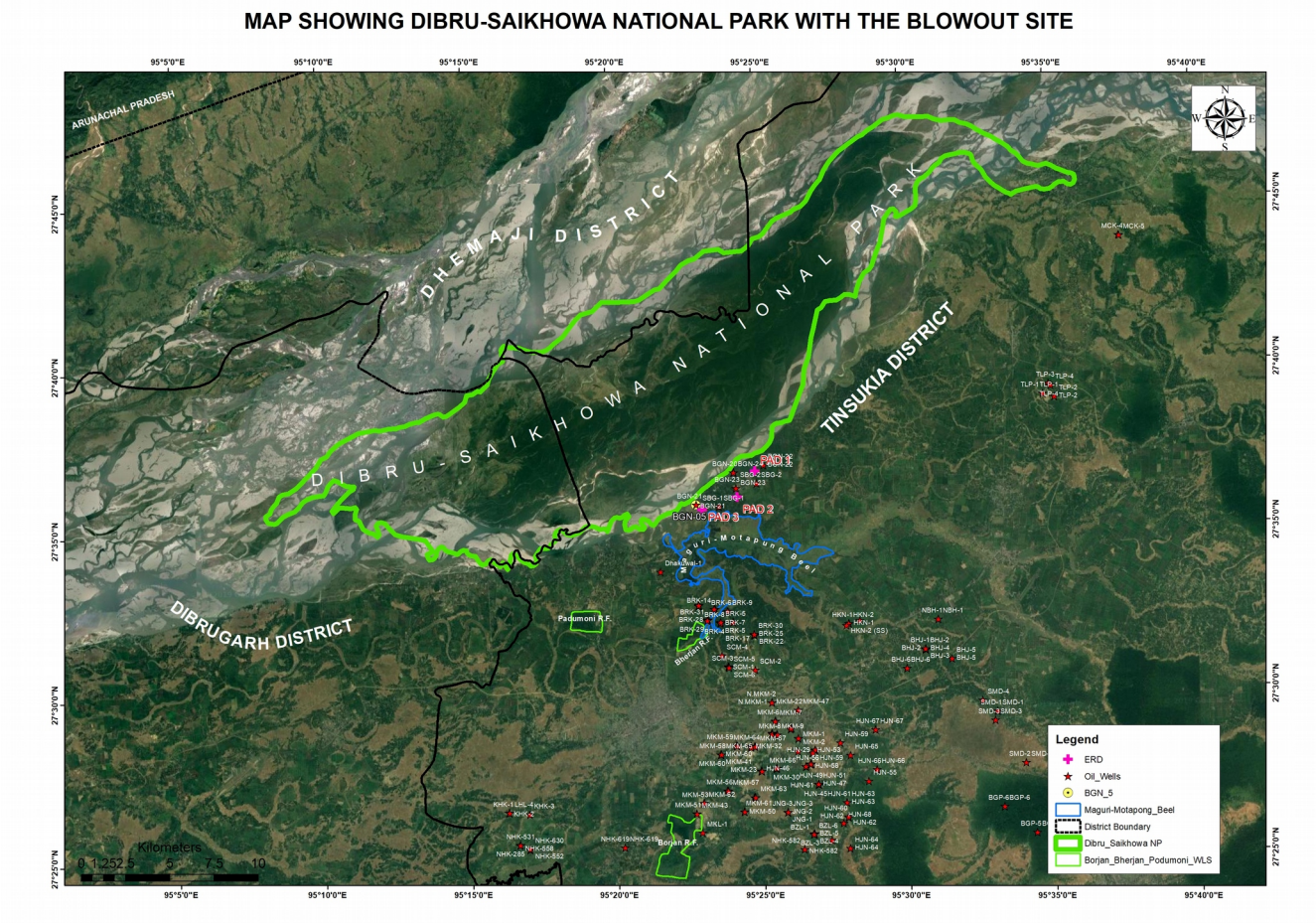


Fig. No. 4.3: Location Map of the Three PADs of the 7 ERD Sites

4.4 Baghjan Oil Wells Under EC Dt. 1.11.2011

M/S OIL was granted Environmental Clearance vider order Dt. 1st November, 2011 for drilling of 26 development wells and 15 exploratory wells. Development wells are drilled generally in proven areas, whereas exploratory wells are drilled in unproven areas. The total area permitted was 650 sq km bounded with the geographic latitudes 27^0 27' N to 27^0 37' N, and longitudes 95^0 20' E to $95^0$32' E under the North Hapjan – Tinsukia – Dhola block of OIL. Of these 41 wells, 29 fall within 5 km radius of the Dibru-Saikhowa NP. The GPS coordinates of the 29 wells were provided by OIL. These are shown in the figure below.

As can be seen from the figure, the lease area falls within the Dibru-Saikhowa National Park, and completely covers the Bherjan RF part of the Borajan Bherjan Podumoni WLS. Further, it can be seen that BGN#25, 26 and 27 fall outside the EC area.

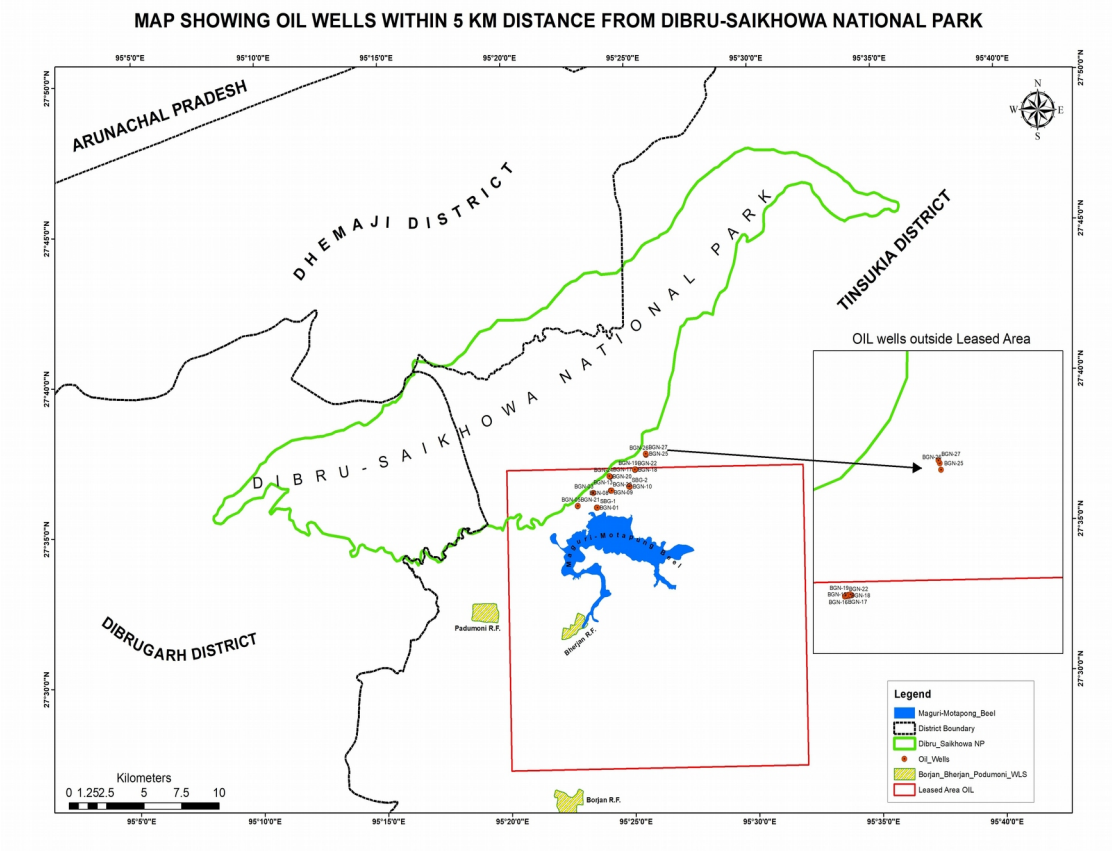


Fig. No. 4.3A: Map Showing EC Area around Baghjan

4.5 Climate Change, GDP And Energy Mix 2050

This section, and the next one that follows, have been strategically placed here to bring into debate on climate change (in view of the Baghjan disaster and large scale destruction of ecosystems) and weigh the balance and trade off between choosing "oil and natural gas" as the pathway for the future economic growth or sustainably balance it by a mix of change of pathway and adopt a new strategy altogether, so that not only growth happens, but also the ecosystems remain well protected.

4.5.1 Climate Change *Bavardage*

Energy is a major driver of Climate Change and climate variability. Global CO_2 levels continue to rise. As per latest Muana Loa Observatory reports, the CO_2 level for September, 2020 was at 411.29 ppm while for September, 2019, it was 408.54, while 10 years ago it was ~387.83[15]. The rise in global levels of CO_2 is obvious and clear. The question is how does a global rise of CO_2 affect us? It affects the economy by inducing climate triggered disasters. For example in Assam, some tell tale signs are already visible, such as, high frequency of floods, bouts of drought, rain in rain shadow areas,

15 https://www.esrl.noaa.gov/gmd/ccgg/trends/

contamination of ground water with Arsenic and fluoride, fall in tea production (rather higher costs of production due to changing climatic conditions), impact on flowering and fruiting of certain plants and trees, loss of agricultural production due to changing climate etc. It is projected that by 2050, India's GDP would fall by 7-11%, as one can see in the map placed below by BP (2020)[16]. The crux of this problem lies in decarbonizing the economy (which is, again, not an easy option for developing countries like India) by changing the energy mix.

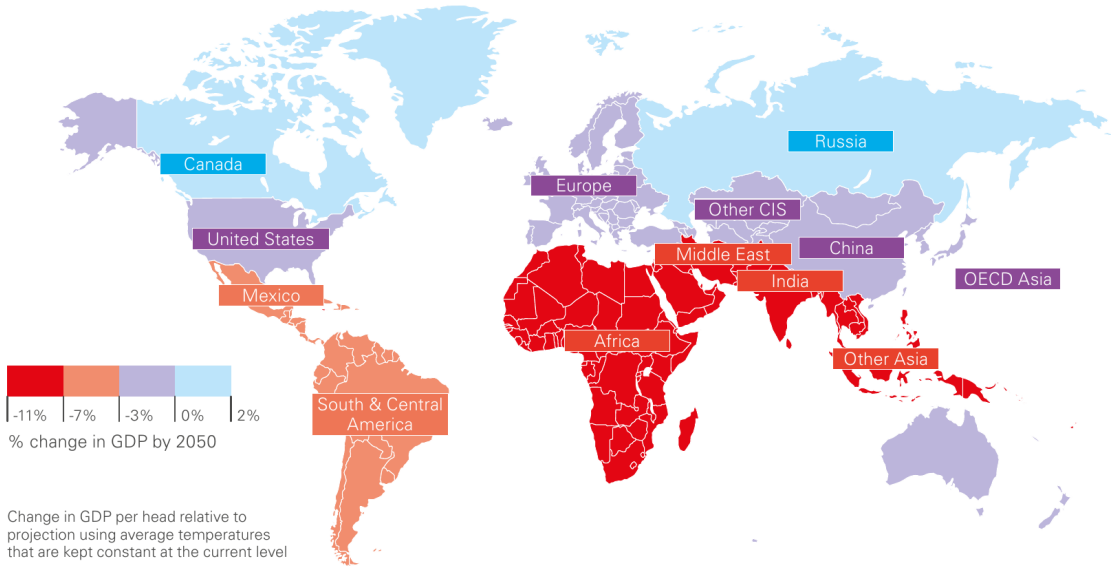


Fig No. 4.4: Impact of climate Change on GDP of the Countries

4.5.2 Energy and Climate Change

Energy and climate change are intimately and rightly linked. The economic growth of mankind is associated with increased energy usage. Energy and climate change are often linked together because, since the industrial revolution, the fossil fuels that have powered the global economy have also altered the atmosphere and are highly likely to cause climate change that may be difficult and expensive to adapt to[17]. According to the New York Times[18], that conducted a study/ debate, "As energy demand rises around the globe, so does concern about climate change. The science seems clear: Ninety-seven percent or more of scientists active in the field are convinced the climate has been warming over the past century, the pace of warming is accelerating and human activities — particularly the burning of coal, oil and other fossil fuels — are a primary cause. Many of these scientists also concur that the best option to mitigate the

16 BP Energy Outlook, 2020
17 Stephenson Michael, 2018, https://doi.org/10.1016/B978-0-12-812021-7.00009-9
18 New York Times, October 7th, 2019

potentially catastrophic consequences of climate change is to reduce the use of fossil fuels and speed up the transition to renewable forms of energy, such as solar and wind".

The contribution of energy use is the highest in global rise in CO_2 levels, as can be seen in the figure produced below from the BP Energy Outlook 2020 [BP(2020)] Report :-

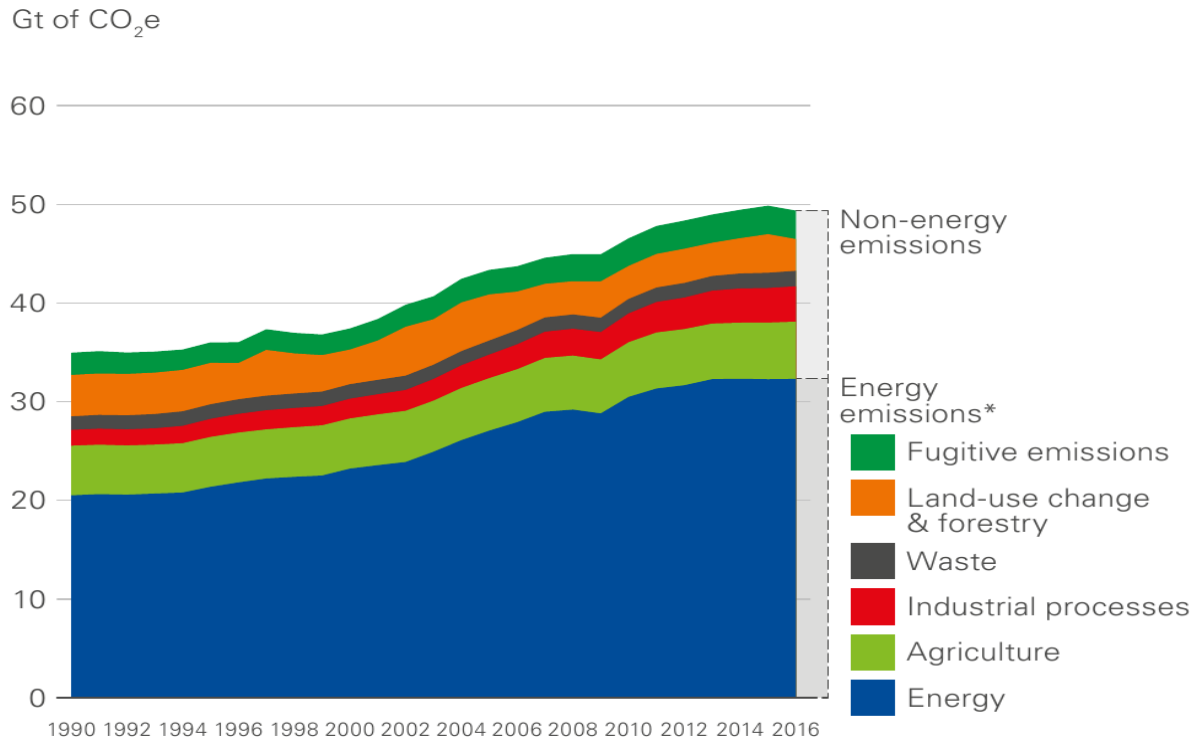


Fig No. 4.5: Sectoral Contributions to Global CO_2 Emissions

As per the Chart above, 33.9 Gt of the total 49.4 Gt CO_2 emitted was from energy usage. The composition of the energy usage is spread variously in sectors such as building (comfort heating and cooling, lighting & appliances etc.), industry (energy/fuels to run the processes, especially iron & steel, cement, brick sectors), Transport (energy/ fuel in various sectors such as aviation, marine/ships/ ferries, road & rail sectors), Agriculture and farm sector etc. to mention the broad categories. The BP Energy Outlook 2020 [BP(2020)] provides a quantitative break of the 33.9 Gt CO_2 of energy related emissions for various key sectors of the economy. The Fig. No. 4.6 below may be seen to get a snapshot of contributions of the various sectors of the economy to the emissions.

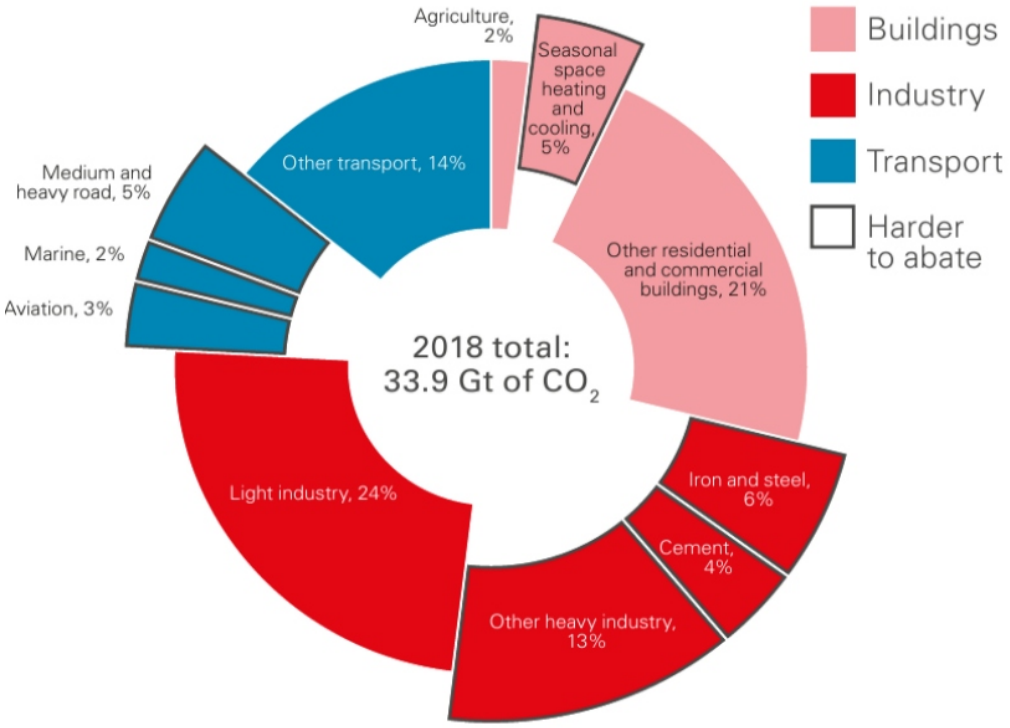


Fig. No. 4.6: Contributions to Global CO2 Emissions from Various Energy Usages

4.5.3 THREE SCENARIO PATHWAYS

The basic questions of climate change and pathways remain as to whether we shall continue this (BAU) way and overshoot 2^0 rise in surface temperature by 2100 AD, or take steps to keep it below 2^0, or else take stern measure and keep it under 1.5^0 by 2050. Three pathways have now been suggested as per the BP (2020) :- 1. Business as Usual (BAU), 2. Rapid Transition Scenario & 3. Net Zero. While BAU does not require any explanation, the definitions of the rest of the two pathways is quoted from BP (2020).

Rapid Transition Scenario: The Rapid Transition Scenario would require "a series of policy measures, led by a significant increase in carbon prices and supported by more targeted sector specific measures, which cause carbon emissions from energy use to fall by around 70% by 2050. This fall in emissions is in line with scenarios which are consistent with limiting the rise in global temperatures by 2100 to well below 2-degrees Celsius above pre-industrial levels" [BP (2020)]

Net Zero Scenario: "The Net Zero Scenario (Net Zero) assumes that the policy measures embodied in Rapid are both added to and reinforced by significant shifts in societal behaviour and preferences, which further accelerate the reduction in carbon emissions. Global carbon emissions from energy use fall by over 95% by 2050, broadly in line with a range of scenarios which are consistent with limiting temperature rises to 1.5-degrees Celsius" [BP (2020)]. Primary energy demand increases by around 10% in Rapid and Net

Zero and by around 25% in BAU. With the three scenarios, the possible reduction in CO_2 levels is shown below:-

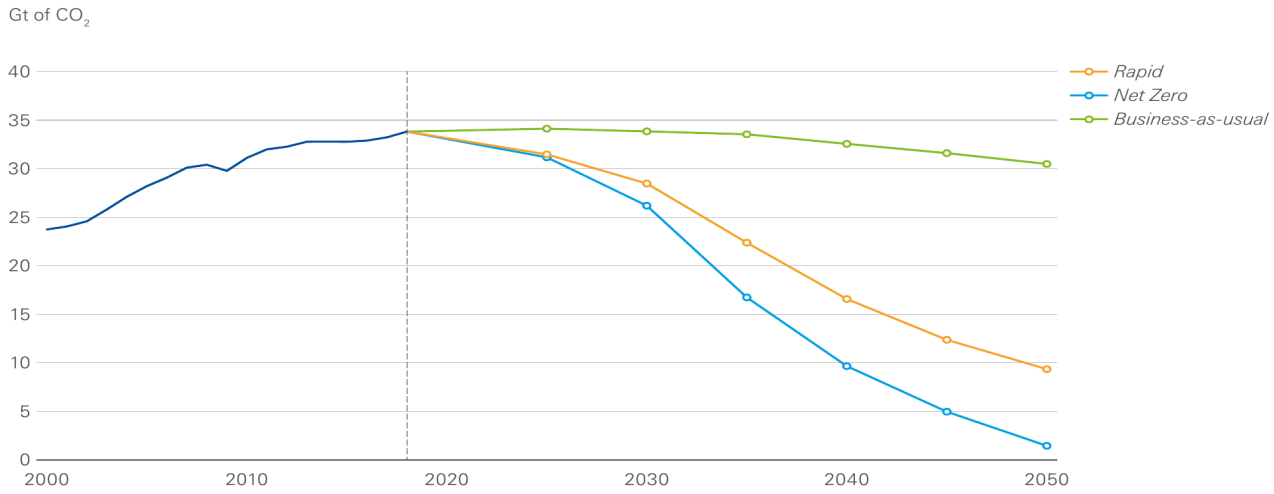


Fig. No. 4.7: The Three Scenario Pathways for Reduction in CO_2 Emissions

This shows that eventually, the energy mix needs to change, if we have to avoid the 2^0 rise catastrophe or bring to 1.5^0 C to be on the safer side a bit. The suggested energy mix for the three scenarios for 2018-2050 is shown below as per BP (2020):-

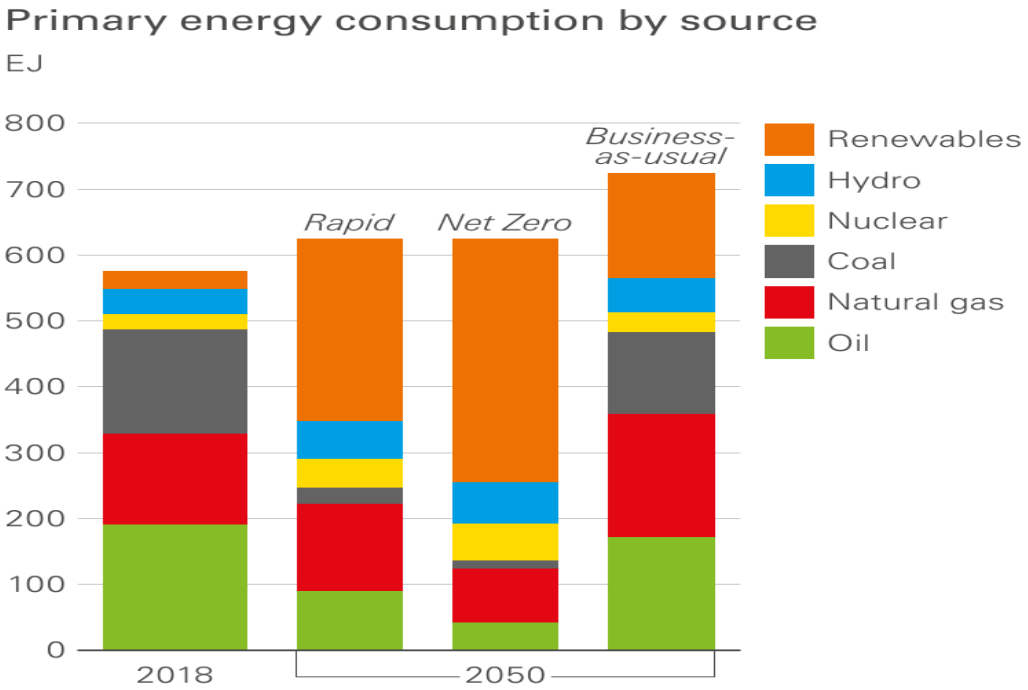


Fig. No. 4.8: Energy Mix of 2018 and in the Three Scenario Pathways

As can be seen from the figure above, when we compare the 2018 level of fossil fuel use such as oil and natural gas we observe that in BAU scenario, the oil gets reduced a bit in 2050, but natural gas consumption goes up. In the rapid scenario, the natural gas consumption remains the same (almost), but the oil consumption falls drastically.

However, when we look at the Net Zero scenario, the renewal energy sector completely takes over the energy mix. The consumption of oil falls drastically in 2050, and natural gas consumption is lower than the 2018 levels. The increase in renewable energy is by 60%. ***The moral of the story is that we can keep our production levels at 2018 level, and still grow in a healthier manner which is climate and environment friendly***. This would mean that we as a country may chalk out altogether different strategies of growth which would be a radical departure from business as usual.

4.5.4 Carbon Prices

Another key assumption which differs from BAU is the rising carbon prices in Rapid and Net zero scenario according to BP (2020). Quoting the Report here, "*Both Rapid and Net Zero assume a significant increase in carbon prices, which reach $250/tonne of CO_2 ($2018 prices) in the developed world by 2050 and $175 in emerging economies. This increase in carbon prices incentivizes significant gains in both energy efficiency and the use of lower-carbon energy sources. This policy impulse is much smaller in BAU, with carbon prices reaching only $65 and $35 per tonne of CO_2 by 2050 in developed and emerging economies respectively*". As a country or State this option must seriously be explored.

4.5.5 Advantage of the New Scenarios

While global surface temperatures are rising, as the energy demand is increasing for comfort cooling, transport, heating, power generation etc., the issue always remains local vs global (*Do local actions have impact on global surface temperature rise? Or simply put, why should we do something which nobody else seems to be doing? Or why should I not enjoy comfort cooling in my home and office, when the whole world seems to be enjoying these for ages?*). The issues of the north and south divide (developed economies vs. developing economies) is also to be pondered. The map in Fig. No. 4.4 clearly shows the north south divide. The two issues of local vs global and north vs south are debates which would continue, but some degree of positive local action may impact the rest of the world. We may adopt locally a pathway that tries to strike balance between nature and development by striking a balance. This needs to be cautiously studied.

4.6 India's Fossil Fuels' Production And Imports

The arguments developed in the previous section seem to melt down when we look at our own demand for petroleum products and the fact that more than 80% of the demand is met from oil imports. In this section, we shall look at very briefly on oil imports and production.

4.6.1 Crude Oil Imports

As per the MoPNG data, India imported a total of 205 MMT of crude oil in 2019-20, which has more than doubled since 2006-07 when it was just under 100 MMT. In INR, the total import value was Rs. 588,725 cr in 2019-20. In US$, it amounted to 83.217 Billion US$. The next highest imported item is "electronics goods", and the imported value of it was about 53 Billion US$. [*A time may come when electronics import may actually take over crude oil imports*]. Due to COVID19, the net oil imports have fallen to US$ 15.345 Billion US$ till August, 2020. It is a drop of more than one fifth. If we compare the situation of last fiscal year, till August, 2019, the imports were to the tune of US$ 37.58 Billion. This was almost 45% of the total imports for that year. Thus, we see that this year, it is a drop of almost 2.45 times in the imports due to COVID19 pandemic.

4.6.2 Oil and Natural Gas Production

As per the latest annual report of the MoPNG, the highest production of crude oil was in 2013-14 to the tune of 37.79 MMT which has steadily fallen to 34.20 MMT in 2019-20. The table below speaks more about this trend:-

Table No. 4.9: Production vs Imports of Crude Oil and NG in India

Import/Production	2013-14	2019-20	% ±
Net Import of Crude Oil (MMT)	138.07	198.75	**43.95**
Production of Crude Oil (MMT)	37.79	34.20	**-9.50**
% Production of Net Import	27.37	17.21	**-37.13**
Share of OIL in production	3.47	3.29	**-5.19**
% of OIL's share in Production in Oil	9.18	9.62	**4.77**
Import of Natural Gas (LNG) in BCM[19]	18.54	29.93	**61.43**
Production of Natural Gas (BCM)	35.41	32.87	**-7.17**
% import of LNG	34.37	47.66	**38.68**
Share of OIL in NG Production	2.63	2.72	**3.42**
% of OIL's share in Production in NG	7.43	8.28	**11.41**

Therefore, it is clear that India imports more than 82% of its requirement of crude oil and more than 45% of its natural gas requirement. Currently, the crude oil production is almost 17% of the net crude oil imports. There is saving grace in natural gas, such that home production is more than the imports. *M/S OIL holds roughly **10% share** in total crude oil production and ~**2.8%** in natural gas production in India*.

19 LNG 1 Million Metric Tonne = 1.38 BCM; 1 BCM = 0.73 MMT LNG

4.7 Royalty On Oil And Gas

Royalties on oil and natural gas are important sources of revenue for the oil producing states. Further, as would be seen in the next Chapter, as one of the international best practices, the loss of royalty in any blowout is required to be made good by the owner of the well, so that the State does not lose its revenue. Therefore, it was thought fit to bring this topic here itself. In India, the royalty payable to the States is at the rate of 12.50% on crude oil and 10% on natural gas. The royalty calculation has been taken from the NE Hydrocarbon Vision 2030 document of MoPNG. The calculation tables are given below:

4.7.1 Royalty on Crude Oil

Table No. 4.10: Royalty Calculation of Crude Oil

For crude oil	Calculation
Barrel to MT	7.3
Exchange rate (INR/US$)	63
Crude price ($/bbl)	50
Production (MMT)	1
Royalty rate	12.50%
Crude price in INR/MT	22,995
Royalty per MMT (INR Cr)	287.44

4.7.2 Royalty on Natural Gas

Table No. 4.11: Royalty Calculation of Natural Gas

For Natural Gas	Calculation
M^3/MMBTU	39.683
Exchange rate (INR/US$)	63
Gas price ($/MMBTU)	4.66
Production (MMSCMD)	1
Production (MMSCM)	365
Royalty rate	10.0%
Gas price INR/SCM	11,650
Royalty (INR crore) per 365 MMSCM	42.5

The current prices of natural gas as of 1st October, 2020 has been fixed by the Govt. of India at USD 1.79/MMBTU. The crude oil price currently is 37.01 US$. The current exchange rate can also be taken at **1USD=74 INR**. Therefore, exact values of royalty

would change. Additionally taxes would also apply. However, these are only model calculations. Towards the end of the Report, an attempt would be taken to assess the possible royalty loss of the Government of Assam due to the Baghjan blowout. The subject of petroleum and natural gas mining is handled by the Mines and Minerals Department of the Government of Assam. Actually speaking the PEL/PML are granted to the oil companies by the Mines & Mineral Department of the State Government. Therefore, the Department must have some say in the matters of blowout and accidents.

4.8 CAG Report On Oil & Natural Gas

No enquiry can be said to be complete without a reference to the audit findings of the Comptroller & Auditor General of India (CAG). Though due to paucity of time and resources, all relevant reports of CAG could not be gone through, an attempt was made to understand what CAG has to say in respect of Mines & Minerals Department. One of the Reports namely the Audit Report (Revenue Sector) for the Year ended 31 March, 2017 by CAG[20] would be briefly discussed here. The Performance Audit (PA) on 'Working of Geology and Mining Department, Assam' by the CAG was conducted between April 2017 and July 2017 with revenue implication of Rs.1,396.90 crore.

4.8.1 Bouquet Laws Examined by The CAG

The various legal and policy aspects, relevant to the present enquiry, that the CAG examined are:- Mines and Minerals (Development & Regulations) (MMDR) Act, 1957, Mineral Concession Rules (MCR), 1960, Mineral Conservation and Development (MCD) Rules, 1988, Mines Act, 1952; Mines Rules, 1955, Petroleum Act, 1934, Petroleum and Natural Gas (PNG) Rules, 1959; Oil Fields (Regulation and Development) (ORD) Act, 1948, Publications of Indian Bureau of Mines (IBM), Indian Stamp Act, 1899, Registration Act, 1908, Assam Financial Rules, the Water (Prevention & Control of Pollution) Act and Rules; the Air (Prevention & Control of Pollution) Act and Rules; the Environment (Protection) Act, 1986.

4.8.2 A Brief on The Mines & Minerals Department

The Mines and Minerals Department, GoA is headed currently by an officer of the Additional Chief Secretary rank. He is assisted by a number of Secretaries/ Joint Secretary/ Deputy Secretary etc. The Secretariat is assisted by the Director of Geology & Mining (DGM). The Directorate does not have any office in the districts other than the

20 CAG, 2017, Chapter VI, Mines & Minerals Department, Audit Report (Revenue Sector) for the Year ended 31 March, 2017, AG (Audit), Assam

one at Dibrugarh for receiving the returns from Oil India Limited (OIL), Oil and Natural Gas Corporation Limited (ONGCL) and Coal India Limited (CIL). The CAG had earlier conducted a Performance Audit of the Department in 2010. During 2011-2017, it was seen that the Department accounted for almost 67.16% of the non-tax revenue of the Government of Assam.

4.8.3 OBSERVATIONS OF THE CAG

Without going into details of the CAG Performance Audit Report of 2017 on the Mines & Minerals Department, the key observations relevant to the enquiry at hand are produced below:-

1. The production of crude oil from 2011-12 to 2016-17 in the State was 27.01 MMT, and the royalty received by the Govt. of Assam during the period was rs. 10,474.91 cr. [*Average per annum production: 4.5 MMT, and average royalty: Rs. 1745.82 cr.*]
2. The production of natural gas from 2011-12 to 2016-17 in the State was 13,762.15 MSCUM, and the royalty accrued to the State Government was Rs. 1053.63 cr. [*Average per annum production: 2293.69 MSCUM, and average royalty: 175.61 cr*]
3. Audit observed that that production was taking place from ten lease areas prior to approval/ grant of lease from the Government of Assam.
4. Audit observed that in respect of 30 out of 37 PELs, neither the licensees furnished any information regarding relinquishment of the leased area nor did the Department ask for the same after expiry of the PELs. In the absence of any information in this regard, Audit could not ascertain whether the licensees relinquished the area in good order or the licensees still held the areas in an unauthorised manner.
5. As per MCR and also Rule 15 of PNG Rules, at the time of granting lease, survey at the expenses of the lessee, is to be carried out by State Government for demarcation of the lease area. Audit noticed that the Department had not initiated any action for survey and demarcation of 75 leases granted till March 2017. Hence, occupation of area in excess of leased area granted to the lessees could not be ruled out.
6. Rule 11(2) of the PNG Rules, 1959 provides that the licensee of a PEL shall pay yearly in advance by way of licence fee, a sum calculated for each square kilometer or part thereof covered by the licence at the prescribed rates. Rule 23

of the PNG Rules further provides that all licence fees, lease fees, royalties and other payments have to be paid within the specified time. They would, if not, be increased by a penal rate of 200 basis points over the Prime Lending Rate of State Bank of India for the delayed period. Audit observed that out of 37 petroleum exploration licensees (PELs), two licensees paid licence fee amounting to Rs. 45 lakh against Rs. 46.53 lakh actually payable and 11 licensees had not paid any fees amounting to Rs. 5.96 crore during October 2007 to March 2017. Audit observed that 16 out of the 37 licensees paid licence fees with delays ranging between 4 and 961 days. The Department had not demanded/ levied penal interest for delayed payment of licence fee which worked out to Rs. 38.06 lakh. As per Rules 6 and 13(1) of the PNG Rules, 1959, the applicant of PML shall, before the lease is granted to him, deposit statutory fees such as Security Deposit, Preliminary Expenses and Lease Fee at the prescribed rates. Audit observed that 17 out of 44 petroleum leaseholders paid statutory fees amounting to Rs. 50 lakh against payable statutory fee of Rs. 1.65 crore. This led to short payment of statutory fee of Rs. 1.15 crore

7. The Department assessed the amount of royalty exclusively on the basis of monthly returns furnished by the leaseholders. Thus, the royalty paid by the leaseholders was accepted by the Department without cross-verification of important data/details, essential for making a correct assessment, like; lease-wise annual quantity of production/ extraction Statement for oil and natural gas separately; trading and manufacturing account; profit and loss account, Annual Financial Statement and Annual Report, wherever required; and, sales invoices.

8. ***Audit cross checked the figures of net production of crude oil and natural gas of OIL as shown in its monthly returns for the years 2011-16 (except 2012-13) with those shown in the Annual Accounts. It was noticed that the net production during the aforesaid period was shown less in the monthly returns leading to short payment of royalty amounting to Rs. 128.91 crore***.

9. ONGCL prepared its annual accounts for the whole of India without mentioning the production of crude oil and natural gas for Assam separately. Therefore, in order to obtain ONGCL's net production of crude oil and natural gas Audit took the figures of total net production in Assam as declared in the Mineral Year Books and from this deducted the net production of OIL as disclosed in its annual accounts for the years 2011-15. The net production so worked out was more than that disclosed in monthly

returns submitted by ONGCL. This resulted in suppression of production figures leading to short payment of royalty amounting to Rs. 222.88 crore.

10. Section 6A (3) of the ORD Act, 1948 and Rule 14 of the PNG Rules, 1959 stipulate that no royalty shall be payable in respect of any crude oil, casing head condensate or natural gas which is unavoidably lost or is returned to the reservoir or is used for drilling or other operations relating to the production of petroleum or natural gas, or both. The Rules do not, however, specify any standard norms or maximum permissible limit for quantity utilised for operations relating to production or any unavoidable loss. The GoA had taken up the matter (May 2002 and November 2008) with the MoPNG, GoI to restrict the element of 'unavoidable loss' to a maximum limit of 0.5 per cent for crude oil and 5.0 per cent for natural gas through suitable amendment of PNG Rules, 1959. Approval for the same from GoI was awaited (February 2018).

11. Audit observed that during 2011-17, ONGCL and OIL had claimed unavoidable loss in respect of natural gas which varied from 8.00 to 19.33 per cent and 4.57 to 6.84 per cent respectively. The claims for unavoidable loss of crude oil and natural gas were not consistent. Had the norms been approved by the GoI, the GoA would have for 2011-17 earned additional royalty of Rs. 51.72 crore. Audit noticed from monthly returns that one mining lessee115 had produced 19,56,875 SCUM116 natural gas, of which 17,51,175 SCUM (89.49 per cent) had been utilised for mining operations and claimed 2,05,700 SCUM (10.51 per cent) as unavoidable loss during 2011-17. Another lessee 117 had produced 98,68,731 SCUM natural gas and utilised entire quantity of natural gas for mining operations during the same period without claiming unavoidable loss. In both the cases, there were '**nil**' production and hence the State did not earn any royalty from those two leases during 2011-17.

12. The PNG Rules stipulated that a lessee shall pay to the State Government a royalty at 10 per cent of the value of natural gas. The price of natural gas is declared on a six-monthly basis by MoPNG, GoI. Audit noticed that OIL paid royalty to the State Government on natural gas during the periods 2011-17 at annual average rates ranging from Rs. 606.97 to Rs. 937.29 per thousand SCUM. However, ONGCL during the same period paid royalty at annual average rates ranging from Rs. 697.12 to Rs. 1,184.53 per thousand SCUM. OIL was paying royalty on natural gas at the lesser rates compared to that of ONGCL. This resulted in short levy of royalty to the extent of Rs. 195.76 crore by OIL. The

Department did not analyse the reason for difference of rates of royalty on natural gas.

13. Rule 13(2) (b) of the PNG Rules, 1959 provides that the lessee has to pay surface rent for the area of land actually used by him/her for the purpose of operations conducted under the land, at such rate not exceeding the land revenue and cess assessed or assessable on the land as specified by the State Government with the approval of the Central Government. Audit noticed that out of 57 PMLs (ONGCL: 40 PMLs and OIL: 17 PMLs) granted in Assam upto March 2017, ONGCL and OIL paid surface rent for only three and 15 PMLs respectively. The Department did not initiate action for realisation of surface rent in respect of remaining PMLs since the date of their commencement of mining operations. This resulted in loss of revenue amounting to Rs. 20.34 crore (calculated upto March 2017).

14. The PNG Rules and the MMDR Act have provisions for payment of dead rent to act as a deterrent against the tendency of leaseholders of mining leases to keep mines idle. Rule 13 (2)(a) of PNG Rules prescribes that the lessee shall pay for every year, fixed yearly dead rent at the prescribed rates, provided that lessee shall be liable to pay only the dead rent or the royalty, whichever is higher in amount but not both. Audit noticed that there was no production in respect of 19 PMLs (ONGCL: 15 and OIL: 4) for which dead rent of Rs. 14.24 crore was not realised. The Department did not raise any demand for recovery of dead rent since October 2002.

15. The Demand, Collection and Balance (DCB) Register/ Statement is a key control document, required to be maintained for effective monitoring and control over the assessment and collection of royalty and other government dues. Audit observed that the Department did not maintain DCB Register/Statement to watch the assessment and collection of royalty, dues, fees, etc., from the licensees or lessee.

16. Section 23 of the MMDR Act, empowered the State Government to frame rules for preventing illegal mining, transportation and storage of minerals. Such rule may provide for inspection, checking and searching of minerals at the place of excavation or storage or during transit, establishment of check-posts and weighbridges to measure the quantity of minerals being transported. Audit noticed that the State Government has yet to frame any rules in pursuance of the provision of the Act. Failure to frame rules showed lack of determination on the part of the Department to effectively tackle illegal mining; the Department had

not prescribed any system for inspection of the leased areas to check whether mining activities were being carried out in lawful manner as per approved mining plan.

17. The GoI while granting PMLs instructed that Forest Clearance from the Competent Authority should be obtained for the Reserved Forest areas falling in the leased areas. Test check of records revealed that 17 lease holders of PMLs did not obtain the said clearance from the concerned Divisional Forest Officer (DFO) though parts of the leased areas fell in Reserved Forest areas.

4.8.4 RECOMMENDATIONS OF THE CAG

The CAG Audit recommended that the Department may consider instituting a system to monitor overall administration of the responsibilities assigned to the Department relating to grant/ re-grant, monitoring and reporting relating to leases; strengthening of internal controls and mandatory maintenance of Demand, Collection and Balance (DCB) Register to ensure correct assessment and realisation of revenue; framing of rules for preventing illegal mining, transportation and storage of minerals and establishing sufficient numbers of check-posts and weighbridges besides regular inspection of mining operation sites; digitisation of old records and use of GIS technology to control illegal mining and degradation of forests due to excess/uncontrolled mining activities.

4.9 Oil Spills And Blow Outs

This sections focuses on blowouts and risk assessment. Blow outs have been as old as drilling industry itself. Until the blow out preventers were invented in 1924, high pressure gushing wells to heights of 60m or more were common. A very apt quote on a blow out from the past, which is quite close to the Baghjan blow out fire, is reproduced here:-"*With a roar like a hundred express trains racing across the countryside, the well blew out, spewing oil in all directions. The derrick simply evaporated. Casings wilted like lettuce out of water, as heavy machinery writhed and twisted into grotesque shapes in the blazing inferno*"[21] We just need to replace the "express trains" by "turbo jets" for Baghjan.

4.9.1 QUANTITATIVE RISK ASSESSMENT

Quantitative Risk Assessment, according to the EIA-ERM (2019), is a part of the EIA for the Oil and Gas and provides a systematic analysis of major risks. The assessment provides a proper and rational of the identified risks and provides an outline of the risk

21 https://en.wikipedia.org/wiki/Blowout_(well_drilling)

mitigation measures. It also helps to develop a structured Emergency Response Plan (ERP). The quantitative measure of the risk uses standardized risk matrix system. Of all the risks, the risk of blow out and any consequent fire or explosion. Frequency analysis is deployed to determine the probabilities of occurrence of failures, which is obtained from various accident and published oil industry database.

4.9.2 Frequency Occurrence Criteria

Events are allotted a "Likelihood Ranking" from 1 to 5, 1 being least probable or "Improbable" and 5 being "≥1.0" being "Frequent". These criteria rankings are based on number of incidents per year. The range is from "$>10^{-6}$" to "$>10^{0}$". The ranking table is reproduced from the EIA Report (Page 153) below.

Table No. 4.12: Oil Mining Accident Criteria Ranking Classes

Likelihood Ranking	Criteria Ranking (cases/year)	Frequency Class
5	>1.0	Frequent
4	$>10^{-1}$ to <1.0	Probable
3	$>10^{-3}$ to $<10^{-1}$	Occasional/Rare
2	$>10^{-5}$ to $<10^{-3}$	Not Likely
1	$>10^{-6}$ to $<10^{-5}$	Improbable

4.9.3 Consequence Analysis

Having determined the frequency of an accident or event which is identified as risk, the next step is to carry consequent analysis. It is a mixed assessment of 1. Nature of impact on environment & community, 2. Occupational health and safety, 3. Asset and property damage, 4. Corporate image (DAMAGE), 5. Timelines for restoration of environmental and property damage & 6. Restoration cost of environmental and property damage.

There are five Consequence ranks defined from least to most consequent on a scale of 1 to 5, and are termed in the increasing order of consequence as 1. "Insignificant", 2. "Minor", 3. "Moderate", 4. "Major" & 5. "Catastrophic".

When one evaluates the Baghjan blow out on the five parameters, and ranks it on the consequence scale, it ranks 5 meaning it has been **catastrophic** to the maximum on all five counts. We shall be discussing this in a little more detail in Chapter 6, wherein this would be the first conclusion drawn.

4.9.4 Risk Evaluation

Based on the frequency analysis and consequence analysis, a risk matrix is prepared, with "consequence values in first column, and frequency analysis values in the 1st row. The remaining of the cells get filled up with the multiplication value of the row and column values. The value of a cell R_{ij}=i x j. where I is the i^{th} row and j is the j^{th} column of the risk matrix. Therefore,

Significance = Likelihood X Consequence

The values are then reclassified as "High", "Medium" and "Low". The risk matrix from the EIA-ERM (2020) is reproduced below.

Consequence →			Likelihood →				
			Frequent	Probable	Remote	Not Likely	Improbable
			5	4	3	2	1
	Catastrophic	5	25	20	15	10	5
	Major	4	20	16	12	8	4
	Moderate	3	15	12	9	6	3
	Minor	2	10	8	6	4	2
	Insignificant	1	5	4	3	2	1

Fig. No. 4.9: Risk Matrix of Oil Accidents

4.9.5 Blow Out Frequency and Probability

Two EIA Reports were consulted namely EIA-ERM (2019), and ONGC's Ramnathpuram PML EIA of 22 wells in Tamil Nadu referred to as QRA-ONGC (2016)[22]. There is a striking similarity in that one is quite a replica of the other with change in numbers and names. However, both have used the Alberta Energy & Utilities Board (EUB) database of 87994 wells drilled from 1975 to 1990. During 2002-2006, there were 39 blowouts. The probability of a blow out is simply f=No_of_blowouts / No_of_wells. According to this, the frequency comes to $4.4x10^{-4}$ per wells. While both the QRA assessments take the figures differently [EIA-ERM (2019) as $4.4x10^{-4}$, and QRA-ONGC (2016) as $4.9x10^{-4}$], the approach is the same i.e. finding the probability of only the project wells, and no consideration is taken for other existing wells nearby from earlier projects. It is forgotten that, if there are already existing wells in vicinity, new wells would only add to the probabilities. Therefore, the probability calculations in the QRA are actually faulty,

22 QRA Report for Exploratory drilling of 22 wells (onshore) in Ramanathpuram PML, for ONGC, by M/S Senes Consultants India Pvt. Ltd, 2016

and the Reports also do not mention the new total of wells in the surrounding area that would be after the project is taken up.

Throwing more light on the frequency part, it is seen that, as per IOPG (2019)[23], the frequencies depend upon whether the wells are onshore or offshore and or whether sweet or sour [*meaning absence or presence of Sulphur*], and the local standards enforcement. While off-shore blowouts are 30-70% more than onshore blowouts, onshore to onshore blowouts cannot be directly compared with each other. We shall be discussing here briefly the Off-shore, Texas database, Alberta database and then what could be the possible local probability in Tinsukia district.

The Off-shore databases of Blowouts: The Section 2 of the IOGS (2019) provides blowout frequencies for off-shore wells. The authors of the Report, however, reiterate that "*The data presented in Section 2 is valid for the North Sea (UK and Norway) and US GoM OCS. They can also be applied to other countries in the North Sea region and other areas of the world, depending on whether standards are considered to be equivalent to those in the UK and Norway sectors. For onshore operations, it is recommended to use the offshore data presented in Section 2 but noting that there will be a greater degree of uncertainty.*"

The database summary shows many types of wells and incidents such as blowouts (topside and subsea) in the North Sea, US GoM OCS, Canada East and other parts of the world. The highest frequency of blowout encountered in IOGS 92019) was found to be $2.5x10^{-3}$ (Topside blowout in development drilling in USGoM OCS). [*Since blowouts are in nature of ecological disaster, the highest safety margins should be applied by working on the worst case scenario. It is seen that the EIA reports have no place for worst case scenario evaluation, or any worst case environmental mitigation plan*.]

The Texas Database of Blowouts: The Railroad Commission of Texas maintains database of blowouts and well control problems within the State of Texas. The database is very comprehensively maintained since 2008. From 2000 to 2016, there were 281500 active wells and 14195 wells drilled every year. In all 356 incidents occurred during the period. As per the IOPG (2019) analysis, average per year frequency of blowouts comes to $7.4x10^{-5}$ per year. Else the incident blowout during the lifetime comes to $1.26x10^{-3}$.

The Alberta Database of Blowouts: This is the database most frequently quoted by the Indian EIA consultants. The Alberta Energy Resource Conservation Board (formerly known as Alberta Energy and Utilities Board) previously maintained onshore drilling

23 IOPG, 2019, Risk Assessment Data Directory, Blowout Frequencies, International Association of Oil and Gas Producers, Report No.434-02, September, 2019

database of blowouts etc. From 1975 to 1990, it had 87944 number of wells. In all 96 incidents occurred of which 43 were blowouts and 53 were well releases. This gives frequency of blow outs as $4.9x10^{-4}$, and well release as $6.0x10^{-4}$, but the overall frequency is $1.1.x10^{-3}$. During 2000 to 2006, there were 39 blowouts while the number of wells in operation was 88856, giving a frequency of $4.4x10^{-4}$. [*Therefore, it is clear that the EIA agencies have used the data to show lower frequencies. Whereas, if we combine Texas and Alberta both, the probability still comes* $1.1x10^{-3}$].

Blowouts in Tinsukia District: The Baghjan blow out is the second blowout of Tinsukia district, and the first blowout happened at Dikom oil well, owned by M/s OIL, in 2005. Both the wells belong to M/S OIL. As per the ESZ notification of Dibru-Saikhowa National Park, there are listed 268 well locations (though the actual status, whether abandoned, in operation, killed, exploratory or planned, is not known). This gives a straight probability of $7.5x10^{-3}$. Therefore, using this frequency [*why go to USA?*], the probability of the 7 ERD wells for which the EIA-ERM (2019) was authored, would stand at 0.0525 as against $3.08x10^{-3}$ reported. [*Further, it has to be noted that even then the frequency class does not change*]. It also needs to be noted that as per Oskarsen (2004)[24], "… that on average there is a blowout for every 110 kicks[25]. A reliability study of blowout preventers found an average of 52 kicks for every 100 wells drilled, 79 % of the kicks caused significant problems and 21 % resulted in loss of all or part of the well." This means that more than 220 kicks might have happened in Tinsukia oil/gas wells in last 15 years. There is no record of such events in public domain. **There seems to be no third party record keeper in India**.

4.10 Some Blow Outs From The Past

As already explained briefly, blow outs were very common prior to invention of the Blow Out Preventer (BOP) in 1920. However, wells often require work-overs and maintenance or change of damaged BOPs. Blow outs have been there, even thereafter, but frequencies have much diminished. Some of the major blow outs have changed the entire thought process on blow out and brought the focus rightly on the ecological damages that have occurred on the aftermath of these accidents. Off-shore blow outs

24 Oskarsen Ray Tommy, 2004, Development of a dynamic kill-simulator for ultradeep water, Ph.D Dissertation, Texas A&M University, August, 2004

25 Kick means "an entry of water, gas, oil, or other formation fluid into the wellbore during drilling. It occurs because the pressure exerted by the column of drilling fluid is not great enough to overcome the pressure exerted by the fluids in the formation drilled. If prompt action is not taken to control the kick, or kill the well, a blowout may occur" [https://www.osha.gov/SLTC/etools/oilandgas/glossary_of_terms/]

are most damaging. Deep Water Horizon in the Gulf of Mexico is one such disaster. There is a vast difference between off-shore and on-shore blow outs, explosion and fire. It was seen that comparison of one blowout to another was not at all easy, as all required data are not available in public domain. Very few parameters can be found common among the various blowouts described in the public domain and media reports. Some of the onshore blowouts are given below:-

Table No. 4.13: Some On-shore Blow Outs in the World

S. No.	Name of the Incident	Place & Country	Blowout date	No. of people, families and villages evacuated	Casualties & Impact on biodiversity	Remarks
1	Dandewala blowout in Thar Desert	Dandewala, Jaisalmer, Rajathan, India	29 Sept 2015	Data not available	Data not available	Only blowout
2	Elgin platform blowout	North Sea	25 Mar 2012	As the blowout occurred on a production platform located in the North Sea, more than 200 workers were evacuated	Data not available	Only blowout
3	Dikom Blowout	Dikom, Assam, India	13 Sept 2005	3000 people and 500 families	Data not available	Blowout and fire; it took 20 days to douse the fire
4	Pasarlapudi blowout, Onshore	Pasarlapudi, East Godavari, Andhra Pradesh, India	8 Jan 1995	1500 people and 7 villages	No casualties; the trees around were burnt to cinders and in a 500 m radius turned ash brown	Blowout and fire; it took 65 days to douse the fire
5	Ohio blowout	Belmont County, Ohio, USA	15 Feb 2018	Data not available	Data not available	Blowout and fire; it took 20 days to douse the fire
6	Mingbulak oil spill or Fergana Valley oil spill	Fergana valley, Uzbekistan	2 March 1992	Data not available	Data not available	Oil spill and fire; fire kept burning for 2 months and well dried

It appears that of all the onshore blowouts, the Baghjan blowout could be the ***largest and biggest onshore blowout so far in the world***, as it continued for more than 5 months without any change in its intensity or exhausting/ drying of the well, 3 persons were killed and 3 persons were injured, and it caused widespread damage to the terrestrial ecosystems.

4.11 Chronology Of Events Of The Present Blow Out

Table No. 4.14: Chronology of the Baghjan Blow Out

Date	Day	Time	Incident
27/05/2020	Wed	10.30 AM	Blow out at BGN#5 Well
29/05/2020	Fri	05.45 AM	Death of a Gangetic River Dolphin reported
02/06/2020	Tue		Expert Committee Constituted by Forest Department to assess damages
06/06/2020	Sat	11.00 AM	1st meeting of the Expert Committee
09/06/2020	Wed	7.00 AM	The Expert Committee members depart for Baghjan
09/06/2020	Wed	01.30 PM	The BGN # 5 Well explodes with a big mushroom cloud
10/06/2020	Thu	10.30 AM	Bodies of two dead firemen located by Expert Committee members and subsequently retrieved by NDRF from the ground zero
10/06/2020	Thu	11.00 AM	Ecological Assessment work begins
24/06/2020	Wed		Hon'ble NGT constitutes a 8 member Committee under the Chairmanship of Justice B. P. Katakey, Retired Judge of the Hon'ble Gauhati High Court
26/06/2020	Fri	1.00 PM	After the first wave of floods, large scale oil spread reported, many fishes and other wildlife died in the grassland
27/06/2020	Sat		Death of animals continued. Assessment carried out
28/06/2020	Sun		Death of animals continued. Assessment carried out.
22/07/2020	Wed	12.30 PM	Accidentally, while adjusting BoP alignments, the flame got lowered, and injured the three foreign experts working at the site
31/07/2020	Fri	1.00 PM	Attempt to arrest fire fails, as the Athey Wagon and rope snapped
10/08/2020	Mon		Blow Out Preventer (BOP) placed unsuccessfully on the well
17/08/2020	Mon		Blow Out Preventer (BOP) placed successfully on the well
13/09/2020	Sun		Diversion to EPS and flair points, 2000 psi pressure, production starts

Date	Day	Time	Incident
09/09/2020	Wed		One Young engineer died due to electrocution at the site
04/11/2020	Wed		The Snubbing Unit arrived at Site
15/11/2020	Sun	12.30 PM	The Well killed successfully.

4.12 Conclusions

1. M/S Oil India Ltd. which is a Central PSU in the MoPNG has annual profits to the tune of Rs. 2500 cr (after taxes), while all its owner companies, who hold stake together of 21.46%, have together profit after tax amounting to more than Rs. 33,000 cr. On the other hand, MoPNG has a budget of Rs. 27,000 cr and the IEBR of the MoPNG CPSUs stands at about Rs. 89,000 cr and actual spending about Rs. 100,000 cr. All these figures are approximations for 2018-19. M/S OIL hold more than 22,600 sq km of PML/PEL leases in India and owns more than 44,600 sq km of assets abroad.
2. In Assam, M/S OIL has drilled more than 1000 wells. It took 49 wells afresh in 2009 under the North Hapjan PML, and has now proposed another 7 ERD wells in Baghjan area.
3. The Climate Change energy use pathways for 2050 and 2100 foretell that if we have to overcome the 1.5^0 and eventually 2^0 rise in surface temperature, the use of natural gas and oil must either remain constant at 2018 levels or dip to lower than (more than half of) present consumption levels.
4. India's import of crude oil and LNG has been increasing steadily, and is about 200 MMT of crude oil and 30 BCM of LNG. Further, the inhouse production of crude oil and natural gas are falling gradually- standing at 17% of crude oil and 48% of LNG. M/S OIL share of crude oil production is roughly 10% of crude oil and 8% in natural gas. The total oil imports amounts to US$ 83 billion.
5. In addition to taxes etc, the Govt. of Assam would get Rs. 287 cr per MMT of crude oil production, and Rs. 42.5 cr per 365 MMSCM (~0.4 BCM) of natural gas production. These are at USD 1=63 INR exchange rates and crude oil price at $ 50 / bbl and LNG being at $4.66/MMBTU.
6. The CAG Audit Report of 2017 brings out several shortcomings and regulatory issues including under-reporting of production by the oil and natural gas producing companies of MoPNG.

7. Oil spills and blow outs are due to human errors. The effective blow out probability in the Tinsukia district comes to $7.5x10^{-3}$, and internationally $1.26x10^{-3}$, taking off-shore blow out probabilities. The EIA reports do not seem to focus on worst case scenarios possible. There also does not seem to be any oil related accidents' database in the country maintained in public domain. A study showed that for every 100 wells drilled, one can expect 52 kicks, of which 21% can be very serious. There is, therefore, chances of 1 blowout every 110 kicks. Given the well concentration in Tinsukia district, there is every chance of one more blow out happening in next 5 to 10 years. Tinsukia district should be very well studied in terms of oil and gas industry and its impacts on local populations, ecosystems and environments.
8. There does not seem to be any public record keeping of oil exploration and drilling related accidents including kicks in India.
9. Baghjan could be the largest onshore blowout that would last for more than 5 months at the same intensity of fire without the well drying up.

CHAPTER-5

5 MATTERS OF LAW AND POLICY

5.1 Outline Of The Chapter

This is the last Chapter of Part I that deals with the breaches and contraventions, if any, of the statutes of the land, as well as examining certain provisions and principles of environmental compensation followed internationally and in India.

While dealing with the laws and statutes, as may be applicable, an attempt has been made to provide a brief description of the contents at the beginning of the relevant Chapters in Part II of the Report. Therefore, here we shall confine to the overall contours of the legal and policy matters. There are various precedents of the Hon'ble Supreme Court that either lay down or reiterate some of the doctrines. This Chapter is in the nature of a legal and policy framework for the Report, specifically to point out the omissions and commissions in respect of the environmental damages caused. At the outset, it must be borne in mind that estimating civil liability towards ecosystems, ecosystem services and biodiversity does not have an applicable strait jacket formula unlike other compensatory jurisprudence pertaining to land, building, infrastructure, livestock, agricultural produce and other economic and opportunity losses for which there are well established methods. That as human beings we have the natural propensity to neglect the smaller creatures that play a pivotal role in maintaining and balancing the ecosystem, more so, since our jurisprudence, from the days of Manu and Moses, is based on man and his material possessions and myriads of situations arising therefrom.

The adverse effects on nature, ecosystems and atmospheric concentration of 440 ppm (parts per million) of CO_2 were never a consideration in the past unless it pertained to harm caused environmentally to the State Sovereignty (*i.e.* external aspect of the right not to be harmed by other States) which has risen in the recent past due to

inundation in pollution levels that have started to hit the sovereignty of States. Only when the Ozone depletion impacted human health, it dawned on people that environment was important for human beings. However, one does not realize that even the ubiquitous refrigerants in our households (a symbol of a developed economy, which was not so common in India about 30-50 years ago) had the potential to cause skin cancers and make people blind[26].

Only in recent times, people have started taking the environment and climate change a bit more seriously. In the past, the environment, ecosystems and biodiversity, were not matters of concern, as the population levels were low, technological growth was low and hence were the damages were limited; but today not only the population is high world over, the per capita demands are high, and the technologies have also exponentially grown in scale and capabilities, that have further caused damages to the environment, ecosystem and biodiversity, which are enormous. We are losing our ecosystems and biodiversity at unprecedented rates and we are threatened as never before[27,28] notwithstanding the fact that we are yet to fully understand the human impact on biodiversity[29]. The destruction of the natural environment by deliberate and/or negligent human action namely “ecocide” should weigh heavily on perpetrators of such crime, far more in comparison to homicide. For this purpose, this Report shall briefly touch upon the International Criminal Court and the Rome Statute.

26 Anwar, Fakhra & Nazir, Fahad & Nazeer, Saiqa & Zaman, Noshila & Azam, Saba. 2016) Causes of Ozone Layer Depletion and Its Effects on Human: Review. Atmospheric and Climate Sciences. 06. 129-134. 10.4236/acs.2016.61011.

27 Díaz S, Fargione J, Stuart Chapin F III, Tilman D (2006) Biodiversity loss threatens human well-being. PLoS Biol 4(8): e277. DOI: 10.1371/journal. pbio.0040277 DOI: 10.1371/journal.pbio.0040277

28 https://www.saveearth.info/loss-of-biodiversity/

29 Cardinale Bradley J, Duffy J. Emmet, Gonzalez Andrew, Hooper David U, Perrings Charles, Venail Patrick, Narwani Anita, Mace Georgina M., Tilman David, Wardle David A., Kinzig Ann P., Daily Gretchen C., Loreau Michel, Grace James B., Larigauderie Anne, Srivastava Diane S. & Naeemi Shahid, 2012, Biodiversity loss and its impact on humanity. *Nature* **486,** 59–67 (2012). https://doi.org/10.1038/nature11148

5.2 Rome Statute And Ecocide Amendment

The United Nations General Assembly had convened a conference in June, 1998 to finalize and adopt a convention on the establishment of an International Criminal Court. Accordingly 60 countries ratified the resolution and the law came into force from 1st July, 2002. Currently 120 countries are signatories to the provisions of the International Criminal Court, and it is governed by the Rome Statute. The Court has jurisdiction over 4 kinds of International Crimes namely 1. Crime of genocide, 2. Crime against humanity, 3. War crimes & 4. Crime of aggression. India is not a signatory to this Statute.

Almost a decade back, an amendment had been moved to include "Crime of Ecocide" as the 5th international crime.

Ecocide is defined as "***The extensive damage to, destruction of or loss of ecosystem(s) of a given territory, whether by human agency or by other causes, to such an extent that peaceful enjoyment by the inhabitants of that territory has been or will be severely diminished***". It is expected that the law of ecocide would prevent the risk of and/or actual extensive damage to, destruction of or loss of ecosystem(s); prohibit decisions that result in extensive damage to or destruction of or loss of ecosystem(s); pre-empt decision-making of a political, financial and business nature that may lead to significant harm.

5.3 The Ecocide Act

A group of lawyers led by Polly Higgins in 2011 drafted the Ecocide Act that defined ***Right to Life*** as: "The right to life is a universal right and where a person, company, organisation, partnership, or any other legal entity causes extensive damage to, destruction of or loss of human and or non-human life of the inhabitants of a territory … is guilty of the crime of Ecocide". The Ecocide Act, UK version, was actually used in a mock trial in the Hon'ble Supreme Court of the UK. However, due to untimely demise of the pioneer for the recognition of ecocide- Ms. Polly Higgins, the fate of the Ecocide Act is uncertain. Her views on ecocide law briefly can be seen in her paper entitled "Protecting the planet: a proposal for a law of ecocide"[30].

30 Higgins Polly, Short Damien & South Nigel, 2013, Protecting the planet: a proposal for a law of ecocide, Crime Law Soc Change DOI 10.1007/s10611-013-9413-6

5.4 Doctrines & Principles Of Compensation

The materials for this section has been largely picked from Assaf G. B. et al (1986)[31]. The paper is divided in two parts, first part deals with various neo-economic methods of non market valuation such as gross expenditure method, cost method, market value of catch method, value of services method, replacement cost method, willingness-to-pay method, and hedonic pricing method. We shall be describing a few universally accepted doctrines here.

It should be noted that reliance on these principles may be placed by the Hon'ble Courts of Law and Tribunals. There is a plaintiff or complainant who is the sufferer of a disaster such as oil spill, and defendant is usually the company/ firm/ agency / owner who caused the oil spill. A claim can be filed under some of these doctrines for private cause or public cause (say private nuisance and / or public nuisance), and in some cases may involve specific private reliefs, and in some or all of them common public interest at large. The discussion would be limited to the key principles of these doctrines and whether they apply or not privately or publicly. We shall confine to only to three most common doctrines such as the Doctrine of Nuisance, the Law of Negligence, the Doctrine of Strict Liability.

5.4.1 The Law of Nuisance

The Law of Nuisance can be applied publicly or as a case of private nuisance. However, the nuisance should not be of temporary nature, but rather ongoing or permanent. There are judgments wherein the Courts have held that a single case of oil spill did not constitute an ongoing phenomenon. On the other hand some Courts have admitted claims without any reference to the oil spill being an ongoing phenomenon. The issues such as rights of fishing in the sea or a public water body is a public right (held by the State in trust) which some may exercise and some may not. There are out-of-work fishermen and others who have lost their livelihood and their homes to this disaster, who have suffered pecuniary losses, but cannot establish a public nuisance, and hence may be liable to be considered under the category of "pecuniary losses"

Therefore, in case of Baghjan, if this law were to be invoked then the complainant would have to establish it as an "ongoing" nuisance and if the public nuisance is ought to be raised, then how the collective rights of groups of people such as fishermen are affected would have to be established. One may argue whether the blowout and fire at

31 Assaf George B, Kroetch Brent G, Mathur Subodh C, 1986, Nonmarket valuations of Accidental Oil Spills: A Survey of Economic and Legal Principles, Marine Resource Economics, Vol 2, No. 3, p211-237, 0738-1360/86/010211-00$02.00/0

Baghjan be considered a temporary phenomenon or ongoing one. Since the doctrine itself requires that the nature of nuisance must be permanent or ongoing, this may be difficult to establish in the case of the blow out and fire. However, drilling and rigs, oil mining activity carried out (albeit without proper permissions) and the pollution (noise, PAH, emissions etc.) caused can be a case fit for this doctrine, for which a detailed independent and transparent Environment Impact Assessment (EIA) is to be looked into. The onus of proof lies on the complainant to prove the law of nuisance.

5.4.2 THE LAW OF NEGLIGENCE

Unlike the Law of Nuisance, this doctrine is applicable to the defendants (the polluters). This law has been applied to almost all oil spills. The complainant, however, has to prove that the defendant was bound to take full care of the complainant, but he (they) breached and failed to exercise the amount of care that would be exercised by a reasonably prudent person under the circumstances. While on onus of proof is still with the complainant, the doctrine of *res ipsa loquitor* ("*Let the matter speak for itself*") allows the complainant to show his injury, and its the defendant who has to prove that he was not negligent. [That in relation with the blow out case, it is evident that it is a case of human error and negligence. For example Section 7.4.1 of the EIA-ERM (2019) on Page 156 under the heading "Blow Outs/ Loss of Well Control, the first paragraph reads as "*Blow out is an uncontrolled release of well fluid (primarily hydrocarbons viz. Oil and/or natural gas and may also include drilling mud, completion fluid, water etc.) from an exploratory or development well. Blow outs are the result of failure to control a kick and regain pressure control and are typically caused by equipment failure or human error.*" Equipment failure and human error both come under the category of negligence. Either the equipment used was faulty or it was mishandled or it had fatigued and not replaced in time or damaged and not detected well in time or any other operational issue. Conclusively blow out is through and through a human error and a fit case of negligence.

Another component of this case is that once negligence is established, the complainant may have to show that the defendant's conduct was an important contributory factor to the damages and injuries received by the complainant. In the case of Baghjan, on at least on four occasions the defendant (herein M/s OIL) has publicly lapsed on many counts and hence leaving cogent proof of their negligence. Firstly, the blow out itself, secondly, the accidental spark and explosion that killed two firemen and which further damaged and burnt the ecosystem along with a lot of endangered and scheduled protected animals, big and small, thirdly, another accident on 22nd July when the foreign

experts narrowly escaped from death, when the big flame got deflected accidentally, and fourthly, in September when a young engineer died of electric shock while working near the blow out site. Therefore, Baghjan is a case of negligence galore [*However, all such cases of negligence need to be investigated fully and thoroughly*.]

5.4.3 THE LAW OF STRICT LIABILITY

The doctrine of Strict Liability imposes full responsibility of a wrong doing emergent out of a risky enterprise on the person who undertakes such an enterprise or activity. In another words, "any person who for his own purposes brings on his land and collects and keeps there anything likely to do mischief, if it escapes must keep it at his peril and if he does not do so, is prima facie answerable for all the damage which is the natural consequence of its escape". This doctrine has been applied consistently abroad and in India in almost all industrial disasters including the Bhopal Gas Tragedy and the recent Vizag tragedy[32]. An equivalent principle is that of the "Law of Absolute Liability" which was applied for the first time in India by the Hon'ble Supreme Court in 1986 in Order Dt. 20th December, 1986[33]. The Hon'ble Court opined,"*an enterprise which is engaged in a hazardous or inherently dangerous industry which poses a potential threat to the health and safety of the persons working in the factory and residing in the surrounding areas owes an absolute and non-delegable duty to the community to ensure that no harm results to anyone on account of hazardous or inherently dangerous nature of the activity which it has undertaken. The enterprise must be held to be under an obligation to provide that the hazardous or inherently dangerous activity in which it is engaged must be conducted with the highest standards of safety and if any harm results on account of such activity, the enterprise must be absolutely liable to compensate for such harm and it should be no answer to the enterprise to say that it had taken all reasonable care and that the harm occurred without any negligence on its part*." The Hon'ble Supreme Court further opined

32 Beg Wasim, Chatterjee Swarnendu & Khanna Kritika, Bhopal To Vizag – A Jurisprudential Analysis Of The Tortious Liability For Companies, The SCC Online Blog, Https://www.scconline.com/blog/post/2020/06/15/bhopal-to-vizag-a-jurisprudential-analysis-of-the-tortious-liability-for-companies/

33 M. C. Mehta Vs Union of India and Others, Sriram-Oleum leak case, AIR, 1080, 1987, SCR(I) 819

in a forceful disposition, "*Article 32 does not merely confer power on this Court to issue direction, order or writ for enforcement of the fundamental rights but it also lays a constitutional obligation on this Court to protect the fundamental rights of the people and for that purpose this Court has all incidental and ancillary powers including the power to forge new remedies and fashion new strategies designed to enforce the fundamental rights. It is in realisation of this constitutional obligation that this Court has, in the past, innovated new methods and strategies for the purpose of securing enforcement of the fundamental rights, particularly in the case of the poor and the disadvantaged who are denied their basic human rights and to whom freedom and liberty have no meaning*"

The Hon'ble Supreme Court further posits, "*Law has to grow in order to satisfy the needs of the fast changing society and keep abreast with the economic developments taking place in the country. Law cannot afford to remain static. The Court cannot allow judicial thinking to be constricted by reference to the law as it prevails in England or in any other foreign country. Although this Court should be prepared to receive light from whatever source it comes, but it has to build up its own jurisprudence, evolve new principles and lay down new norms which would adequately deal with the new problems which arise in a highly industrialised economy. If it is found that it is necessary to construct a new principle of law to deal with an unusual situation which has arisen and which is likely to arise in future on account of hazardous or inherently dangerous industries which are concomitant to an industrial economy the Court should not hesitate to evolve such principles of liability merely because it has not been so done in England*." The Hon'ble Apex Court further opines, "*If the enterprise is permitted to carry on an hazardous or inherently dangerous activity for its profit, the law must presume that such permission is conditional on the enterprise absorbing the cost of any accident arising on account of such activity as an appropriate item of its overheads. The enterprise alone has the resource to discover and guard against hazards or dangers and to provide warning against potential hazards*" Thus, it is seen that the Hon'ble Supreme Court has laid down in clear terms the standard legal liability by way of the Law of Absolute Liability in case of hazardous and dangerous activities.

5.4.4 How Much Compensation is Adequate Compensation?

The quantum of compensation is a very complex subject, especially since there are various methods of civil liability imposed in case of damage to the ecosystem services and the natural resources including the various species of the biodiversity, as proposed by the western as well as Indian ecological economists, that may or may not be applicable as is to the Indian scenario. Putting a price tag to the natural environment is not part of the Indian cultural landscape from East to West, and North to South. How can one weigh the bounties of nature with a sackful of coins?

However, in this regard, the Hon'ble Supreme Court has clearly stated [in the matter discussed in the previous sub section], "*The measure of compensation in such kind of cases must be co-related to the magnitude and capacity of the enterprise because such compensation must have a deterrent effect. The larger and more prosperous the enterprise, the greater must be the amount of compensation payable by it for the harm caused on account of an accident in carrying on of the hazardous or inherently dangerous activity by the enterprise*"

The principle of compensation, therefore, should be based on the capacity of the enterprise to pay. We shall be examining this capacity towards the end of the Part II of this Report. We shall also try to examine the capacity of the owners of the enterprise to pay. Meanwhile, the financial capability of the company and its owners have already been dealt with in some detail in Chapter 4.

The question here that arises is that of the principle of natural justice.

In case of private enterprises, the tendency is to look at the pocket size of the owners, and we often forget that it is the enterprise that actually is liable. In case of Government enterprises, we tend to forget the owner altogether, as it is the Government that is liable, and try to measure the pocket of the enterprise. ***This should not be allowed to happen for sake of natural justice***. We must not forget that while in case of the private enterprises, the pocket size of the owner and the company in question are the same (in fact, the pocket sizes of companies floated are smaller than those of the owners).

Therefore, in case of Government enterprises also the same should true, the owners, i.e. the Government ministries or departments who "contrive" to float the enterprise to achieve certain profit motives [which is, indeed, a cherishable and desirable output of any enterprise] and to attain public good as well, have bigger pockets than the enterprises that they create. Hence, the pocket size must be always measured from the "owners" point of view of which the enterprise-pocket is only a small part. It is for the Hon'ble Courts and the Tribunal to decide whether in the cause of natural justice, the compensation amount should be decided based on the hosting departments'/ ministries' pockets as one would do instinctively for a private enterprise. It is important that the government departments are also held equally accountable and liable for ecocidic disasters, the effects of which have not unfolded fully and the impact may not be entirely comprehensible even to the Hon'ble Courts as not only the poor rural people have suffered, but also the multitude of helpless and hapless creatures, trees, plants, flora and fauna, who have none to speak for them other than the benevolence of the Hon'ble Courts and Tribunals. It is most unfortunate that even in the 21st century the "foresters and wildlifers" are often perceived as "anti-development". Every time the industries/corporates take forward the baton as "priests of development" in the name of their projects by promising growth and prosperity by invoking the language of sustainability by housing their projects either within or near to the remnant tiny patches of green forests, sanctuaries, national parks, animal corridors and such places which are becoming scarce and are the natural habitat of the poor creatures, and hence 'ecologically very costly' but of little value to them as compared to other land parcels, there is a cry for necessity of so-called 'development, employment and economy boosting' projects. The Baghjan incident highlights the stakes involved in corporate claims about sustainability. This event has become intimately familiar to the public at large through images of underwater oil plume, polluted wetlands, and endangered species burnt alive and coated in oil. This event begs the question whether corporate discourse on sustainability represents a market shift in how business operates or just a shift in how corporations market themselves. It is surprising how quickly these

"worshipers of development" forget the discourse of sustainability and abandon their responsibility for protecting the local people, flora and fauna. It is even more disheartening that the companies in their pursuit of vested interests forget to take reasonable care so as to circumvent disasters that are 'this' colossal, and despite which at no point do these companies and their owners consider investing their financial resources to future proof such ecological the disasters or come forawrd generously to aid nature in rejuvenation process. The pockets of the companies fall short and their projects become nonviable when it comes to pay for the compensation or do good to the planet's ecology. Therefore, it is not the sole responsibility of M/s OIL and/or ONGC, it is also the bounden duty of the MoPNG to contribute in restoring the environment as well as provide compensation to those who have suffered physical or economic losses due to the oil pollution, such as fishermen or those engaged in the tourist industry or the local people who have been dislocated from their homes.

5.5 Off-shore Oil Spills And International Conventions

There is a fundamental difference between an onshore and off-shore oil spill. While onshore oil spills are not large in scale and confined to some territory of a nation, and is less likely to become international, on the other hand, the off-shore oil spills such as a blow out or tanker leak can spread far and wide and may touch territorial waters of two or more countries, and are difficult to control. Further, while neither off-shore blow out nor oil spill is applicable in the case of Baghjan, the difference is being discussed for the approach being adopted in best international practice.

The Outer Continental Shelf Lands Act, (OCSLA) 1953 of USA is a unique Act which brings all the continental shelf around USA under singular control of the Federal Government, where, otherwise, all land belongs to various states, and an amendment to it was made in 1978, by which oil pollution damage onus was placed on the owners and operators of vessels or off-shore facilities. The Act also established Off-shore Oil Pollution Compensation Fund in order that money is available immediately for removal of spilled oil. The fund has to be maintained at all times at the level of US$ 110-200

million. It is maintained by a collection of cess not more than US$0.03 per barrel on all oil produced on the Outer Continental Shelf of America. Through this fund, not only individuals (for loss of at least 25% of their income), even the Government bodies can seek relief for loss of tax revenues. The governments can claim cost of damages for the natural resources.

In the international arena, *International Convention for the Prevention of Pollution of the Sea by Oil* (OILPOL) was the first international convention in 1954 that dealt with oil spills on high seas and shorelines. It was later replaced by MARIPOL, which was established after the "Torrey Canyon Disaster in the English Channel [on the 18th March, 1967 in which 15000 sea birds were estimated to have died. The compensation of UK was about GBP 6 Million, and FRF 40 million to France.], in 1973 as I*nternational Convention for the Prevention of Pollution from Ships*[34]. Further, the international funds for compensation have also been established. Under the aegis of the International Maritime Organization (IMO), the 1992 International Convention on Civil Liability for Oil Pollution Damage, in short 1992 Civil Liability Convention, and the 1992 International Convention on the Establishment of an International Fund for Compensation for Oil Pollution Damage, in short 1992 Fund Convention, have been set up to pay for compensation arising out of oil spills in the high seas and shore-lines[35]. The 1992 Conventions apply to cargo ships which carry oil in bulk as generally laden tankers, as well as to spills of bunker oil from unladen tankers in certain circumstances. In the aforesaid two conventions, the shipowners have strict liability for pollution damage (with very limited defences) and are obliged to cover their liability by insurance. Shipowners' limited liabilities are calculated on the basis of the tonnage of the ship, and may range from US$7 million for small ships to US$136 million for large tankers. Shipowners are deprived of the right to limit (mitigate) their liability if it is proved that the pollution damage resulted from the

34 Ekaterina Anyanova, 2012, Oil Pollution and International Marine Environmental Law, IntechOpen, https://doi.org/10.5772/37399

35 Jacobsson M. (2007) The International Oil Pollution Compensation Funds and the International Regime of Compensation for Oil Pollution Damage. In: Basedow J., Magnus U. (eds) Pollution of the Sea — Prevention and Compensation. Hamburg Studies on Maritime Affairs, vol 10. Springer, Berlin, Heidelberg. https://doi.org/10.1007/978-3-540-73396-6_11

shipowner's personal act or omission, recklessness or knowledge that such a damage would occur.

5.6 Indian Environmental Laws

The key environmental laws of the country are:-

1. Water (Prevention and Control of Pollution) Act, 1974
2. Air (Prevention and Control of Pollution) Act, 1981
3. Environment (Protection) Act, 1986
4. Environment (Protection) Rules, 1986
5. The National Green Tribunal Act, 2010

The key Forestry and Wildlife statutes are:-

1. Assam Forest Regulation, 1891
2. Wildlife (Protection) Act, 1972
3. Forest (Conservation) Act, 1981
4. The Biological Diversity Act, 2002

The environmental and industrial disasters are covered under:-

1. Public Liability Insurance Act, 1991

The Environmental Clearance (EC) is granted under the orders of MoEF&CC vide;

1. MoEF&CC Notification No. S.O. 1533 (E) Dt. 14th September, 2006

In addition, there are three major criminal acts in the country: 1. The Indian Penal Code, 1886, 2. The Criminal Procedure Code, 1973 and 3. The Evidence Act, 1872. However, the relevant Acts (other than the major criminal Acts, with the exception of IPC, have not been referred to herein) have been dealt with in detail at the beginning of each of the Chapters 8, 9,10, 11 & 12. These are not being repeated for sake of brevity of this Report. Here, it is proposed to discuss, in the paragraphs that follow, some relevant provisions of the Forest (Conservation) Act, 1981, the Public Liability Insurance Act, 1991 and the Notification of MoEF&CC No. S.O. 1533 (E) Dt. 14.9.2006. In addition, some procedural issues such as grant of Consent to Establish (CTE), Consent to Operate (CTO), relevant provisions of Eco-Sensitive Zones (ESZ). To start with the Environmental Clearance followed by Forest Clearance (FC) shall be discussed.

5.7 The System Of Environmental Clearance Explained

The Environmental Clearance (EC) is accorded with the objectives of the National Environment Policy approved by the Union Cabinet and the procedure specified under the Notification No. S.O. 1533 (E) Dt. 14th September, 2006 which has been issued by the Ministry of Environment Forests and Climate Change, New Delhi in exercise of the powers conferred by sub-section (1) and clause (v) sub-section (2) of section 3 of the Environment (Protection) Act, 1986, read with clause (d) sub-rule (3) of rule 5 of the Environment (Protection) Rules, 1986.

5.7.1 Categories of Industrial Projects

The Notification No. 1533 (E) Dt. 14.9.2006 of the Ministry of Environment, Forests & Climate Change (MoEF&CC) lays down all the procedural aspects of prior Environmental Clearance, for which all projects needing prior EC have been divided into two categories namely A and B. Category A are typically major projects, for which the power to grant EC is with the Govt. of India, and for minor projects falling in Category B, the State EIA Authority (SEIAA) has been authorized to issue prior EC. All Offshore and onshore oil and gas exploration, development & production projects, as per the notification, listed at Serial 1 (b) of the Schedule to the Notification, are categorized as **A Category** projects. Hence, prior EC can only be granted by the Govt. of India. However, Exploration Surveys (not involving drilling) are exempted provided the concession areas have got **previous clearance for physical survey**.

5.7.2 Procedure for EC of A Category Projects

All projects or activities included as Category 'A' in the Schedule, including expansion and modernization of existing projects or activities and change in product mix, require **mandatory prior Environmental Clearance (EC)** from the Central Government in the MoEF&CC on the recommendations of an Expert Appraisal Committee (EAC) to be constituted by the Central Government for the purposes of the Notification. The Notification sets out the clearance process in 4 stages:-

1. Screening [Not needed for Category A projects]
2. Scoping [Not needed for category B projects]
3. Public Hearing [Certain projects exempt, but NOT petroleum mining]
4. Appraisal [by EAC for category A projects]

The public hearing is required to be conducted by the State Pollution Control Board (PCBA in case of Assam) as per detailed procedure laid down in the Notification.

There is a rider. In case a B category project that falls within 10 km of a National Park or a Wildlife Sanctuary, it gets to be treated as Category A. Any project falling within 10 km of a protected area also requires wildlife clearance.

Any project requiring prior EC must take a certificate from the Chief Wildlife Warden of the State if the project area, or any part thereof, falls within 10 km of a protected area. While this is not explicitly written, but the implication is discernible.

5.8 The System Of Forest Clearance (FC) Explained

Forest Clearance is required in case the project area or a part of it falls in a notified forest or a National Park or a Wildlife Sanctuary or a Deemed Forest [in Assam deemed forest is considered as an area having minimum 200 trees per ha – naturally growing or USF land]. In such a situation the user agency (project owner-whether Govt. or private) is required to proceed under the Forest (Conservation) Act, 1981. This, then, becomes a case of diversion of forest land, and one needs to proceed as per the Rules and Guidelines framed under the FC Act, 1981.

5.8.1 Stage 1 and Stage 2 Forest Clearances

The clearance is two step process: Stage 1 (In Principle Approval) and Stage 2 (final Approval). When the project is appraised by the Forest Advisory Committee of the Government of India in the MoEF&CC, after the proposal has been placed before the Govt of India from the State. In 1st stage, the proposal is agreed to “In Principle” in which usually the conditions relating to transfer, mutation and declaration as RF/PF

under the AFR, 1891 of non-forest land, wherever required, for compensatory afforestation, funds for raising compensatory afforestation thereof, realization of Net Present Value (NPV) are stipulated. There could also be wildlife related conditions in addition to the above, if the area diverted is a part of a protected area or falls in the ESZ or within 10 km of a protected area, as the case may be, certain additional conditions may be imposed, and the proposal may require approval of SBWL & NBWL. Once all the conditions are met by the user agency, including deposition of the moneys as directed, the State Government sends a compliance report to the Government of India for issuance of the Stage 2 or "Final Approval".

5.8.2 WILDLIFE CLEARANCES

As already stated above, and just to lay emphasis, in case the project area falls within 10 km of a protected area or falls in an ESZ or diversion pertains to a protected area, the clearance of the CWLW, SBWL & NBWL is required prior to granting of Stage 1 clearance. Further all the stipulated conditions must be fulfilled prior to grant of the Stage 2 clearance. In case of Baghjan oil fields, there was no diversion of forest land or any protected area involved. However, the proposed fields were within 10 km of the Dibru-Saikhowa National Park and the Bherjan Borajan and Podumini WLS. Hence, wildlife clearance was required.

5.8.3 ECO-SENSITIVE ZONE CONDITIONS

There is a restriction in mining activities in respect of ESZs within 1 km boundary of the protected areas. As per the ESZ notifications (all, without exception), mining is a prohibited activity, and "*(a) All new and existing mining (minor and major minerals), stone quarrying and crushing units are prohibited except for the domestic needs of bona fide local residents. (b) The mining operations shall strictly be in accordance with the orders of the Hon'ble Supreme Court dated the 4th August, 2006 in the matter of T. N. Godavarman Thirumulpad Vs.Union of India in Writ Petition (Civil) No.202 of 1995 and dated the 21st April, 2014 in the matter of Goa Foundation Vs. Union of India in Writ Petition (Civil) No.435*

of 2012." As of now, all the oil wells within 1 km of the Dibru-Saikhowa National Park and the Bherjan Borajan and Podumoni WLS, which are existing in violation of the orders of the Hon'ble Supreme Court of India, must be extinguished forthwith.

5.8.4 FOREST (CONSERVATION) ACT, 1980 AND OIL LEASES

As already stated in Chapter 4, it was pointed out by CAG (See Sl. 17 of Para 4.8.3) that "*The GoI while granting PMLs instructed that Forest Clearance from the Competent Authority should be obtained for the Reserved Forest areas falling in the leased areas. Test check of records revealed that 17 lease holders of PMLs did not obtain the said clearance from the concerned Divisional Forest Officer (DFO) though parts of the leased areas fell in Reserved Forest areas*". Let us examine the legal position. As per the Section 2 of the Forest (Conservation) Act, 1980, "*Notwithstanding anything contained in any other law for the time being in force in a State, no State Government or other authority shall make, except with the prior approval of the Central Government, any order directing-*" (iii) "*that any forest land or any portion thereof may be assigned by way of lease or otherwise to any private person or to any authority, corporation, agency or any other organisation not owned, managed or controlled by Government*". It appears from the reading of the above that "leasing" to the Government owned agencies may not be against the Act.

However, the Hon'ble Supreme Court in its order Dt. 12th December, 1996 in the WPC 202/1995, directed "*1. In view of the meaning of the word "forest" in the Act, it is obvious that prior approval of the Central Government is required for any non-forest activity within the area of any "forest". In accordance with Section 2 of the Act, all on-going activity within any forest in any State throughout the country, without the prior approval of the Central Government, must cease forthwith. It is, therefore, clear that the running of saw mills of any kind including veneer or ply-wood mills, and mining of any mineral are non-forest purposes and are, therefore, not permissible without prior approval of the Central Government. Accordingly, any such activity is prima facie violation of the provisions of the Forest Conservation Act, 1980. Every State Government must promptly ensure total cessation of all*

such activities forthwith". Therefore, if no prior clearance was taken under the FCA, for grant of lease over forest areas, then, it is clear cut violation of the FCA.

5.9 Laws Applicable To Blow Outs

Among other statutes, it is seen that the Oil Mines Regulations, 1984 deals comprehensively with blow out and blow out prevention. The section 2 (6) & (7) define blow out and blow out prevention, 2(44) defines "kick", 2 (36) defines "gas free" environment and 2(40) defines "hazardous atmosphere". The Regulation also defines the regulatory mechanisms including "inspectors", "managers" and "competent persons". The Chapter IV provides all the required procedures for "workover" or well maintenance. The Regulation says that during blow out conditions an area of 500 m radius from the outer periphery of the well installation site shall be declared hazardous. Section 45 and 46 are quoted here for sake of a general reference, even though, finding fault and fixing responsibility as to "*who done it*" is not a part of the mandate of this Committee. It is for the appointed Regulators to see whether any of the provisions of the Law and Regulations have been violated at any point of time.

5.9.1 SECTION 45 – PRECAUTIONS AGAINST BLOW OUT

(1) The following control equipment for the drilling mud system shall be installed and kept in use during drilling operations : (a) A pit level indicator registering increase or reduction in the drilling mud volume and shall include a visual and audio warning device near the driller's stand. (b) A device to accurately measure the volume of mud required to keep the well filled at all times; (c) A gas detector or explosimeter at the primary shale shaker and connected to audible or visual alarm near the driller's stand; (d) A device to ensure filling of well with mud when the string is being pulled out; (e) A control device near the driller's stand to stop the mud pump when the well kicks, Provided that where special conditions exist which make the compliance with the provision of this sub regulation not reasonably practicable, the Chief Inspector may, by a general or special order in

writing and subject to such conditions as he may specify in such order, grant relaxation from the aforesaid provision.

(2) If the control equipment mentioned in sub-regulation (1) indicate that formation fluids are entering the well, immediate steps shall be taken to control the well.

(3) (a) The manager of every mine in which blowout preventor assembly is installed, shall submit to the Regional Inspector within 60 days of the coming into force of these regulations or in the case of a new installation within 30 days of the installation, standing orders specifying the action to be taken when a well kicks and the duties of each person employed on the rig and such order persons as may be necessary for blowout drills and actual emergencies. (b)The Regional Inspector may, by an order in writing approve of such standing order either in the form submitted to him or with such additions and alterations as he may think fit; the standing orders so approved shall be enforced at the mine. (c) A copy of the standing orders shall be posted prominently near the rig.

(4) Each persons employed on a rig shall have an adequate understanding of the warning signs of a kick, the standing orders mentioned in sub-regulation (3), the blowout preventer assembly and be able to operate the controls for blowout preventers. Blowout prevention drill shall be conducted for this purpose once in seven days.

(5) Suitable control valves shall be kept available near the well which can be used in case of emergency to control the well.

(6) When running in or pulling out tubings, a gate valve and tubing hanger shall be preassembled and kept readily available at the well.

5.9.2 SECTION 46- PRECAUTIONS AFTER A BLOW OUT

(1) On the appearance of signs indicating that a well is blowing out persons other than those whose presence is deemed necessary for controlling blowout shall be immediately withdrawn from the well.

(2) During the whole time that any work of controlling a blowout is in progress, the following precautions shall be taken - (a) Competent person shall be present on the spot throughout; (b) An area not less than 500 metres measured from the outer most point of the installation shall be considered as danger zone. (i) all electrical installations within the danger zone shall be de-energised; (ii) approved safety lamps or torches shall only be used within the danger zone; (iii) no naked lights or vehicular traffic shall be permitted within the danger zone. (c) a competent person shall ascertain the condition of ventilation and presence of gases with an approved instrument; (d) there shall be available at or near the place, adequate number of self contained breathing apparatus or any other apparatus of approved type for use in emergency; (e) adequate fire-fighting equipment shall be kept readily available for immediate use.

5.9.3 CONDITIONS ENSHRINED IN THE EC

All conditions enshrined in the EC are supposed to be monitored at regular intervals.

5.10 The Public Liability Insurance Act, 1991

The Public Liability Insurance Act, 1991 was enacted post Bhopal gas tragedy. While a quick search and review about its implementation[36] showed its applicability is more to minor accidents and third party insurance, its applicability to large environmental disasters caused by large industrial accidents such as blow outs and oil spills in very limited. We shall briefly dwell upon the Act in the paragraphs below[37].

5.10.1 OBJECTIVES OF THE PUBLIC LIABILITY INSURANCE ACT, 1991

1. The Public Liability Insurance Act, 1991 ("**Act**") provides for mandatory Public Liability Insurance. The purpose of the Act is to provide for immediate relief to victims and persons (other than workmen) affected by accidents occurring while handling hazardous substances through the insurance amount paid by the company/owner engaging in the activity of the hazardous substance.

2. The speciality of this Act is that it provides for `No Fault Liability' against the owners of hazardous substances. In other words, the owner of a hazardous substance must have insurance coverage so that any person injured or

36 Kaur Amanpreet, 2013, Law relating to accidental claims in India a socio legal study, Department of Law, Punjab University, http://hdl.handle.net/10603/28179,

37 Dhwaj Gaurav, 2020, New Delhi [unpublished work]

died of any hazardous substance could claim compensation, without going into any question of fault on the part of the owner.

3. According to the Act, owners of companies that use hazardous substances shall take out insurance policies to cover liabilities from accidents that cause death, injury, or disability.

4. The Act also provides that the Central Government can establish an 'Environmental Relief Fund' to be used to give assistance to accidental victims in hazardous/dangerous companies. The Act also regulates business owners to take insurance policies that cover obligations not less than the paid-up capital of the business and not more than Rs 50 crore.

5. Any person who has sustained injury, the owner of the property to which the damage has been caused, the legal representatives of the deceased, in case of death occurred as a result of the accident and the authorized agent of the above mentioned can apply for the claim/ relief under the Act.

The major reason for enacting this law was the ***Bhopal Gas Tragedy Union Carbide Corporation vs. Union of India***, in which more than 3000 people lost their lives.

5.10.2 ENVIRONMENT RELIEF FUND (ERF)

1. The Central Government established 'Environment Relief Fund' under the Section 7A of the PLA Act, 1991, towards the utility of paying relief under an award made by the collector under whose jurisdiction the accident occurred/hazardous substance lies. The funds so disbursed by the Collector are to be recouped from the owners back to the ERF.

2. The primary purpose of the ERF is to provide relief to persons (except workmen) who are injured or have died or suffered damage to their property due to an accident that is attributable to the handling of the hazardous substances by the industry. The liability of the owner to provide the relief is of a nature of no-fault liability. Thus, it is not necessary for the claimants to establish any negligence, fault or wrongful act of the industry that has resulted in the death, injury or loss of property of the claimant. Therefore, the Act requires the owner of an industry handling hazardous substances to subscribe to an insurance policy to insure against the liability arising out of such claims.

3. ERF makes it mandatory for companies that can be regulated under the Act to deposit a sum of money equal to one premium of its insurance policy with a fund manager, which is presently United India Insurance Company Limited (UIICL).

4. The Act requires the following amounts to be credited to the ERF:

    1. An amount that is equivalent to the premium of the insurance policy that is taken out by the owner[38]
    2. The income from investments
    3. Any other money that is mentioned in Section 4(2C) of the Act.[39]

The process of disbursement of relief has been enunciated in the Environmental Fund Relief Scheme, 2008. It has been reported that there has been little or no expenditure from the fund till now, except the fees to the Fund Manager. The Fund Manager admitted to the fact that the funds have not been used in the financial year of 2017-18. While the Hon'ble NGT has been functional since 2010, and from 2014-2019, more than Rs. 645 Cr has been awarded as compensation, but little fund has flown to the ERF. The current accumulation of fund appears to be about Rs. 374. 8995 cr. The matter is quite complicated. The reader is referred to an independent study which relates the sorry state of affairs[40].

5.10.3 RELEVANCE OF THE PLI ACT TO THE BAGHJAN INCIDENT

Due to the mass destruction and contamination of air, water, land, wetlands, flora and fauna including aquatic mammals, fishes, birds, wildlife habitats and their breeding ground, not only the source of livelihood of the local people/families which includes agriculture, fishing and animal rearing have been devastated but also their land has become infertile. Most of the families in and around the oil site have lost their primary source of livelihood. The oil well blowout had displaced close to 11000 residents living in the vicinity of the site, who were huddled in temporary shelters set up in schools amidst the already a global pandemic called COVID-19. That, even in order to provide immediate relief to persons affected by accident involving hazardous substances under this Act, the policy value limits stipulated in the Public Liability Insurance Act are extremely meagre [and need upward revision, the same may be augmented with the binding precedents of the **Supreme Court** – (i) *M.C. Mehta and Anr. vs. Union of India & Others, AIR 1987 SC 1086* and (ii) *Indian Council for Enviro-Legal Action and others vs. Union of India and others 1996 (3) SCC 212, AIR 1996 SC 1466*], it proves to be a handicap.

38 Public Liability Insurance Rules, 1991 § 11.
39 Public Liability Insurance Act 1991 § 4.
40 Sinha Debadityo, 2020, Report on the management of the Environment Relief Fund, Vidhi Centre of Legal Policy, March, 2020,

The financial limits in the PLI Act, 1991 are imposed in the Schedule appended to the Act, which are highly limited at the current price points. The details of the Schedule to the Act as per Section 3 (1) are described in the next para. In case of insurance, the Section 4 (2A) limits it to Rs. 50 crore. In case of M/s OIL, the paid up capital is Rs. 1084 cr, but they only need to do an insurance of Rs. 50 cr for all of their hazardous material operations across the country.

5.10.4 IMPORTANT SCHEDULES OF THE ACT

Section 3(1) of the Act stipulates payments where death or injury to any person (other than a workman) or damage to any property has resulted from an accident, the owner shall be liable to give such relief as is specified in the Schedule for such death, injury or damage. The Schedule has the following provisions for the said costs:-

1. Reimbursement of each medical expense up to a maximum of Rs 12,500.
2. In case of a fatal accident, the assistance is Rs 25,000 per person, in addition to reimbursement of medical expenses incurred by the victim up to a maximum of Rs 12,500.
3. In the case of permanent partial or partial permanent disability or injury or other illness, the assistance is to reimburse medical expenses up to a maximum of Rs 12,500 each and cash benefits based on the percentage of Disability certified by an authorized doctor. Assistance for total permanent damage is Rs 25,000.

A fixed monthly allowance of a maximum of Rs. 1000 per month for a maximum of 3 months is given for salary loss due to the temporary partial inability to work which reduces the victim's profit capacity provided the victim is hospitalized for more than 3 days and is over 16 years old. Up to Rs 6,000, depending on actual damage, for damage to personal property.

The above submissions pertaining to the PLI Act, 1991 are based on several readings of the Act and discussion with a couple of lawyers. The views expressed in this section and elsewhere in the Report are only in the nature of improvements sought for its applicability to large scale disasters.

5.11 Conclusions:

We may draw the following conclusions based on the discussion above:-

1. The State may claim damages on account of loss of taxes and revenues. Therefore, the State shall have a claim of the total revenue loss and taxes thereof.
2. The injury caused to natural systems such as ecology and ecosystems, and loss of biodiversity form another component of the damages.
3. The losses to individuals by way of actual damages and those by way of damages in public nature need to be looked into as the third component of the damage universe.
4. The amount of compensation or cost of damages should be commensurate to the pocket size of the owners of the Company that inflicted the damages, even if its a Government company.
5. The compensation claim can be challenged in the Court of Law/ Tribunals having jurisdiction on the subject matter.
6. The PLI Act, 1991 has a very limited or insignificant role in large ecological disasters such as Baghjan blowout. The Act needs complete overhauling.



The Baghjan Flame after Affixing of the BOP Riser



GOVERNMENT OF ASSAM

ONE MAN ENQUIRY COMMITTEE

(ORDER No. FRW.6/2020/1 Dt. 12th June, 2020)

REPORT PART-II

ON

DAMAGES TO

ENVIRONMENT, BIODIVERSITY, WILDLIFE, FORESTS

&

ECOLOGY

ON ACCOUNT OF

BLOW OUT AND EXPLOSION AT OIL WELL No. BGN-5

BAGHJAN, TINSUKIA
ASSAM (INDIA)

BY

MAHENDRA KUMAR YADAVA I.F.S.
ADDITIONAL PRINCIPAL CHIEF CONSERVATOR OF FORESTS (WILDLIFE)
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10th February, 2021

VOLUME-I



An aerial view of the landscape



Oil condensate in the waterbody

CHAPTER-6

6 UNDERSTANDING THE BAGHJAN BLOWOUT - I

6.1 Introduction

Before one gets to the ecosystem and biodiversity damages, an attempt must be given, though very preliminary and rudimentary, to understand the phenomenon, in physical terms, that was responsible for ravaging the Maguri Motapung Beel completely, and throwing almost 3000 families to refugee camps, burning the homes and hearths of almost 100 families, and putting almost 11000 people in the surrounding of the blow out to a series of multiple disasters one after the other.

In this Chapter and next [*actually till Chapter 11*] an attempt would be made to get to the basic physical, chemical and thermal characteristics of the blowout, the explosion that followed and the gigantic flame that stood shining for months after having scorched the nearby lands, and burnt almost everything that the wind could bring in its path. The undertaking in this Chapter would not have been so onerous, arduous and time consuming, had the owners of the well, M/S Oil India Ltd, provided the requisite information asked for. It would have been a much better situation, had they voluntarily supplied the information/data. It is very surprising that some of the basic details being dug in this Chapter were yet to be made public.

The subject matter of this Chapter is mostly the first level conjectures comprising of a series of parameters that possibly went into making the blowout, explosion and the flame at Baghjan, such as the amount of fuel supply at the well head in kg/s or in cubic meter per day per chemical constituent, the amount of fuel available in the vicinity of the blow out at any point of time (total combustible material lying around- from the well, in the surroundings, and in the air) in million cubic meters or kilo tons, the flame height and flame temperature together with its sonic properties. Some of the estimates given in this Chapter may either remain unchanged or may change on closer examination in subsequent Chapters based on the premises developed in this Chapter.

6.1.1 The Philosophy Behind the Report

The author had option, on being appointed as the One Man Enquiry Committee to make a quick reconnaissance, submit a straight line report, and be over with it. However, the matter of environment, wildlife and biodiversity is very delicate. In the existing system of jurisprudence, the world over, one cannot equate “some x sq km of

land parcel being affected by oil" or "one thousand earthworms and molluscs gone dead" with a human tragedy even on a one in hundred thousand fraction. Therefore, objectivity in the enquiry becomes a prime factor, and all due care must be taken so that the "actual damages" can "actually be assessed". Quoting the Norwegian[41] document, "Guidance on calculating blow out rates and duration for use environmental risk analysis", it presents a very scientific viewpoint on the matter, and to which the author subscribes fully.

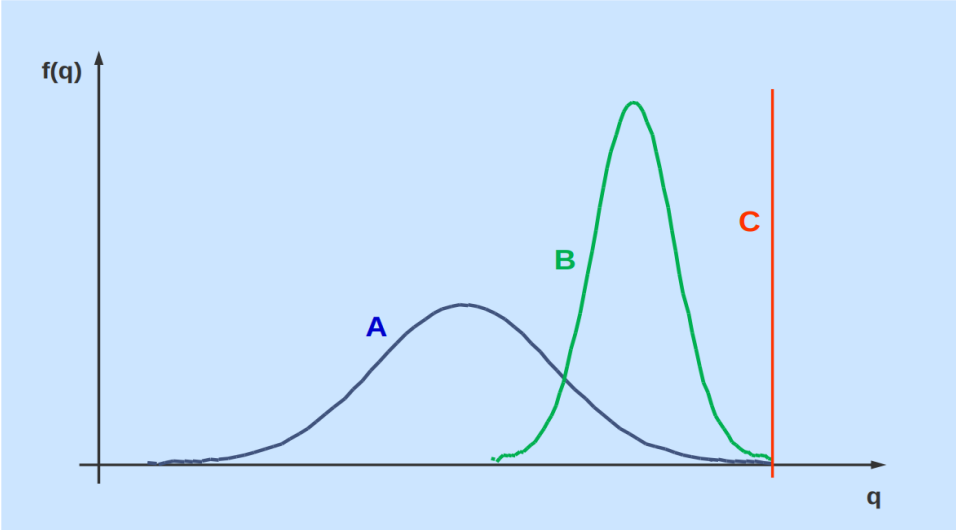


Fig. No. 6.1: The Three Types of Blowout Assessment Reports

The chart above describes three types of assessment reports. Type C: Greatly simplified, conservative analysis; Type B: Less detailed analysis with conservative simplification; and Type A: Detailed Analysis. Type A is supposed to be a "**normally distributed**" report. **This report is proposed to be a TYPE A REPORT**.

6.1.2 THE PATH TO BE FOLLOWED IN THE REPORT

A detailed normally distributed Type A Report is needed for the Baghjan blow out. The steps involved are outlined diagrammatically, once again from the Norwegian Report:-

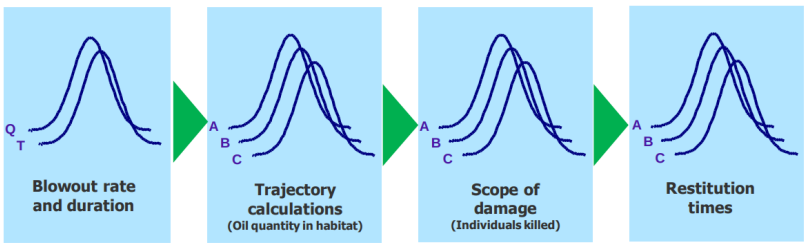


Fig. No. 6.2: The Steps involved in Distributed Type A Report of a blowout

41 Anonymous, Guidance on calculating blow out rates and duration for use environmental risk analysis, Norsk olje & gass, Norwegian Oil & gas Association, 2014

The diagram clearly elucidates the steps to be followed in case of any environmental assessment of a blow out. This report has been planned accordingly. The first two Chapters of the Report are devoted to estimating the various parameters of the blowout such as flame height, lift-off, mass flow rate, and the resultant trajectories thereof such as flame power, acoustics, including estimating of products and reactants in the combustion reaction etc. These would provide a fairly good estimate of the spread of products and emissions into the ecosystems of the terrestrial land, water and air. Thereafter, sectoral damage assessment has been attempted and lastly possible remediation measures and modalities of compensation assessment. However, as spelt elsewhere too, it is reiterated here that damage assessment cannot be a one time process, and must continue for at least three years to assess any impacts on flora and fauna, soil, air or water, or even the people that may show up subsequently. It would require research studies in future to identify and isolate such occurrences.

6.2 About Baghjan Incident

As per the PCBA Report, the drilling of the site was done in 2006, and production started in 2007. The well was a natural gas well; and it produced 1.5 lakh cubic meter of gas in a day. The Oil Well vertical profile is presented below. As can be seen from the diagram, the well head casing is of 8" (=0.2032 m). The internal bore of the well can be taken approximately to be 5" (=0.1270 m). The depth of the well can be taken as 3870 m approximately.

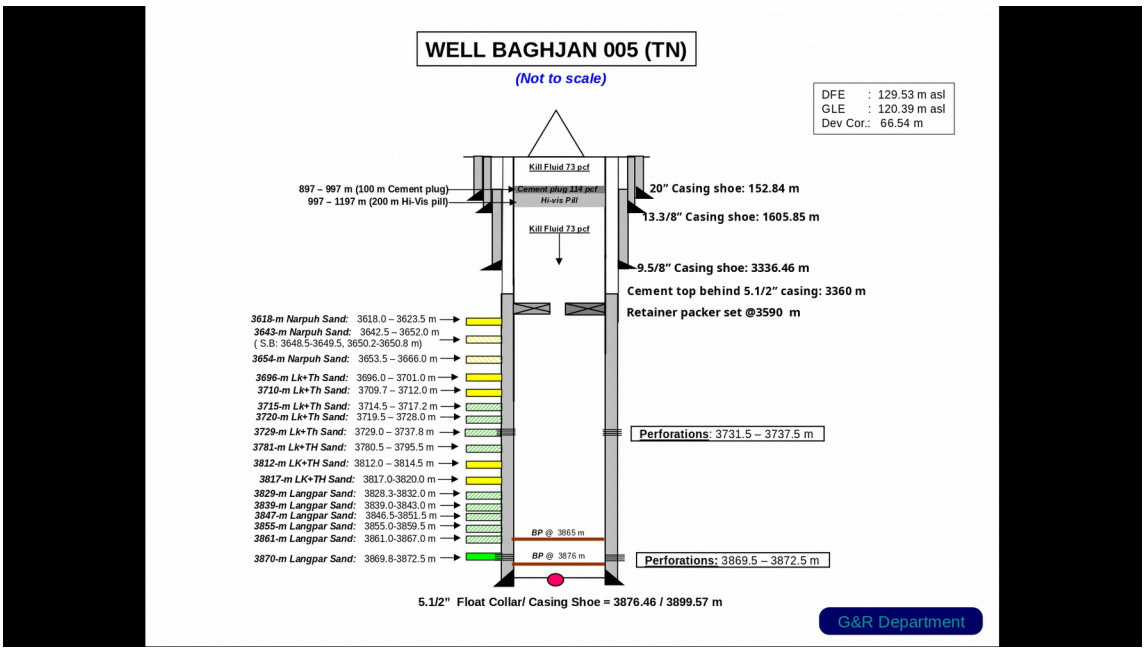


Fig. No. 6.3: Sectional Profile of the Oil Well BGN#5

The blow out happened on 27th May, 2020 at 10.30 AM. The gas pressure as reported by OIL was 4000 psi (=27.578 MPa). The well exploded on 9th June, 2020 at 1.30 PM in which 2 (two) OIL firemen lost their lives. From the 11th June, 2020 onwards tremors started being felt within 2-3 km range, and cracks in walls of many houses started to appear. The incident was a matter of national and international coverage. It left a long term devastating impact on the ecology of the nearby Maguri Motapung Beel, and adversely impacted the dolphin populations in the nearby river ecosystem. The Hon'ble National Green Tribunal in the order dt. 25th June, 2020, slapped an interim fine of Rs. 25.00 crore (250 Million INR) on OIL.

As per the OIL, EIA-ERM (2019) Report of the OIL for the Extended Reach Drilling of 7 (seven) Oil wells in the region, Table 7.2 on Page 154, the Baghjan Oil Well Blow out is a "**CATASTROPHIC EVENT**". It meets all the 7 (seven) criteria of the catastrophic category mentioned in the Report. **This is the 1st conclusion of this Chapter.**

6.3 The Blowout Fluid

As per the PCBA Report prepared after the visit of the Chairman and Member Secretary, PCBA to the blow out site on 1st June, 2020, there were three types of materials that were reported to be emitted, namely Natural Gas (C1-C6), Condensate (C5-C9) and other gases (could be Nitrogen, H_2S and CO_2). Even the approximate quantities of these substances coming out from the well were either not known or not made available. The stand of OIL authorities is that the natural gas coming out is 1.5 lakh CuM per day (=0.15 MMSCMD). The estimates by PCBA show that the other two materials are approximately 1.33% of the natural gas quantity. The condensate is the heavier hydrocarbon and got easily condensed in the air and fell down due to gravity to the ground and spread upon all surfaces including water bodies, plants and animals (including the humans) in the risk zone (depending upon the wind directions and wind speed).

6.3.1 Natural Gas

Natural Gas is a naturally occurring hydrocarbon gas mixture consisting primarily of Methane (CH_4), but commonly including varying amounts of other higher alkanes (C2-C6), and sometimes a small percentage of Carbon dioxide (CO_2), Nitrogen, Hydrogen Sulfide (H_2S), or Helium[42]. The laboratory test reports of the emitted natural gas from the BGN-5 site by chromatography, provided by OIL, shows that it is about 93% Methane, 3% Ethane, 1% Propane, smaller quantities (0.1 to 0.3%) of Butane, Pentane

42 https://en.wikipedia.org/wiki/Natural_gas

and Hexane, 1.2% of CO_2, and 0.09% of Nitrogen. The Gross Calorific Value of the natural gas was found to be about 9768 Kcal/SCUM[43] (=40.87 MJ/SCUM). The Net Calorific Value of the sample tested was 8823 Kcal/SCUM (=36.92 MJ/SCUM). The density (ρ) of the fuel was found to be 0.7710 Kg m^{-3}.

6.3.2 CONDENSATE

Condensate[44] is a mixture of low-boiling hydrocarbon liquids obtained from the gas emissions from the wells. It is predominately Pentane (C_5H_{12}) with varying amounts of higher-boiling hydrocarbon derivatives (up to C_8H_{18}). Propane (C_3H_8), Butane (C_4H_{10}) may be present in condensate by dissolution in the liquids. Depending upon the source of the condensate, Benzene (C_6H_6), Toluene ($C_6H_5CH_3$), Xylene isomers ($CH_3C_6H_4CH_3$), and Ethyl Benzene ($C_6H_5C_2H_5$) may also be present. However, little or no Methane and/or Ethane is present. The condensate is typically a clear or translucent liquid with API gravity higher than 45. Lower gravity condensate may be near black color and, like crude oil, has higher concentrations of higher molecular weight constituents. The sample test of the BGN-5 condensate shows that its API gravity is 35.8. The report also confirms that the collected samples contains "mostly heavier hydrocarbons". It further says that this condensate is a "mixture of kerosene and diesel fraction of petroleum". The report also shows that 8% of the volume of the sample tested was "residue", meaning The members of public in the hearing have also confirmed falling of black color liquid everywhere in the vicinity of the blow out (prior to the explosion, of course). Thus, **the 2nd Conclusion of the Chapter is that the condensate was nothing but oil with heavier hydrocarbons and mostly black in color**.

6.3.3 OTHER GASES

As per the natural gas chromatography report, the other gases possibly could be Nitrogen and CO_2, and could amount together almost 1.3% of the volume emitted from the well blowout. This finding tallies well with the PCBA estimation of other gases being 1.33%. White CO_2 would contribute to the flame temperature, burning of Nitrogen would produce NOx. This part would be examined separately in the Air Pollution Chapter. The flame temperature shall be dwelt upon in this Chapter only. It needs to be mentioned that flame temperature estimation, along with other quantitative parameters, would find place in subsequent chapters too.

43 SCUM stands for Standard Cubic Meter at 1 atm pressure and 288.56K

44 Speight James G, History and Use, Natural Gas (2nd Edition, 2019), p3-24 [https://doi.org/10.1016/B978-0-12-809570-6.00001-1]

6.3.4 Estimation of Quantities of Gas Emits

The actual quantities of natural gas, condensate and other gases being emitted in the blow out needs to be estimated by various possible assumptions and conjectures and indirect evidences and measurement, as no estimates of these quantities could be provided by the OIL, except that 1.5 lakh cubic meters of natural gas was being emitted per day from the blow out well. This fact also needs to be verified from indirect estimations and conjectures. The two biggest evidences are the explosion and the flame. Sadly, however, little or no measurement of these physical phenomena are available with OIL. Therefore, firstly, the explosion and, thereafter, the flame characteristics would be examined in the ensuing paragraphs [*and revisited in the next Chapters too*].

6.4 The Explosion And Its Characteristics

The explosion at the Baghjan Blowout site on the 9th June, 2020 at 1.30 PM killed two firemen. The answer to the "what-if" the explosion had happened 30 minutes before, is that atleast 7 persons, including two local researchers, would have died on the spot. As it was lunch time, people moved out to have lunch. The explosion was accidental. Since it is not in the scope of this One Man Enquiry Committee to enquire into the causes that led to the explosion, such conjectures and enquiries are out of scope. Therefore, it sufficeth to assume that an accidental spark might have caused the fire that turned into a massive explosion. Let us try to understand the magnitude of the explosion. The explosion led to the typical "mushroom" cloud formation at the site of the blast. The physics of the mushroom cloud says that these are **pyroculumus** cloud formations caused by sudden rise of hot gases and smoke into the cold surroundings. As there is a resistance of cold air at the top that suppresses the upwardly mobile hot gases, the top gets flattened and takes a mushroom shape. How high the hot gases would rise and get flattened would depend upon how strong the explosion is. The strength of the explosion, on the other hand, would depend upon what quantities of "fuel" or explosives that got ignited, and their explosive power in terms of TNT equivalent.

6.4.1 Explosions and Mushroom Cloud Heights

The mushroom cloud automatically reminds one of the nuclear holocaust. The pyrocumulus cloud or the ball of fire can get formed by a large explosion, forest fires, volcanic eruptions or nuclear blast. The artificial cloud so formed is often called homogenitus (caused by the *Homo sapiens*, or anthropogenic or artificial) cloud[45]. There

45 https://en.wikipedia.org/wiki/Flammagenitus_(cloud)

is a correlation between the height of the cloud and the power of the explosion. Such explosions are usually measures in tons of TNT. The smallest explosion could be a fraction of a kiloton of TNT. Nuclear explosions are of the order of 100-1000 kilotons or more. The cloud height and the yield (power of explosion in units of tonnes of TNT) are also matters of research and conjecture[46,47,48]. Without intending to complicate matters further by venturing into into a full fledged research on mushroom cloud dimensions and yield, support is taken from a very intuitive and useful graph[49] which is reproduced below:-

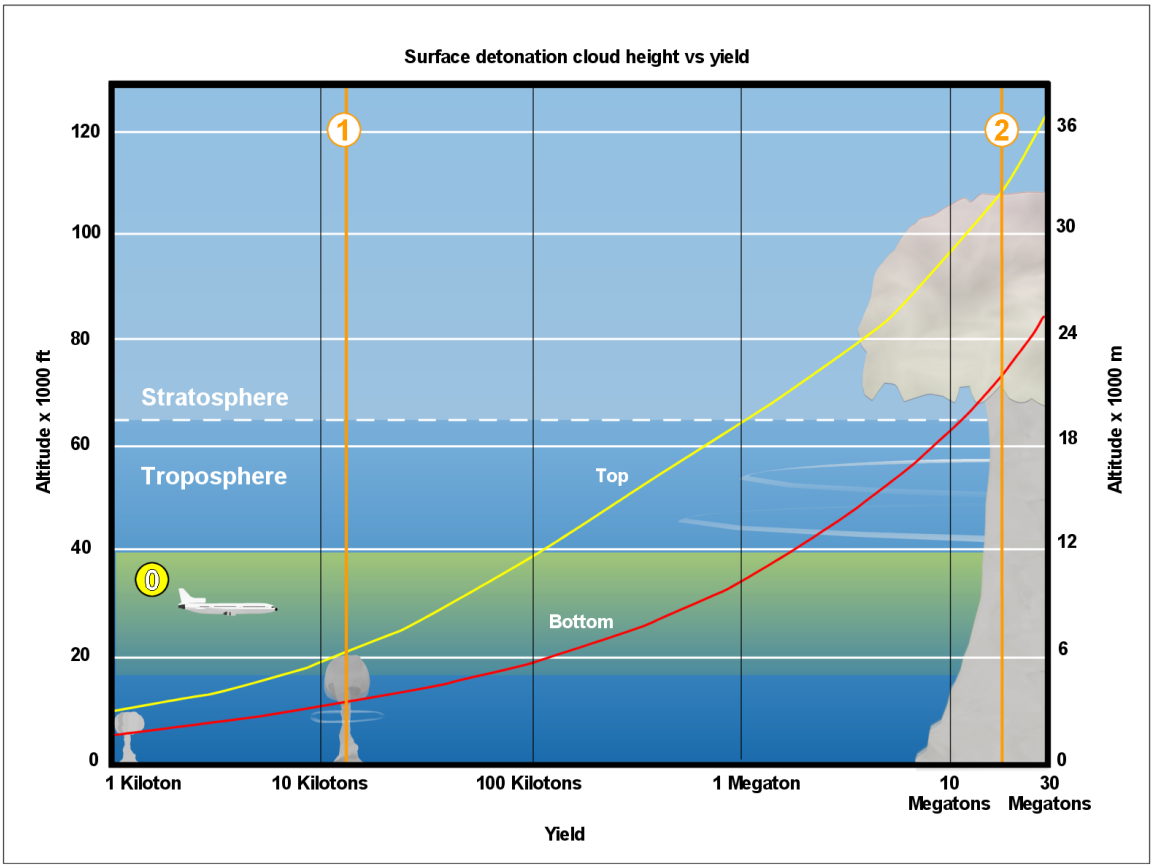


Fig. No. 6.4: Mushroom Cloud Heights and Explosion Yields

It shows the relationship, which is somewhat exponential in nature, between cloud top height and the yield. Now, the only issue remains to be resolved is measuring the height of the mushroom cloud of Baghjan.

46 https://www.bbc.com/future/article/20170816-the-monster-atomic-bomb-that-was-too-big-to-use
47 https://www.sciencealert.com/these-are-the-12-largest-nuclear-detonations-in-history
48 Masashi Baba et al, height estimation of Hiroshima A-bomb Mushroom cloud from photos, Revisit the Hiroshima A-bomb with Database: 55-67, ISBN 978-4-9905935-0-6
49 https://en.wikipedia.org/wiki/Mushroom_cloud

6.4.2 Measuring the Baghjan Mushroom Cloud Height

The first photograph used in this report showing the Baghjan Mushroom cloud is credited to Sri Rajendra Bharti IFS and the Dighaltarrang APC staff of the DSNP who happened to be at opposite sides at the same time when the explosion took place. The DFO was at Tinsukia Guijan road crossing at the time of explosion. The Forest staff was at 10 km distance away on the river side. The smoke column covered 40% of the frame from the 1st point. Assuming Angle of View (AoV) to be 37.8^0 ($\equiv$35mm), the column height comes to 3100 m.

The formula used is: L (m) = Distance*tan(AoV)*Coverage/100 [*Image pixels being equal*]

Fig. No. 6.1: Estimation of Height of the Baghjan Mushroom Cloud

Sl. No.	Distance from G0 (m)	% Coverage	AoV (^{0})[50]	Length (m)	Camera
1.	10000	40	37.8	3100	IPhone 7 ($\equiv$35mm)
2.	2200	72	53.1	2100	Samsung J8 ($\equiv$24mm)

Therefore, the mean distance is 2600 m. However, assuming the flame length in the photograph of the mushroom cloud to be 70m[51], the length of the cloud comes to 2499m. Thus, the length of the mushroom cloud from the base to the top can be safely assumed to be 2500 m. It is, now, therefore, **the 3rd conclusion that the mushroom cloud was 2500m high**.

6.4.3 Measuring the Baghjan Mushroom Yield

As can be seen from the Fig. No. 6.4, the cloud height of 1 kiloton explosion is about 10000 ft ($\equiv$3000m). The Baghjan cloud is actually very close to it as per the first measurements [*and more than 1 kT from current measurements*], as can be seen from the table in the previous section. However, having assumed the height to be 2500m, it comes to 83% of 1 kiloton yield. Therefore, the Baghjan mushroom cloud yield can be assigned a value of 0.833 kilotons. Now, we can convert this energy to cubic meters of natural gas that would possibly have exploded on the 9th June, 2020 at 1.30 PM:

50 https://en.wikipedia.org/wiki/Angle_of_view

51 *Flame height being 70 m was an initial raw estimate. Taking now flame height to be ~108m, the mushroom cloud height comes to 4500 m*

1kT=1GJ
NCV of natural gas=36.92 MJ/SCUM
0.833 kT=3485 GJ
=3485*10^3MJ
Cubic Meters of Gas= 94393 cum
≅0.1 Million m^3 (YIELD)

Box No. 6.1: Yield equivalence of Natural Gas wrt TNT

Therefore, at the time of explosion, about 0.1 MSCUM of natural gas equivalent material exploded. The question now remains to be answered if the well spewed only 0.15 million m^3 d^{-1} of gas in 24 hours, how was it possible that 66% of the day's yield caught fire within seconds? Also one needs to answer how much condensate was lying on the ground at the time of the explosion? [*Some of these answers would be clear only in later Chapters*]

6.5 The Flame

The flame at Baghjan has been dominating the sky since the night of 9th June, 2020. In the paragraphs that follow an attempt would be made to study a few properties of the flame, so as to gain a deeper understanding of the disaster. While the explosion discussed in the previous paragraphs was accidental and sudden and short-lived, making it difficult to study or measure, the flame, on the other hand has been for several months, and always presented itself for any study. However, the studies on the flame continued to be neglected by M/s OIL and MoPNG. Due to utter lack of useful data from M/s OIL, most of the flame parameters had to be conjectured and cross verified.

6.5.1 The Flame Temperature

There were only two ways to get the flame temperature: firstly compute/simulate the fire from the basics using Computational Fluid Dynamics (CFD), but for which neither not enough parameters were available, nor computing resources. Secondly, the other option was actually to measure it. Through AMTRON, a thermal mapping device Testo885 (with a 30^0 lens and a telephoto 11^0 lens). It measures temperatures from -300^0 to 100^0C, 0^0 to 350^0C and 350^0 to 1200^0C. The equipment was fully calibrated prior to measurement and also was NABL certified. The only limitation was its upper limit of 1200^0C. Measurements were taken by a team from AMTRON, and analysed using the

supplied software Testo IRSoft. The tests revealed that the highest flame temperatures observed by the Testo885 were 1223.9^{0}C, 1119.2^{0}C, 1098.6^{0}C, 966.3^{0}C, just to mention a few temperature reading directly off the flame using 11^0 telephoto lens of the equipment. Thus, the actual measurements confirm that the flame temperatures were as high as 1223.9^{0}C, against the reported figures of flame temperature being 600^{0}C by OIL.

However, the possibility of temperatures higher than 1200^{0}C needs to be verified from at least another source, before taking it as an accepted value. M/S OIL had informed the One Man Committee that the Radiating Power at source (at 5m distance) of the flame was 260 kW m^{-2}. The temperature of the radiating flame can be obtained from the Stefan-Boltzmann Equation:-

$$\frac{P}{A} = \varepsilon \sigma T^4 \qquad \text{..... } Eq.\ No.\ 6.1$$

where P=Radiating Power of the black body in Joules m^{-1} (W), A is the surface area of the radiating body, ε is the emissivity (taken as 1 here), σ = 5.6703x10^{-8} Wm^{-2}K^{-4}, and T is the temperature of the radiating body in Kelvin. Using the given Radiative power of 260 kW m^{-2}, the temperature of the flame comes to 1463.33K i.e. 1190.33^{0}C. [*This is indeed very close to the observed value of the flame from the Testo885 device. However, we need to revisit this topic again with more facts. Nevertheless, there is every possibility that the actual fire temperatures could be more than 1200^0 C and can go upto 2000^{0}C*[52].]

It needs to be mentioned here that this fire at the BGN#5 had been also captured on the 9th June, 2020 and other dates by MODIS and VIRS satellite sensors. However, these shall be discussed in a subsequent chapter [Chapter 11].

In short, **the 4th conclusion of this Chapter is that the flame temperature is at least 1200^{0}C**.

6.5.2 The Flame Height

The flame height is a complex function of the rate of fuel supply, the well head diameter and also the mixing of cold air and turbulence. For example on the 7th July, 2020 at about 2.50 PM, the flame almost vanished for about 5-6 seconds. Such a phenomenon can happen when the burning is excellent, and temperature is uniformly “white”, no soot only CO_2 and H_2O.

52 Bio Sun et al, Dynamic simulation on deflagaration of LNG spill, Journal of Combustion, Volume 2019, Article ID 7439589, https://doi.org/10.1155/2019/7439589

While there are several empirical equations to calculate height of the flame based on various parameters, lets first see what was the outcome of attempts to measure the flame height directly using the simple Trigonometry (P=D.tanθ). On two occasions, angle and distance measurements were done using GPS and Laser Range Finder. These are given below:-

Table No. 6.2: First Estimates of the Baghjan Flame Height

Sl. No.	Distance (m)	Angle (^{0})	Height (m)
1.	400	12	85
2.	740	7.5	97

The mean height of the flame would be 91m or say 90m. **Therefore, the 5th conclusion of this Chapter is that the flame height can be assumed to be 90m at mean value**. However, the flame height could easily fluctuate by 30m at any given time. It could be between 60 to 120m depending upon so many factors. [*This shall be revisited*]

6.5.3 Fuel Supply Rates

Lets first examine that a fuel emit rate of 1.5 lakh cubic meter per day would produce what kind of flame? This requires once again Computational Fluid Dynamics (CFD). However, instead, a ready reckoner chart[53] modeled in FLUENT was used to calculate the fuel requirements to sustain a given flame heights.

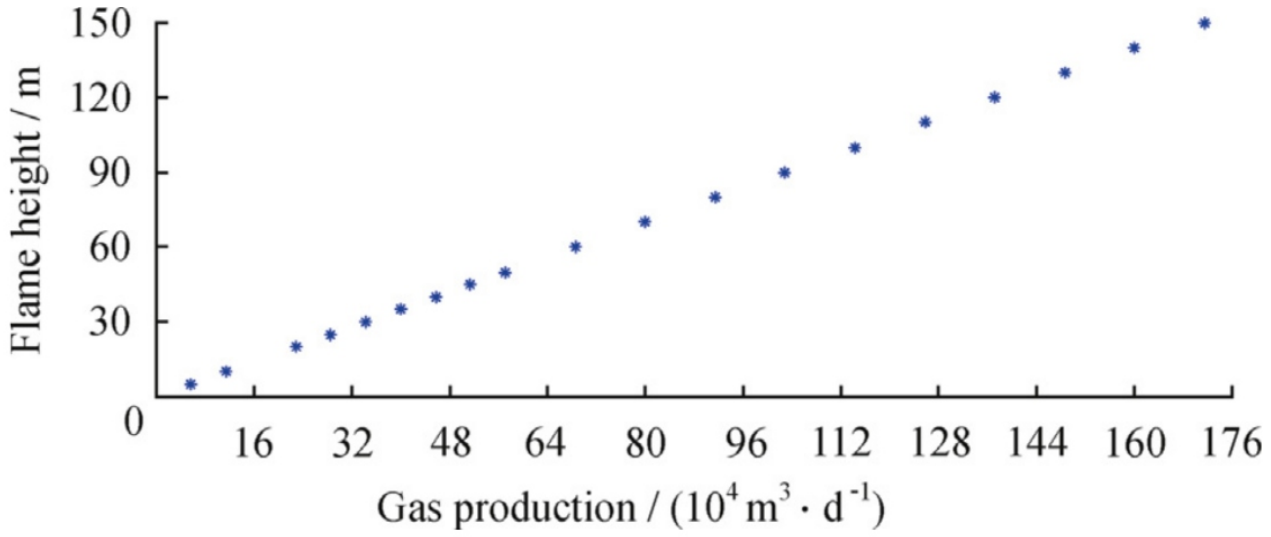


Fig. No. 6.5: Flame Height vs Natural Gas Flow Rate

53 Jialin Tian, Yinglin Yang, Lingrui Yang, Zhenglian Liu, Lin Yang, 2017, Estimation of gas blowout volume in wells with uncontrolled blowout and laboratory studies, Natural Gas Industry B 4 (2017) 399-404.

The units of the fuel supply are in tens of thousands cubic meter per day. The graph above gives the theoretical values. The theoretical values against 1.5 lakh cubic meter of gas per day, and again fuel rates at 60m, 90m and 120m flame heights have been read straight off the graph above and shown in another plot given below:

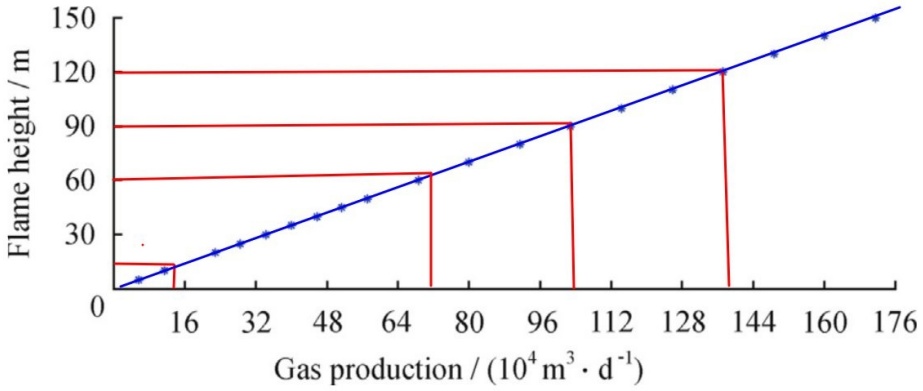


Fig. No. 6.6: Gas Flow Rates read off against Flame Height Values

The relationship shown above translates to:

$$L = 1.6515242 + 0.826482765*V \quad \text{..... } Eq.\ No.\ 6.2$$

$$V = \frac{L - 1.6515242}{0.826482765} \quad \text{..... } Eq.\ No.\ 6.3$$

where L is the flame height in meters, V is the volume of gas supply at the well in units of 10^4 m^3d^{-1}.

The linear regression graph from which the above relationship was drawn is reproduced below. The correlation coefficient, r, was found to be r=0.97789455

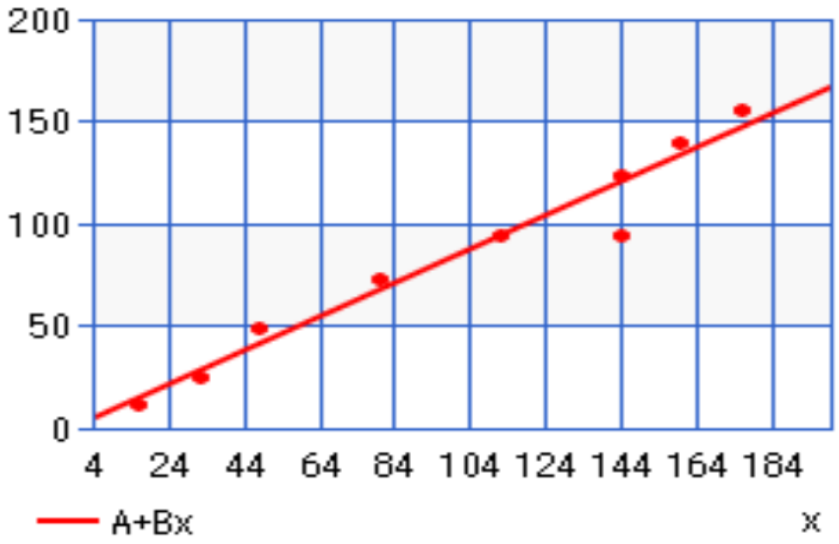


Fig. No. 6.7: Correlation between Gas Flow Rates and Flame Heights

From the two equations above, the required values have been tabulated here below for an easy comparison[54].

Table No. 6.3: Flame Heights and Fuel Rates

Sl. No.	Flame Height L (m)	Fuel Rate, V (10^4 m^3 d^{-1})	Fuel Rate, v# (Kg s^{-1})	Remarks
1.	14	15	1.34	Flame height predicted for 1.5 lakh cubic meter of gas per day
2.	60	70.60	6.30	Predicted fuel rate
3.	90	106.90	9.54	-Do-; *makes it worst case & large blow out (as per OIL ERM EIA)*
4.	120	143.20	12.78	Predicted fuel rate

 # 86400 seconds in 1 day & natural gas fuel density taken as 0.7710 Kg m^{-3}

Firstly, the flame height predicted against 1.5 lakh cubic meter gas per day (15 units in the Table) being released from the well, is 15m. Theoretically, such an amount of gas only can sustain a flame height of 15m or even less. Now, 90m high flame needs a fuel supply of about 10.7 lakh cubic meter of gas emission per day. Therefore, the supply of natural gas from the well at BGN-5 may be taken to be atleast 10.7 lakh cubic meter per day against what is being claimed to be 1.5 lakh cubic meter of gas. **This is the 6th conclusion of this Chapter**. [*This estimate would be revisited in the next Chapter.*]

6.6 Estimation Of Various Emits From The Blowout

Based on the parameters estimated so far, now one can arrive at the estimated amounts of substances emitted from the well. Since natural gas is only a mixture, and its various constituents, which are independent chemical entities, would also be released at the same time, a tentative estimate, component wise, can be arrived at easily. Based on the sample analysis of gases from BGN-5 as provided by OIL, the following are the estimates of the various constituents of the emitted natural gas:-

Table No. 6.4: Natural Gas Composition at Baghjan

Sl. No.	Substance	% of NG (10.7)	Rate (10^5 m^3 d^{-1})	Total (10^5 m^3) till 9/6/20	Remarks
1.	Methane	92.97	9.95	129.32	
2.	Ethane	2.91	0.31	4.05	

54 *Valid for sub sonic flows only- fluid treated as incompressible*.

Sl. No.	Substance	% of NG (10.7)	Rate (10^5 m^3 d^{-1})	Total (10^5 m^3) till 9/6/20	Remarks
3.	Propane	1.06	0.11	1.47	
4.	Butane	0.43	0.05	0.6	
5.	Pentane	0.17	0.02	0.24	
6.	Hexane	1.15	0.12	1.6	
9.	Nitrogen	0.09	0.01	0.13	
10.	CO_2	1.22	0.13	1.7	
11.	Condensate[55]	0.015	0.16	2.09	*Assumed Ratio as per PCBA*
	Natural Gas Total	**100**	**10.7**	**139.1**	
	Total of All		**10.86**	**141.19**	

These emits are largely reactants, and the combustion reaction per se, and the product output shall be discussed in the next Chapter. The figures given in the Table above may also change, once all other parameters get frozen. [*Needs a revisit. See Chapter 7.*]

6.7 Validation Of The Explosion Yield

At the beginning, it was seen that the kind of explosion that occurred on the 9th June, 2020 at 1.30 PM at Baghjan needed almost 0.1 million or 1 lakh cubic meter of combustible volume at the site. With the flame height at 90m, it is seen that from the 27th May till the 9th June, 2020, there was enough condensate, not less than 2 lakh cubic meter, in the vicinity of the blow out. However, all of it might not have caught fire. Given the yield of the explosion, it can be assumed that 50% got burnt, but the rest 50% would have remained in the surrounding areas.

The exact figures can be disclosed by the Oil India authorities alone. The presentation in this Chapter has been largely based on observations; and the approximate amount of of chemical, physical and thermal quantities that would have been required to cause the phenomenon of the explosion and fire observed at Baghjan have been estimated approximately using conjectures and scientific principles based on literature review. However, these are first estimates at this point, and most of these would be revisited in the coming Chapters.

55 Abdus Satter, Ghulam M.Iqbal, Reservoir engineering, 2016: https://doi.org/10.1016/B978-0-12-800219-3.00004-8

6.8 Conclusions

The conclusions drawn in this Chapter are summarized below point wise:-

1. The blowout at Baghjan BGN-5 OIL Well was not only a “catastrophic” but also a large and worst case blow out (As per definitions provided under OIL ERM EIA, December, 2019)
2. The condensate was “oil” with heavier hydrocarbons
3. The explosion on the 9th June, 2020 at 1.30 PM gave rise to a mushroom cloud that rose 2500m into the sky, and its yield was 0.1 million m^3 of natural gas (≡0.9 kiloton of TNT)
4. The flame temperature was estimated to be 1200^{0}C.
5. The flame height was estimated at 90m.
6. The discharge from the well head was estimated at about 10.7 lakh cubic meter per day (≡ 9.54 or 10 kg s^{-1} discharge)



A Night's View of the Baghjan Flame [13th June, 2020]

CHAPTER-7

7 UNDERSTANDING THE BAGHJAN BLOWOUT – II

7.1 From The Back Pages

In the previous Chapter, some of the very basic parameters about the Baghjan blowout were analyzed and a preliminary level estimation of a few of the parameters was arrived at. The key determinants of the disaster studied in the previous Chapter are: estimation of the explosion height and yield, amount of fuel being spewed from the well head, estimation of flame height and flame temperature and estimation of various chemicals emerging from the well.

In this Chapter, estimation of some more characteristics would continue, while some parameters estimated earlier in the previous Chapter may be revisited. Based on the various estimates arrived in these two Chapters, further assessment of damages would be attempted in subsequent Chapters. [*Originally, only the previous Chapter was planned*]

7.2 Exploring The Supersonic Nature Of The Flame

Sound and vibrations have been associated with the flame from the very beginning. The sound emanating from the flame is characteristic of "Jet planes" taking off or flying past with breakneck speeds during the war times. People also complained of very high intolerable noise. Tremors were felt from the 11th June, 2020 within 2-10 km radius, leading to appearance of cracks in the walls and floors. Therefore, lets examine some supersonic characteristics of the flame.

7.2.1 THE FLAME LIFT OFF

The well head casing diameter is 8" (0.2032 m), and the internal diameter of the well is 5" (0.1270 m) from which fluid is gushing at more than 10.7 kg per second. There would be no fire at the rim of the well from which the gas is gushing out, mainly because, the temperatures cannot sore to inflammable levels, as the area is cooled by the background air. The flame can be seen actually dancing above the gas with a gap between the well head and the start of the flame. This gap is known as "Lift-off". The gap distance is known as the lift-off height. The bigger the flame, the larger is the lift-off height. It is this area that is responsible for supply of fresh cool air to the flame, allowing fuel-air intermixing. Higher lift-offs are associated with larger turbulences at the bottom, and impart a "sonic" character to the flame. It could switch to supersonic or hypersonic modes too.

A couple of good photographs were requested from the OIL authorities. Mr. Sanjai Rai, ED (F HQ Affairs), OIL on the 15th July, 2020. [Meanwhile a controversy already arose in the media when in electronic media the lift-off portion of the flame was shown and it was claimed that the flame had been extinguished!] The lift-off portion of the flame was not visible earlier due to debris at the site. After clearing all debris, the lift-off could be seen clearly. An illustration of the flame with its key features is placed below:-

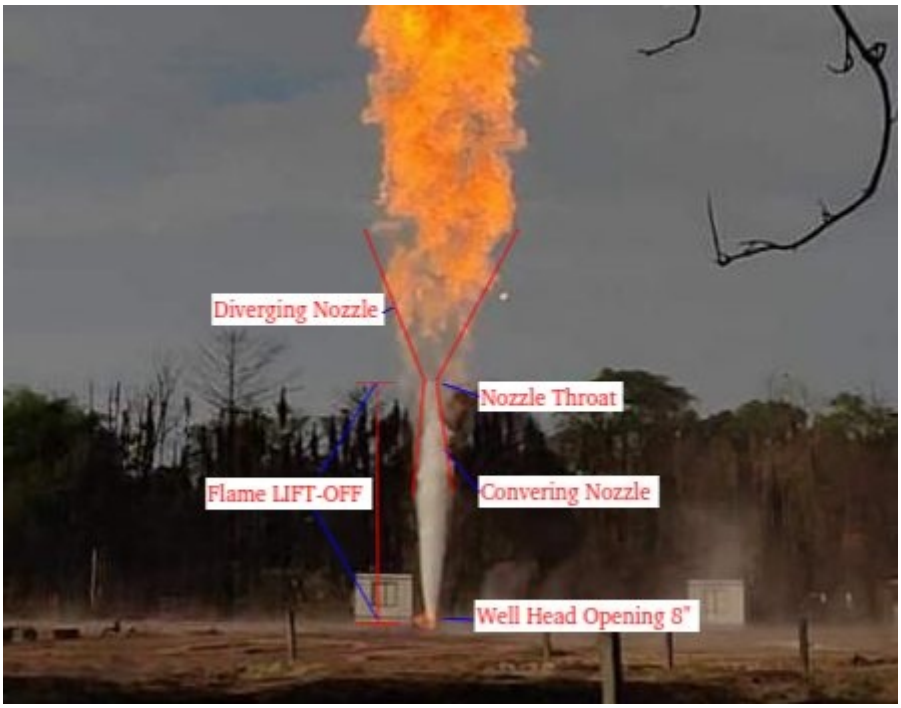


Fig. No. 7.1: Flame Lift-off and the Supersonic Burning Mechanism

From the photograph[56] (partly shown above), full photograph may be seen in the Photofile, the lift-off was estimated to be 11.00 m [*Based on the dimensions of the HVLR Box at the ground zero*]. The diameter at the wellhead was taken as 8" (≡ 0.2032m). The exit diameter at which the flame was starting to be formed, was found to be, from the photograph, about 0.63 m. The exit diameter is a hypothetical "throat" of a hypothetical converging-diverging nozzle where the fuel and air mix, and the gas exits from this hypothetical burner and burning happens. The conditions around the exit are supersonic. The ratio of exit diameter (D_e) to orifice diameter (D) i.e. $D_e/D=3$. **Therefore, the conclusion drawn here is that the Lift-off height of the flame was 11m**. There is a relation between the lift-off height and the Mach number associated with the flame, which shall be discussed in the next paragraph. [After the Explosion Yield, this is the second parameter frozen]

56 Photo Courtesy: Sri Sajai Kr. Rai, ED (FHA), Oil India Ltd, Duliajan

7.2.2 Flame Height Revisited

With lift-off estimate having been arrived at accurately, its time that the flame height be revisited to confirm the actual value to be used in further estimation of other key quantities. Direct measurements of the flame height from two photographs with clear lift-off, [Courtesy: Sri Sanjay Kr. Rai, ED, OIL], came to 114.29 and 105.70m, averaging to 110m. Keeping ~2% error margin for calculations, the flame height for all subsequent calculations was fixed at 108m. **Therefore, the average Flame Height of the Baghjan flame is fixed at 108m**. This estimate alone would be used in all subsequent estimations. [This is the third parameter frozen] [*This mean height was confirmed subsequently with Drone based measurements*].

7.2.3 Mass Flow Rate and Well Head Pressure Revisited

As there is quite uncertainty over the actual pressure operating at the blowout. It is difficult to assume whether it is 4400 psi or 440 psi, as the end calculations of mass flow rate show that for 440 psi, the flow rate would be quite less and for 4400 psi, quite high. The material that exploded on the 9th June, 2020 at 1.30 PM does not fit either extremes. Therefore, the well gushing pressure needs to be arrived at indirectly.

MASS FLOW RATE:

From the flame height, both the parameters of mass flow rate and pressure can be derived. Normally, its the other way round. The flame height is a direct function of flame power and can be best fitted with experimental / field data to the equation[57,58,59]:-

$$H_f = A x Q^B \quad \text{..... } Eq.No.7.1$$

One such equation with high correlation between H_f & Q has been provided by Lowesmith et al[60]:-

$$L = 2.8893 x Q^{0.3728} \quad \text{..... } Eq.No.7.2$$

Solving inversely for Q from L=108, we get **Q=16378 MW**. This value shall be used once again in a subsequent paragraph on flame power. As of now, this value can be used directly to calculate mass flow rate in Kg s^{-1}, as

$$Q = M x H \quad \text{..... } Eq.No.7.3$$

57 Khargarpour M. A., Journal of Petroleum Exploration and Production Technology (2019) 9:2375–2386
58 McCaffrey B. J. Purely Buoyant Diffusion Flames:Some experimental results, BSIR:79-1910, 1979
59 Lawson J R. & Quintiere J.G, Slide rules estimates of fire growth, Fire Technology, Vol. 21, No. 4, November 1985, p. 267
60 Lowesmith B.J, Hankinson G, Acton M.R, Chamberlain G, Process Safe % Env. Prot, Trans IchemiE, Part B, 2007 DOI: 10.1205/psep06038

where M=Mass flow rate in Kg s^{-1}, H=Net Calorific Value in MJ Kg^{-1}. Putting

$$H=47.89 \text{ MJ } Kg^{-1} \quad \text{..... } Eq.No.7.4$$

we get **M**=Q/H=16378/47.89=**342 kg s^{-1}** ..... $Eq.No.7.5$

GAS PRESSURE:

For natural gas, M has been approximated in terms of orifice/hole dia D (mm) and Pressure of gas P in MPa. This relationship was suggested and developed by Gilbert (1954)[61]. A detailed theoretical derivation is provided by Kargarpour (2019)[62]. However, this over simplification of estimating mass flow rate using an empirical relationship based on dia of the pipe/orifice and pressure alone, comes with a rider of overestimation by almost 40%. Hawkins et al[63] (1981) call it a "short-cut" and state that results are 43% greater than "using sophisticated computer programs". Therefore, while using the relationship in the reverse direction in the formula given below, the M value has been "jacked up" by a factor of 1.67. The results are in overall agreement and acceptable. The formula by Lowesmith et al (2007) and provided for as :-

$$M=D^2xPx10^{-3} \quad \text{..... } Eq.No.7.6$$

P can be estimated accurately by enhancing M by a value of 1.67, and the inverse function becomes:-

$$P=\frac{1666.67\times M}{D^2} \quad \text{..... } Eq.No.7.7$$

Since, M=342 Kg m^{-1} and D=203.2 mm, we get

$$\textbf{P= 13.8 MPa} \quad \text{..... } Eq.No.7.8$$

This value of 13.8 MPa pressure means 2001 psi at the well head. This translates to 2688 psi at the well bottom. These estimates appear to be still a low estimate of the pressures working at the base of the flame, and at the bottom of the well. However, the dia of 203.2 is the outer casing dia, the actual orifice as per design seems to be 5" (≡127mm). This would mean that the actual operating pressure at the well head is 35.49 MPa (5147.38 psi), in place of 4000 psi as claimed by M/s OIL. The pressure at the well bottom would, then, be 6920 psi.

61 Gilbert, W. E., Flowing and Gas-Lift Well Performance, API Drilling and Production Practices (1954) 126.

62 Kargarpour Mohamaad Ali, 2019, Journal of Petroleum Exploration and Production Technology (2019) 9:2375–2386, https://doi.org/10.1007/s13202-019-0629-6

63 Hawkins M.F, Bassiouni Z, Bourgyne A.T, McMullan J.H, Veazey M.J, Whitehead W.R, DOE/BETC-3000-1 DE81030779, 1981

7.2.4 VELOCITY OF FLOW

While the mass flow rate has been worked out in the previous paragraph, now the velocity of the flow can be worked out deploying several methods. The first method outlined is V in m s^{-1} based on the mass flow rate, M in Kg s^{-1}.

$$V = \frac{M}{\rho \times \left(\frac{\pi \times D^2}{4} \right)} \qquad \text{..... } Eq.No.7.9$$

We get, for M=342 Kg s^{-1} & D_e=0.63m, **V_e= 1423 m s^{-1}**. This is the exit velocity at the hypothetical nozzle.

7.2.5 MACH NUMBER OF THE FLAME

Mach number is a unit less quantity which defines the number of times a given speed exceeds the speed of sound (343 m s^{-1} in air at 293K). If a jet plane flies at speeds 1100 KMPH, it is said to be flying at 0.9 Mach. Large oil jet fires[64] are often associated with subsonic, supersonic and hypersonic properties.

The fuel under high pressure gushes from the well, and gets to expand after leaving the orifice. This expansion has been treated in literature as an "isentropic" process i.e. there is no change in the entropy of the system. The Mach number (M_e) at the exit point (meaning from where the flame starts after the lift-off), for the isentropic flow is given by the relation:

$$M_e = \sqrt{\frac{2}{\gamma - 1}\left[\left(\frac{P_0}{P_\infty}\right)^{\frac{\gamma-1}{\gamma}} - 1\right]} \qquad \text{..... } Eq.No.7.10$$

where γ (=C_v/C_p), the ratio of the specific heats of the gas, also known as Adiabatic Ratio, P_0 is the pressure at the exit, and P_∞ is the ambient atmospheric pressure. For natural gas (93% Methane, γ =1.3. However, as we know the P_0 to be 13.8 MPa, substituting this value in Equation above results in Me = **3.8** [*with 34.49 MPa, the Mach Number would be **4.4***]. Now, let us estimate the Mach Number from the lift-off height estimated in the previous paragraph to verify the calculations so far. A treatment to this effect is available in literature[65,66].

64 *There are typically two types of oil fires: Pool fire- when fire is caught over a pool of hydrocarbon material that may be lying on the surface after a leakage, say from a tanker. The condensate lying around the Baghjan area that caught fire was typically a pool fire; the second type being jet fire- when a flowing stream of gas or oil leaks or blows out through an orifice/hole & catches fire. A blow out well catching fire subsequently is often a combination of pool fire and jet fire.*

65 McCaffrey B.J, & Evans D.D., 1988, Very large methane jet diffusion flames, Centre for Fire Research, National Bureau of Standards, Gaithursburg, MD, 20899 USA, Volume 21, Issue 1, 1988, Pages 25-31

66 Kalghatgi Gautam T. (1981), Comb. Sc & Tech, Vol. 26(5-6), p233

To achieve this, the Fig No. 2 of McCaffey & Evans was regenerated using the following exponential best fit:

$$\frac{H_f}{D} = 129.5018828 \times e^{0.467379543 \times M_e} \quad \text{..... } Eq.No.7.11$$

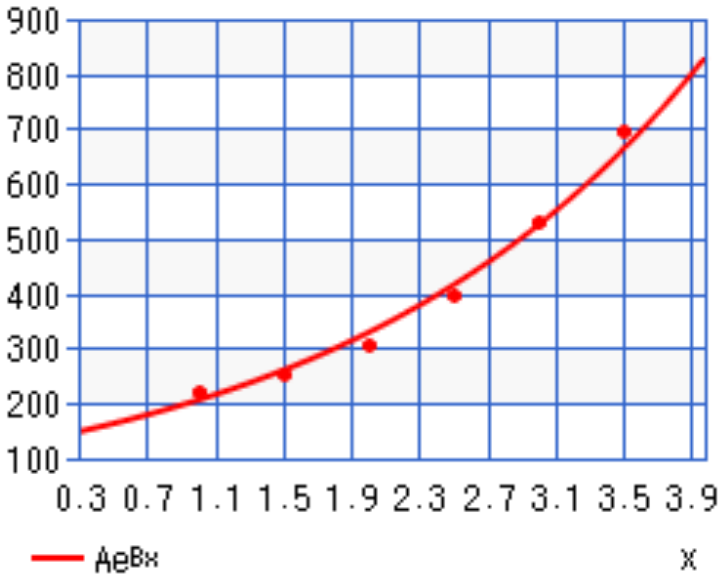


Fig. No. 7.2: Relationship between Mach Number & Flame Height/Dia Ratio

The equation above, when written in inverse, would provide for the value of M_e:-

$$M_e = \frac{\ln\left(\frac{H_f}{D}\right) - \ln 0.467379543}{129.5018828} \quad \text{or} \quad \text{..... } Eq.No.7.12$$

$$M_e = \frac{\ln\left(\frac{H_f}{D}\right) - 4.86369542003004}{129.5018828} \quad \text{..... } Eq.No.7.13$$

The Mach numbers for some flame heights are tabulated below using the above relationship:-

Table No. 7.1: Mach Number & Flame Height/Dia Ratio

Sl. No.	H_f/D Ratio	Mach Number	Flame Height (D=0.20) m
1.	207	1	41
2.	479	2.8	96
3	**540**	**3.1**	**108**
4.	578	3.2	116
5.	**850**	**4.0**	**108 (D=0.127)**
6.	922	4.2	184

Mach number can also be calculated from the flow velocity worked out in the previous paragraph. The flow velocity of 1423 m s^{-1} at the hypothetical exit nozzle is responsible for generating $\mathbf{M_e}=V_e/c$ = **4.15** Mach Number, where c is the speed of sound in ambient air, taken as 343 m s^{-1}.

Thus, it can be seen that the flame height is a factor of turbulence, as it is mostly in the supersonic region. At the least, flame would be of 40m height, and could go up even upto 180 meters or more, if there were any further rise of pressure in the well to happen. If the flame went below Mach 1, it would be almost a quiet flame. The flame is, therefore, in supersonic regime, and **the Mach number may vary from 3.1 to 4.4** However, a Mach value of **3.15,** on the lowest side, would be assumed. [The average Mach Number would hover around **4.4 as the well head pressure is actually 35.49 MPa, giving rise to flow velocities of 1292 m s^{-1}**. It may be noted that Mach Number 5 and above is considered hypersonic. Therefore, the flame appears to be a borderline case between supersonic and hypersonic.]

7.2.6 REYNOLD'S NUMBER

Reynold's number is an indicator of turbulence in a fluid. It is a dimensionless quantity. In the instant case, Reynolds number can be had for the turbulence at the hypothetical nozzle at the lift-off, or any point in the flow itself. The lift-off exit point Reynold's number is denoted here, as in literature, R_h. Relying on Kalghatgi (1984)[67], and assuming ρ=0.7710 Kg m^{-3} &

S_u (Maximum Laminar Burning Velocity) = 0.39 ms^{-1} ..... $Eq.No.7.14$

v_e (Kinematic Viscosity) =17.08x10^{-6} m^2s^{-1} ..... $Eq.No.7.15$

$$R_h=\frac{h\times S_u}{v_e} \quad \& \qquad \text{..... } Eq.No.7.16$$

$$R_h=C_2\times\left(\frac{U_e}{S_u}\right)\times\rho^{1.5} \qquad \text{..... } Eq.No.7.17$$

and combining equations 1 and 3 of Kalghatgi, we get for every 1m lift-off height (h) of natural gas flame,

R_h=22834 ..... $Eq.No.7.18$

U=263.46 ms^{-1} ..... $Eq.No.7.19$

Therefore, the Reynold's Number for the flame with lift-off height 11 m comes to ~251170; and the gas exit velocity U comes to 2898 ms^{-1}, responsible for a Mach

67 Kalghatgi Gautam T, Comb Sc & Tech, 1984, Vol 41, p17

Number of 8.5. This flow velocity , here, is found to be hypersonic, and would consume fuels upto 697 Kg/s. While these values seem to be very much possible given the very powerful nature of the flame, and we can say that Mach Number could vary actually from 3.1 to 8.5, but it would suffice for us to assume a lower value of **3.1 to 4**, as the flame has been considered to be supersonic. [*We don't have the advantage of very accurate and pin pointed measurements or computer based CFD simulations to support a higher order mass flow rate. Well, it must be said that while such a mass flow rate only could support the explosion that happened on the 9th June, 2020 at 1.30 PM, but one more independent measurement/ estimate is needed to confirm, which we don't have as of now. However, the flame is surely Mach 4.*]

7.2.7 SHOCKWAVE GENERATION BY THE FLAME

Since no single measurements about the flame physical properties are available, nor was the flame monitored continuously for observing variations in the parameters, one has to depend heavily on indirect estimates. Assuming the flame to be supersonic, it would generate a series of shockwaves starting from the tip of the lift-off (from where the flame starts).

A diagram from one of the Physics text books is placed below to explain the shockwaves:-

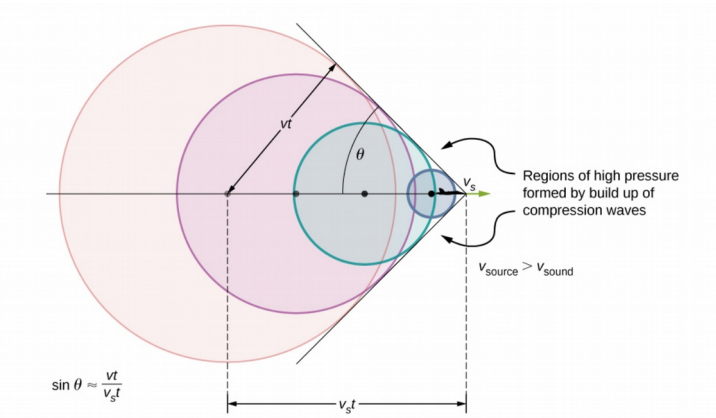


Fig. No. 7.3: Shockwave Propagation

The shockwave makes a cone of angle (θ) sine of which is inverse of the Mach Number:-

$$\sin\theta = 1/M \quad \text{..... } Eq.No.7.20$$

When the flame operates in Mach 1 conditions, the shockwaves would make a 90^0 cone, and impact wider areas around the flame. However, the cone angle would get narrower as Mach Number increases from 1 to 4. At 3.1 Mach, the cone angle would be roughly 19^0. At Mach 8.5, it would be very narrow at 6.7^0.

7.2.8 Thermal Properties of the Flame (Power of the Flame)

The total Heat Release Rate (HRR) of the flame depends upon the mass of fuel burnt and the heat value of the fuel. This has two components namely radiative power and convective power. The radiative power for natural gas has been found to be only 13% of the total power of the flame[68]. The Power of Flame Q (MW) is related to the Flame Length L (m) by an empirical relation:

$$L = 2.8893 \times \dot{Q}^{0.3728} \quad \text{or} \qquad \ldots\ldots Eq.No.7.21$$

$$\dot{Q} = \left[\frac{L}{2.8893}\right]^{\frac{1}{0.3728}} \qquad \ldots\ldots Eq.No.7.22$$

Assuming L=108, as arrived in the previous paragraphs, we get ~ **Q=16450[69] MW.** This is equivalent to 16.5 GW of flame power, which is high compared to many flames reported in blowouts. A detailed primary study was done of the oil well fires of 1991 in Kuwait[70], and based on the findings, an empirical relationship between the Power of the Flame (Q), or the Heat Release Rate (HRR) and its Length L was arrived at. The same is given here (Read Z for L):-

$$\dot{Q}_k = \left(\frac{L}{0.21}\right)^{\frac{5}{2}} \qquad \ldots\ldots Eq.No.7.23$$

where the Q_k values are in kW. It would be interesting to compare the flame power and mass flow rates from all the three sources that now are available with us as of now:-

Table No. 7.2: Flame Heights and HRR from Various Sources in Literature

Flame Height (m)	Jialin Tian et al (2017)		Lowesmith BJ et al (2007)		Evans DD et al (1994)	
	Q (MW)	M (Kg s^{-1})	Q (MW)	M (Kg s^{-1})	Q (MW)	M (Kg s^{-1})
14	64	1.34	69	1.44	36	0.75
60	301	6.30	3402	71.04	1380	28.82
74	374	7.81	5970	124.6	2331	48.67
90	456	9.54	10090	210.69	3802	79.39
108	**550**	**11.48**	**16450**	**343.50**	**5998**	**125.25**
120	612	12.78	21819	455.61	7806	163.00

The highest rate of Heat Release (**HRR**) for a 108 m flame is, therefore, taken to be **16450 MW.**

68 Lowesmith B.J. et al, Process Safe & Env. Prot, Trans IchemiE, Part B, 2007 DOI: 10.1205/psep06038

69 *If the index value is rounded off to 0.373*

70 Evans D. D. et al, Fire Safety Science- Proceedings of the fourth international symposium, pp. 1279, International Association for Fire Safety Science, 1994

7.2.9 RADIANT HEAT FLUX

The flame is about 6.5 m at the base and 12m in diameter in the middle. We know

$$\dot{Q} = \dot{M} \times H \quad \text{..... } Eq.No.7.24$$

An object O at a distance R_o from the centre of the flame would experience a flux of

$$\ddot{Q} = \frac{\chi \times \dot{Q}}{4 \times \pi \times R_o^2} \quad \text{..... } Eq.No.7.25$$

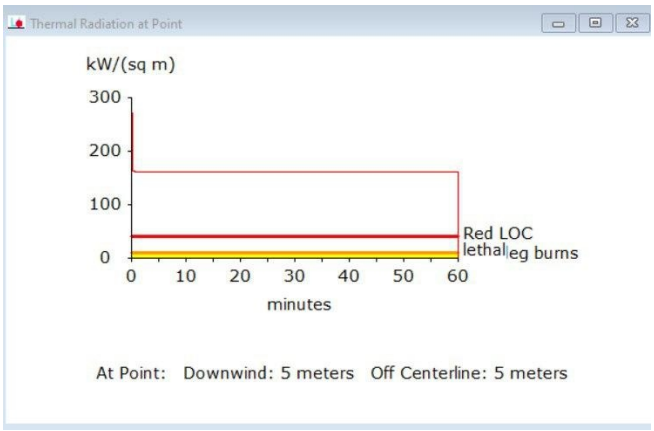
where χ is the radiative component of the HRR ($\dot{Q}$). Literature shows that for methane/ natural gas jet flames, the radiative component of the heat is almost one third of the total heat. Based on this relationship, the radiant flux at various distances from the flame have been worked out and given below:-

Table No. 7.3: Radiant Flux Predicted & Measured

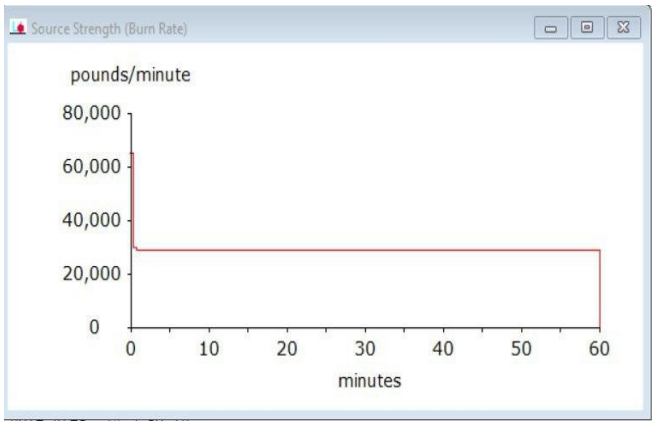
Distance (m)	Radiant Heat Flux (kW m^{-2})	Measured Values by ERM
100	42.97	15.0
200	10.74	3.57
300	4.77	1.52
400	2.69	0.829
500	1.72	0.517
1000	0.43	0.119
1500	0.19	0.0503
2000	0.11	0.0273
2500	0.07	0.0169
3000	0.05	0.0115

The values supplied by ERM are off by two to three times of the calculated values. Since the flux is very sensitive to distance, an error of 20-25m would be enough to equalize these values, as can be seen from the descriptive deliberation given below. The flame in itself is so wide (12m) that a 5m distance from the flame would mean actually 11-17 m. Now, the Consultants M/S ERM of OIL India have measured radiative flux at 5m from the flame and found it to be 260 kW m^{-2} using ALOHA (ver 5.4.7). In order to verify the ERM estimates, the ALOHA simulation was also run in AMTRON[71], and the radiative flux at 5m was found to be 275 kW m^{-2}. Additionally, the initial burn rate was found to be 482 Kg s^{-1}, and constant burn rate was found to be 225 kg s^{-1}. The two ALOHA charts from where these values were worked out are given below:-

71 By Sri Monoj Baruah, Addl Mgr, with ALOHA 5.4.7 the following parameters: Pipe length: 4000m, Dia 10 inch, Infinite Gas source, Pipe roughness smooth, Pressure:4000 psi (also run at 2000 psi), temp 31 0C, wind: 2.2. m/se from north, open country, cloud cover 5/10, Humidity 85%, Fuel: Methane, Stability class B. (of course, these parameters were obtained from M/S ERM)



ALOHA Radiative Flux at 5m



ALOHA Burn Rate

Fig. No. 7.4: ALOHA Burn Rates for Baghjan Fire

However, with the ALOHA burn rates, the following HRR and radiative flux can be easily derived using the NCV of the fuel:-

Table No. 7.4: HRR & Radiative Flux for Baghjan Flame (ALOHA)

Burn Rate (Kg s^{-1})	HRR (MW)	Radiative Flux (MW)
492	23562	7854
225	10775	3592

The previous Table is now reproduced by populating with radiative flux derived from ALOHA max and constant burn rates given above:-

Table No. 7.5: Radiant Flux for Baghjan Flame from Various Sources

Distance (m)	Radiant Heat Flux (kW m^{-2})	Measured Values by ERM	ALOHA (492 Kg s^{-1})	ALOHA (225 Kg s^{-1})
100	42.97	15.0	47.52	21.73
200	10.74	3.57	11.88	5.43
300	4.77	1.52	5.28	2.415
400	2.69	0.829	2.97	1.358
500	1.72	0.517	1.9	0.869
1000	0.43	0.119	0.475	0.217
1500	0.19	0.0503	0.2112	0.097
2000	0.11	0.0273	0.1188	0.543
2500	0.07	0.0169	0.076	0.348
3000	0.05	0.0115	0.0528	0.0241

A chart showing the above Table is shown below:-

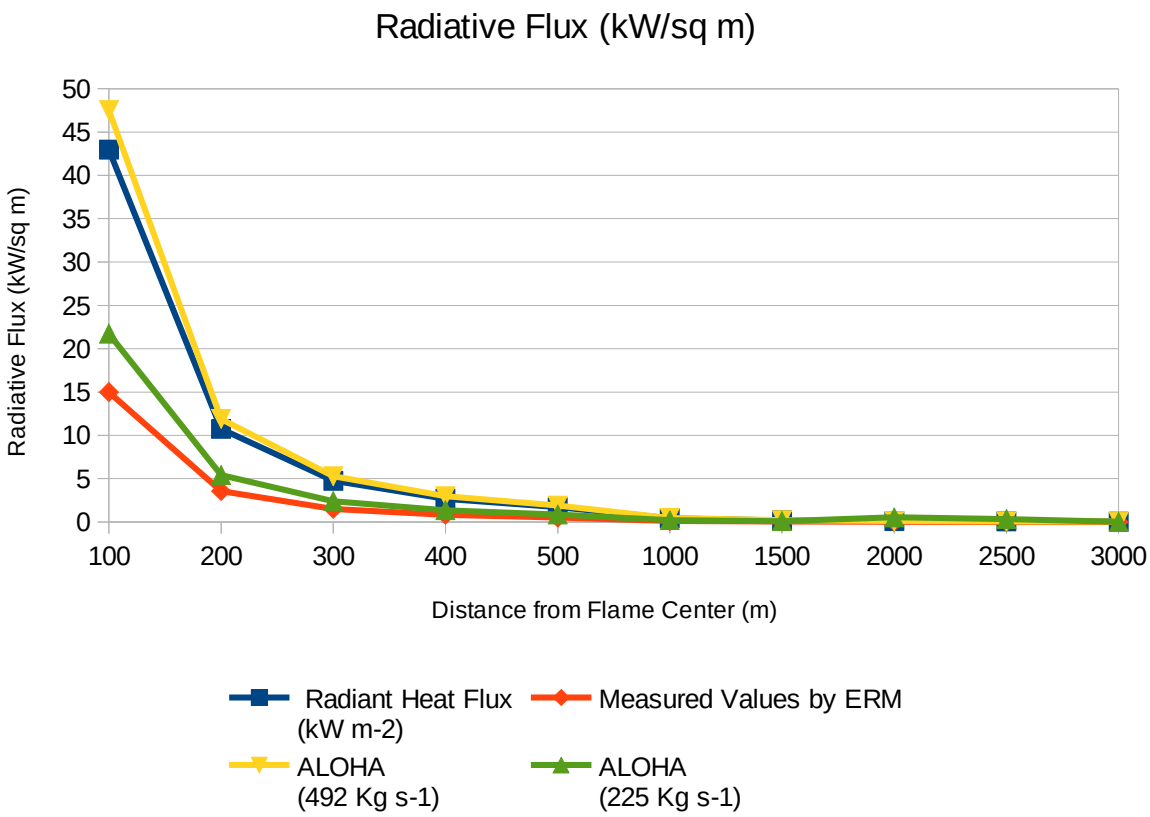


Fig. No. 7.5: Radiant Heat Flux for Baghjan Flame from various Sources

7.2.10 Plume and Air Temperatures

Plume is an important region residing at the top of the flame, and plays role in spread of fire. It has been seen from literature that the upper part of the flame is always more radiant. In case of a natural gas flame, the soot amount is low, and all the hot gases escape through the top of the flame along the plume centre-line. The Heskestad temperature of the plume appears to be 270^{0}C, and the McCaffrey temperature 201^{0}C. Using an online tool, the thermal profile above the plume was worked out. The air temperatures upto a height of 1000 m is shown in the graph below[72]. The temperature at 1000m above the flame is estimated to be 34^{0}C. The normal temperature is supposed to be 8.7^{0}C (*Calculated*[73]), [*This is a clear case of "thermal pollution"*[74]*. It has been this way now for almost 5 months. However, the impact of the flame in the upper levels of atmosphere has not been studied in this Report.*]

72 https://www.sbenkorichi.com/calculators/flame-height-plume-centerline-temperature-calculator/
73 https://www.translatorscafe.com/unit-converter/en-US/calculator/altitude/
74 *Thermal pollution is normally defined as infusion of excessive heat into a water body, but not into the upper reaches of the atmosphere*.

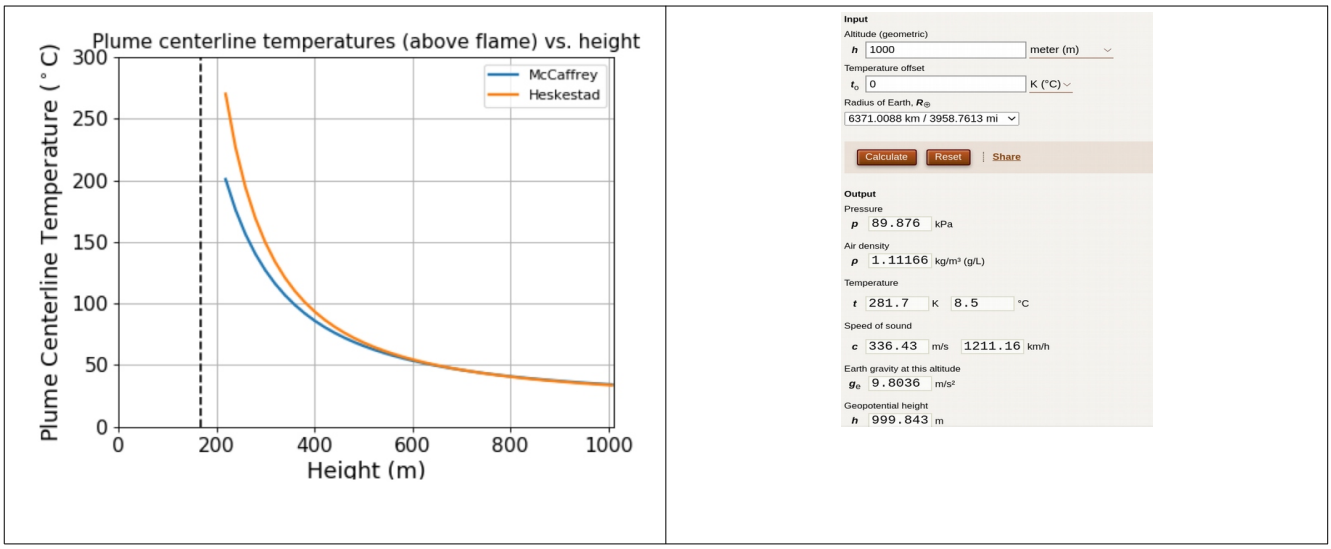


Fig. No. 7.6: Plume Temperature Profile, and Actual Temperature at 1000m Elevation

7.2.11 Acoustic Properties of the Flame

As can be seen from the discussions in the previous paragraphs, there is considerable variation in flame height, HRR, mass flow rate, flow velocity, Mach Number and Reynold's Number. These fluctuations are caused by varying pressures at the well head, surrounding temperature, wind speed among other possible factors. The HRR (which, in turn, is affected by the changes in the mass flow rate and air flow), gives rise to direct combustion noises. Indirect noise sources in the flame are changes in the velocity of the gases, local vorticities (spinning movements in the flame), generation of entropy waves emanating from hot and cold spots and various accelerations therein. A typical combustion noise in a jet flame is represented by a curve as shown in the graph below[75]:

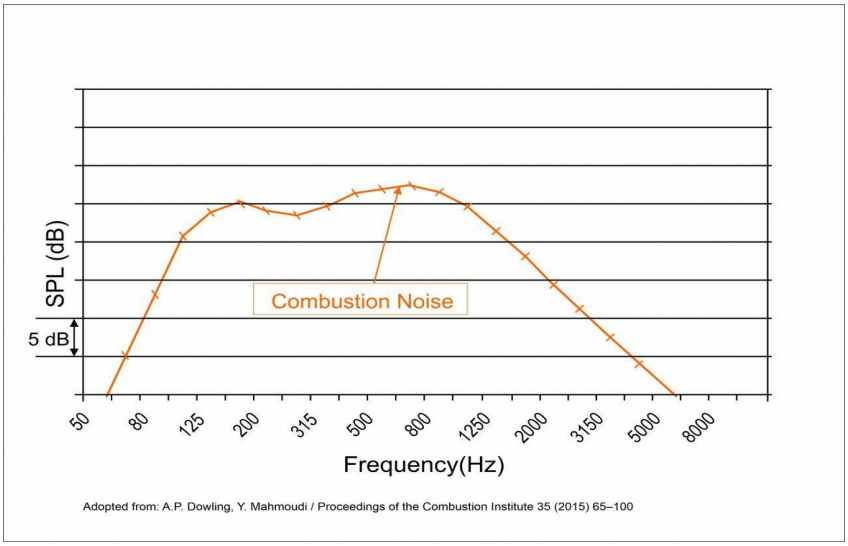


Fig. No. 7.7: A Typical Jet Flame Noise Spectrum

75 A.P. Dowling, Y. Mahmoudi, 2015, Proceedings of the Combustion Institute 35 (2015) 65–100

Steady combustion, leading to a constant rate of expansion, is ***silent***. A turbulent flame is a collection of eddies with their own heat release rates. Each eddy acts as a monopole source of sound and is statistically independent of the other adjacent eddies. Combustion noise has two main contributors, one from the thermo-chemical processes and another from the turbulence. However, even a basic treatment of these subjects would pose computational and modelling challenges beyond the scope of this Report. Therefore, in brief, only two simplifications would be conjectured namely the possible conversion of the thermal power of the flame to the acoustic power and examining possible frequencies that would be observable in the acoustic emissions from the flame.

ACOUSTIC POWER OF THE FLAME :

Based on certain research studies[76,77], it can be said that there is an efficiency of conversion of thermal power (HRR $\dot{Q}$) to acoustic power P:

$$P = \eta_{TA} \times \dot{Q} \qquad \text{..... } Eq.No.7.26$$

The thermal to acoustic efficiency can be expressed as

$$\eta_{TA} \cong 5.4 \bullet 10^{-2} \times (\epsilon - 1) \times (\gamma - 1) \bullet M_N^2 \bullet M_1 / R_e^{0.16} \qquad \text{..... } Eq.No.7.27$$

where ε= ρ_2/ρ_1 is the ratio of the densities of the reactants (ρ_1) and products (ρ_2), γ is the Adiabatic Ratio (C_p/C_v), M_N is the Mach Number and M_1 (=U_N/U_1) is the ratio of the average flow velocity to the turbulent flame flow velocity[78,79], and R_e being the Reynold's Number (<10^5). The value of M_1 was estimated from the values of U_1 from the works of Abugov et al (1979), Andrews et al (1975) and Karlovitz et al (1951). More so, it was deduced by extrapolation of U values at various Reynolds Numbers given by Karlovitz et al (1951). The turbulent flame flow velocities for natural gas (at experimental level in laboratory), when plotted against Reynolds number, give the following best fit with r=1:

$$U_1 = 4.9 \times 10^{-4} . R_e \qquad \text{..... } Eq.No.7.28$$

76 Carl-Christian Hantschk and Edwin Schorer, AFRC-JFRC 2004 Joint International Combustion Symposium October 10-13, 2004

77 Abugov D.I, Obrezkov O.I, 0010-5082/78/1405-0606$07.5, 1979, Plenum Publishing Corp

78 Andrews G.E, Bradley Derek, Lwakabamba S.B, Symposium (International) on Combustion, Volume 15, Issue 1,1975, Pages 655-664

79 Karlovitz Béla, Denniston D. W. Jr. and Wells F. E., J. Chem. Phys.19, 541 (1951); https://doi.org/10.1063/1.1748289

The Thermo-acoustic efficiency comes to the order of 10^{-9}. However, these conditions are largely for small Mach numbers and Reynold numbers <10^5. In the instant case, the Reynold's number (R_e) has been estimated to be >10^5, and the exit Mach Number (M_e) has been estimated to be atleast 3.1. Further, Lighthill (1952, 1954)[80,81] also estimated thermo-acoustic efficiencies, but for Mach number <1. He gave thermo-acoustic efficiency as:

$$\eta = \frac{accoustic\ power}{\frac{1}{2}\rho_0 U^3 \frac{1}{4}\pi d^2} = \frac{8}{\pi} \times K \bullet M^5 \qquad \ldots\ldots\ Eq.No.7.29$$

for M<1, the value of η is of the order of 10^{-6} to 10^{-5}, but for 1>M>3, η get to the order of 10^{-4} to 10^{-2}. Such high efficiencies of conversion would produce sound levels for which we may not have an example or even an opportunity to measure. The most appropriate case was found from the study of Hantschk and Schorer (2004)[82] from whence the Fig 1 of the study is reproduced here:-

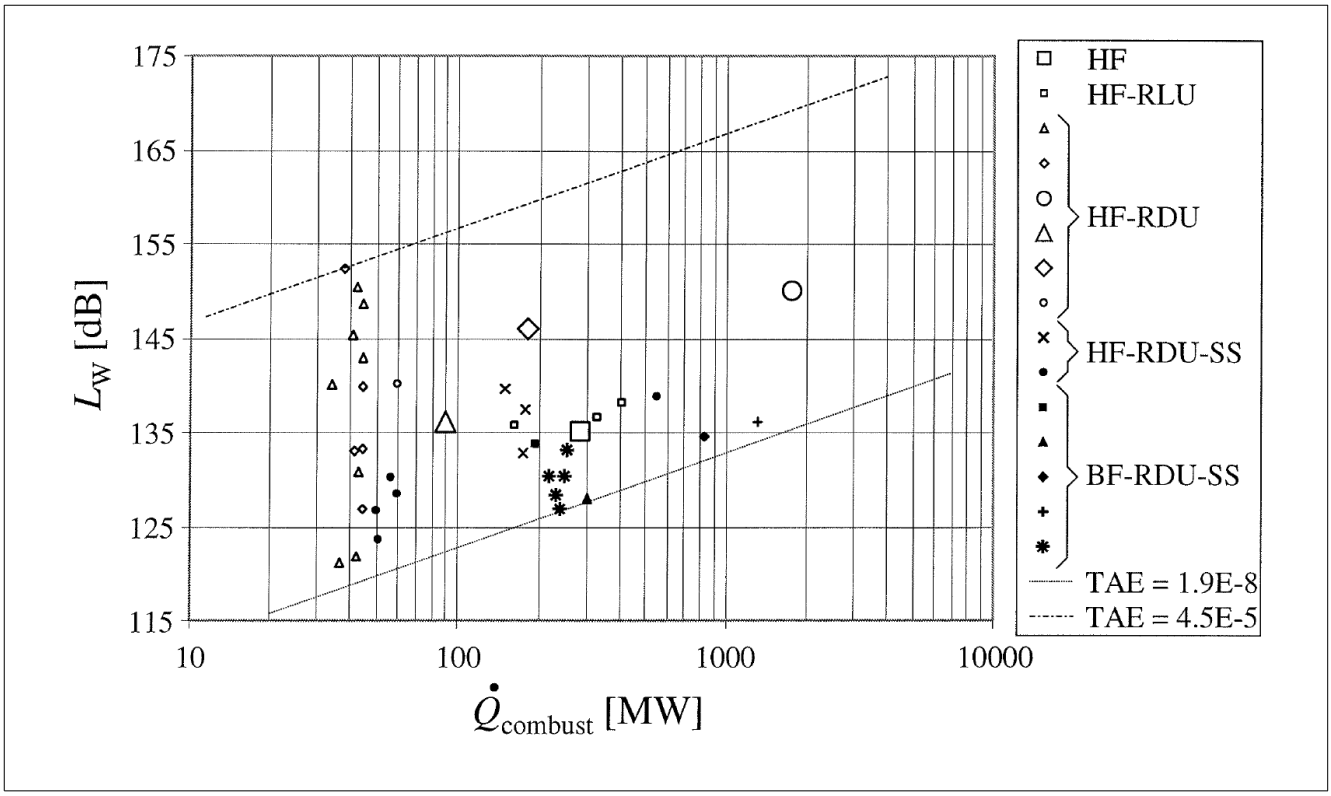


Fig. No. 7.8: Thermo-Acoustic Efficiency (TAE) Plot

This is relevant as because, it depicts one case of high flame (elevated) denoted by HF in the diagram, and the HRR rates are of similar order as the instant case in hand. A simple extrapolation of the graph on the X-axis to the right says that the Baghjan flame could

80 Lighthill M. J, Proc. Royal Soc., London, A211 (1952)
81 Lighthill M.J, Proc. Royal Soc., London, A222 (1952)
82 See footnote 76

have a sound power level of anything from 145 dB to 185 dB. The straight lines are the maximum and minimum of observed Thermo-Acoustic Efficiency (TAE) measurements. Therefore, it is proposed here to take both the values for the Baghjan flame, and work out the Sound Power of the flame as Maximum and Minimum. Using the equations given below, the sound power is calculated as below:-

Table No. 7.6: HRR, TAE & Sound Power Estimation for Baghjan Flame

HRR (MW)	TAE (η)	L (W)	L_W (dB)
16450	1.9×10^{-8}	325.71	145.13
16450	4.5×10^{-5}	740250	178.69

The equations are:-

$$L_W = 10 \bullet \log\left[\frac{P\ Watts}{10^{-12}\ Watts}\right] \quad \text{or} \quad \text{..... } Eq.No.7.30$$

$$L_W = 10 \bullet \log\left[\frac{\eta_{TA} \bullet \dot{Q}\ \ Watts}{10^{-12}\ Watts}\right] \quad \text{..... } Eq.No.7.31$$

Substituting the values η_{TA} and taking $\dot{Q}$ = 16450 MW=16450x10^6 W, we get **L_W=178-145 dB**. While the values of $\dot{Q}$ would fluctuate as the mass flow rate and the flow velocity change depending upon the pressures at play near the orifice and at the hypothetical burner at the lift-off height, the average sound power of the flame can be taken as **160 dB** and the Sound Power to be **10000 W (=10kW)**. The average **TAE** of the flame works out to be, therefore, **6.079×10^{-5}**. This sound power level of the flame matches very well with the sound level of a Turbojet engine[83]. *This also very well validates the assumptions and estimates arrived about the flame so far*. Since the flame could not be approached very close (at least till 17th of August, 2020 when it got lifted further up from the ground due to affixing of BOP riser), these values could not be confirmed by ordinary measurements. On average the Oil Well campus boundary itself is at 60-90m radius, and the flame was lifted up in the air.

The actual impact of the sound would depend whether the flame is sighted directly or there are sound absorbing objects in the path. [*On the ground, clear visibility is available only on the Dibru river side towards the Dibru-Saikhowa National Park after about 500m of tall trees*]. Most other areas have a lot of tall tree cover, houses and other sound absorbing objects. Assuming that there are no obstacles between the fire and the

83 https://www.engineeringtoolbox.com/sound-power-level-d_58.html

observer for any given distance, the intensity of the sound in Watts can be calculated, at a distance R from the flame source: (radiating about 10kW of sound) by the relation:-

$$I = \frac{W}{4\pi R^2} \quad \text{..... } Eq.No.\ 7.32$$

As the sound power W at the flame is **10,000W**, its Sound Intensity Level (L_I)[84] in dB at various distances have been worked out and given below. These are theoretical values only assuming no barrier/ obstacle in between (Direct Field/ Free Field). Without obstructions in between, the level can be assumed to decrease by 6dB for every distance doubled (Free Field). A detailed discussion would be presented again in the Chapter on Noise Pollution with actual observations.

Table No. 7.7: Distance vs. Free & Far Field Sound Levels

Distance (m)	Sound Level L_I (dB) Direct (Free) Field	Sound Level L_I (dB) Far Field[85]
0	160	-
50	115	115
100	109	109
200	103	103
500	95	**68**
1000	89	62
1500	85	58
2000	83	56
2500	81	54
3000	79	52
5000	75	48
10000	69	42
20000	63	36
30000	59	32

84 *There are several other associated terms such as Sound Pressure Level and Sound Intensity Level among other terms. Their definition, mathematical expression and inter-relationships are given in the Chapter on Noise Pollution & Vibrations*.

85 *Assuming a sound barrier at 500 m affecting a decrease of 27 dB, as ERM value at 500m is 68. The column is only indicative of the impact of sound barrier, and not based on deterministic calculations*

7.3 Combustion Properties And Combustion Species

Combustion and turbulence are at the root of the various properties exhibited by the lifted jet flame, as we have seen so far. It is, therefore, important to understand the combustion process of the natural gas and the species involved in it so that a broader understanding and the levels of pollution can be arrived at with some good approximation. Physico-chemical properties of natural gas, its combustion behaviour, adiabatic flame temperature etc. are some of the subjects that would be dealt with in some detail.

7.3.1 Physico-chemical Properties of Natural Gas

Natural gas, as tested in the laboratory by taking samples of the Baghjan blowout well (BGN#5), is a mixture of gases in the following proportions by volume:-

Table No. 7.8: Baghjan Natural Gas Composition

Constituent Species	Formula	V/V %	Equivalent Formula[86]
Methane	CH_4	92.97	$C_{0.9297}H_{3.7188}$
Ethane	C_2H_6	2.91	$C_{0.0582}H_{0.1746}$
Propane	C_3H_8	1.06	$C_{0.0318}H_{0.0848}$
Butane	C_4H_{10}	0.43	$C_{0.0172}H_{0.043}$
Pentane	C_5H_{12}	0.17	$C_{0.0085}H_{0.204}$
Hexane	C_6H_{14}	1.15	$C_{0.069}H_{0.161}$
Nitrogen	N_2	0.09	0.0009 N_2 (Moles)
Carbon dioxide	CO_2	1.22	0.0122 CO_2 (Moles)
		100	**$C_{1.1144}H_{4.2026}$**

The Molecular Mass can be calculated using the formula:-

$$M = \sum_{i=1}^{n} \chi_i \bullet M_i \qquad \ldots\ldots \; Eq.No.\; 7.33$$

where χ_i is the volume fraction of the constituent i and M_i is its molecular mass. A few other properties can also be worked out as above. Here is a summary of most required physio-chemical properties of natural gas[87] for the Report:-

86 *Deduced by the Author of this Report*

87 Zhou Kuibin, Wang Xiuzhen, Liu Meng, Liu Jiaoyan, https://doi.org/10.1016/j.ijhydene.2018.10.122

M, Molecular Mass (gms)[88]	:	18.14
γ (C_p/C_v)	:	1.3
ρ Density (Kg m^{-3})[89]	:	0.771
H_{NCV} (MJ/SCUM)	:	36.92
H_{NCV} (MJ/Kg)	:	47.89
a, van der Waals constant	:	843 (m^6 Pa kg^{-2})
b, van der Waals constant	:	0.0026 (m^3 kg^{-1})
T_{ad}, Adiabatic Temperature[90]	:	2334 K
f, Mass fraction[91]	:	0.0569

7.3.2 C-H-O Combustion System

Natural gas is a mixture of several gases, mainly CH_4. Taking the equivalent weights of all the constituents, barring CO_2, the natural gas at Baghjan Well No. 5 can be chemically represented as **$C_{1.1144}H_{4.2026}N_{0.0018}$**. [*However, the natural gas has **0.0009 moles** of N_2 and **0.0122 moles** of CO_2 as well.*] Hydrocarbon combustion can be generalized as under:-

$$C_n H_m + \left(n + \frac{m}{4}\right)\left(O_2 + 3.76\, N_2\right) \rightarrow nCO_2 + \frac{m}{2} H_2 O + 3.76\left(n + \frac{m}{4}\right) N_2 \quad \text{..... } Eq.No.\ 7.34$$

For every mole of C_nH_m fuel, $4.76 \times \left(n + \frac{m}{4}\right)$ mole of air is required and $4.76 \times \left(n + \frac{m}{2}\right) + \frac{m}{4}$ moles of combustion products are generated. The product mole fractions for CO_2, H_2O and N_2 are given as below:-

$$Y_{CO_2} = \frac{n}{4.76\left(n + \frac{m}{4}\right) + \frac{m}{4}} \quad \text{..... } Eq.No.\ 7.35$$

$$Y_{H_2O} = \frac{\frac{m}{2}}{4.76\left(n + \frac{m}{4}\right) + \frac{m}{4}} \quad \text{..... } Eq.No.\ 7.36$$

88 *Calculated (Courtesy Ms. Yadava Ekansha, XI, LFS, Guwahati*
89 *OIL Laboratory Report*
90 Adiabatic Flame Temperature
91 *Fuel mass fraction at stoichiometric conditions in combustion*

$$Y_{N_2} = \frac{3.76 \times \left(n + \frac{m}{4}\right)}{4.76\left(n + \frac{m}{4}\right) + \frac{m}{4}} \quad \text{..... } Eq.No.\ 7.37$$

The molar stoichiometric fuel/air ratio is given by:-

$$\left(\frac{m_f}{m_a}\right)_{st} = \frac{12 \times n + m}{4.76\left(n + \frac{m}{4}\right) + \frac{m}{4}} \quad \text{..... } Eq.No.\ 7.38$$

Thus, at stoichiometric combustion, 1 mole of the hydrocarbon fuel would produce n moles of CO_2, m/2 moles of H_2O and $3.76 \times \left(n + \frac{m}{2}\right)$ moles of N_2. Though in reality combustion of CH_4 alone produces 53 species, we shall adhere to only the three species mentioned above, and now look at NO_x production in the following paragraphs.

7.3.3 ADIABATIC FLAME TEMPERATURE (AFT)

Adiabatic[92] conditions assume that no heat is released from the combustion system. This leads to rise in temperature of the gases inside the system. As per Thermodynamics, Adiabatic Flame Temperature (AFT) is the maximum temperature that can be achieved for any given type of fuel. The calculations for estimating the temperature are long, and may require use of computer programs. Therefore, these are being omitted from the scope of the Report. However, adiabatic flame temperature along with other physio-chemical properties of the natural gas are given in the paragraph 7.3.1. The AFT for natural gas is 2334 K. It means that the temperatures in the flame could go as high as 2000^0C. Therefore, we need to have a relook at the C-H-O combustion system discussed in the previous paragraph.

7.3.4 C-H-O-N SYSTEM

We have already looked at C-H-O system and the species involved in a simplified mode. However, as the flame is likely to be more than 1700 K (AFT being 2334 K), there is every possibility that N_2 molecules would also react and produce NO_x. Additionally, at high temperatures it is expected that CO would also be produced, as oxidation of carbon is a two step process. Since the gas is "Sweet" as per the laboratory report [meaning no Sulphur], SO_x components would be rightfully treated as "absent" in the combustion system.

92 *Adiabatic condition is said to be met in a process when there is no transfer of heat between the system and its surrounding. In combustion, the heat released in the reaction, in adiabatic conditions, does not escape the system, but is used internally to heat up the product species in the system*.

NO_x:

There are several pathways through with NO (Nitric Oxide) can be formed in a flame. While the basic reaction given below is highly endothermic and slow, and can operate only in the highest flame temperature zones in highly adiabatic conditions, the easier ways are dissociation of N_2, O_2 and H_2O molecules. The other three reactions are more probable.

$$\frac{1}{2}N_2+\frac{1}{2}O_2 \rightleftharpoons NO$$

$$½\ O_2 \rightleftharpoons O$$

$$½\ N_2 \rightleftharpoons N$$

$$N_2 + O \rightleftharpoons NO + N$$

$$N+O_2 \rightleftharpoons NO + O$$

$$½\ H_2O+¼\ O_2 \rightleftharpoons OH$$

$$N+OH \rightleftharpoons NO+H$$

There are many entities in the flame combustion reaction. Another pathway is through a maze of species originating from HCN formation, and this pathway needs lower temperatures.

$$CH + N_2 \rightleftharpoons HCN + N$$

$$HCN+O \rightleftharpoons NCO + H$$

$$NCO + H \rightleftharpoons NH + CO$$

$$NH + H \rightleftharpoons N + H_2$$

$$N+OH \rightleftharpoons NO+H$$

Similarly, Nitrogen Dioxide (NO_2) is also formed in the flame combustion reaction. It is an exothermic reaction, but the kinetics proceeds at slower speed.

$$NO + ½\ O_2 \rightleftharpoons NO_2$$

CO:

Carbon monoxide is formed due to lack of sufficient oxygen. Oxidation of carbon is a two step process. The unoxidized CO escapes from the reaction system.

$$C + ½\ O_2 \rightleftharpoons CO$$

$$CO+O_2 \rightleftharpoons CO_2 +O$$

The main reaction producing CO in hydrocarbon burning is the following reaction:-

$$CO_2 + H \rightleftharpoons CO + OH$$

CO carries high health hazard, as it has 200 times more affinity to attach to Fe in the Hemoglobin in blood leading to unconsciousness and even death.

7.3.5 THE C-H-O-N SYSTEM - II

As the chemistry of the combustion reactions get complex, and more than 500 species are possible that would be appearing on the product side, the reader is referred to a few good resource material here[93,94,95]. However, now that we have a total of 4 (four) polluting species namely CO_2, CO, NO and NO_2, their quantities need to be estimated from the burning of the flame and the combustion reactions taking place therein. While there is plethora of literature, a reference is drawn here of the study on the subject of emissions from natural gas from flares by Umukora and Ismail (2015)[96], whose combustion equation R-3, and which fits the instant Baghjan flame case, has been picked up, and presented below:-

$$[C_xH_y + \alpha CO_2 + jN_2] + \beta(O_2 + 3.76N_2) \rightarrow$$
$$\eta x CO_2 + \eta\frac{y}{2}H_2O + (1-\eta)xCO + (1-\eta)\frac{y}{2}H_2 + \frac{\delta}{4}O_2 + jN_2 + \alpha CO_2 + \left(3.76\beta - \frac{\delta}{2}\right)N_2 + \frac{d}{2}NO + \frac{d}{2}NO_2$$

..... $Eq.No.$ 7.39

where $\delta = \left[x\left(\frac{1}{2} - \frac{\eta}{2}\right) + y\left(\frac{1}{Z} - \frac{\eta}{4}\right)\right]$ x, y, α, j are the stoichiometric properties of the fuel gas, β is the stoichiometric requirement of O_2, and η is the combustion efficiency. Here, $Z = \frac{y}{\beta - x}$, $\beta = \Delta \times k$ and $k = \left(x + \frac{y}{4}\right)$. It may be noted that $\beta = k$ and Z=4 for complete combustion, and Δ is the ratio of actual air available for combustion to stoichiometric air quantum required.

Putting this equation to use for the Baghjan Well No. 5, natural gas (as tested in laboratory), and whose parameters already described in para 7.3.1, and working through steps of calculating the various parameters from one step to the other, we get the following values of the variables mentioned above:-

93 McAllister Sarah, Fernandez-Pello A Carlos, Chen J-Y, Fundamentals of Combustion Processes, Springer, New York, 2011, ISBN 978-1-4419-7942-1
94 https://authors.library.caltech.edu/25069/4/AirPollution88-Ch2.pdf
95 https://authors.library.caltech.edu/25069/5/AirPollution88-Ch3.pdf
96 Umukoro G. E, Ismail, O. S, http://dx.doi.org/10.1016/j.jksues.2015.08.001

NG Hydrocarbon: $\mathbf{C_{1.1144}H_{4.2026}}$

x=1.1144; y=4.2026, α = 0.0122, j = 0.0009

η = 0.74 **[**Ref: Umukora and Ismail (2015)**]**

Δ = 0.90, k=2.6854, β=2.41686, Z=5.1566

δ = 0.23625 **[**Calculated as above**]**

This implies that 1000 moles of $\mathbf{C_{1.1144}H_{4.2026}}$ would produce the following quantities of emissions:-

CO_2: ηx+α = 1.108294x44 = 48.765 kg per 1000 moles of C_xH_y.

CO: (1- η)x = 0.386906x28=10.833 kg per 1000 moles of C_xH_y.

NO=δ/2 = 0.118125x30=3.544 kg per 1000 moles of C_xH_y.

NO_2= δ/2 = 0.118125x46=5.434 kg per 1000 moles of C_xH_y.

Working out the value of the emissions in moles, firstly, for 1000 moles of reactants, the values estimated work out approximately quite in agreement with Umukuro & Ismail (2014)[97] for 90% air and η = 0.74 (Table-2 of the publication referred to). The values were, then converted to emission from 1 cum of natural gas and the following figures were, thus, obtained:-

Table No. 7.9: Species Emission Rates from Natural Gas Combustion

Species	Emissions (Kg/1000 m)	Emission Kg m^{-3}
CO_2	48.765	2.05
CO	10.833	0.45
NO	3.544	0.15
NO_2	5.434	0.23

These figures, however, do not match well with the figures arrived at by Umukora & Ismail (2015)[98].

97 http://dx.doi.org/10.1016/j.jksues.2014.02.003.

98 *There appears to be some conflict between the research paper of 2014 and 2015 of Umukora & Ismail. Dr. Ismail from Mechanical Engineering Department, Ibutan University, Nigeria, was contacted over phone and a series of emails to get the reasons for differences in emissions as arrived in Table 2 of 2014, and Table 3 of 2015 of their publications. The authors responded on 4th August, 2020 with corrections in the calculations. Dr. G. E. Umukoro gave revised calculation sheets, which are annexed in Vol-I of this Report.*

7.3.6 CONDENSATE COMBUSTION

In addition to the natural gas burning, there is condensate also mixed in the "Single Phase" flow from the well. At first, estimates of emissions from the condensate has been worked out, followed by estimates of condensate in the BGN#5 well. The OIL did not have the chemical analysis of the condensate. From literature[99], the chemical composition is given in the Table below:-

Table No. 7.10: Chemical Composition of Condensate [Pedersen et al (1989)]

Constituent Species	Formula	Mole %	Equivalent Formula[100]
Methane	CH_4	70.86	$C_{0.7086}H_{2.8344}$
Ethane	C_2H_6	8.53	$C_{0.1706}H_{0.5118}$
Propane	C_3H_8	4.95	$C_{0.1485}H_{0.396}$
Butane	C_4H_{10}	2.00	$C_{0.08}H_{0.2}$
Pentane	C_5H_{12}	0.81	$C_{0.0405}H_{0.0972}$
Hexane	C_6H_{14}	0.46	$C_{0.0276}H_{0.0644}$
Heptane	C_7H_{16}	0.61	$C_{0.0427}H_{0.0976}$
Octane	C_8H_{18}	0.71	$C_{0.0568}H_{0.1278}$
Nonane	C_9H_{20}	0.39	$C_{0.0351}H_{0.078}$
Decane	$C_{10}H_{22}$	0.28	$C_{0.028}H_{0.0616}$
Undecane	$C_{11}H_{24}$	0.20	$C_{0.022}H_{0.048}$
Dodecane	$C_{12}H_{26}$	0.15	$C_{0.018}H_{0.039}$
Tridecane	$C_{13}H_{28}$	0.11	$C_{0.0143}H_{0.038}$
Tetradecane	$C_{14}H_{30}$	0.10	$C_{0.014}H_{0.03}$
Pentadecane	$C_{15}H_{32}$	0.07	$C_{0.0105}H_{0.0224}$
Hexadecane	$C_{16}H_{34}$	0.05	$C_{0.008}H_{0.017}$
Heptadecane +	$C_{17}H_{36}$	0.37	$C_{0.0629}H_{0.1332}$
Nitrogen	N_2	0.71	0.0071 N_2 (Moles)
Carbon dioxide	CO_2	8.65	0.0865 CO_2 (Moles)
		100.01	$\mathbf{C_{1.4881}H_{4.7892}}$

The chemical formula of condensate as per the chemical composition as provided by Pedersen et al (1989) would be $\mathbf{C_{1.4881}H_{4.7892}}$. The combustion is assumed to follow the

99 Pedersen, K. S, Fredenslund, Aage, and Thomassen, P, 1989, "Properties of Oils and Natural Gases", Gulf Publishing Company

100 *Deduced by the Author of this Report*

same principles as already discussed for the natural gas, and the various stoichiometry constants can be found out in exactly the same way as discussed for the natural gas in the previous paragraph (7.3.5). However, instead of generalizing, an attempt was made to see if one can be more specific about the Baghjan condensate.

The Baghjan Condensate:

The Baghjan oil well BGN#5 condensate that had fallen in the pits surrounding the blow out was collected on the 31st May, 2020 and analyzed on the 6th June, 2020. Results of another seized sample of condensate tested was also given by M/S OIL. The chemical compositions of the two samples are given below:-

Table No. 7.11: Chemical Composition of Another Condensate Sample from Baghjan

Constituent Species	Formula	Mole % (BGN#5)	Mole % (Seized)
Methane	CH_4		
Ethane	C_2H_6		
Propane	C_3H_8		4.98
Butane	C_4H_{10}		55.91
Pentane	C_5H_{12}	0.17	34.40
Hexane	C_6H_{14}	0.10	3.64
Heptane	C_7H_{16}	1.45	0.70
Octane	C_8H_{18}	0.43	0.22
Nonane	C_9H_{20}	0.55	0.14
Decane	$C_{10}H_{22}$	0.63	0.01
Undecane	$C_{11}H_{24}$		
Dodecane	$C_{12}H_{26}$	20.26	
Tridecane	$C_{13}H_{28}$	29.53	
Tetradecane	$C_{14}H_{30}$	24.20	
Pentadecane +	$C_{15}H_{32}$	22.68	
		100	**100**

Equivalent chemical formula of the BGN#5 condensate would be $\mathbf{C_{13.323}H_{28.646}}$, and that of the seized one would be $\mathbf{C_{4.4044}H_{10.8088}}$. Thus, it is seen that there is a lot of variation from the generic composition as quoted by Pedersen et al (1989)[101]. Therefore, having

101 See 99

observed such variations in the condensate composition that would be caused by evaporation losses or the very nature of the condensate whether it was light, heavy or very heavy, M/S OIL was asked to carry out testing of a fresh sample from either BGN#3 or BGN#5 (if possible). Accordingly, M/S OIL supplied a newly tested sample from Barekuri#18 (BRK#18) well (collected on the 4th August, 2020 and tested on 5th August, 2020), which turned out to be a sour well. However, since BGN#5 was a sweet well, all the Sulphur concentration was simply ignored, as the mole% was 100 even without it. The reworked table of the "sweetened" BRK#18 condensate composition is given below:-

Table No. 7.12: Chemical Composition of a Fresh Sample of Barekuri-Baghjan Condensate

Constituent Species	Formula	Mole % (BRK#18-BGN#5)
Methane	CH_4	
Ethane	C_2H_6	
Propane	C_3H_8	
Butane	C_4H_{10}	
Pentane	C_5H_{12}	5.12
Hexane	C_6H_{14}	12.60
Heptane	C_7H_{16}	29.91
Octane	C_8H_{18}	25.40
Nonane	C_9H_{20}	0.42
Decane	$C_{10}H_{22}$	12.63
Undecane	$C_{11}H_{24}$	
Dodecane	$C_{12}H_{26}$	0.22
Tridecane	$C_{13}H_{28}$	10.42
Tetradecane	$C_{14}H_{30}$	0.52
Pentadecane +	$C_{15}H_{32}$	2.59
Nitrogen	N_2	0.10
Carbon Dioxide	CO_2	0.07
		100

The hydrocarbon formula of the condensate comes to $\mathbf{C_{8.2808}H_{18..5582}}$ with molecular weight of 117.9278, density 0.7943 gm/cc (≡ 794.3 Kg m^{-3}) and API 46.48. The detailed calculation for combustion of the condensate at 90% air availability and 74% burning efficiency was carried out as per modified Umukoro & Ismail (2020)[102], the emission values in appropriate units are given in the table below:-

Table No. 7.13: Species Emission Rates from Condensate Combustion

Species	Emission (Kg/ 1000 m)	Emission Kg m^{-3}
CO_2	269.654	1812
CO	60.284	405
NO	14.85	100
NO_2	22.77	153

7.3.7 Amount of Condensate in Natural Gas

No data is available on the BGN#5 concerning most properties. However, the nearby well BGN#3 is in production, and the following production data has been obtained from M/S OIL through email queries:-"*Similar capacity well BGN 3 is producing around 1, 35,000 scumd Gas and 22 klpd condensate through 6 mm bean. This well is currently producing from LK+TH SG I+II 3693 m Sand (BGN003E SWP) with existing perforation in the range 3693.0-3705 m (12 m Open). Well BGN#5 is currently perforated in the range 3731.5-3737.5m (6m Open)*". As the characteristics and well depth are quite similar, it can be well assumed that the BGN#5 would be producing in a similar manner. Of course, the production capacities of the BGN#5 are supposed to be higher, as the natural gas production capacity would have been 1.5 scumd (or even more). The capacity of BGN 5 can be safely assumed to be 11.11% higher than that of BGN#3. Therefore, the condensate production at BGN#5 can be assumed to be 24.444 klpd.

As submitted by M/S OIL, the GOR (Gas Oil Ratio) for the BGN#3 is 6000 SCUM/kl. By the above production figures, the actual GOR comes to 6136.36. We shall take 6136 as the GOR for BGN#5 too. This would roughly mean that **for every 6136 m^3 of natural gas, there is 1 m^3 of condensate associated with it**.

7.3.8 Combined Emission from Combustion of Natural Gas and Condensate

Since the well fluid is in single phase, the natural gas and condensate are in mixed state in the oil well. Also, it is established that for every 6136 m^3 of natural gas, there is one

102 See Annexure (Vol. I) : Umukoro & Ismail Correction Sheet

m^3 of condensate. This implies that for every 1 m^3 of gas, there is 0.00163 m^3 of condensate. This has been assumed in absence of any other alternate conjecture.

With these figures, now one can easily estimate the emissions from combustion of 1 m^3 of the BGN#5 well fluid. The table given below provides the requisite estimates:-

Table No. 7.14: Species Emission Rates from the Baghjan Fluid Combustion

Species	1 m^3 of N.G. (kg)	1 m^3 of Condensate (kg)	Proportion of Condensate emission from 1 m^3 of fluid (kg)	Total emission from 1 m^3 of well fluid (kg)
1	**2**	**3**	**4**	**5=2+4**
CO_2	2.05	1812	0.3	2.35
CO	0.45	405	0.07	0.52
NO	0.15	100	0.02	0.17
NO_2	0.23	153	0.02	0.25

7.3.9 Polycyclic Aromatic Hydrocarbons

Polycylic Aromatic Hydrocarbons (PAH) are a special category of chemical compounds formed in the rich zone of the flame with acetylene (C_2H_2) as precursor. These compounds are important soot makers and reach sizes to several nanometers. Several of their species are known to be carcinogens. The C_2, C_3 or C_4 chains get together to make Benzene (C_6H_6), Cyclopentene (C_5H_8), Naphthalene ($C_{10}H_8$), Indene (C_9H_7), Toluene (C_7H_8), Styrene (C_8H_8), Phenathrene/ Anthracene ($C_{14}H_{10}$), Naphthacene/Tetracene ($C_{18}H_{12}$) and a host of other aromatic cyclic compounds of benzene and/or Cyclopentene rings put together. More than 28-30 species of PAH have been identified that evolve in a pyrogenic process. PAH is largely associated with soot production, which could be under 0.1% of the fuel combusted in case of natural gas as apparent from literature[103,104,105,106]. Soot could vary from 10-400 mg per Kg of fuel in case of natural gas. As there is no clear cut picture emerging, in absence of field experiments on the Baghjan flame, we can assume **soot production @ $200x10^{-6}$ kg per kg of fuel.** Most of the PAH would be generated from soot in the atmosphere, that would settle down in the nearby areas with rain.

103 Gruenberger T. M, Moghiman M, Bowen P. J. & Syred N, 2002, http://dx.doi.org/10.1080/713713038
104 Atiku F.A. Mitchell, E.J.S. Lea-Langton, A.R. Jones, J.M. Williams, Bartlemm A. K.D, 2016, http://dx.doi.org/10.1016/j.fuproc.2016.05.032
105 Seljak T., Rodman O.S., Kunaver M., Katrašnik T, Effect of primary air temperature on emissions of a gas turbine, fired by liquefied spruce wood. Biomass & Bioenergy, Vol. 71, pp 394-407, 2014
106 Wahl Claus, https://www.nanoparticles.ch/archive/2010_Wahl_PO.pdf

7.4 Conclusions

The following conclusions can be drawn from this Chapter:-

1. The flame is supersonic and its lift-off height was found to be 11m, flame height was estimated at 108m.
2. The Heat Release Rate (HRR) of the flame was estimated to be 16450 MW, and the mass flow rate to be 343.50 Kg m^{-1}.
3. The well-head pressure during the blow out/burning was estimated to be 13.8 MPa, (with 20.32 outer dia of 203.2 mm) & 35.5 MPa (with inner dia 127 mm) and the fluid exit velocity (single phase) to be 1082 m s^{-1} at the hypothetical converging-diversing nozzle just below the flame. Therefore, the blowout pressure could have been more than 5100 psi.
4. The Mach number estimated for the flame could vary from 3.1 to 8.5. It depended on the combustion conditions at any given point of time. Similarly, the Reynold's Number was estimated to be ~251170, but it would vary too.
5. The flame is expected to generate shock waves traveling in a narrow cone of 19^0 to 90^0 in the wind direction axis.
6. The radiative flux estimated at 5m from the edge of the flame was 2742 kW, while that measured by M/S ERM was 260 kW.
7. The air temperature above the flame at 1000 m height was estimated to be 34^0C, where at that elevation, normal temperature is supposed to be 8.7^0C. This is a case of thermal pollution. It has been this way now for almost 4 months. The damages to the upper levels of atmosphere have not been studied.
8. The Thermo-Acoustic Efficiency of the flame was estimated at $4x10^{-4}$, and the acoustic power to be 158 dB. The noise level at 500 m from the flame could be from 61 to 68 dB estimated.
9. The Baghjan natural gas chemical composition was seen to be $C_{1.1144}H_{4.2026}$.
10. The emission from 1 m^3 burning of the gas estimated to be: CO_2: 1.54 Kg, CO: 0.34 Kg, NO: 0.92 Kg, NO_2: 1.42 Kg.



The Baghjan Blowout Before Explosion and Fire



Smoke from the Baghjan Flame

CHAPTER-8

8 ATMOSPHERIC POLLUTION

8.1 Introduction

Atmospheric pollution is a subject that deals with emission of pollutants from various sources such as combustion (from vehicle ignitions and fires), gas leaks, fermentation etc, their transport, dispersal and transformations through the air columns and finally their removal from the atmosphere. The subject also encompasses effects of the air pollutants on human health, animals, wildlife, forests, water bodies and other ecosystems. Therefore, the subject is vast, and only specific species are considered such as:-

1. CO_2
2. CO
3. NO
4. NO_2
5. Particulate Matter

The Baghjan Well No. BGN#5 is assumed to be "sweet" and hence no Sulphur based emissions of SO_2 or H_2S were estimated. The Chapter deals with the methodologies of estimation, description of field studies and measurements, discussion on the results and conclusions with respect to atmospheric pollution from the Baghjan blowout, explosion and fire. It needs to be explained here, and also applicable for subsequent Chapters as well, that field measurements were carried out by several agencies at Baghjan at different points of time with a variety of equipment. It cannot be said that all measurements adhered to the manner in which the ambient air quality or water quality parameters are measured in conformity with the CPCB Guidelines. A large number of measurements were electronic, and all measurements were accepted for this Report irrespective of the equipment or methodology.

8.2 Air Quality Standards In India

Air quality in the country is governed by the Air (Prevention & Control of Pollution) Act, 1981, under which the Central Pollution Control Board (CPCB) has notified the fourth version of National Ambient Air Quality Standards (NAAQS) in 2009. This is a pan India norm and 12 identified health based parameters are monitored. In this Report, a sub-set of these parameters was considered in addition to a few others related directly with combustion. The National Ambient Air Quality Standards are given below[107]:-

107 http://cpcb.nic.in

Table No. 8.1: National Ambient Air Quality Standards

Pollutants	Time Weighted Average	Concentration in Ambient Air		Methods of Measurement
		Industrial, Residential, Rural and other Areas	Ecologically Sensitive Area (Notified by Central Government)	
Sulphur Dioxide (SO_2), µg/m^3	Annual * 24 Hours **	50 80	20 80	-Improved West and Gaeke Method -Ultraviolet Fluorescenc
Nitrogen Dioxide (NO_2), µg/m^3	Annual * 24 Hours **	40 80	30 80	-Jacob & Hochheiser modified ($NaOH-NaAsO_2$) Method -Gas Phase Chemiluminescence
Particulate Matter (Size less than 10µm) or PM10 , µg/m^3	Annual * 24 Hours **	60 100	60 100	-Gravimetric -TEOM -Beta attenuation
Particulate Matter, (Size less than 2.5µm) or PM2.5, µg/m^3	Annual * 24 Hours **	40 60	40 60	-Gravimetric -TEOM -Beta attenuation
Ozone (O_3) µg/m^3	8 Hours * 1 Hour **	100 180	100 180	-UV Photometric -Chemiluminescence -Chemical Method
Lead (Pb) µg/m^3	Annual * 24 Hours **	0.50 1.0	0.50 1.0	-AAS/ICP Method after sampling on EPM 2000 or equivalent filter paper -ED-XRF using Teflon filter
Carbon Monoxide(CO), mg/m^3	8 Hours * 1 Hour **	02 04	02 04	-Non dispersive Infrared (NDIR) Spectroscopy
Ammonia (NH_3), µg/m^3	Annual * 24 Hours **	100 400	100 400	-Chemiluminescence -Indophenol blue method
Benzene (C_6H_6) µg/m^3	Annual *	05	05	-Gas Chromatography (GC) based continuous analyzer -Adsorption and

				desorption followed by GC analysis
Benzo(a) Pyrene (BaP) ng/m^3	Annual *	01	01	-Solvent extraction followed by Particulate phase only, HPLC/GC analysis
Arsenic (As), ng/ m^3	Annual *	06	06	-AAS/ICP Method after sampling on EPM 2000 or equivalent filter paper
Nickel (Ni), ng/m^3	Annual *	20	20	-AAS/ICP Method after sampling on EPM 2000 or equivalent filter paper

** Annual Arithmetic mean of minimum 104 measurements in a year at a particular site taken twice a week 24 hourly at uniform intervals.*

*** 24 hourly or 8 hourly or 1 hourly monitored values, as applicable, shall be complied with 98% of the time in a year. 2% of the time, they may exceed the limits but not on two consecutive days of monitoring.*

NOTE: Whenever and wherever monitoring results on two consecutive days of monitoring exceed the limits specified above for the respective category, it shall be considered adequate reason to institute regular or continuous monitoring and further investigations.

8.3 Ill Effects Of Air Pollution

The impact of air pollution on health and other associated hazards is a matter of great research and plethora of literature is available. However, at this stage the objective is to touch briefly upon the health hazards of the air pollutants in most rational and objective way (and in brief). A point wise compilation[108] is produced below:-

Table No. 8.2: Ill Effects of Air Pollution

Species	Short-term exposure to high levels	Long-term exposure
CO_2[109]	• Suffocation by displacement of air • Incapacitation and unconsciousness • Headaches • Vertigo and double vision • Inability to concentrate • Tinnitus • Seizures Inhaling high amounts of CO_2 may pose a threat to life	• Changes in bone calcium • Changes in body metabolism

108 *Credit of compilation is given to Ms. Arundhati Yadava, Consultant, UNDP, Guwahati*

109 *Source: https://toxtown.nlm.nih.gov/chemicals-and-contaminants/carbon-dioxide*

CO[110]	• Headache • Nausea and vomiting Blurred vision • Confusion • Dizziness • Chest pain • Weakness • Difficulty breathing • Damage to the heart and brain • Unconsciousness	• Miscarriage • Damage to a developing fetus • Seizures • Coma • Heart failure
Nitrogen Oxides[111]	• Irritation of the respiratory system, eyes, and skin • Aggravation of respiratory diseases, particularly asthma • Coughing and choking • Nausea • Headache • Abdominal pain • Difficulty breathing	• Asthma • Respiratory infections Health effects from very high levels of nitrogen oxides can include: • Death • Genetic mutations • Harm to a developing fetus • Decreased female fertility • Spasms • Swelling of the throat • Rapid pulse • Dilated heart
Particulate Matter[112]	The size of particles is directly linked to their potential for causing health problems. Small particles less than 10 micrometers in diameter pose the greatest problems, because they can get deep into your lungs, and some may even get into your bloodstream. Exposure to such particles can affect both your lungs and your heart. Numerous scientific studies have linked particle pollution exposure to a variety of problems, including: • premature death in people with heart or lung disease • non-fatal heart attacks • irregular heartbeat • aggravated asthma • decreased lung function	

110 *Source: https://toxtown.nlm.nih.gov/chemicals-and-contaminants/carbon-monoxide*

111 *Source:https://toxtown.nlm.nih.gov/chemicals-and-contaminants/nitrogen-oxides#what-happens-when-i-am-exposed-to-nitrogen-oxides*

112 Source: https://www.epa.gov/pm-pollution/health-and-environmental-effects-particulate-matter-pm

	• increased respiratory symptoms, such as irritation of the airways, coughing or difficulty breathing People with heart or lung diseases, children, and older adults are the most likely to be affected by particle pollution exposure.	
Volatile Organic Compounds (VOCs)[113]	• Irritation of the eyes and respiratory tract • Headaches • Dizziness • Visual disorders • Memory problems	• Irritation of the eyes, nose, and throat • Nausea • Fatigue • Loss of coordination • Dizziness • Damage to the liver, kidneys, and central nervous system • Cancer

8.4 Legal Provisions Pertaining To Air Quality

In India air pollution norms are governed under the Air (Prevention and Control of Pollution) Act, 1981, the Environmental (Protection) Act, 1986 and the Environmental (Protection) Rules, 1986. Under section 21(1) of the Air Act, no one is authorized to establish and operate an industrial plant without written consent of the State Pollution Control Board. This section mandates operators of industrial plants to obtain two mandatory 'certificates' - Consent To Establish (CTE) and Consent To Operate (CTO), from the Pollution Control Board. No person, under Section 22 of the Act, is allowed to cause emission of air pollutants in excess of the standards laid down. Additionally, the Act empowers, under Section 31 (A), the Board to issue directions to any person or authority, including power to direct the closure, prohibition or regulation of any industry, operation or process or stoppage of electrical supply or water supply or any such other service. Under Section 37, the Act prescribes penalties/ punishments for "*each such failure, be punishable with imprisonment for a term which shall not be less than one year and six months but which may extend to six years and with fine, and in case the failure continues, with an additional fine which may extend to five thousand rupees for every day during which such failure continues after the conviction for the first such failure*". Section 40 of the Act deals with offences by companies.

113 *Source: https://toxtown.nlm.nih.gov/chemicals-and-contaminants/volatile-organic-compounds-vocs*

The Section 5 of the EPA, 1986, gives powers to issue directions, in the manner already mentioned in the previous paragraph. Under Section 7 of the Act, persons carrying on industry, operation etc. are not to allow emissions or discharge of environmental pollutants in excess of the standards. Under Section 8, persons carrying hazardous substances are required to comply with procedural safeguards. Under Section 9(2), both the polluter and the authorities concerned are bound to prevent or mitigate the environmental pollution. Further, under Section 9(3), all the expenses incurred by any authority or agency with respect to the remedial measures together with interest may be recovered by the said authority from the person concerned as arrears of land revenue or of public demand. The Section 15 prescribes the penalties for contravention of the provisions of the Act, Rules, orders and directions issued under the Act and its various provisions, punishable with imprisonment upto five years and fine upto Rs. 1.00 lakh Rupees, and with additional fine of five thousand Rupees per day during which such failure or contravention continues after the conviction for the first such failure. The section 16 defines offences by companies.

The Rule 3 of the EP Rules, 1986 sets the standards for emissions or discharge of environmental pollutants. It has a "Proviso" clause under Rule 3-A(i) for the State Board to specify more stringent standards for any specific industry or location, as the case may be. Under Rule 14 of the EPR, 1986, persons are required to submit an environmental statement in Form V to the concerned State Board every year before 30th of September, beginning 1993. However, the Schedules I to VI of the EPR, 1986 do not have any industry categorization as "Oil Exploration and Drilling". It has Oil refineries and Petro-chemical industries, however.

The Manufacture, Storage And Import Of Hazardous Chemicals Rules, 1989 promulgated under the EPA, 1986 defines "Major Accident" under Rule 2(j), as one that "*means an occurrence including any particular major emission fire or explosion involving one or more hazardous chemicals and resulting from uncontrolled developments in the course of an industrial activity or due to natural events leading to serious effects both immediate or delayed, inside or outside the installation likely to cause substantial loss of life and property including adverse effects on the environments;*" According to the Manufacture, Storage and Import of Hazardous Chemical (Amendment) Rules, 2000, under Rule 2(j), "major accident" means "*an incident involving loss of life inside or outside the installation, or ten or more injuries inside and/or one or more injuries outside or release of toxic chemicals or explosion or fire or spillage of hazardous chemicals resulting in on-site or off-site emergencies or damage to equipment leading to stoppage of process or adverse affects to the environment*;". Under Rule 5, the occupier is required to report within 48

hours of a major incident to the authority concerned, and the authority concerned is required to send a "full analysis" report to the MOEF&CC, New Delhi within 90 days of occurrence of the accident. Under Rule 7, the occupier cannot start any activity without prior approval of the authority concerned, and "*An occupier shall not undertake any industrial activity unless he has been granted an approval for undertaking such an activity and has submitted a written report to the concerned authority containing the particulars specified in Schedule 7 at least 3 months before commencing that activity* ". Under Rule 10, after the commencement of the Manufacture, Storage and Import of Hazardous Chemicals (Amendment) Rules, 1994, "*the occupiers of both the new and the existing industrial activities shall carry out an independent safety audit of the respective industrial activities with the help of an expert, not associated with such industrial activities*". Under Rule 13, the occupier is required to keep ready an up-to-date- emergency management plan. Under Rule 15, the occupier is required to "*take appropriate steps to inform persons outside the site either directly or through District Emergency Authority who are likely to be in an area which may be affected by a major accident* ". It has to be noted that while "Methane" and "Liquefied Petroleum Gas" find mention in the list of hazardous chemicals, "natural gas", "condensate" and other petroleum products do not occur in the list of chemicals/ substances in the Rules.

8.5 Methodology

The estimation of atmospheric pollutants can be divided in two distinct categories. Firstly, estimation from conjectural principles applied to CO_2, CO, NO and NO_2 emissions. Secondly, estimation based on field based measurement using instrumentation and laboratory reports. Both have been described briefly in the ensuing paragraphs. It would, however, be not possible to describe in any detail equipment used or the laboratory methods used by the various agencies involved in the process of environmental assessment.

8.5.1 Conjectural Estimation Principles

The estimation of CO_2, CO, NO and NO_2 has been done through a theoretical approach by a conjectural process based on the physico-chemical transformations. A detailed treatment of the subject matter has already been provided in the previous Chapter (See 7.3). The emissions can be simply summarized as below:-

$$E_i = e_i \times V \qquad \text{..... } Eq.No.\ 8.1$$

where E_i is the total emission of i^{th} specie in kg (or tons or kilo tons), e_i being its emission rate in kg m^{-3}, and V being the volume of blowout fliud in m^3 (or in 10^3 m^3 or 10^6 m^3).

The emissions, then, also be converted into equivalent CO_2 emissions by using the following relation:-

$$EV_i^{CO_2} = E_i \times \mathscr{F}_i \quad \text{..... } Eq.No.\ 8.2$$

where $EV_i^{CO_2}$ is the CO_2 equivalent emission a green house specie i, E_i being total emission from i^{th} specie and $\mathscr{F}_i$ being its forcing power wrt CO_2.

As the emissions have happened in three distinct phases of the entire incident, these are being outlined below for clarity, as these phases are important from the emission perspective.

BLOW OUT PHASE:

The blow out phase is taken to have started at 10.30 AM on 27th May, 2020. The well just prior to blow out had the following formation as per the OIL authorities:-

0-897 m	= 73 pcf Sodium Formate solution
897-997m	= 114 pcf Cement slurry
997-1197m	= Hi-vis Pill (73 pcf)
1197-3865 m	= 73 pcf Sodium Formate solution

where pcf is pound-force per cubic feet, and Hi-vis is High Viscous Fluid.

It is assumed that all the formations as above were spurted out before the actual "single phase" natural gas condensate mixture started to flow out fully. The time taken would have been anything from 10 minutes to 30 minutes. However, for sake of brevity, and in absence of any concrete information, it has been assumed that the well started to spurt out gases from 10.30 PM of 27th May, 2020 till about the explosion time i.e. 1.30 PM of 9th June, 2020.

The time period of the blow out, therefore, is: **13 days, 3 hours** (13.125 days or **1134000s**)

During the blow out, it is assumed that natural gas and proportionate amount of condensate (in the **ratio 6136:1**) got spurted out continuously. While the natural gas escaped into the atmosphere, the condensate separated into a liquid formation and fell off on the ground, vegetation, water bodies etc. mostly following the wind directions. Therefore, for atmospheric pollution, the contribution of condensate would be ignored. Furthermore, since other small chain alkanes, C_6 and below, have low life in the atmosphere, their contribution to the emissions have been ignored. Therefore, the entire volume of gas and condensate released during the blow out period has been

treated as only CH_4 (Methane) emissions along with traces of CO_2 occurring in the natural gas mixture as already indicated in the natural gas composition table in the previous Chapter. Therefore, the following alone has been considered for the blow out period:-

1. Methane gas emissions in absolute terms
2. Methane gas emissions in equivalent of CO_2 emissions
3. CO_2 emissions in absolute terms

Explosion Phase:

The explosion phase has been considered for a moment (though the burning continued almost till next day morning at certain points) only on the 9th June, 2020 at 1.30 PM. Here, it is assumed that most of the condensate lying on the ground surrounding the well, and in the direction of the wind, got combusted producing CO_2, CO, NO and NO_2 emissions. An estimation of the area over which the condensate got combusted and its quantity are required to be done [*See Chapter 11*].

Burning Phase:

The burning phase is taken to start from 1.30 PM, seconds after the explosion, of the 9th June, 2020 and is continued till the flame is extinguished and the well is capped. In this phase, only CO_2, CO, NO and NO_2 emissions from combustion of natural gas and condensate would be considered. [However, for sake of calculations the day the flame was diverted from its original point and part of the blowout was diverted for production, i.e. 13th September, 2020 12 Noon is being considered. Total time of free flowing blowout, post explosion, is considered to be from 9th June, 2020 1.30 PM to 13th September, 2020 12 Noon, being **95 days 22 hours 30 minutes i.e. 8289000 s**. While the fire got finally extinguished on 15th November, 2020 at 12.30 PM, this period after 13th September, 2020 has been ignored for two reasons, firstly the flame was diverted and part of the blowout fluid was used for production (possibly about ¼ of the 38 Million Cu M natural gas per day was put to production), and secondly as the protests on the site started to intensify, it was becoming increasingly difficult to make any further measurements. Measurements other than photography from a distance, sound levels measurements and spectra, were difficult to carry out. [*A brief on Post 13th September, 2020 status of the flame and its acoustic properties have been given in Chapter 9.*] Nevertheless, one must say that air pollution, emissions and acoustic disturbances continued till the flame was extinguished on 15th November, 2020.

8.5.2 EMPIRICAL ESTIMATION METHODOLOGIES

In the empirical studies, two sub streams can be found namely direct measurement using equipment, and indirect assessment using remotely sensed data from airborne/ satellite platforms. Both the systems were deployed in the case of Baghjan incident. These are described briefly below:-

Direct Measurements:

Direct measurements were carried out primarily by two agencies, namely Pollution Control Board, Assam (PCBA) and M/S Assam Electronics Development Corporation Ltd (AMTRON). The two methodologies differ, and are described in the paragraphs below:-

PCBA: The Pollution Control Board, Assam, under the Ambient Air Quality Monitoring Program measures SO_2, NO_2 and Respirable Suspended Particulate Matter (RSPM) PM_{10}. PCBA follows the CPCB methodologies issued under the National Ambient Air Quality Monitoring Program[114]. PCBA follows the manual methods prescribed. For SO_2 monitoring, the "Improved West & Gaeke Method"[115] is followed. The units are μg m^{-3}. Similarly, NO_2 is measured using "Modified Jacob and Hochheiser Method"[116]. The units are μg m^{-3}. The PM_{10} is measured using Gravimetric Method[117]. The units are μg m^{-3}. PCBA conducted 4 sets of measurements of the above parameters, in the manner prescribed, on 8th, 12th, 13th, and 14th June, 2020 at 4 (four) different locations ranging from 1 to 4 km from the blast site.

AMTRON: The State owned PSU, AMTRON, which has considerable experience in electronics systems and IT solutions, was requested to carry out air quality

114 CPCB, 2011, Guidelines for the measurement of ambient air pollutants, Vol I, http://cpcb.nic.in

115 From 114, SO_2 from air is absorbed in a solution of potassium tetrachloromercurate (TCM). A dichlorosulphitomercurate complex, which resists oxidation by the oxygen in the air, is formed. Once formed, this complex is stable to strong oxidants such as ozone and oxides of nitrogen and therefore, the absorber solution may be stored for some time prior to analysis. The complex is made to react with para-rosaniline and formaldehyde to form the intensely coloured pararosaniline methylsulphonic acid. The absorbance of the solution is measured by means of a suitable spectrophotometer capable of measuring absorbance at 560nm wavelength. (Page 1-5)

116 From 114, Ambient NO_2 is collected by bubbling air through a solution of NaOH and sodium arsenite $NaAsO_2$. The concentration of nitrite ion (NO_2) produced during sampling is determined colorimetrically by reacting the nitrite ion with phosphoric acid, sulfanilamide, and N-(1-naphthyl)-ethylenediamine di-hydrochloride (NEDA) and measuring the absorbance of the highly coloured azo-dye at 540 nm (Page-7-10)

117 From 114, Air is drawn through a size-selective inlet and through a 20.3 X 25.4 cm (8 X 10 in) filter at a flow rate, which is typically 1132 L/min. Particles with aerodynamic diameter less than the cut-point of the inlet are collected, by the filter. The mass of these particles is determined by the difference in filter weights prior to and after sampling. The concentration of PM10 in the designated size range is calculated by dividing the weight gain of the filter by the volume of air sampled. (Page 11-14)

measurements using electronic sensors. However, due to lock down etc. all the sensors could not be obtained. AMTRON could obtain a few sensors and measured values for CO and CO_2 in ppm levels around the site at 11 different locations. Three sets of measurements were taken at each site for the two parameters. AMTRON used TESTO 440 Indoor Air Quality (IAQ) probes. During testing of the equipment for CO/CO_2 measurements, ambient outdoor CO was found to be 1.1-1.3 ppm. Ambient humidity was 83-95%. CO_2 measurements were not considered, as emission values were directly worked out from theory of combustion. It also does not form a part of ambient air quality parameters.

OIL: It ought to be mentioned here that M/S OIL on their own calling had engaged M/S ERM and M/S Mitra SK Pvt Ltd. to carry out environmental impact studies. It was thought fit to induct the data so generated by M/S OIL, firstly as it would fill the vacuum in the availability of data, and secondly, it could be effectively cross-checked and verified with other available data-set. M/S MSKPL conducted air quality monitoring tests for SO_2, NO_2, PM_{10}, $PM_{2.5}$, CO, VOCs, H_2S, C_6H_6, CH (Methane) and CH (non-Methane HC). The studies are done as per IS:5182. These tests were conducted on various dates from 22nd to 29th June, 2020 at 8 different sites. In addition, M/S OIL has been generating data at the site on $PM_{2.5}$, PM_{10} and TVOC on a daily basis since 12th June, 2020 and sending to the Govt. of Assam daily to the office of the Chief Secretary, Assam. The Report, which is a single page product, also contains noise monitoring. Further, M/S OIL engaged TERI to carry out environmental studies. They have conducted studies at 0 km (which seems to be a notional distance, as 0 km lies at the centre of the fire) and thereafter at every 500 m distance upto 2 km distance. $PM_{2.5}$ was measured from 19th to 30th June, 2020. Further, SO_2, NO_2 were measured from 19th to 14th July, 2020. Methane (CH_4), Non Methane Hydrocarbons (NMHC) and Total Hydrocarbons (THC) were measured from 19th June to 4th July, 2020. Thereafter, VOC and Noise levels in dB (A) were measured from 21st June to 26th July, 2020. The equipment details are not available. In addition, M/S OIL had also been conducting a series of ambient air quality tests at the EPS Baghjan (Lat: 27^{0}36'12.12"N Long: 95^{0}24'17.16"E) almost every month regularly through labs such as M/S Arihant Analytical Laboratory Pvt. Ltd and M/S Netel India Ltd. About 17-19 parameters were sampled every month, notable among them being PM_{10}, $PM_{2.5}$, SO_2, NO_2, CO, C_6H_6, O_3, NH_3, Pb, As, Ni, HC (CH_4), HC (non CH_4), TCH, VOC. After the blow out at Baghjan on 27th May, 2020, the ambient air quality monitoring programme appears to have been intensified by M/S OIL. Every day, two hourly samples were being taken from the Baghjan EPS and the Baghjan Relief Camp site (*Lat Long wrongly stated*) from

9.00 AM to 9.00 AM on a daily basis. Testing was done by M/S Arihant. Several of these reports of air quality monitoring before the blow out and during the blow out were made available to this Committee.

Baseline Studies 2009-10: Pre-Drill EIA for the Hapjan Tinsukia Dhola stretch of the lease areas of M/S OIL was conducted by Gauhati University in the year 2007-10. As there were no drilling activities in the area in question prior to this period, it can be considered a "true" baseline assessment. Ambient air quality stations were set up at Tinsukia, North Hapjan and Borhapjan among the total 8 stations. Total Suspended Particulate Matter (TSPM), Respirable PM, SO_2, NO_x, CO and VOC were measured on 24 hours average basis from 22nd March, 2009 to 2nd May, 2009.

Baseline Studies 2017: Another set of baseline studies are available from M/S ERM who carried out the EIA for the Extension Drilling at 7 locations under the Dibru-Saikhowa National Park area, at 8 stations, (and the Report was submitted in December, 2019) under the North West Baghjan PML in Tinsukia district. The ambient air quality was measured from October 2017 to December, 2017. The parameters were PM_{10}, $PM_{2.5}$, Nox, SO_2, CO, HC (Methane & Non Methane) and VOC. Out of a total of 8 stations, 3 stations were close to the blow out site namely Baghjangaon, Baghjan 1 No. gaon and Guijan. It can be said that by 2017, several well of M/S OIL were drilled in the area, and the operations were going in full. The first baseline of 2009-10 should be considered as "true" baseline, the 2017 baseline as "Operative Baseline". The blow out time air quality data needs to be understood in this context only, as to how much air quality degraded after the wells got set up and became operational in the area, and how much degradation occurred on top of that during the blowout phase.

Indirect Measurements:

Indirect or passive measurements mostly use satellite based data. There are several satellites revolving around the planet to measure various environmental parameters. Among them most frequently used satellite by researchers is European Space Association Sentinel 5 Precursor, in short Sentinel 5P. WII used Sentinel 5P to arrive at NO_2, SO_2, HCHO (Formaldehyde) and CO changes in the atmosphere. These were in % change, but not in absolute concentration values such as ug/m^3. Therefore, this set of data can be used only for corroborative purposes while analyzing other empirical data.

8.5.3 UNIT CONVERSIONS FOR SPECIES

Most often concentration of substances and particles in the air/ atmosphere are reported either in ppm/ ppb or mg/m^3 or µg/m^3 (or ug/m^3) or ng/m^3. While these

conversions in terms of mass to mass and mass to volume in soil and water are straight forward (by maintaining a ratio of 1:1 million or 1:1 billion between the numerator and denominator), the same is not true for air. The generic conversion from mg/m^3 to ppm and back is given by[118]:

$$C_{specie}\ (mg/m^3) = 0.0409 \times C_{specie}\ (ppm) \times M_{specie} \quad \ldots\ldots\ Eq.No.\ 8.3$$

$$C_{specie}\ (ppm) = 24.45 \times C_{specie}\ (mg/m^3) / M_{specie} \quad \ldots\ldots\ Eq.No.\ 8.4$$

where C_{specie} is concentration of the specie in either mg/m^3 or ppm and M_{specie} is the molecular weight of the specie. Based on the above two relations, a ready reckoner is given in the table below for the common pollutants being discussed in this Report:

Table No. 8.3: Concentration Unit Conversion Factors

Species	Molecular Weight	ppm to mg/m^3 Factor	mg/m^3 to ppm Factor	Remarks
CO_2	44.01	1.800	0.5556	ug= µg
CO	28.01	1.146	0.8729	mg to µg=10^3
SO_2	64.066	2.620	0.3816	
NO	30.006	1.227	0.8148	mg to ng=10^6
NO_2	46.0055	1.882	0.5315	µg to ng=10^3
C_6H_6	78.11	3.195	0.3130	
O_3	48	1.963	0.5094	ppm to ppb=10^3
Ni	58.6934	2.401	0.4166	« ppb to µg/m^3
Pb	207.2	8.474	0.1180	
BaP	225.2492	9.213	0.1085	« µg/m^3 to ppb
H_2S	34.1	1.395	0.7170	

8.5.4 Assessing Breach or No Breach

In respect of ambient parameters which are required to be assessed for a specific number of days/hours and often throughout the year for a minimum number of hours or repeat measurements, it would not be possible to come out with certainty whether the parameter has been breached or not. As per the NAAQS Guidelines, annual emission levels are to be determined by "*Annual Arithmetic mean of minimum 104 measurements in a year at a particular site taken twice a week 24 hourly at uniform*

118 Boguski Terrie K, Understanding units of measurement, Environmental Science & Technology Briefs for Citizens, Issue 2, 2006, http://www.engg.ksu.edu/CHSR/

intervals". This translates to 2 measurements per week for all the weeks of the year. Such a level of measurement would not be possible. Similarly for 24 hours or 1 hourly measurements, the Guideline says: "*24 hourly or 8 hourly or 1 hourly monitored values, as applicable, shall be complied with 98% of the time in a year. 2% of the time, they may exceed the limits but not on two consecutive days of monitoring*". Now, 98% of time in 1 year would imply measurements on atleast 357 days. The third option was "*Whenever and wherever monitoring results on two consecutive days of monitoring exceed the limits specified above for the respective category, it shall be considered adequate reason to institute regular or continuous monitoring and further investigations*". This is a matter of Regulation and the Regulator alone can implement such schemes, provided the Regulator is in proper shape to undertake such an enterprise.

It becomes necessary to bring on record this issue, as the ground conditions at Baghjan blowout site were very harsh, difficult, inaccessible and compounded by continuous rains and floods on one hand and protesting crowds and unrest around the site on the other hand. Provisioning of quality electrical power supply for the equipment or making provisions for long term installation of equipment for a general researcher was a daunting task. The requisite number of repeat observations, or maintaining of standard time intervals, or even doing the repeat experiments at the same spot again were not always possible. In order to overcome this situation, and to have a fair assessment, it was decided to use all possible available measurements that one could lay one's hands on. Further, for a given parameter, all available measurements whether from OIL sources or otherwise were taken into account. Accordingly, to overcome the complicated issues of assessment, a different but statistically consistent, strategy was chalked out. The following three strategies were evolved thereupon:-

Baseline values: M/S OIL had gotten two EIA studies conducted, one in 2009-10 prior to start of the drilling activities in the area, and another in 2017 (for a new project) when almost 5-30 wells were already drilled or in operation in the area. The changes in parameter from 2009 to 2017 were, therefore, examined, for all parameters that were common to both the EIAs. The mean of the maxima of the 2017 values was taken as the ambient value of the parameter in absence of the blowout or the fire for rest of the year.

24 Hour Measurements: Though as per NAAQS, a minimum of two repeats at the same station atleast on two consecutive days was the requirement, and knowing that it was not always possible, it was decided to treat the basket of available measurements as repeat experiments within the zone of influence of the blowout/ fire. Most of the

sensitive parameters were measured within 3-5 km of the fire. Therefore, these have been assumed to have been measured as "repeats". Accordingly, the highest value among all, and the lowest value among all were treated as Maxima/Minima. Mean was computed out of all available values. The period of blowout before the fire broke out was taken as 15 days, and the period of fire (after the blow out) was taken as 65 days[119]. Rest of the year was either taken as 300 or 285 depending upon the actual period when the parameter was measured. If the maxima of all the measurements breached the prescribed 24 hours/ 8 hours/ 1 hour value under the NAAQS, the parameter was taken as "**BREACHED**" for the entire period where similar conditions continued to exist.

Estimating Annual Levels: The breech was also examined in terms of annual levels, as the fire itself lasted for more than 3 months. Annual levels till May, 2021 were estimated using the following methodology:-

Let B be the value of the 2017 baseline (if available), M1, maxima for blowout period (prior to fire) for T1 days, and M2, maxima during the fire for T2 days (when the fire is on- as of now 65 days), then the annual ambient level, A is given by a weighted average:-

$$A = \frac{M1 \times T1 + M2 \times T2 + B \times [365 - (T1 + T2)]}{365} \quad \text{..... } Eq.No.\ 8.5$$

If A exceeded the prescribed limit of the NAAQS, the said parameter was treated as "BREACHED". However, it has two major drawbacks. Firstly, it assumes that either M1 or M2 or any such value abruptly disappears after T1 or T2 days, and this would not happen generally. Secondly, the baseline parameter has a very high "levelling effect" on the actual emission levels M1 and M2. If these are not very high, ambient emissions levels are most unlikely to be found as breached. However, despite these short-comings, the above methodologies were adopted to arrive at "BREACH / No BREACH" decisions.

8.6 Estimates Of Emissions And Ambient Level Of Pollutants

The emission estimates for various species arrived at from various methods described in the previous paragraphs are presented below species wise. Just to clarify here that two types of assessment have been done:- firstly, emissions from the blowout/ fire that escaped directly into the atmosphere such as CO/CO_2/NOx etc., and secondly, ambient levels of certain pollutants in terms of the NAAQS. The first set of values were arrived at

119 The number of days of the fire has been taken to be 95 days and 22.5 hours, but here, the calculation which was done in August, 2020 sometime, has not been changed. It was kept at 65 days, as breach in 65 days would actually signify higher intensity of the breach.

by deploying theoretical conjectures and the second set were arrived at by direct measurement using equipment. No attempt has been made to convert the emissions arrived at by conjectural methods to convert to ambient values measured by instruments in concentration units. First we shall be examining the emissions that escaped into the atmosphere directly from the blowout/fire, and thereafter, we shall dwell upon the ambient levels of certain pollutants in the air surrounding Baghjan.

8.6.1 Methane and CO_2 Emissions from blowout

As described in the methodology part, the blow out, meaning spurting of gases, which started at 10.30 AM on 27th May, 2020 continued till 1.30 PM of 9th June, 2020 when the well exploded. It has been assumed that this blow out event lasted for 1134000 seconds, and the well was spewing natural gas and condensate at the rate of 343.50 kg per second. The fluid contained natural gas and condensate in the ratio of 6136:1. The natural gas in turn contained 1.22% of CO_2, while the condensate contained 0.07% of it. The contribution of condensate to total CO_2 would, therefore, come to 0.00001141%. It can be ignored. Further, condensate does not contain any CH_4, while natural gas from Baghjan contains 92.97% CH_4. The total fluid spewed out during the blow out comes to 389529000 Kg or 389529 tonnes. The emissions have accordingly been worked out in the Table below:-

Table No. 8.4: Green House Gas Emission Estimates

Species	% Content	Emission (Kg)	Emissions (Tonnes)	Emissions (Million Tons)	Equivalent CO_2 Emissions (MT)[120]
CH_4	92.97	362145111.3	362145.11	0.362	10.140
CO_2	1.22	4752253.8	4752.25	0.005	0.005
TOTAL					**10.145**

CH_4 = 28 times GWP than CO_2

8.6.2 Emissions from Combustion

The CO_2 emissions have been derived from conjectured estimates of combustion of natural gas and condensate in the fire that has been blazing since 9th June, 2020 at 1.30 PM. All other emissions such as CO, NO and NO_2 also have been worked out on the same principles in the two tables given below using the factors :-

120 https://www.ghgprotocol.org/sites/default/files/ghgp/Global-Warming-Potential-Values%20%28Feb%2016%202016%29_1.pdf

Table No. 8.5: Total Fluid Mass Flow

Mass Flow Rate (Kg s^{-1})	No of days (Flame ON)[$]	No of Seconds	Mass Flowed (Kg)[#]	Mass Flowed (Million Tons)
343.50	95.9375	8289000	2847271500	2.85

$ Till Noon of 13th September, 2020 (95 days, 22 hours & 30 min)

In volume units = 3170.79 Million m^3 or 3.17 Billion m^3

Table No. 8.6: Species Wise Total Emissions

Unit of Emission[121]	CO_2	CO	NO	NO_2
Kg/m^3 [$]	2.35	0.52	0.17	0.25
Kg/Kg [$$]	2.62	0.58	0.19	0.28
Kg [$$$]	7451365778.07	1648812853.02	539034971.18	792698487.03
Million Tons (MT) [$$$]	**7.451**	**1.649**	**0.539**	**0.793**

$ per cubic meter of well fluid. (See Para 7.3.8)

$$ per Kg of well fluid (See footnote 121)

$$$ Absolute values for the whole period of the Flame/ Combustion

It is to be noted that the world consumed 3929.2 billion m^3 of natural gas in 2019[122]. Baghjan blow out is producing gas at 1.0 billion m^3 per 30 days, or 32.6 million m^3 per day under high pressures. Assuming the well has sufficient reserves, in 1 year of blow out, it could spew 12 billion m^3 of gas, which is 0.3% of the global consumption. Further, the world CO_2 emission for 2019 was 37 Giga tons[123]. The Baghjan fire already contributed 0.00745 Giga tons of CO_2 emissions, which is almost 0.02% of the global production of CO_2. If the fire burns for 1 year, it would contribute about 0.028 Giga tons of CO_2.

8.6.3 Ambient Levels of SO_2

Before one goes into the current levels of ambient air quality, it is necessary to look at the baselines. The baseline data reveal the following:-

121 Assuming that density of natural gas at Baghjan is 0.7710 Kg/m^3, and that of condensate is 794.3 Kg/m^3. Further, 1 m^3 of well fluid would contain gas and condensate in 6136:1 ratio, meaning 6136/6137=0.99984 fraction of natural gas, and 1/6137=0.00016 fraction of condensate. In all, 1 m^3 of well fluid would have a mass of 0.897968 (=0.770880+0.127088) Kg. Therefore, a factor of 0.897968 is used to convert 1 m^3 of volume of well fluid to mass in Kg

122 https://www.statista.com/statistics/282717/global-natural-gas-consumption/

123 https://bit.ly/2PDMan7

Table No. 8.7: Baseline SO_2 Levels

Baseline Year	SO_2 Mean	SO_2 Max	S.D.	Place
2009	3.5	9.2	3.3	Tinsukia
2009	3.4	7.3	2.9	Bar Hapjan
2009	1.8	8.1	2.3	North Hapjan
2017	5.37	6.5		Baghjan
2017	5.89	8.5		Baghjan 1 no
2017	5.5	6.7		Guijan
2019-07	24.6			EPS Baghjan
2019-08	25.4			EPS Baghjan
2019-09	26.3			EPS Baghjan
2019-10	24.1			EPS Baghjan
2019-11	25.8			EPS Baghjan
2020-02	13.4			EPS Baghjan

The table above shows that the mean SO_2 in 2009 was **2.9 µg/m³**. The average (mean) for 2017 comes to **5.59 µg/m³**. Thus, it is clear that the SO_2 levels have doubled after the drilling operations have started in the area, while the levels are much below the prescribed limit of 80 µg/m³. As can be seen, the average values for 6 months in 2019-20 comes to **23.27 µg/m³** which is a jump of 4 times from 2017 and 8 times from 2009. Thus, the baseline situation itself is alarming, as emission levels are climbing up year after year.

SO_2 levels during the Blow Out: The SO_2 levels were measured by PCBA, OIL (Arihant, MSKPL & TERI) and WII on various dates and locations. The basic data contours are presented here:

Table No. 8.8: Measured SO2 Levels during Blowout

Period	Max SO_2 (µg/m³)	Min SO_2 (µg/m³)	Mean SO_2 (µg/m³)	Agency	Remarks
BO	52	-	52	PCBA	1 obs.
F	33	4	13.6	PCBA	3 obs.
BO	15.5		11.75	Arihant	24 obs.
F	10.5		10.15	Arihant	12 obs.
F	12.6	6	8.76	MSKPL	16 obs.
F	14	5	7.9	TERI	91 obs.

BO: Blow out; F: Fire

Before some in depth analysis is done, the spectrum of data from the three agencies shows that prior to the explosion and fire and after the blowout the SO_2 levels were as high as 52 µg/m^3. It got down to 33 µg/m^3 four days after the well caught fire, and eventually all measurements done after 19th of June show maximum value of 14 µg/m^3. The National Ambient Air Quality Standard prescribes that annual average cannot exceed 50 µg/m^3 in general areas, and 20 µg/m^3 in ecologically sensitive areas, and it cannot exceed 80 µg/m^3 in any given 24 hours. Therefore, it can be assumed that the SO_2 values were constantly not below 55 for atleast 15 days from the day of the blow out. Assuming a figure of 9 µg/m^3 for the rest of the year, it can be easily seen that the weighted average comes to 10 µg/m^3 which is 50% of the prescribed levels in an ecologically sensitive area. The analysis of WII corroborates the above finding qualitatively [*as the WII Report provides the value of SO_2 levels in % Concentration change, and not in absolute concentration values*]. According to WII, the values peaked during the blow out on 28th May, 2020, [no data for 27th May, 2020], and attained highest values on 9th June, 2020 and then subsided thereafter. The WII graph for SO_2 levels (see Fig 4.5 on page 31 of the WII Report Dt. 20th July, 2020) shows two peaks, one each for 28th May and 9th June, 2020.

Breach or No Breach?: While the SO_2 values were very high from the baseline values, they never exceeded any of the prescribed limits of the National Ambient Air Quality Standards either for 24 hours or for annual periods. **Therefore, NO BREACH in respect of SO_2 emissions**.

8.6.4 Ambient Levels of NO_2

The baseline data reveal the following:

Table No. 8.9: Baseline NO_2 Levels

Baseline Year	NO_2 Mean	NO_2 Max	S.D.	Place
2009	2.78	8.6	3.0	Tinsukia
2009	2.26	6.1	2.2	Bar Hapjan
2009	1.92	6.6	2.2	North Hapjan
2017	12.20	27.30		Baghjan
2017	12.20	28.50		Baghjan 1 no
2017	12.20	27.50		Guijan
2019-07	19.5			EPS Baghjan
2019-08	20.1			EPS Baghjan
2019-09	20.6			EPS Baghjan

2019-10	18.4			EPS Baghjan
2019-11	19.5			EPS Baghjan
2020-02	24.2			EPS Baghjan

The table above shows that the mean NO_2 in 2009 was **2.32 µg/m³**. The average (mean) for 2017 comes to **12.20 µg/m³**. Thus, it is clear that the NO_2 levels have increased to more than 5 (five) times the baseline value after the drilling operations have started in the area, while the levels are much below the prescribed limit of 80 µg/m³ for 24 hours, and 30 µg/m³ for annual averages. The baseline average for 2019 comes to **20.38 µg/m³**. This shows that the emission values have gotten a jump of 1.67 times from 2017 and 8.8 times from 2009. However, the trend of maxima shows that the values are about to be breached for the limits prescribed for an ecologically sensitive area. A close continuous monitoring of the parameter is required. The maxima values might cross the prescribed limits.

NO_2 levels during the Blow Out: The NO_2 levels were measured by PCBA, OIL (MSKPL & TERI) and WII on various dates and locations. The basic data contours are presented here:

Table No. 8.10: Measured NO2 Levels during Blowout

Period	Max NO_2 (µg/m³)	Min NO_2 (µg/m³)	Mean NO_2 (µg/m³)	Agency	Remarks
BO	97	-	97	PCBA	1 obs.
F	69	8	35.33	PCBA	3 obs.
BO	39.6		27.63	Arihant	24 obs.
F	18.3		18.05	Arihant	12 obs.
F	34.2	17.5	24.1	MSKPL	16 obs.
F	32	9	16.40	TERI	91 obs.

BO: Blow out; F: Fire

Before some in depth analysis is done, the spectrum of data from the three agencies shows that, prior to the explosion and fire and after the blowout, the NO_2 levels were as high as 97 µg/m³ . It got down to 69 µg/m³ four days after the well caught fire, and eventually all measurements done after 19th of June show maximum value of 34.2 µg/m³. The National Ambient Air Quality Standard prescribes that annual average cannot exceed 50 µg/m³ in general areas, and 30 µg/m³ in ecologically sensitive areas, and it cannot exceed 80 µg/m³ in any given 24 hours. Therefore, it can be assumed that the NO_2 values were constantly not below 97 for atleast 15 days from the day of the blow

out. Assuming a figure of 34 µg/m^3 for the rest of the period of the fire, and 28 µg/m^3 for the rest of the year [baseline maxima for 2019], it can be easily seen that the weighted average comes to 31.8 µg/m^3 which is higher than the prescribed levels in an ecologically sensitive area[124]. The analysis of WII corroborates the above finding qualitatively [*as the WII Report provides the value of NO_2 levels in % Concentration change, and not in absolute concentration values*]. According to WII, the values peaked during the blow out on 27th May, 2020. The WII graph for NO_2 levels (see Fig 4.4 on page 31 of the WII Report Dt. 20th July, 2020) shows one peak, for 27th May, 2020.

Breach or No Breach?: The observed NO_2 values were significantly higher than the baseline values, and they exceeded the 24 hours prescribed limits of the National Ambient Air Quality Standards for at least 15 days from the date of the blow out. Further, there is a very high probability that the annual prescribed limits would be breached by May, 2021. However, to ascertain this, a series of permanent monitoring stations need to be established. **Therefore, M/S OIL BREACHED the NAAQS in respect of NO_2 emissions**.

8.6.5 AMBIENT LEVELS OF CO

The baseline data reveal the following:

Table No. 8.11: Baseline CO Levels

Baseline Year	CO Mean	CO Max	S.D.	Place
2009	0.08	0.23	0.1	Tinsukia
2009	0.04	0.21	0.1	Bar Hapjan
2009	0.04	0.21	0.1	North Hapjan
2017	0.34	0.67		Baghjan
2017	0.47	0.75		Baghjan 1 No
2017	0.45	0.67		Guijan
2019-07	0.32			EPS Baghjan
2019-08	0.34			EPS Baghjan
2019-09	0.31			EPS Baghjan
2019-10	0.35			EPS Baghjan
2019-11	0.33			EPS Baghjan
2020-02	0.40			EPS Baghjan

124 Ecologically sensitive area does not necessary mean ESZ.

The table above shows that the mean CO in 2009 was **0.054 mg/m³**. The average (mean) for 2017 comes to **0.42 mg/m³**. Thus, it is clear that the CO levels have increased to about ~8 (7.9) times more than the baseline value after the drilling operations have started in the area, while the levels are much below the prescribed limit of 4 mg/m^3 for 8 hours, and 2 mg/m^3 for annual averages. The baseline 2019 average values are **0.34 mg/m³**. However, the trend of maxima shows that the values are about to be breached for the limits prescribed for an ecologically sensitive area. A close continuous monitoring of the parameter is required. The maxima values might cross the prescribed limits.

CO levels during the Blow Out: The CO levels were measured by Arihant, MSKPL and AMTRON during the blow out. The details have already been described in the methodology section of the Chapter [See para 8.5.1]. The basic data contours are presented here:

Table No. 8.12: Measured CO Levels during Blowout

Period	Max CO (mg/m³)	Min CO (mg/m³)	Mean CO (mg/m³)	Agency	Remarks
BO	1.8		1.2	Arihant	24 obs.
F	1.4		1	Arihant	12 obs.
F	1.06	0.37	0.79	MSKPL	16 obs.
F	20.5	4.7	9.05	AMTRON	92 obs.

BO: Blow out; F: Fire

Before some indepth analysis is done, the spectrum of data from the agencies shows that after the blowout fire, the CO levels were as high as 17.9 ppm (=20.51 mg/m^3). The minimum observed value was 4.1 ppm (=4.7 mg/m^3). The average value of the CO levels comes out to 7.9 ppm (=9.05 mg/m^3). The National Ambient Air Quality Standard prescribes that annual average cannot exceed 2.0 mg/m^3 in general areas or even in ecologically sensitive areas for any given 8 hour period, and it cannot exceed 4.0 mg/m^3 in any given 1 hour period. Therefore, it can be assumed that the CO values were constantly not below 9 mg/m^3 for all days when the fire has been burning since 9th June, 2020 (assuming 65 days). Assuming a figure of 0.7 mg/m^3 [baseline mean of maxima for 2019] for the rest of the year (300 days), it can be easily seen that the weighted average comes to 2.2 mg/m^3 which is higher than the prescribed levels in any area.

Breach or No Breach?: The observed CO values were significantly higher than the baseline values, and they exceeded the 8 hours prescribed limits of the National Ambient Air Quality Standards for at least 65 days from the date of the blow out fire.

Further, there is a very high probability that the annual prescribed limits would be breached by May, 2021. However, to ascertain this, a series of permanent monitoring stations need to be established. **Therefore, M/S OIL BREACHED the NAAQS in respect of CO emissions**.

8.6.6 AMBIENT LEVELS OF PM_{10}

The baseline data reveal the following:

Table No. 8.13: Baseline PM_{10} Levels

Baseline Year	RPM (PM_{10}) Mean	RPM (PM_{10}) Max	S.D.	Place
2009	38.1	62.3	11.8	Tinsukia
2009	40.2	65.2	13.9	Bar Hapjan
2009	37	65.2	12.2	North Hapjan
2017	76.75	132		Baghjan
2017	79.71	122		Baghjan 1 no
2017	84.21	132		Guijan
2019-07	45.3			EPS Baghjan
2019-08	46.2			EPS Baghjan
2019-09	46.7			EPS Baghjan
2019-10	44.5			EPS Baghjan
2019-11	46.3			EPS Baghjan
2020-02	48.5			EPS Baghjan

The table above shows that the mean PM_{10} in 2009 was **38.43 µg/m³**. The average (mean) for 2017 comes to **80.22 µg/m³**. Thus, it is clear that the PM_{10} levels have increased twice the baseline value after the drilling operations have started in the area, and the levels are **already breached** for the prescribed limit of 60 µg/m³ for annual averages. However, the trend of maxima shows that the values are also already breached for the limits of 100 µg/m³ prescribed for 24 hours. The average for 2019 shows a value of **46.25 µg/m³**. A close continuous monitoring of the parameter is required. The ambient annual and 24 hours values might have well crossed the prescribed limits by now.

PM_{10} levels during the Blow Out: The PM_{10} levels were measured by PCBA, Arihant and MSKPL, only during the blow out. The details have already been described in the methodology section of the Chapter [See para 8.5.1]. The basic data contours are presented here:

Table No. 8.14: Measured PM10 Levels during Blowout

Period	Max PM_{10} ($\mu g/m^3$)	Min PM_{10} ($\mu g/m^3$)	Mean PM_{10} ($\mu g/m^3$)	Agency	Remarks
BO	78	-	78	PCBA	1 obs.
F	70	43	53.67	PCBA	3 obs.
BO	64.8		50.55	Arihant	24 obs.
F	34.2		32.85	Arihant	12 obs.
F	135.6	51.8	80.60	MSKPL	16 obs.

BO: Blow out; F: Fire

Before some in depth analysis is done, the spectrum of data from the agencies shows that after the blow out and fire, the PM_{10} levels were found to be as high as 135.6 $\mu g/m^3$. The average of all measurements was found to be 70.17 $\mu g/m^3$. The National Ambient Air Quality Standard prescribes that annual average cannot exceed 100 $\mu g/m^3$ in general areas or even in ecologically sensitive areas for any given 24 hour period, and it cannot exceed 60 $\mu g/m^3$ in the whole year. Since the baseline average in 2017 itself was 80.22 $\mu g/m^3$, and it was also found to be 135 $\mu g/m^3$ in 24 hours, it can be easily deduced that seen that the weighted annual average comes to 78 $\mu g/m^3$ which is higher than the prescribed levels in any area.

Breach or No Breach?: The observed PM_{10} values are found to exceed both the 24 hours as well as annual limits prescribed under the National Ambient Air Quality Standards for all round the year, even without the blow out or fire. However, to ascertain this, a series of permanent monitoring stations need to be established. **Therefore, M/S OIL BREACHED the NAAQS in respect of PM_{10} emissions**.

8.6.7 AMBIENT LEVELS OF $PM_{2.5}$

The baseline data reveal the following:

Table No. 8.15: Baseline $PM_{2.5}$ Levels

Baseline Year	RPM ($PM_{2.5}$) Mean	RPM ($PM_{2.5}$) Max	S.D.	Place
2009	-	-	-	Tinsukia
2009	-	-	-	Bar Hapjan
2009	-	-	-	North Hapjan
2017	39.08	68		Baghjan
2017	42.75	65		Baghjan 1 No
2017	45.92	74		Guijan
2019-07	20.9			EPS Baghjan
2019-08	21.4			EPS Baghjan
2019-09	21.8			EPS Baghjan
2019-10	20.3			EPS Baghjan
2019-11	21.6			EPS Baghjan
2020-02	35.5			EPS Baghjan

The table above shows that the no data is available for $PM_{2.5}$ in the EIA Report of 2009, which rather has TSPM vales. TSPM is supposed to include PM_{100} as well. Therefore, the data cannot be deduced straightaway from it. The average (mean) for 2017 comes to **42.58 µg/m³**. The mean of maxima for 2017 comes to **69 µg/m³**, The PM2.5 average for 2019 comes to **23.58 µg/m³**. Thus, it is clear that the $PM_{2.5}$ levels are **already breached** for the prescribed limit of 40 µg/m³ for annual averages, and 60 µg/m³ for 24 hours way back in 2017 itself, which are clearly seen from the trends of mean and maxima. A close continuous monitoring of the parameter is required. The ambient annual and 24 hours values might have well crossed the prescribed limits by now.

$PM_{2.5}$ levels during the Blow Out: The $PM_{2.5}$ levels were measured by Arihant, MSKPL and TERI only during the blow out. The details have already been described in the methodology section of the Chapter [See para 8.5.1]. The basic data contours are presented here:

Table No. 8.16: Measured PM2.5 Levels during Blowout

Period	Max $PM_{2.5}$ ($\mu g/m^3$)	Min $PM_{2.5}$ ($\mu g/m^3$)	Mean $PM_{2.5}$ ($\mu g/m^3$)	Agency	Remarks
BO	38.4		31.89	Arihant	24 obs.
F	22.8		22.05	Arihant	12 obs.
F	67.8	26.8	43.53	MSKPL	16 obs.
F	47	9	22.20	TERI	44 obs.

BO: Blow out; F: Fire

Before some in depth analysis is done, the spectrum of data from the agencies shows that after the blow out and fire, the $PM_{2.5}$ levels were found to be as high as 67.8 $\mu g/m^3$. The average of all measurements was found to be 29.92 $\mu g/m^3$, and the average maxima was found to be 44 $\mu g/m^3$. The National Ambient Air Quality Standard prescribes that annual average cannot exceed 60 $\mu g/m^3$ in general areas or even in ecologically sensitive areas for any given 24 hour period, and it cannot exceed 40 $\mu g/m^3$ in the whole year. Since the baseline average in 2017 itself was 42.58 $\mu g/m^3$, and it was also found to be 67.8 $\mu g/m^3$ in 24 hours during the blow out, it can be easily deduced that the weighted annual average comes to 48.2 $\mu g/m^3$ which is higher than the prescribed levels in any area for the year.

Breach or No Breach?: The observed $PM_{2.5}$ values are found to exceed both the 24 hours as well as annual limits prescribed under the National Ambient Air Quality Standards for all round the year, even without the blow out or fire. However, to ascertain this, a series of permanent monitoring stations need to be established. **Therefore, M/S OIL BREACHED the NAAQS in respect of $PM_{2.5}$ emissions**.

8.6.8 An analysis of Ambient Air Quality

When the air quality parameters such as SO_2, NO_2, CO, PM_{10}, $PM_{2.5}$ are compared over a period of time around the Baghjan oil fields, it is seen that either in the mean or max of the observed values for several parameters, the prescribed limits have been breached.

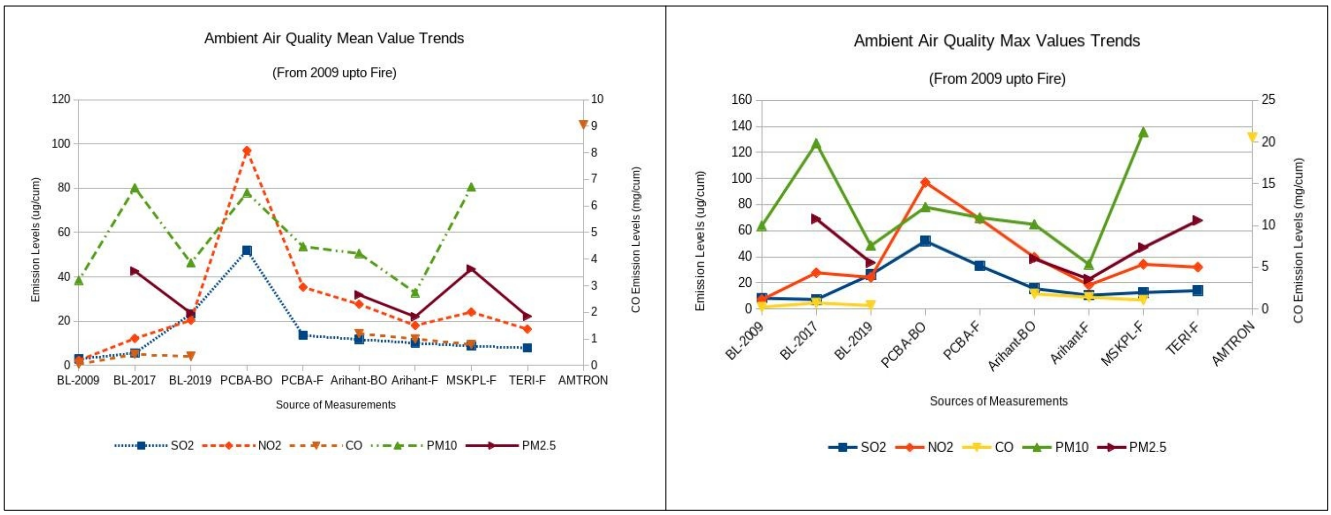


Fig. No. 8.1: Ambient Air Quality at Baghjan

As can be seen from the charts above, NO_2, CO, PM_{10} and $PM_{2.5}$ prescribed emission levels have been breached continuously/intermittently. A continuous monitoring should have been done. Some values in the EIA Reports themselves show as breached. However, these have been ignored all throughout. PCBA should have carried out independent monitoring (*in hind sight*). During the period of the blowout and at the time of explosion maximum emissions occurred, but due to lack of adequate monitoring, one has to depend upon measurements from M/S OIL (some of which are not acceptable). Therefore, all the max values had to be picked up. Some of the measurements give values, at the time of blow out, which are lower than 2017/2009 values. This is actually beyond explanation! It required a ***grid based systematic sampling*** approach, but neither PCBA nor M/S OIL could put any such thing into action. This has resulted in randomized data collection by a variety of agencies in which no planning is apparently visible. The tests by M/s OIL should have been "checked" once in a while by agencies such as PCBA to ensure data authenticity and accuracy of measurements in a transparent manner. Most of the measurements carried out by the different agencies do not tally, as can be seen in the broad differences easily discernible in the tables presented in the previous paragraphs.

8.6.9 Scatter Plot Analysis

The statistic of the measurements by AALPL, TERI, PCB, and MSKPL pertaining to the measured air concentrations/ambient levels of PM_{10}, $PM_{2.5}$, SO_2, NO_2, and CO is given below in the Table.

Table No. 8.17: Statistic of Air Pollutants' Levels at Baghjan

Param	PM10	PM2.5	SO2	NO2	CO
N	36	75	127	127	32
Min	31.5	9	4	8	0.37
Max	135.6	67.8	52	97	1.8
Mean	62.96	28.53	8.86	19.56	0.97
Median	61.9	26.2	8	17.8	0.91
Mode	61.9	26.2	8	17.8	0.91
Variance	545.06	156.23	26.33	115.54	0.13
SD	23.35	12.5	5.13	10.75	0.36
SE	3.89	1.44	0.46	0.95	0.06

As can be seen, most of the 'Max' values are in breaching limits (PM10, PM25, NO2). Further, one can see that the spread of the measured values, variance, for each of the parameters is very high (more than 5 times) for PM_{10}, $PM_{2.5}$, NO_2. This is also reflected in the Standard Deviation values. One can easily see that almost for all parameters, the SD values are more than ⅓ of the respective mean values, indicating a very wide spread of values. All the measured values were plotted in a XYZ scatter plot with Distance (X) in meters, Date (Y) in numbers (43980 being 29th May, 2020 and 44024 being 12th July, 2020), and Value (Z) axes for the measured levels of each of the pollutant (in µg/m^3).

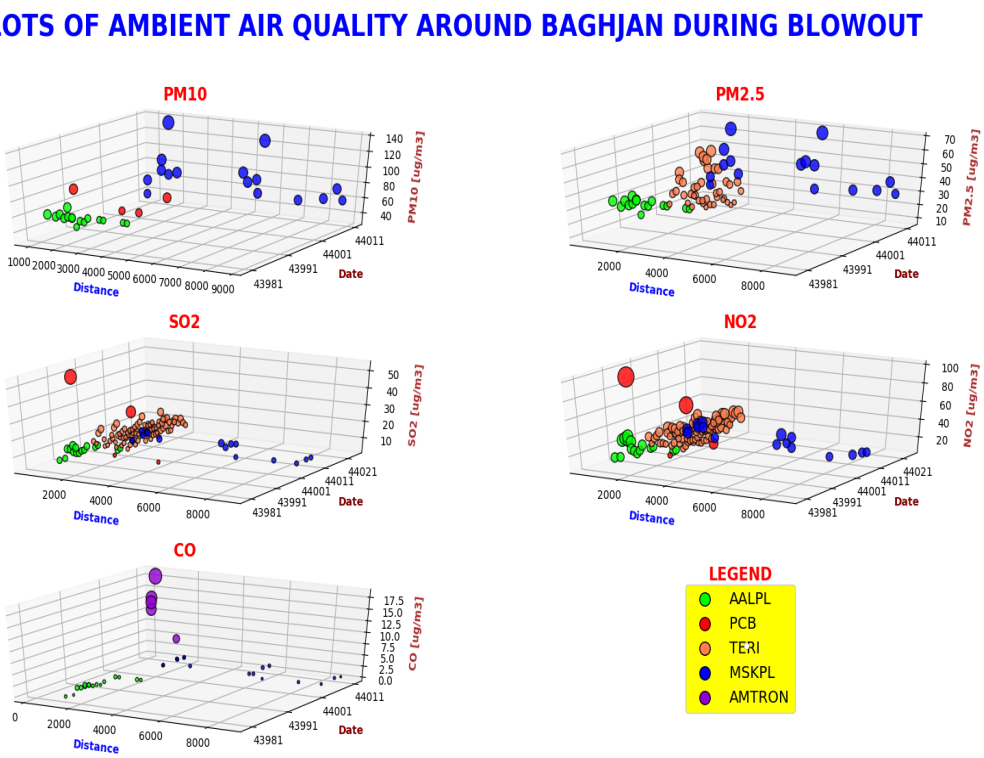


Fig. No. 8.2: Scatter Plots of Air Quality Values at Baghjan

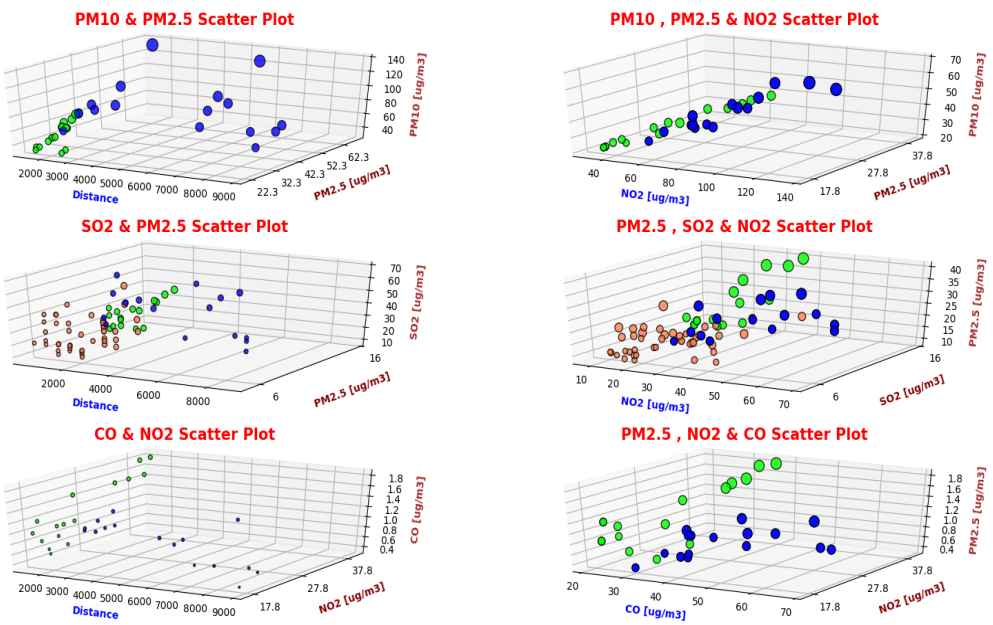


Fig. No. 8.2A: Multivariate Scatter Plots of Air Quality Values at Baghjan

While the 3D scatter diagrams for PM_{10} and CO show one spread each in Z axis direction, the $PM_{2.5}$ scatter shows two distinct vertical scatters in z direction, indicating high values all along. The SO_2 and NO_2 scatters show similar patterns in two distinct groups along the Y axis (DATE). The multivariate scatter shows possibilities of inter-relationships between a few of the pollutants.

8.7 Valuing Emissions In Monetary Terms

The ecological and environmental damages are best ameliorated by taking to mitigation measures and assessing costs of such possible recoveries over a span of time. In respect of the atmospheric pollution caused by accidental blow out, explosion and burning of the gas at Baghjan well No. 5, unprecedented amount of CO_2, CO, NO_X has been emitted into the atmosphere over a very short span of time [172 days]. Additionally, during the blow out, explosion and fire, several of the prescribed National Ambient Air Quality Standards were breached, but also many of the ambient air quality parameters have been breached even prior to the blow out. Therefore, there has been a huge environmental cost to be paid for these breeches. Further, people had to breathe impure air, and had to literally get "bathed" in the blow out fluid and their skin also might have absorbed the carcinogenic hydrocarbons. This also equally applies to cattle and wildlife. All these aspects in some manner or the other need to be dealt with.

However, actual monetary assessment of these damages appears to be very difficult and time consuming.

8.7.1 Estimating Cost of GHG Emissions

Methane and CO_2 are the two Green House Gases (GHGs) involved majorly in the blow out and the fire that ensued. As per the IPCC 5th Assessment Report, the Global Warming Potential (GWP) of CH_4 is 28 times higher than that of CO_2. The two put together have spewed not less than 17 Million Tons of CO_2 and 1.5 Million Tons of CO into the atmosphere. The remediation action is Carbon Capture and Storage (CCS). These are also called Carbon Dioxide Removal (CDR) technologies. Direct removal is by sequestering carbon through plantations, direct capture from air and conversion to pure CO_2, Bioenergy with carbon Capture and Storage (BECC) technologies. Some direct experiments[125,126] have been going around in the world as of now. Since a very large volume of pollutants have entered the atmosphere in a short time due to the accident, and CO2 being the largest pollutant of all, we can take CO_2 as a representative candidate, leaving all other pollutants aside, and work out amelioration/mitigation costs. The carbon capture costs can be taken to be, at the lower end, around US$ 60.00 per tonne. With basic cost at US$ 60, and adding up 10% cost for the people who "suffered", and 5% for cost of land, compensations, security etc, the total cost per tonne for carbon sequestration can be assumed to US$66.60. Further, out of actually 172 days of emissions, damages for only 95 days have been worked oot. Therefore, the environmental compensation due to pollutants, upto 13th September, 2020, comes to:

Table No. 8.17: Carbon Capture Cost for Baghjan

CH_4 Emission (MT)	CO_2 Emissions (MT)	Total Emissions (MT)	Capture Cost (US$/ton)	Capture Cost (Mil US$)	Exchange Rate (INR/US$)	Capture Cost (Cr INR)
10.145	7.451	17.6	66.60	1171.89	74	**8672.01**

8.7.2 Cost of CO and Other Emissions

While carbon capture is easier and more tangible than removal of other emissions such as carbon monoxide and nitrogen gases, the large environmental cost is in terms of health hazards to human, cattle and wildlife populations, and adverse impact on flora and fauna are not easy and straight forward to evaluate. While these issues would be discussed and debated separately in subsequent chapters, no additional cost is being put to these. As far as this Report is concerned, the CCS cost is deemed to represent all

125 https://www.bbc.com/news/science-environment-41816332
126 https://www.bbc.com/news/science-environment-44396781

the environmental cost due to air and other pollutants. The damages have been ascertained only upto 13th September, 2020, being 95 days, against the fire actually raging upto 15th November, 2020, being 172 days altogether. Monetary valuation of CO_2 alone was done, as a majority representative pollutant among all the pollutants.

8.7.3 Cost of Breach of Ambient Air Quality

Breach of air quality is as per provisions of the Environmental (Protection) Act, 1986, Environmental (Protection) Rules, 1986, Air (Prevention and Control of Pollution) Act, 1981, Manufacture, Storage and Import of Hazardous Chemical (Amendment) Rules, 1989, are some of the provisions of law which would determine the legal and penal provisions for the people/ entities responsible for the Baghjan blow out disaster. It would be out of scope of this Committee to judge penal costs. This is the job of the Hon'ble Courts to dwell upon and impose upon those who would be found guilty. Meanwhile under O.A. No. 44/2020, the Hon'ble National Green Tribunal has already initiated legal proceedings and hearing on the Baghjan blow out case. The Hon'ble Tribunal has also appointed a Committee under Chairmanship of Justice B.P. Katakey, retired Judge of the Hon'ble Gauhati High Court to look into the various aspects of the Baghjan case. This Report would, surely, be placed before the said Committee. Nevertheless, nowhere in this Report any 'penal' amount has been prescribed for contravention of any provisions of law. This is a purely judicial power, and this Committee does not have any such power to exercise.

8.8 Conclusions

The following key conclusions are placed below in short:-

1. The National Ambient Air Quality Standards (NAAQS) were prescribed by CPCB in 2009 for the country as a whole; and these are binding under the various legal provisions of the EPA, 1986, EP Rules, 1986 and the Air (P&CP) Act, 1981 for all industrial units.
2. The emissions into the air were estimated using conjectural as well as empirical methods; and in addition to the field measurements of various emission levels, baseline data from the EIA reports provided by M/S OIL was taken into account.
3. From conjectural estimates, methane (in equivalent CO_2 terms) and CO_2 emissions from the blow out, prior to the explosion and fire, were estimated at 10.145 Million Tons till 15th August, 2020.

4. Based on similar methodology, emissions of CO_2, CO, NO, NO_2 from combustion of the well fluid during and post explosion and fire were estimated to be 7.451, 1.649, 0.539 and 0.793 Million Tonnes respectively.

5. The study reveals that no breach in terms of ambient levels of SO_2 were observed at any point of time.

6. The NO_2 levels were found to be as high as 97 µg/m^3 during the blow out, and projected estimates till May, 2021 come to 31.8 µg/m^3. The base levels were already running 20.38 µg/m^3 in 2019. Thus, there is found to be breach in ambient NO_2 levels in 24 hourly as well as annual prescribed levels.

7. Due to direct CO emissions from the fire, the CO levels reached a high average of 9.05 mg/m^3, and the annual levels are projected to cross 2.2 mg/m^3. Thus, there is found to be breach in ambient CO levels in 1 hourly as well as annual prescribed levels at 8 hourly.

8. The baseline levels of PM_{10} were at 80.22 µg/m^3 levels in 2017 already. The values touched 78 µg/m3 during the blow out, and levels are expected to be not below 78 µg/m^3 during the year. Thus, there is found to be breach in ambient PM_{10} levels in 24 hourly as well as annual prescribed levels.

9. The baseline values for $PM_{2.5}$ were already 42.58 µg/m3 for 2017. During blow out the emission levels touched 67.8 µg/m3, and the projected annual value for the year is expected to be 48.2 µg/m3. Thus, there is found to be breach in ambient $PM_{2.5}$ levels in 24 hourly as well as annual prescribed levels.

10. There was lack of systematic sampling design by PCBA. Due to lack of a proper design, the outcome appeared to be random. The capacities of PCBA need to be upgraded. It needs to be modernized with a new lease of life. It simply does not have the capacity, in the present shape, to handle such a disaster.

11. The estimated environmental damages, in terms of costs to be incurred for remediation of the emitted green houses gases, comes to Rs. 8672 cr INR.

12. The damages have been ascertained only upto 13th September, 2020, being 95 days, against the fire actually raging upto 15th November, 2020, being 172 days altogether. Monetary valuation of CO_2 alone was done, as a majority representative pollutant among all the pollutants.

CHAPTER 9

9 NOISE POLLUTION AND VIBRATIONS

9.1 Introduction

Noise is a subset of air pollution. Noise is caused by one or more sources of vibration that generate sound waves in the air. Human ear is capable of hearing sound between the frequencies 20-22000 Hz. Higher frequency sound is termed ultra sound. Sound travels at a speed of 343 m s^{-1} in the air at standard temperature and pressure. Waves travelling at rates higher than the speed of sound are termed supersonic waves (but less than 5 times- *some say 8 times*). When waves travel at about 5 times the speed of sound or higher, these are termed hypersonic. Supersonic and hypersonic waves generate strong vibrations in the air that are capable of shattering door and window glass panes, inducing vibrations in the walls, and producing "earth-quake" like conditions with sonic boom equivalent in scale to Richter Scale 3-4[127]. Further, fire induced vibrations may cause collapse of buildings. Research in this direction accelerated after the 9/11 disaster[128]. This Chapter looks at two key aspects of the Baghjan blowout, post explosion: firstly, sound pollution (which is a part of air pollution covered under the Air (Prevention and Control of Pollution) Act, 1981 and the EPA 1986 and EP Rules, 1986 under Schedule III of Rule 3) and secondly, reported vibrations and shaking of ground and houses in the surrounding areas of the fire.

9.2 Noise Standards In India

The Schedule III of the Rule 3 under the Environment (Protection) Rules, 1986 framed under the Section 6 and 25 of the Environment (Protection) Act, 1986, prescribes the Ambient Air Quality Standards in respect of Noise in the country. The Table given below gives the prescribed limits:-

Table No. 9.1: National Ambient Air Quality Standards (Noise)

Area Code	Category of Area	Limits in dB(A) L_{eq}	
		Day Time	Night Time
(A)	Industrial Area	75	70
(B)	Commercial Area	65	55
(C)	Residential Area	55	45
(D)	Silence Zone	50	40

127 https://journals.aps.org/prl/abstract/10.1103/PhysRevLett.115.128001
128 https://tsapps.nist.gov/publication/get_pdf.cfm?pub_id=101379

Note-1: Day time is reckoned in between 6.00 AM and 9.00 PM

Note-2: Night time is reckoned in between 9.00 PM and 6.00 AM

Note-3: Silence Zone is defined as areas upto 100 meters around such premises as hospitals, educational institutions and courts. The silence zones are to be declared by the Competent Authority. Use of vehicular horns, loudspeakers and bursting of crackers shall be banned in these zones.

9.3 Sound Power

At the outset the language of the subject requires a bit of description. Sound or Noise levels are measured in dBA. When a source emits sound, it is radiating sound energy into the medium (As we all know from our basic knowledge of physics that sound needs a medium to travel; and that sound does not travel in vacuum). The amount of energy released per second by an emitting source is called Sound Power (W). W stands for Watts. Sound power per unit of surface area is called Sound Intensity. The relation between the two is:-

$$N=4\bullet\pi\bullet r^2\bullet I \quad \text{..... } Eq.No.\ 9.1$$

where N is Sound Power in Watts, r is distance from the sound source and I is the sound Intensity in Wm^{-2}. Sound is often measured in "Levels" which is a dimensionless number on the logarithmic scaled ratio of the measured quantity divided by the reference value. This is called a "Bel" and represented by "B". One tenth of it is denoted as dB and called Decibel. The next para looks at some of the key sound levels and their relations.

9.3.1 Levels of Sound

Human ear is able to hear sound from 10^{-12} W to 100 W. 10^{-12} W is taken as reference sound, and Sound Power Level (L_N) is defined in Logarithmic scale as below[129]:-

$$L_N=10\bullet\log_{10} N+120 \quad \text{..... } Eq.No.\ 9.2$$

where L_N is the Sound Power Level in dB (Decibels), N is the sound power in Watts.

Similarly, the Sound Intensity can also be expressed in logarithmic scale as given below:-

$$L_I=10\bullet\log_{10} I+120 \quad \text{..... } Eq.No.\ 9.3$$

where L_I is the Sound Intensity Level in dB and I is the Sound Intensity in Wm^{-2}.

Sound Pressure is the force per unit area from a sound source. In SI units, it is expressed in Pa or Nm^{-2}. Since, energy level of a sound wave is square of the pressure, the Sound Pressure Level in Logarithmic scale is defined as

129 Long Marshall, Architectural Acoustics, 2nd Ed, 2014, Academic Press, https://doi.org/10.1016/B978-0-12-398258-2.00002-7

$$L_P = 2 \bullet 10 \bullet \log_{10} \left(\frac{P}{P_{Ref}} \right) \quad \text{..... } Eq.No.\ 9.4$$

where L_P is the Sound Pressure Level, P is the sound pressure in Pa and P_{Ref} is the reference sound pressure, taken to be $2x10^{-5}$ Pa (=20 μPa). Sound pressure and intensity are related by the following relation:-

$$I = P^2/\rho C \quad \text{..... } Eq.No.\ 9.5$$

where I is the sound intensity in Wm^{-2}, P is sound pressure in Pa, ρ is the density of air at a given temperature and pressure, C is the velocity of sound in air. Therefore, sound intensity level and sound pressure level are related by the following equation[130]:-

$$L_P = L_I + 10 \bullet \log K \quad \text{..... } Eq.No.\ 9.6$$

where K=ρC/400. The value of 10 log K at normal temp and pressure comes to 0.13 dB which is negligible. Thus, the above equation becomes:-

$$L_P \approx L_I \quad \text{..... } Eq.No.\ 9.7$$

Sound Intensity Level and Sound Power level are also related by the following equation:-

$$N(W) = I \bullet S \quad \text{..... } Eq.No.\ 9.8$$

$$L_W = L_I + 10 \bullet \log S \quad \text{..... } Eq.No.\ 9.9$$

$$L_I = L_W - 10 \bullet \log S \quad \text{..... } Eq.No.\ 9.10$$

where N(W) is the Sound Power in Watts, I is intensity in Wm^{-2}, S is the surface area around which the intensity is uniform, L_W is the Sound Power Level and L_I is the Sound Intensity Level.

9.3.2 A Weighted Sound Pressure Level

A weighted sound pressure level is an average of a set of noise pressure levels defined over certain fixed frequencies of sound to which the human ear is sensitive from 10 Hz to 20000 Hz comprising of 34 individual frequencies and their associated dB levels. The average of the A-weighted (these frequencies also have weights defined in two other categories called B and C as well) frequencies over long periods of time such as 8 hours or 24 hours or "day and "night" is called L_A or L_{eq}, and is defined as:-

130 Beranek Leo L & Ver Istavan L, Noise and Vibration Control Engineering- Principles and Applications, 2nd Ed, John wiely & Sons, 2006

$$L_{A,T} = L_{eq} = 10 \bullet \log\left(\frac{1}{T}\right)\frac{\int_0^T P_A^2\, dt}{P_{Ref}^2} \quad \text{..... } Eq.No.\ 9.11$$

where $L_{A,T}$ or L_{eq} is the A-weighted sound pressure level, T is the time period, P_A is the instantaneous sound pressure using the standard weighting scale A and P_{Ref} is the standard reference sound pressure (20 µPa) (Beranek & Ver, 2006).

This is also denoted as SPL in dBA or dB(A). SPL in dBA is now recognized as the standard for any environmental assessment of sound/noise pollution.

9.4 Ill Effects Of Noise Pollution

Noise exposure can cause two kinds of health effects[131]. These effects are non-auditory effects and auditory effects. Non-auditory effects include stress related physiological and behavioral effects, and safety concerns. Auditory effects include hearing impairment resulting from excessive noise exposure. Noise-induced permanent hearing loss is the main concern related to occupational noise exposure. The main auditory effects include:

Acoustic trauma: Sudden hearing damage caused by short burst of extremely loud noise such as a gun shot.

Tinnitus: Ringing or buzzing in the ear.

Temporary hearing loss: Also known as Temporary Threshold Shift (TTS), which occurs immediately after exposure to a high level of noise. There is gradual recovery when the affected person spends time in a quiet place. Complete recovery may take several hours or days (up to 48 hours).

Permanent hearing loss: Permanent hearing loss, also known as Permanent Threshold Shift (PTS), usually progresses constantly as noise exposure continues month after month and year after year. Most individuals do not notice the impairment at first. The hearing impairment is noticeable only when it is substantial enough to interfere with routine activities. At this stage, permanent and irreversible hearing damage has occurred. Noise-induced hearing damage cannot be cured by medical treatment and worsens as the noise exposure continues. When the noise exposure stops, the person does not regain the lost hearing sensitivity. As the person ages, hearing may worsen as "age-related hearing loss" adds to the existing noise-induced hearing loss. Permanent hearing loss can also occur from a single traumatic event.

131 https://www.ccohs.ca/oshanswers/phys_agents/noise_auditory.html

9.5 Legal Provisions Pertaining To Noise Pollution

The Schedule III of the Environmental (Protection) Act, 1986, defines the limits of sound pollution or the Ambient Air Quality Standards in respect of Noise with L_{eq} defined for day time (15 hours from 6 AM to 9 PM) and night time (9 hours 9 PM to 6 AM). Further, the MoEF&CC, New Delhi has notified Noise Pollution (Regulation and Control) Rules, 2000 vide No. S.O. 123 (E) Dt. 14th Feb, 2000 and subsequently amended vide No. S.O. 1046(E) Dt. 22nd Nov, 2000, S.O. 1088(E) Dt. 11th Oct, 2002, S.O. 1569(E) Dt. 11th Sept, 2006 and S.O. 50(E) Dt. 11th Jan, 2010 under the provisions of the EPA, 1986. Under the Rule 4(3), the State PCB is authorized to collect and compile noise pollution data. The Rule 5(5) prescribes "*The peripheral noise level of a privately owned sound system or a sound producing instrument shall not, at the boundary of the private place, exceed by more than 5 dB (A) the ambient noise standards specified for the area in which it is used*". The flame at Baghjan for purposes of this Rules is a perfect "privately owned sound producing instrument" owned by M/S OIL put to use since 9th June, 2020 and producing more than 5 dB(A) sound in excess of the ambient noise standards. Under Rule 6, there is restriction on exceeding prescribed limits in the silence zone, and the offender is liable to be punished. Under Rule 7, any person may complain to the authority if in his area noise level exceeds 10 dB(A) more than the prescribed noise level. The EPA, 1986 under Section 15 prescribes penalty of Rs. 1.00 lakh fine for each violation and / or imprisonment upto five years.

9.6 Methodology For Assessment Of Noise Pollution

Noise pollution, like other air pollution / emissions into the atmosphere has been arrived at from two distinct methodologies of conjectural estimates from theoretical concepts and scientific principles, and secondly through direct instrument based measurements in the field. These two methodologies are briefly described in the ensuing paragraphs.

9.6.1 Empirical/ Conjectural Estimation Principles

NOISE LEVEL:

The conjectural method is based on derivation of acoustic power, N(W), of the flame from the flame power or the Heat Release rate (HRR) through a conversion factor quantity called "Thermal to Acoustic Efficiency" (η_{TA}). The details are given in Para No. 7.2.11.

DOMINANT FREQUENCIES:

An estimate of the dominant frequencies in the sound emitted by the flame was also attempted. For a flame which is a large jet fire (in the supersonic range) the distance from one flamelet to the next gives the natural wavelength, and using the supersonic flow velocity, the frequency of vibration can be worked out from the basic relationship:

$$C=\lambda \bullet \nu \qquad \text{..... } Eq.No.\ 9.12$$

$$\nu\ (\text{Hz}) = \frac{C}{\lambda} \qquad \text{..... } Eq.No.\ 9.13$$

where C is velocity in ms-1, λ is wavelength in m and ν is frequency in Hz. This way, by taking several measurement of the flamelets in the flame, taken from the photographs of the flame, and dominant frequencies can be worked out. Spectrograms also give dominant frequencies.

NOISE SPECTRUM:

Noise spectrum of the flame at different distances from the flame was measured using "Spectro" Mobile App on Android. It gave SPL in dBA and corresponding frequency from 10 to 20000 Hz. These patterns mostly confirm the theoretical noise spectrum presented in the Para 7.2.11.

9.6.2 THE SCALING LAWS FOR THE FLAME PARAMETERS

Noise and acoustics from turbulence are matters of an ocean of literature, research papers and numerous laboratory experiments conducted to unearth the mysterious relationship between various types of flames and noise/ sound produced. It appeared from a series of research publications that most laboratory studies confined to small size burners, and deal with flame lengths varying from a few centimeters to a few meters [*ALOHA estimation also gives low flame lengths*]. Even the burner sizes used in these experiments were found to be of the order of mm [*these come nowhere near the actual 120 mm burner at Baghjan*]. While the problem at hand is a huge flame as tall as 100 m and a fully turbulent jet generating supersonic sound waves, the top and visible end of the orifice being 8" (=200 mm). There are a very few studies on flames of this magnitude, and hence no true comparison or parallel was found in the extensive literature review that was done by the author of this Report. The intent of the author here is not to write a literature review of progress made since 1930s till date in understanding flames, their structure, chemical composition, physical and thermodynamic properties such as entropy, turbulence, eddies, flow velocities, flame velocities, flame surface areas, dimensionless characteristics such as Mach number,

Reynolds Number, Damkohler Number, and so many other factors and parameters. The purpose, here, is in short to be able to provide a quick description of the flame in terms of some relevant parameters, at the least, so that, in future, parallels can be drawn and such blowout events be possibly compared one to one based on real values based on such parameters. The list of papers and literature consulted is shown in References/Bibliography at the end of this Report. It was found that the only help available in literature was to depend upon "scaling laws" that could throw some light on the Baghjan oil well fire. Already, without mentioning, several scaling laws have been used in the previous chapters for characterization of certain properties. However, the challenge is that even scaling laws differ so widely one from the other. After careful examination and a series of rough calculations, the scaling relationships assembled by Strahle & Shivashankara (1975)[132] were used after converting the equations to SI system. The authors have narrowed down to four variables to express the various properties and quantities representing the turbulent flames. These are the U, the flow velocity of the fuel (in m s^{-1}), F (mass fraction of fuel[133] in the mixture), D, the diameter of the orifice (in m), and SL, the laminar flow velocity of flame for the given fuel (in m s^{-1}). The equations are presented here in SI system:-

Acoustic Power of Flame:

$$P=0.021 \bullet U^{2.67} \bullet S_L^{1.83} \bullet F^{-0.40} \bullet D^{2.78} \quad \text{..... } Eq.No.\ 9.14$$

Frequency of Maximum Acoustic Power:

$$f_C=6.994 \bullet U^{0.18} \bullet S_L^{0.88} \bullet F^{-1.21} \bullet D^{-0.13} \quad \text{..... } Eq.No.\ 9.15$$

Turbulent Flame Speed:

$$S_T=1.06 \bullet U^{0.24} \bullet S_L \bullet F^{-0} \bullet D^{0.50} \quad \text{..... } Eq.No.\ 9.16$$

Reacting Volume:

$$V_C=2.9821x10^5 \bullet U^{0.88} \bullet S_L^{0.93} \bullet F^{-3.11} \bullet D^{3.22} \quad \text{..... } Eq.No.\ 9.10$$

132 Strahle W C & Shivashankara B N, A rational correlation of combustion noise results from open turbulent premixed flames, Combustion Symposium International, Volume 15, Issue 1, 1975, Pages 1379-1385

133 $F=\frac{n_F \times M_F}{\sum_{i=1}^{n} n_i \times M_i}$ where n_F and M_F are no. of moles of and Molecular weight of the fuel species and n_i & M_i are the no. of moles and molecular weight of all the n species participating in the reaction.

9.6.3 THE DIMENSIONLESS NUMBERS

There are a few dimensionless entities that play a significant role in understanding combustion and the associated flame, and ways of estimating them are outlined briefly here. We have already estimated a few of these quantities and ratios in the Report, but as a part of the methodology, these have been presented here for sake of comprehension. Some of the quantities have contextual implementation as well, and it would not be possible to provide all the possible contexts, except those which are relevant to the enquiry at hand.

Adiabatic Index (Y): This is the ratio of the specific heats or the specific heat capacities C_P (at constant pressure) and C_V (at constant volume). The ratio is also called Laplace's Coefficient.

$$\gamma = \frac{C_P}{C_V} \qquad \text{..... } Eq.No.\ 9.18$$

For natural gas (mainly Methane), this constant has been taken as **Y=1.31**.

Mach Number (M): It is a ratio of the speed of an object wrt speed of sound (343 m/ sec). The name was kept in the honor of the Austrian physicist Ernst Mach.

Reynold's Number: It is a dimensionless number that is capable of explaining the state of affairs of flow of fluid in geometrically similar systems. The name was kept in the honor of Osborne Reynolds who studied the system of flow of water through pipes. It is an indicator of degree of turbulence in the flow. In a generic way, the Reynold's Number is given by:-

$$R_e = \frac{U \times d}{\nu} \qquad \text{..... } Eq.No.\ 9.19$$

where U is the velocity of the stream, d is the diameter of the pipe, and ν is the kinematic viscosity of the fluid. The ***kinematic viscosity*** is, again, given by the ratio of viscosity (μ) and density (ρ) of the fluid. The dimensions of U are $[LT^{-1}]$, d [L], ν $[L2T^{-1}]$, μ $[ML^{-1}T^{-1}]$ and ρ $[ML^{-3}]$. Depending upon the system being described, the exact expression of the Renold's Number may change.

9.6.4 DIRECT MEASUREMENTS

Direct noise level measurements were done using sound meters by several agencies namely PCBA, WII, BNHS, AMTRON and agencies deployed by M/S OIL namely i.e ERM, MSKPL, TERI, Arihant etc. PCBA used SLM-Frequency Weighting AC&ZIEC-61672 & ANSIS-14C methodology with SLM-100 Model instrument of make Envirotech. AMTRON

used Testo 816 equipment, which measures sound levels in dB using IEC 61672-1 Class 2 and ANSI S1.4 Type 2 standards. Data from all sources was combined into a 2D scatter diagram of Distance (X) and dB (Y), and a linear/power best fit was obtained.

9.6.5 Baseline Data

Noise levels were measured in the area during the EIA in 2009 and 2017. These data would be used as baseline to see the level of noise prior to establishment of the wells in the PML area.

9.6.6 Assessing Breach or No Breach

As per the ambient noise levels, there are two key parameters namely silent zone for schools and hospitals for which night time levels are 40 dBA, and residential night time for which the levels are 45 dBA. Therefore, one needs to look at the distances over which 55 dBA noise levels (residential day time and commercial night time limits) have travelled, and also to see the violations of silence zone, 50 dBA noise levels (day time silence zone) need to be examined. However, in order to keep things simple, 50 dBA and above sound levels may be seen as the breach point (as one can complain only when the sound level is 10 dB above the prescribed limit), and distances over which such breaches are possible needs to be determined. In general, it has been reported (and the Committee has also experienced quite similarly) that sound of the flame has been experienced over more than 30-40 km distance from the point of well fire. At night, the noise levels are more easily discernible.

Another point of breach would be emission of sound from the source. The “sound producing instrument” that the flame is, cannot produce sound 5 dBA higher than the prescribed limit. Assuming that the area where the well is located is to considered industrial, and if the “instrument” emits sounds of levels 5 dBA higher (than 75 dBA) of sound, it would be considered that the “instrument” has caused breach of the levels prescribed.

9.7 Methodology For Assessment Of Vibrations

Other than sound pollution, the most intriguing part of the fire at Baghjan has been the reported tremors at wide distances from the fire, including cracking of walls, floors and ceilings, rattling of doors and windows and difficulty in standing up at times on the ground. These vibrations have reportedly started one day after the fire broke out and continued until the time the well was capped on the 17th August, 2020 with a riser. Once the riser was fitted, the fire rose up by several meters, as the “well orifice” was lifted up.

Since the noise and vibrations, as described in Chapter 6 & 7 of this Report indicate, are outcome of turbulent supersonic flow at the "*hypothetical convergent-divergent nozzle*" at the base of the fire. Hence, when the fire level gets higher vibrations would touch the ground weakly (energy dissipates as square of distance), but the sound could travel larger distances, in the free field, as fire was elevated to about the "tree level" and would be radiating all around with equal intensity. The vibrations resumed, once the fire was shifted to flare pits on 13th September, 2020.

Assessment of vibrations was most challenging as it needed sophisticated equipment. At the behest of the office of the Hon'ble Chief Minister, Assam, the CSIR NEIST Jorhat was asked to conduct vibrational studies, which they conducted. However, no copies of the report were available for study. However, another report was commissioned by OIL through the IIT Guwahati. A copy of the report was made available by the Justice (Retired) B. P. Katakey. Comments on the report has been incorporated herein. However, in order to gain a deeper understanding, conjectural methodology was applied. The details are discussed in the paragraphs below.

9.7.1 Shock Waves

As discussed in detail in Para 7.2.5 and 7.2.9, it is seen that the Mach number could be anything from 3.1 to 8.5. However, a Mach number of 3.15 has been assumed for this Report. From ALOHA alone, it can be deduced that the flow rate could vary from 225 to 492 Kg s^{-1} (or higher), while a mean flow rate of 343.50 has been assumed for all calculations. These burn rates are expected to produce high turbulence and shock waves around the flame, especially near the base of the flame. During high wind conditions, the turbulence is expected to be much higher, and this in principle is expected to generate stronger shock waves. We shall give more details in subsequent paragraphs on shock wave properties and methodologies for their estimation.

9.7.2 Localized Quake in Large Explosions

Explosions which are of order of kilotons of TNT are capable of triggering small to medium earthquakes in the places where they occur. A large number of studies on seismic magnitude and nuclear explosions of yield 1 kt or more have been done. One relationship is given below[134]:-

$$M_N = \frac{2}{3} \bullet \log_{10} \frac{M_{TNT}}{M_t} + 6 \qquad \ldots\ldots \; Eq.\,No.\; 9.20$$

134 https://www.deepspace.ucsb.edu/wp-content/uploads/2015/01/Chapter-13-Waves-and-Acoustics.pdf

where M_N is the seismic magnitude, M_{TNT} is the yield of explosion in Megtons of TNT, Mt is a reference 1 Megaton TNT (to make the quantity dimensionless). Eric P. Chael (2010)[135] studied if these relationships could be taken to much lower yield (1 ton or even 1 kg of TNT) and also the behaviour of the amplitude as to when would the wave die down. One such relationship is

$$m_b = 3.92 + 0.81 \bullet \log (Y, kt) \quad \text{..... } Eq.No.\ 9.21$$

for smaller yield values. According to Chael, even the ML equations meant for the order of kilotons and Megatons TNT fit the equations well, but correction factors may be required to suite local conditions. Several research papers have been quoted by him who have applied local corrections for USA, Iran, Italy etc.

Kohler and Fuis (1992)[136] have given a relationship for velocity with the weight (Yield) of the explosion from a few kg to a few thousand kg. [*It has to be noted that most of these blasts are sub surface or deep borehole blasts, but are in a position to provide considerable insights into the possible explanation of the vibrations in the surrounding of the flame upto several kilometers providing an experience of at least 2.5 to 3.5 magnitude earthquake with epicenter very high up in the surface and very close to the location in question*]. The authors have given a second degree polynomial for distance from the explosion site as well as the yield load in kg. The empirical relationship is also dependent upon soil conditions. The equation below is shown for dry alluvium / wet alluvium and water body:-

$$\log (v) = -2.3642 \bullet \log (d) + 0.3662 \bullet [\log(d)]^2 + 0.5061 \bullet \log (Y, Kg) - 2.9088 \text{ (Dry Alluvium)} \quad \text{..... } Eq.No.\ 9.22$$

$$\log (v) = -2.3642 \bullet d + 0.3662 \bullet [\log(d)]^2 + 0.5061 \bullet \log (Y, Kg) - 2.2934 \text{ (Wet Alluvium)} \quad \text{..... } Eq.No.\ 9.23$$

$$\log(v) = -2.3642 \bullet \log(d) + 0.3662 \bullet [\log(d)]^2 + 0.5061 \bullet \log (Y, Kg) - 2.2456 \text{ (Water body)} \quad \text{..... } Eq.No.\ 9.24$$

where v is velocity of the vibration in cm/s, d is distance from the disturbance in Km, Y is the yield in Kg. It has to be noted that the material in question here is Ammonium Nitrate equivalent material, which is normally 40% of TNT. Therefore, we need to keep in mind the following relations:-

135 Chael Eric P, 2010, Local magnitudes of small contained explosions. SANDIA Report, SAND2009-7941, DOE, US GOV

136 Kohler William M, & Fuis Gary S, 1992, Bulletin of the Seismological Society of America, Vo]. 82, No. 5, pp. 2032 2044, October 1992

1 Kg of AN Eqv = 0.4 Kg of TNT

1 Kg of TNT = 4.184 MJ

1 Kg of AN Eqv = 1.6736 MJ

1 MJ = 0.6 Kg of AN Eqv

Box No. 9.1: Ammonium Nitrate Equivalence

Therefore, with the discussion above, it is seen that there exit empirical relationships between yield and velocities, field measurements and correlation thereof, by virtue of which one can conjecture equivalent seismic magnitude of a given yield, and also approximately estimate the underlying velocities. These estimates, as have been indicated by their authors, have been worked out in specific ground conditions, and site specific corrections are needed often to get to very accurate results. However, it is almost clear from the deliberations above that 1 Kiloton TNT event is most likely to trigger seismic activity of about Magnitude 4 on Richter Scale. The explosion on the 9th June, 2020 would have been of a slightly lesser magnitude than this. Huge quantities of burning of natural gas in a turbulent flame of height about 100m is also an event which is quite capable of triggering acoustic waves that might, in turn, generate vibrations equivalent to about Magnitude 2.3-2.6 seismic activity.

9.7.3 Equivalent TNT Based Shock Wave parameters

The US Department of Defense, the detailed report on "Structures to resist effects of accidental explosions"[137], has provided details of various types of explosions, and the shock wave generation caused by such explosions. The document identifies 6 different types of explosions, namely – Free Air Burst explosion, Burst Explosion, Surface Burst explosion, Partially Confined Explosion and Fully confined Explosion. The Baghjan Oil Well accidental blow out, explosion and fire falls under the first three categories. In order to account fo various blast load conditions, scaled ground distance, Z, has been used to work out various parameters. Z is given by:-

$$Z_G = \frac{R_G}{W^{\frac{1}{3}}} \quad \text{..... } Eq.No.\ 9.25$$

137 US DoD, UFC 3-340-02, 5th December, 2006

where Z_G is the scaled ground distance, R_G is the actual ground distance from explosion point to the point of interest for which parameters need to be worked out, W is the blast charge load in pounds (lb) in equivalents of TNT. Shock wave has been described as having a positive phase during which the incident pressure P_{SO} falls from its maximum value to normal pressure P_0, the time duration being denoted by t_0. The reflected pressure P_r is many times higher and it also fall during the t_0 phase. The negative phase of the shock wave lasts longer for a duration t_0^- when the pressures fall lowest to P_{SO}^- and P_r^-, the total duration of the wave being t_0+ t_0^-. The shock wave velocity U, incident unit impulse i_s, time of arrival of the shock wave at a point of interest, t_A, positive pressure wavelength L_W etc. are some of other important parameters taken into account. All the pressures are in psi, and all distances in foot.

If the blast charge is at a height H, and the point of interest is making an angle with the ground from the blast point in the air, the incident wave, the reflected wave would create a series of points of the shock wave front called Mach Front that would develop and travel away from the blast site. The height of the Mach front at any point of interest is denoted by H_T. The movement of the Mach Front is shown below.

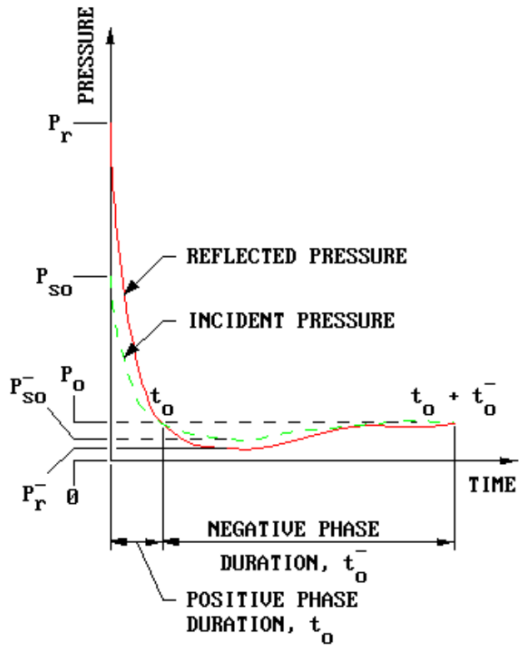


Fig. No. 9.1 A: Shock Wave Profile

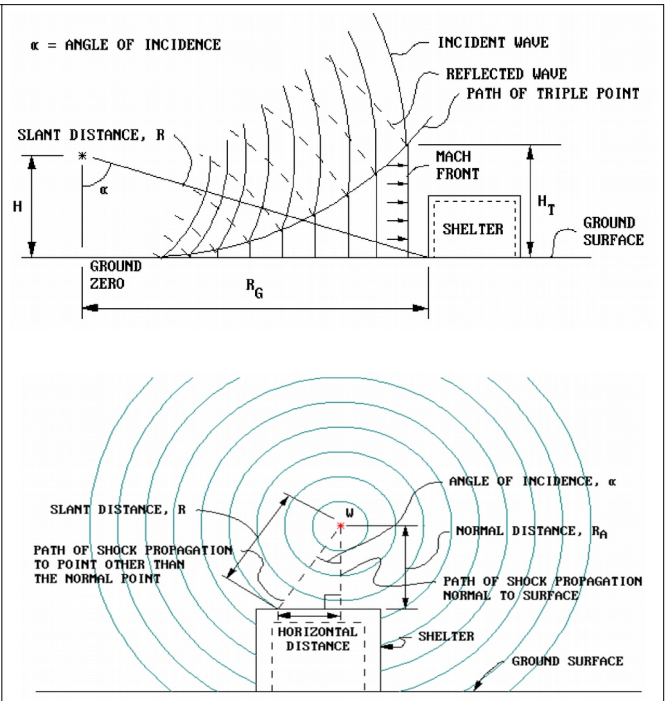
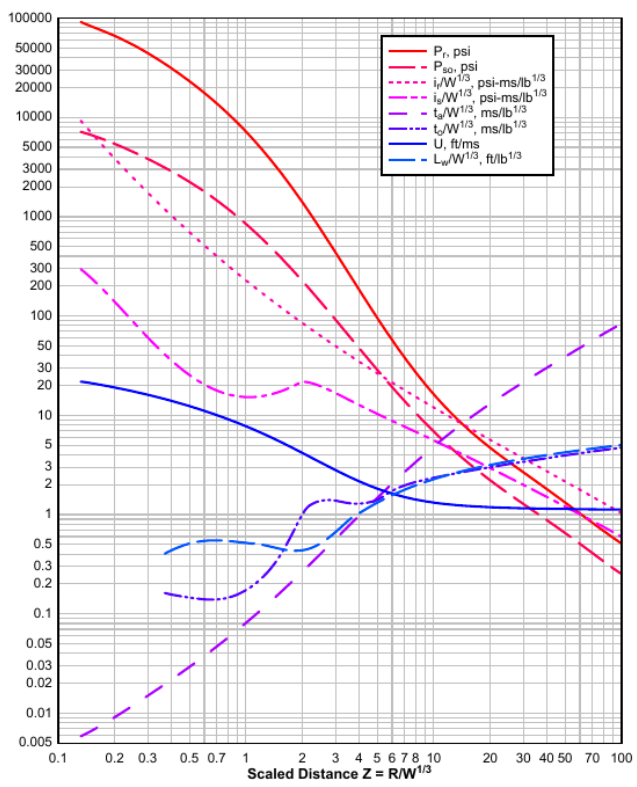
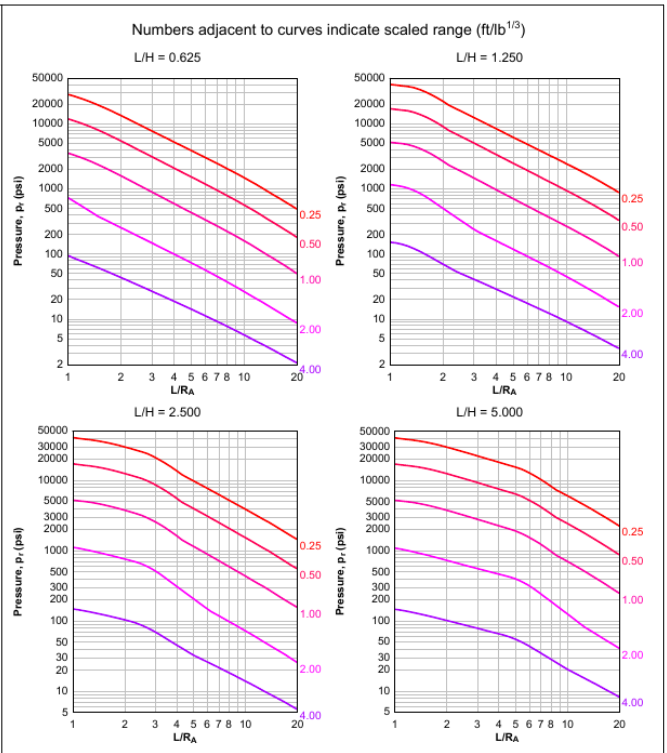


Fig. No. 9.1 B&C: Shock Wave Front Propagation

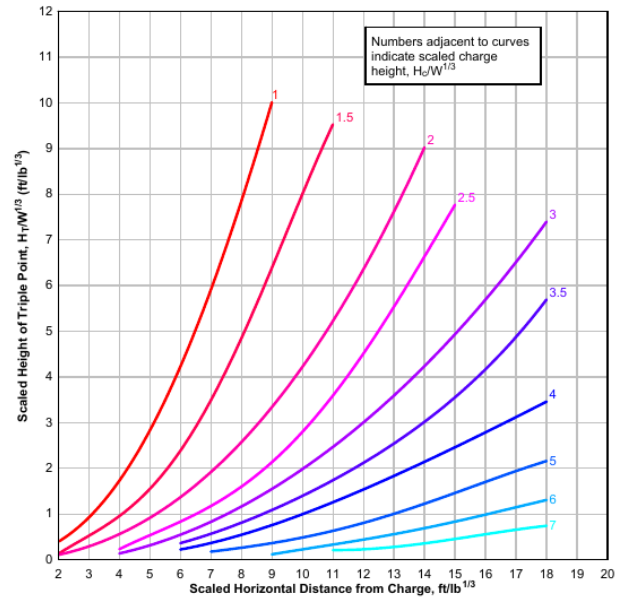
The US Defence UFC Handbook (see footnote 137) is an excellent resource, almost all shock parameters can be read off directly from the charts provided in therein against scaled parameters and distances (in units of $W^{1/3}$, wherever required). Some of the relevant charts for various explosions are reproduced here for a quick reference.



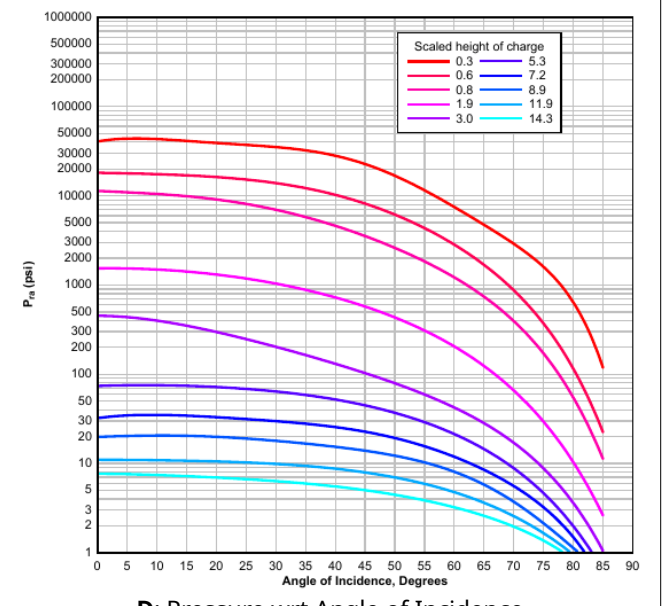
A: Shock Wave Properties



C: Pressure Charts



B: Triple Point Heights



D: Pressure wrt Angle of Incidence

Fig No. 9.2: Ready Reckoner Charts for TNT Eqv. Explosions

The main reason for bringing in the explosions here was to have a tested methodology to understand in some more details, the blast that occurred on the 9th June, 2020 at 1:30 PM. Further, the fire that raged, thereafter, at the well, bears a very high amount of turbulence and is comparable to a blast every now and then. This analogy would help in understanding the shocks and vibrations generated in the Baghjan fire that is still raging [*Extinguished on 15th November, 2020*]. As for so many reasons, tests and

measurements are not possible on the ground. So far accidents have already occurred three to four times, and with three people dead, and several injured, its not a very viable proposal to carry out accurate measurements on the ground, and one has to rely on empirical methods alone and once in a while check with available results from studies carried out in controlled environments.

9.7.4 Velocity and Acceleration of Buildings

Each vibration has its own velocity, and may cause certain amount of acceleration if it impinges onto an object. Objects in rest or motion in the macroscopic world (as opposed to quantum world) follow Newton's Laws of Motion. According to the Second Law of Motion,

$$F=m.a \qquad \text{..... } Eq.No.\ 9.26$$

where F is the force in Newtons, m is the mass of the body impacted by the force (F), in Kg and a is the acceleration (in ms^{-2}) caused in the body by the force. The force may be exerted by a seismic vibration or a surface wave. The object could be a building or even plain ground that is otherwise at rest (and hence inertial in nature). To see the impact of seismic activity or surface waves on buildings, one need to first define acceleration units in terms of g (=9.8 m s^{-2}), which is the acceleration due to gravity. If the impinging force causes an acceleration of 9.8 ms^{-2}, we can say it would cause 1g acceleration. Similarly, 2g, 3g and so on and so forth. For example, an aircraft is most likely to land with 1.65g force on the runway, while a company like Boeing designs aircrafts to land even at 2.5g. Human body is designed (*by God*) to feel even a force as small as 0.001g, and an airplane in fairly severe turbulence is likely to experience a force of 0.2g[138].

Ground Amplification:

Compared to hard rock, soft ground and loose soil may experience ground vibrations 1.5 to 6 times higher. This leads to greater damage to buildings built on softer ground. Poor soil conditions lead to greater damages. It has been proved several times, as reported by FEMA (Arnold C, 2006).

Natural Frequencies of Buildings:

Every object has an inherent or natural period (or frequency[139]) of vibration, if a force acts on it horizontally. Even a swing (on which children play in the parks) has its natural frequency, and a slight horizontal push brings the swing into smooth vibrational

138 Arnold Christopher, 2006, Chapter 4, Designing for Earthquake FEMA 454 / December 2006

139 Period of vibration is the time taken for one complete vibration, end to end and back to original position. Frequency is the number of times an object vibrates in one second.

motion. A one story building is likely to sway at 0.1 s, a 4 story building at 0.5 and a 10 story building at 1 s (Arnold C, 2006). This implies that the natural frequencies of these structures would be:-

Table No. 9.2: Natural Frequency of Buildings (Height)

Building Type	Natural Period (s)	Natural Frequency (Hz)
1 story	0.1	10
4 story	0.5	2
10 Story	1	1
20 story	2	0.5

The kutcha bamboo buildings and Assam Type buildings found generally in Assam also would be having their natural frequencies. According to a research study[140], the natural frequencies of bamboo/Ikora Assam type housing and concrete housing are as follows (period is calculated):-

Table No. 9.3: Natural Frequency of Buildings (Materials)

Building Type	Natural Frequency (Hz)	Natural Period (s)
Bamboo (Ikora system)	1.529	0.654
RCC Brick Masonry	4.380	0.228
Confined Brick Masonry	3.574	0.280

Another study[141] (which was part of a larger study in which AMTRON was also a partner and the undersigned was also associated with it) classified almost all buildings in Guwahati in 9 classes starting from 1.031, 1.534, 2.036, 2.539, 3.042, 3.345, 4.047, 4.55, 5.053 to 5.556 Hz. Majority of the buildings falling in 2.036 to 2.539 class. The natural periods would be:-0.97, 0.652, 0.491, 0.394, 0.329, 0.299, 0.247, 0.220, 0.198 to 0.180 s.

The natural frequency of a building is governed by the following formula:

$$f = \frac{1}{2\pi}\sqrt{\frac{K}{M}} \qquad \text{..... } Eq.No.\ 9.27$$

where f is the natural frequency of vibration, K is the stiffness of the structure and M is the mass of the building. Buildings with lower stiffness and or higher masses would be

140 Kakkad M D & Shangvi C S, 2011, Comparative Study of Bamboo (Ikra) Housing System with Modern Construction Practices, National Conference on Recent Trends in Engineering & Technology, 2011, VV Nagar, Gujarat

141 Pathak Jayant, 2008, Seismic vulnerability of Guwahati Region, Seismology Division, MoES, GoI, 2008

having lower frequencies of vibration. According to the PWD (Buildings & NH)[142], Assam, the average natural frequency of the Assam Type houses is: 2-3 Hz.

Resonance:

When two vibrating objects have similar frequencies or time periods, their vibration match, and the resultant amplitude doubles, resulting in higher displacements. This is called resonance. The natural period of ground varies from 0.4 s (2.5 Hz) to 2 s (0.5 Hz). Hard or rocky ground is expected to experience short period vibration say 0.4 s and would vibrate at frequencies say 2.5 Hz, but soft ground would experience high period vibration, say 2 s and would accordingly vibrate at lower frequencies, say 0.5 Hz. According to FEMA (Arnold C, 2006), the ground may not be able to withstand longer period vibrations. Thus, ground vibrations are well within the natural frequencies of buildings. In such situations, surface waves/ seismic waves may cause resonance in building structures. Even if the ground vibrates at 0.2g, the structures might experience vibrations of 1g force.

9.7.5 VdB and Ground Borne Noise

Vibration Acceleration Level:

VdB or L_A is defined as the vibrational dB and measured in logarithmic scale as given below:-

$$VdB\,L_A = 10 \times \log\left(\frac{a}{a_{ref}}\right) \quad \text{..... } Eq.No.\ 9.28$$

The quantity can be measured in three different terms, root mean square (RMS) displacement amplitude, velocity amplitude and acceleration amplitude of the vibration. Amplitude values for simple harmonic motion are related to each other as given below:-

rms value =0.707 x peak value ..... $Eq.No.$ 9.29

average value = 0.637 x peak value ..... $Eq.No.$ 9.30

rms value = 1.11 x average value ..... $Eq.No.$ 9.31

peak to peak value = 2 x peak value ..... $Eq.No.$ 9.32

Further, acceleration, velocity and displacement for simple harmonic motion are related to each other as:-

velocity = acceleration / $\{2\pi f\}$ ..... $Eq.No.$ 9.33

displacement = acceleration / $\{2\pi f\}^2$ ..... $Eq.No.\ 9.33A$

142 Shantanoo Bhattacharyya, Addl. Chief Engineer (Mech), PWD, Assam, Guwahati

The reference level for acceleration is normally taken as 1 micro G where G=9.8 m s^{-2} is the acceleration due to gravity, i.e. a_{ref} = 9.8 x10^{-6} m s^{-2}. For velocity a_{ref} is taken as 5x10^{-8} ms^{-1}.

Ground Based Noise:

Noise generation could also be ground based due to various vibrations, most common of which are movement of trains on railway tracks, and the houses close to the track feel such vibrations whenever a train passes by. Vehicles, trains, speeding large trucks, pile driving, large rotating mechanical devices, jets flying close overheads etc. are all capable of generating ground vibrations and noise. Such activities are capable of exciting the ground and generate waves that propagate through the soil and reach to the foundations of nearby buildings, causing shaking and vibrations. A normally attentive person can feel the vibrations to the threshold of 65VdB[143]. The normal frequency range of most ground-borne vibrations that can be felt by a normally attentive person varies from less than 1 Hz to ~200 Hz. High-frequency vibrations tend to dissipate rapidly as compared to a low frequency vibrations. Therefore, in the far field it is the low frequencies that tend to dominate. Vibration in buildings is typically perceived as rattling of windows or doors or the motion of building surfaces. Sonic booms can generate rumbling noises. The vibration of building surfaces is also capable of being radiated as sound and can be heard as a low-frequency rumbling noise, which is known as ground-borne noise[144].

9.7.6 VIBRATIONAL SAFETY STANDARDS

Noise traveling through the air has been coded into standards in the country, and the topic was discussed at the beginning of this Chapter. Noise travelling through ground in form of vibrations still does not seem to be coded well in India. Activities such as movement of railways, heavy roadways, construction piling activities, large mechanical/ electro-mechanical rotating devices, such as pumps and rotors, blasting/ mining area activities, flights taking off in airport areas etc. cause ground based noise or vibrations during the activity period. Several cities abroad have already carried out studies to quantify such noises and prescribe Peak Particle Velocity (PPV) in mm s^{-1} limits for all such noise induced vibrations. A fit person can perceive 0.25 mm s^{-1} PPV motion or vibration if it is continuous (as in case of Baghjan which is a continuous event).

143 Zaheer Akhtar S, Power, 30-04-2018, https://www.powermag.com/basics-of-sound-and-noise-propagation/

144 Pittsburg City, Chapter 13: Noise and Vibration, Energy Infrastructure Project, Report, July, 2013

A PPV value of 2.5 m s^{-1} is strongly perceptible[145]. As per ISO 2631-1:1997, the threshold acceleration for an average alert and fit person to recognize the vibration is 0.015 m s^{-2} (ranging from 0.01 to 0.02 m s^{-2}) or 84 dB [*re* 10^{-6} *m* s^{-2}]. From 0.02 to 0.08 m s^{-2} it is easily perceptible, 0.08-0.135 m s^{-2}, the vibration is strongly perceptible, and for values >0.315 m s^{-2}, its extremely perceptible[146].

Building Safety Standards:

Ground borne noise vibration allowed for buildings of different types largely depend upon the nature/ utility of building and the frequency at which the vibration is taking place. As per the German Standards DIN 4150-3:1986[147], the PPV values at various frequency levels of various house types are given in table below[148]:-

Table No. 9.4: Prescribed PPV for Building Safety

Building Type	Prescribed PPV (mm s^{-1})	Frequency (Hz)
Commercial	20	f ⩽ 10
	40	10 < f ⩽ 50
	50	500 < f ⩽ 100
Dwellings	5	f ⩽ 10
	15	10 < f ⩽ 50
	20	500 < f ⩽ 100
Sensitive/ Weak	3	f ⩽ 10
	8	10 < f ⩽ 50
	10	500 < f ⩽ 100

As per Swiss Standards SN 640312A-1992[149], the PPV based vibrational threshold limits for various types of buildings at various frequencies are given as below:-

Building Class	Type of Structures
I	Industrial reinforced concrete and steel buildings and structures
II	Buildings with concrete foundations and floors. Underground structures
III	Buildings with concrete foundations and basement floor, wooden floors and brickwork walls
IV	Buildings sensitive to vibrations or requiring protection

Fig No. 9.3 A: Building Classes & Types of Structures

Fig

Building Class	Frequency Hz	Vibration Limits mm/s
I	10 - 60 60 - 90	30 30-40
II	10 - 60 60 - 90	18 18-25
III	10 - 60 60 - 90	12 12-18
IV	10 - 60 60 - 90	8 8-12

Fig. No. 9.3 B: Max Allowed PPV

145 Chung Tung-Chan, LSA Associates, Appendix G, Groundborne vibrational impact analysis, Shea Baker Ranch project, City Lake Forest, California, 2011

146 Asmussen Bernd, International Union of Railways (UIC), RIVAS Project, 2011

147 https://codehub.building.govt.nz/home/resources/din-4150-31986/

148 Svinkin Mark, ISSMGE, Proc. 19th Conf. SMGE, Seol, 2017

149 https://infostore.saiglobal.com/en-us/standards/sn-640312a-1992-1046645_saig_snv_snv_2439388/

As these values are frequency dependent, some countries do not permit frequencies beyond 0.5 to 80 Hz, some even permit 0.5 to 160 Hz. Some countries rely on velocity, and others on acceleration.

9.7.7 Ground Motion due to TNT Equivalent Blasts

[*The methodology presented here is taken exclusively from the US DoD Report No. UFC 3-340-02.*] Due to explosions near the ground surface, energy released from the blast gets transferred to the ground surface directly or through air induced ground shocks. These events cause stress pulses to be pushed into the ground media (rock, dry soil, wet saturated soil or loose matrix). The interactions are complex and need to be determined based on actual ground configuration. However, subject to certain broad assumptions, it can be said that close to the blast scene, the shock front moves at velocities higher than the seismic wave, and thus, reaches faster. However, as the shock moves further and loses energy, the seismic wave takes over. These waves and shocks cause the ground media to vibrate imparting it vertical and horizontal displacement, velocity and acceleration. Some of these empirical relationships are listed here and shall be used to study the ground movement, shocks and vibrations possibly caused by the Baghjan blowout. It is to be emphasized, once again, here that the actual values of these physical quantities cannot be arrived at without ground based soil tests and geotechnical surveys on one hand, and establishing the vibrational characteristics of the various structures (buildings, bridges, roads, factories etc.) situated on the ground. As of now, these are taken to be beyond the scope of the One Man Enquiry Committee. It would suffice to establish by the underlying methodologies described hereunder, in short though, that a positive relationship exists between the ground shaking and structural vibrations felt by the residents of Baghjan and other surrounding areas, and the Baghjan Well fire raging at Well No. BGN#5. The reason for saying so is that M/S OIL had prepared two EIA Reports one in 2009 and another in 2019, and none of these Reports even mention the possible shocks and ground motions and seismic vibrations that could result from a blowout. Thus, these EIA reports are to be discounted on these grounds, as none of the experts or consultants could even faintly predict the disaster called “Baghjan Blow Out”; and that it would take more than three months even to take the least control of the situation, thus, putting not only the adjoining population to the brink of survival pushed by not one, not two, not three, but four disasters one after the other (Blow out tragedy, explosion followed by fire, ground shakes and terrible noise, 3 rounds of floods and all wrapped up in the world wide pandemic called COVID19), but also smashed the ecology of the Motapung Maguri Beel and adversely impacting the

Dibru-Saikhowa National Park. The words “wave”, “shock”, “ground motion” etc. do not either feature in the two EIA Reports or have passing remarks of little consequence or for historical reference only.

The various equations to work out the vertical and horizontal movements in relation to the ground based and air induced vibrations and shocks are given below:-

$$V_V = \frac{P_{SO}}{\rho C_p} \quad \text{..... } Eq.No. \text{ 9.34}$$

$$D_V = \frac{i_s}{1000} \rho C_p \quad \text{..... } Eq.No. \text{ 9.35}$$

$$A_V = \frac{100 P_{SO}}{1000 \rho C_p g} \quad \text{..... } Eq.No. \text{ 9.36}$$

$$D_H = D_V \tan\left[\sin^{-1}\left(\frac{C_p}{12000\,U}\right)\right] \quad \text{..... } Eq.No. \text{ 9.37}$$

$$V_H = V_V \tan\left[\sin^{-1}\left(\frac{C_p}{12000\,U}\right)\right] \quad \text{..... } Eq.No. \text{ 9.38}$$

$$A_H = A_V \tan\left[\sin^{-1}\left(\frac{C_p}{12000\,U}\right)\right] \quad \text{..... } Eq.No. \text{ 9.39}$$

where D, V and A stand for displacement, velocity and acceleration, and the subscript V for vertical and H for horizontal components, g stands for acceleration due to gravity (32.2 ft s^{-2}), C_p stands for compression wave seismic velocity in the soil and the mass density of soil. All above relationships are meant for air induced shocks, meaning the shock event happens in the air.

For the ground induced motions, i.e. shock events occurring at ground level, the above relationships are given by:-

$$D_V = \frac{0.025\, R_G^{\frac{1}{3}} W^{\frac{1}{3}}}{Z_G^{\frac{1}{3}}} \quad \text{(rock media)} \quad \text{..... } Eq.No. \text{ 9.40}$$

$$D_H = 0.5\, D_V \quad \text{..... } Eq.No. \text{ 9.41}$$

$$D_V = \frac{0.17\, R_G^{\frac{1}{3}} W^{\frac{1}{3}}}{Z_G^{2.3}} \quad \text{(dry or saturated soil)} \quad \text{..... } Eq.No. \text{ 9.42}$$

$$D_H = D_V \quad \text{..... } Eq.No. \text{ 9.43}$$

$$V_V = \frac{150}{Z_G^{1.5}} \quad \text{(all ground media)} \qquad \text{..... } Eq.No.\ 9.44$$

$$V_H = V_V \qquad \text{..... } Eq.No.\ 9.45$$

$$A_V = \frac{10000}{W^{\frac{1}{3}} Z_G^2} \qquad \text{..... } Eq.No.\ 9.46$$

$$A_H = 0.5\ A_V \ \text{(dry soil)} \qquad \text{..... } Eq.No.\ 9.47$$

$$A_H = V_H \ \text{(wet soil or rock)} \qquad \text{..... } Eq.No.\ 9.48$$

where all symbols have usual meaning already explained above and the previous paragraphs. For air blast induced shocks, the arrival time at a point of interest on the ground is given by t_A. The arrival time for direct ground induced shock is given by

$$t_{AG} = \frac{12000\ R_G}{C_p} \qquad \text{..... } Eq.No.\ 9.49$$

9.7.8 SHOCK RESPONSE SPECTRA

As already stated, this para is also based on the US DoD Report UFC 3-340-02. The shock response spectrum is built on the simple linear oscillator having its natural frequency f. The load deflection of the structure (say a building) is measured in terms of maximum response to the incoming shock in terms of displacement (D), velocity (V) and acceleration (A). These are called spectrum displacement, spectrum-pseudo velocity and spectrum acceleration. The Spectrum pseudo velocity V and acceleration wrt D are given by

$$V = 2 \bullet \pi \bullet f \bullet D \qquad \text{..... } Eq.No.\ 9.50$$

$$A = \frac{(2\pi f)^2 D\, g}{387} \qquad \text{..... } Eq.No.\ 9.51$$

9.7.9 VIBRATION MEASUREMENTS BY CSIR NEIST

CSIR-NEIST, Jorhat, on request of the Hon'ble Chief Minister, Assam and also M/S OIL India set up 5 nos of 3D Boradband Seismographs (Nanomatrics Trillium 3D Seismometer with Raftek GPS and Datalogger) at Limbuguri (BJN1), Dhelakhat TE (BJN2), Barekuri PS (BJN3), Baghjan EPS (BJN4) and Baghjan Blowout Site (BJN5). They also installed one Strong Motion Accelerograph (SMA) to study the peak Ground Acceleration (PGA) at the BJN4 site. The logged data is collected from time to time and analyzed. In addition, the NEIST also carried out geophysical investigation in terms of ground

electric resistivity, magnetic declination, and other electromagnetic characteristics around the site to find out if any major deformity in the ground configuration could have happened due to the blow out and explosion. The seismograph data is generated on daily basis. They also used InSAR data 4th and 16th June, 2020 of SENTINEL to study surface deformity.

This way regular waveform generated by the blow out site and other small earthquakes were captured. Amplitude (log) vs frequency plots, Power Spectral Density (PSD) plots were generated. Further, magnetic field declination measurements in decimal degrees from 1st January to 1st July, 2020 were obtained/ measured for the areas surrounding the blow out site to see if there were any abnormal changes in the magnetic declination around the blow out site. [However, as full report was not made available to the author, it has not been discussed any further in this Report.]

9.7.10 Other Measurements

Among other measurement, the author of this Report used Android Mobile App, in absence of any other stratagem, called "Vibrometer" from Exa Tools. It has the capability to measure the strength of vibration, quakes, earthquakes, volcanoes, vibrations of the human body or any other objects around such as mechanical or electrical devices. The App uses Instrumental Intensity Scale (developed by the USGS) which maps Peak Ground Acceleration (PGA) and peak ground velocity on an intensity scale similar to the felt Mercalli Scale[150]. These values can be used to create shake maps.

9.8 Analysing The Noise Pollution Data-sets

The largest number of data sets was created, among all measurements done on the Baghjan fire, around noise. However, before we come to the actual noise data analysis, it would be worth while to look at the baselines available.

9.8.1 Baseline Data

Baseline Noise Levels 2009-10: The first EIA Report submitted by the Gauhati University team records Ambient Noise levels at 8 recording stations at Tinsukia (Railway Station), Makum (Roadside), Mahakali (Roadside), Duliajan (Roadside), Itakhuli (Roadside), Chota Hapjan (Roadside), Bar Hapjan (Roadside), Hansara (Railway Station). The highest values during day time range from 68 to 94 dBA, and at night time from 52 to 83. Therefore, it is obvious that all measured values appear to be already breaching the prescribed noise limits under the law, even before the project started. **Therefore,**

150 https://en.wikipedia.org/wiki/Modified_Mercalli_intensity_scale

there is actually very little that we can blame M/S OIL India for any higher noise levels. However, there are two basic faults with this EIA in respect of ambient quality noise. Firstly, all the stations that were chosen fell in noisy areas such as roadside and railway stations. Secondly, no station was set up in rural or quiet urban areas. Hence, the data levels for ambient noise are not comparable at all with the site conditions.

Baseline Noise Levels 2017: The second EIA by M/S ERM for OIL India carried out a set of 5 monitoring stations near Baghjan in residential areas, and hence merits consideration here. The stations were Dighatarrang No2, Baghjangaon No.2, Baghjangaon No1, Dighaltarrang No.3, and Diamuligaon No.7. The noise levels measured during daytime varied from 53.3 to 57.2 dBA and those for night time from 41.9 to 44.3 dBA. The EIA report also says that daytime noise level for all, except Baghjan No.1 and night time for all villages were compliant to the prescribed noise levels. The Baghjangaon No. 1 was at 57.2 dBA during daytime. It may be noted here that the BGN#5 was drilled for the first time in 2007, a workover was carried out in March, 2015; and the well went for production from September, 2015. [*Therefore, noise standards were already breached by the industrial activities, but no cognizance was taken by any authority. This clearly shows what level of concern we have for our environmental laws and the compliance thereof.*]

9.8.2 Assessment of Noise During Blowout

Ambient Noise Levels during the Blow Out: The number of noise readings taken at various points from the date of the explosion on the 9th June, 2020 till 28th July, 2020 were considered for this purpose were found to be more than 1000 observations by various agencies. Using the principle of maxima for the day (24 hours) and the distance, a subset of 446 readings from various organizations such as PCBA (21), TERI (106), MSKPL (28), ERM (29+19=48)[151], OIL Daily Reportings (156), WII (13), AMTRON (10), Expert Committee Teams (49), Theoretical values from conjecture (14) were only used for this study. As expected, date had no impact on the noise [meaning noise from the fire was behaving almost in the same fashion all throughout (except certain events that occurred in between for a while)]. A 2D scatter plot of date vs noise level was examined to see if the noise had any pattern. The fig shown below clearly demonstrated that not only the observations were equally “noisy” but also the pattern was mostly uniform on all days as expected.

151 ERM had 29 field observations and 19 calculated theoretical values

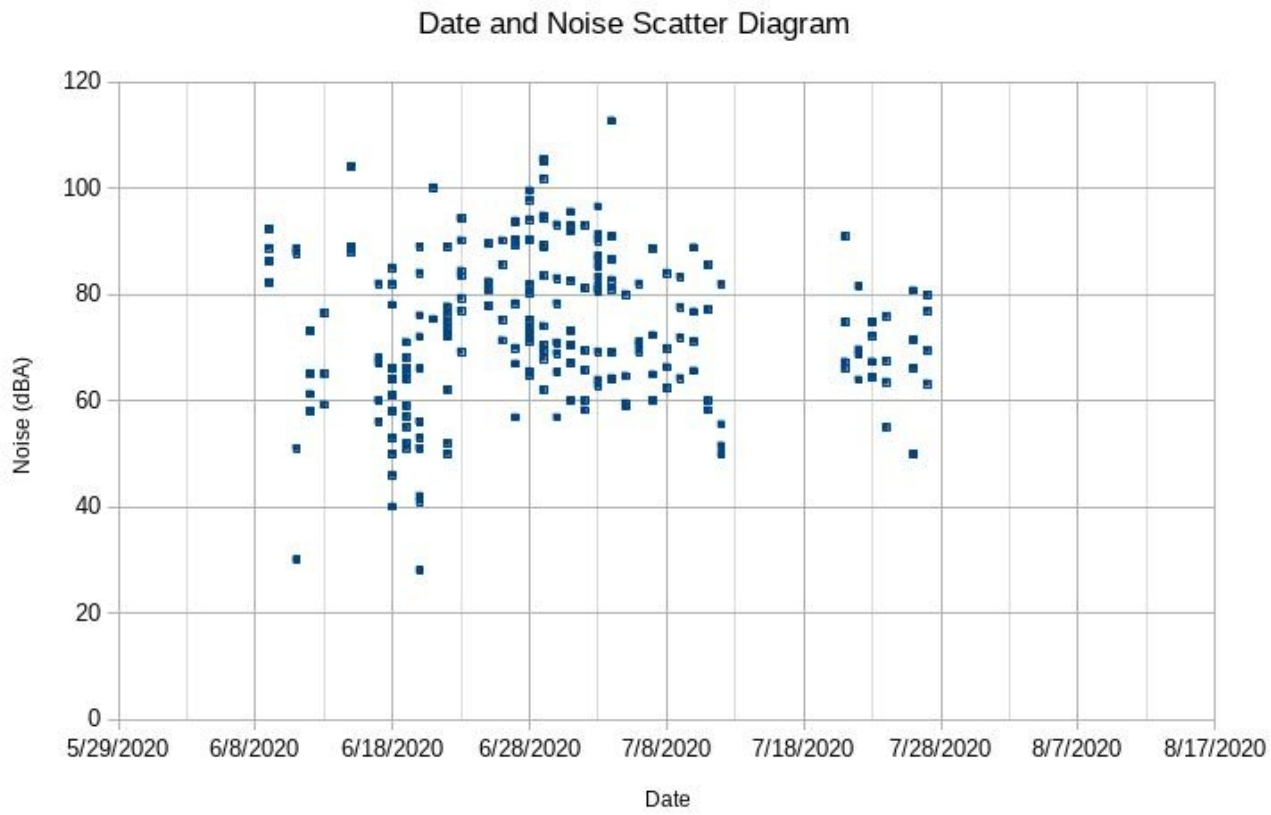
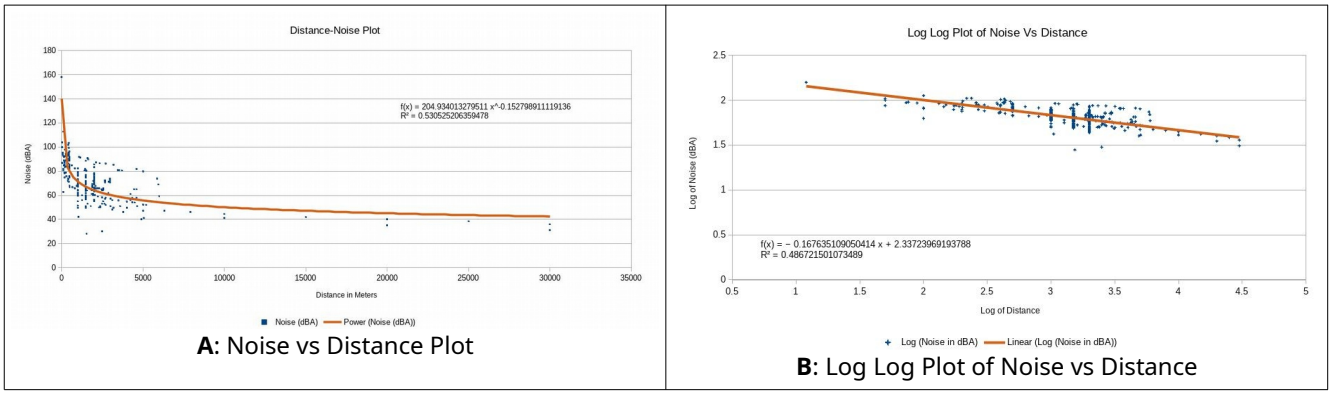


Fig. No. 9.4: Scatter Diagram of Noise Levels at Baghjan wrt Date

However, scatter plot of distance and noise level and scatter of their logs showed a definite trend. The two diagrams are depicted below:-



A: Noise vs Distance Plot

B: Log Log Plot of Noise vs Distance

Fig. No. 9.5: Best Fit for Noise Levels and Distance from Blowout Site

The power equation fit showed higher coefficient of correlation (R=0.72837) than the log-log plot (R=0.69765). The power equation ($Y=AX^B$) best fit appears to be more apt here, and is approximately given as:

$$Y = 204.934\ X^{(-0.1528)} \qquad \ldots\ldots\ Eq.No.\ 9.52$$

where Y is the Noise (dBA) from the flame at a distance of X in meters. The mean, say at 2500m from the flame comes to 64.15 dBA, but the measurements vary from 28-90.88

dBA with 81 measurements in all having been considered. Nevertheless, the data was classified in various classes, and the computed statistics is given below along with derived noise values:-

Table No. 9.5: Noise Data Statistics wrt Distance Classes

Class	$\bar{x}$	N	μ_0	Y_{min}	Y_{max}	SD	N-D	AD t	Fit	Th
0-100	50	11	97.27	62.8	160	24.08	Y	6.82	112.72	109
100-300	200	26	88.57	75	105.3	7.78	Y	47.01	91.20	102.98
300-500	400	55	85.86	67	103.22	8.22	Y	26.63	82.04	96.96
600-1300	950	92	67.77	42	91.94	7.99	Y	5.51	71.88	89.45
1300-1700	1500	90	62.80	28	90.88	10.18	Y	3.86	67.04	85.49
1800-2100	1950	94	59.53	43.5	85.6	10.66	Y	0.01	64.40	83.20
2100-2400	2250	10	64.58	50	87.28	13.5	Y	9.02	60	81.96
1700-2400	2050	104	59.85	43.5	87.28	11	Y	0.01	63.91	82.77
2400-3000	2700	26	61.38	30	86.48	10.73	Y	16.44	61.28	80.38
3000-5000	4000	26	60.09	40	85.98	13.17	Y	0.06	57.71	76.97
5000-8000	6500	7	55.51	41	74	12.38	Y	52.4	53.58	73.74
10-30 Km	20000	8	38.49	31	44.48	4.33	Y	91.05	45.12	62.98
1800-8000	4900	163	59.06	30	87.28	11.36	Y	0.01	55.94	75.20
1800-5000	3400	156	60.32	30	87.28	11.36	Y	0.01	59.16	78.38

The symbols used in the table above are explained below:-

Table No. 9.6: Symbols Used in Table 9.5

Symbol	Meaning	Symbol	Meaning
$\bar{x}$	Class Mid Value (for Distance in m)	**SD**	Standard Deviation in the Class
N	Sample population falling in the Class	**N-D**	Whether Normal Distribution?
μ_0	Mean Noise Value of the Class (dBA) from sampled data	**AD t**	Anderson-Darling Normality Test Statistic (in %)
Y_{min}	Minimum Noise Value of the Class (dBA) from sampled data	**Fit**	Value of Noise in DBA Class Mid value from the Best Fit eqn.
Y_{max}	Maximum Noise Value of the Class (dBA) from sampled data	**Th**	Theoretical value of noise (Free Field) in dB at Class Mid Value

9.8.3 Analysis of Noise Data

Analysis of the Noise Data: The table above is an attempt to analyze the data in terms of distance and noise value and the amount of spread involved in the data. Some of the stark conclusions drawn from the above table are presented below:-

1. While the free field dB value (**Th**) is quite high for a given distance (from a given $\mathbf{Y_{min}}$ value), but it is seen that till 8 km, it is lower than the observed highest value ($\mathbf{Y_{max}}$) for any given distance.
2. The best fit arrived from the noise data tells that the the noise becomes "normal" at 10 km distance (assuming that 50 dBA is acceptable noise level), but the free field noise gets to 50 dB level at almost 85 km distance from the well. However, the common experience is that about 50 dB noise is audible at 25 km distance. If one takes it as most genuine representation of far field noise, then (assuming that the noise level would rise by 6dB for every reduction in distance), the noise at almost 0 distance at the well comes to ~158 dB.
3. The observed noise data between 1800-8000 km is having the poorest AD test score (%) of 0.01, and, thus, becomes unreliable.

9.8.4 Breach or No Breach?

In respect of noise, there are a host of measurements, theoretical predictions and ad hoc measurements. When all data is plotted and a best fit obtained, it is found that the power correlation equation is the best fit. From the best fit equation, the various distances and prescribed sound limit breaches are shown below:-

Table No. 9.7: NAAQS Noise Level and Breach Distance

Sl. No.	NAAQS Noise Level (dBA)	Minimum Distance from Blowout Site (Km)	Remarks
1.	55	5.5	Residential day time limit
2.	50	10.22	ESZ/ Silent zone day time
3.	45	20.50	Residential Night time
4.	40	44.10	ESZ/ Silent zone night time

The Table above shows that the flame had impacted sound levels to as far distances as 44 km from the blast site, if one considers the silence zone at night time. However, if one considers the residential day time noise levels, the impact was limited to 5.5 km only. Therefore, there are five different levels of breach in case of sound pollution:-

1. Residential day time limit of 55 dBA was breached upto a distance of 5.5 km from the blowout site
2. Residential night time limit of 45 dBA was breached upto a distance of 20.5 km from the blowout site
3. For schools and hospitals, the silence zone day time limit of 50 dBA was breached upto a distance of 10.22 km from the blowout site
4. For schools and hospitals, the silence zone night time limit of 40 dBA was breached upto a distance of 44.10 km from the blowout site
5. For the ESZ and Dibru-Saikhowa National Park and Bherjan Borajan Padumoni WLS, the limits of silence zone at night levels were breached fully.

In addition to the above, the sound level was in itself more than 75 dbA within the industrial limits. Therefore, it can be said that while the workmen belonged to M/s OIL directly or indirectly, everyone working at the site including all officials, personnel, contractors, researchers, security personnel and others who were exposed to the noise within 720 m of the blowout site had all the while experienced breach of prescribed sound levels. All people in the vicinity of the blowout site from 9th June, 2020 till the time the flame is extinguished are victims/ have been victims of acute noise pollution. Ear plugs were offered to VVIPs, security and OIL personnel only.

9.9 Noise Spectra And Dominant Frequencies

The noise spectra over 1 to 20 k Hz was mapped on several occasions. Due to several difficulties, the monitoring could not be done constantly. However, snapshots were taken at various times. A set of Charts is included in the Plate that follows. Certain observations have been drawn and are briefly presented here.

9.9.1 The General nature of Noise

The charts (shown a few pages after) below clearly show that almost all frequencies are present from 1 to 20000 Hz. This implies that the noise was of broadband nature as theoretically expected. Therefore, the flame noise can be termed as **Broadband Noise**. However, it is seen that the nature of the spectrum seems to change at various times,

and it is not constant. The flame is not vibrating at a single constant frequency, rather it is an ensemble of frequencies bundled together.

9.9.2 Dominant Frequencies

The charts show instantaneous peaks and their corresponding dB levels. The instantaneous spectrum is shown in green line. The red line above is accumulation of the peaked dB values at the spectrum frequencies upto the point of instantaneous spectrum. The cumulative spectrum is shown in red line. The cumulative spectrum would depend upon the total length for which spectra was recorded. Though the noise is broadband, there are distinct 6 bands, in which there are definite patterns. The bands are briefly described below.

1-20 Hz: This band is considered infrasound, and is generally not audible to humans. There is a distinct footprint of the flame in this band. There are occasional peaks around 7-20 Hz, centering around 10Hz. Thereafter from 7 Hz to 3 Hz the same dB level continues in a flat manner, or sometimes rising and sometimes falling. This band is significant as the infrasound has tendency to get carried away by ground and water, and it may suffer attenuation and/ or magnification in speed depending upon the medium, its density and other prevailing conditions.

60-215 Hz: This is a low frequency band, and is seen to peak around 100 Hz. Some of the frequencies showing peak in this band are: 64, 67, 78, 96, 100, 113, 159, 164, 173, 205, 213 Hz. The flame has been mostly well represented centering this band in the entire range of 1-20K Hz. Therefore, 100-200 Hz can be safely treated as peak frequency for the original flame of the Baghjan. [Two basic changes have happened since 9th June, 2020. The original orifice which blew out was shut with a BOP on 17th August, 2020, and the flame was diverted to a nearby site. Then, again the mechanical flow arrangements were changed on the 13th September, 2020 and the pressure was reduced from likely 4000 psi to 2000 psi, and part of the fluid was sent to production.] The characteristic peak of the flame noise was lost after these operations, as can be seen in some of the spectra after 17th August, 2020. It can be assumed that the flame was radiating 3-4 m sound wave originally.

400-600 Hz: There have been small peaks around 400-600 Hz mostly appearing as doublets/ triplets, but not dominating, except in a few instances.

800-2500 Hz; In the range of 800-2500 Hz, it is seen that there has been mostly a peak around either 1000Hz or 2000 Hz. This is also the band in which most animals are found to communicate.

6000-8000 Hz: The sound of the flame has also a small peak around 7000 Hz and seem to be between 6K to 8K Hz. This is a single and sharp peak in most of the spectra. Thereafter, at 10000 Hz, the dB level drops invariably. The 7000 Hz peak, though small, seem to dominate in the later spectra.

10 K – 20 K Hz: The flame has a typical well separated doublet between 10K-20K in most of the spectra. This characteristic is seen to be lost in the later spectra. Only in one of the new spectra, a small peak at 20K Hz is seen.

9.9.3 CHANGES IN THE NOISE PATTERN:

Technically, the displaced source of the flame is having two burners, one with 4 nozzles and the other with 3 nozzles, as shown below in the image. This is in quite contrast to the 20 cm outer orifice of the blow out.

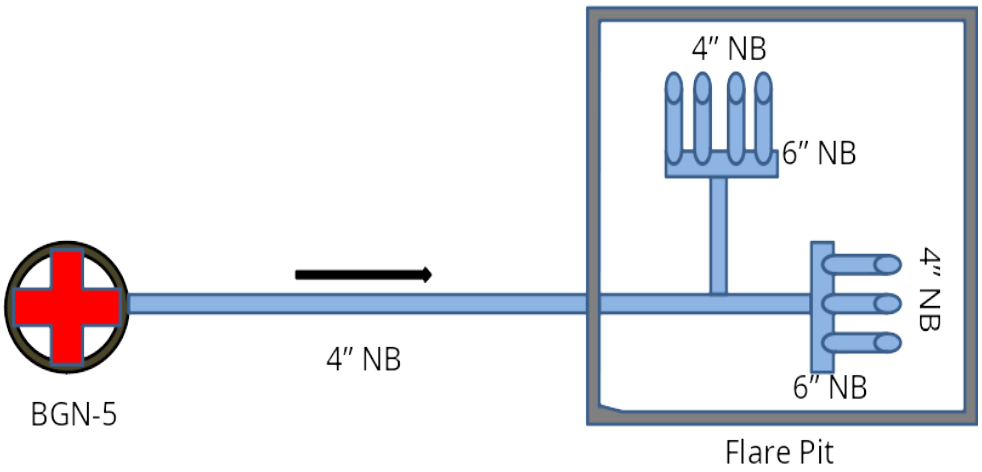


Fig. No. 9.6: Schematic of Diversion of Fluid from BGN#5 to Flare Pit

This arrangement visually presents two flames, one tall and another short (almost half the size of the taller one) very close to each other. However, in the acoustic domain, because of two sources (we can call it burners, actually) close by, [as technically there are two noise sources] but unequal in mass flow rates. A rough estimate showed that the shorter flame is about 25m tall, and the longer one about 50 m. [*These are only initial estimates, and no detailed measurements have been taken*]. This has, in all probability, led to flattening of the spectrum from 50 Hz to 7000 Hz. It implies that all frequencies are equally represented in the noise emitted, and thus, the noise has increased. It could be more painful to the ear.

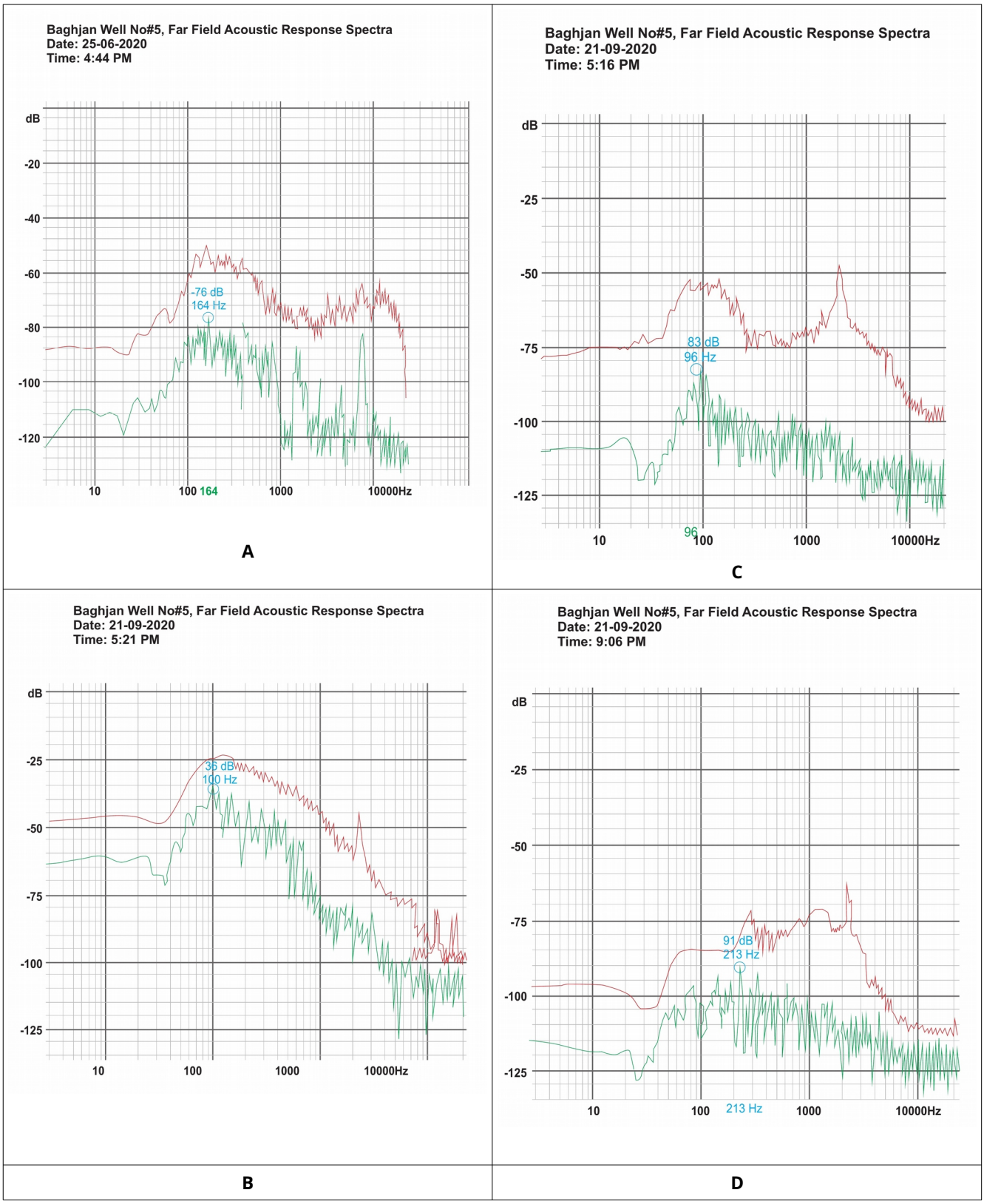


Fig. No. 9.7-1: Noise Frequency Spectra of Baghjan Flame

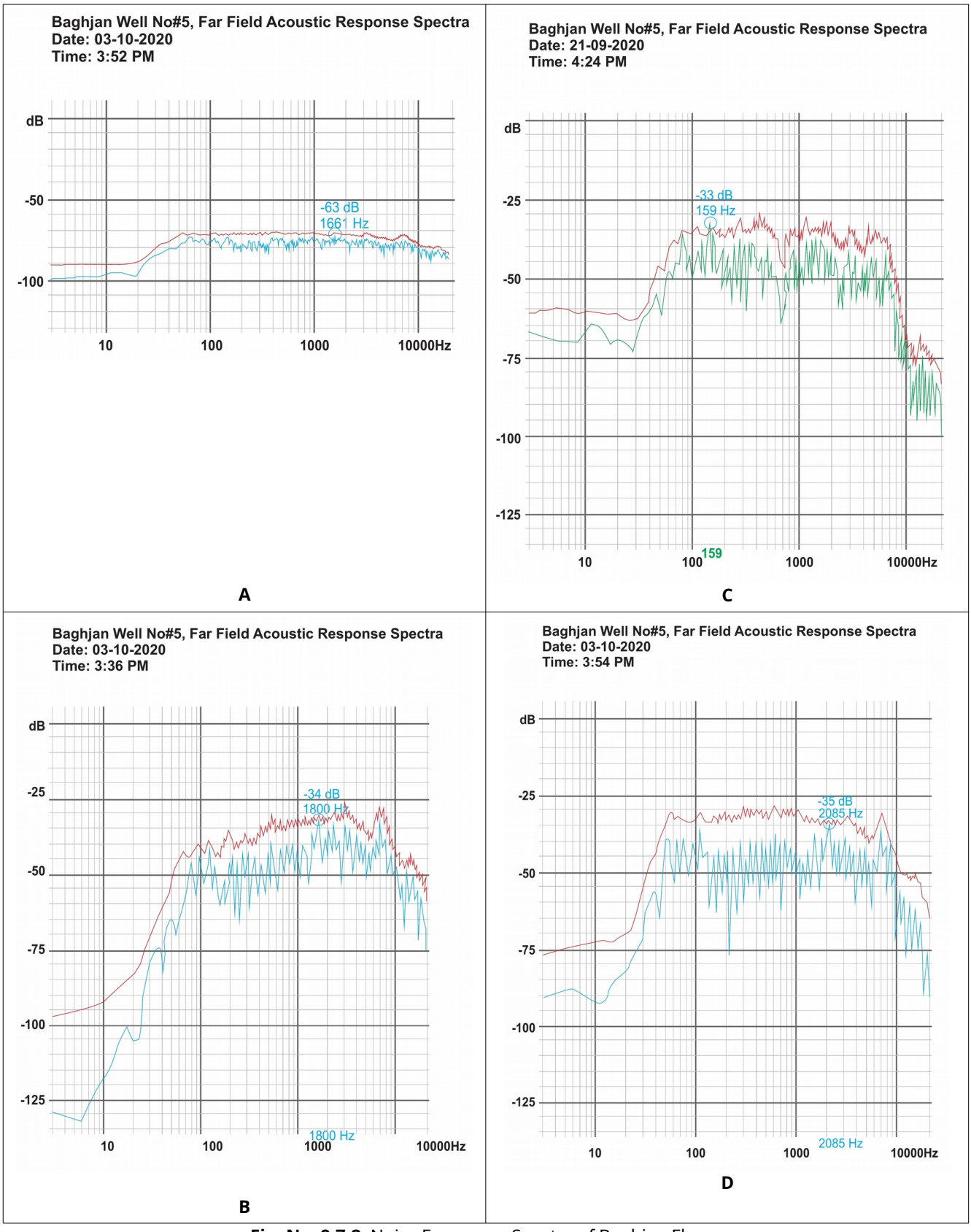


Fig. No. 9.7-2: Noise Frequency Spectra of Baghjan Flame

9.10 Ground Vibrations

At the outset, let us examine the impact of the explosion that occurred on the 9th June, 2020 at 1.30 PM. As already estimated, the yield of the explosion is 0.833 kT of TNT. We shall first examine the equivalent seismic magnitude, and thereafter the peak particle velocity. Thereafter, assuming that the fuel that is flowing out of the burner also is kind of an explosion, we shall work out the parameters accordingly as above when the flame was burning.

9.10.1 Seismic Magnitudes

In the methodology section, two empirical equations were referred to estimate seismic magnitudes of explosions. In both the cases the yields are in TNT equivalents. From the 1st equation we get

$$M_N = \frac{2}{3} \times \log_{10} \frac{M_{TNT}}{M_T} + 6 \qquad \text{..... } Eq.No.\ 9.53$$

Putting the values of M_{TNT} = 0.833x10^{-6}T, we get M_N = 3.855 ≅ 3.9

The second relationship is given by:

$$m_b = 3.92 + 0.81 \times \log (Y, kT) \qquad \text{..... } Eq.No.\ 9.54$$

Putting Y=0.833, we get m_b = 3.94 ≅ 3.9

Thus, from both the models we get that the explosion caused possibly seismic activity of magnitude 3.9 on Richter Scale.

9.10.2 Particle Velocities

Following Kohler & Fuis (1992), the velocities for dry alluvium, wet alluvium and water body have been worked out below. Here, the TNT equivalent has been converted to Amino Nitrate equivalent as:

$$0.833 \text{ kT TNT} \cong 2082500 \text{ Kg AN Eqv} \qquad \text{..... } Eq.No.\ 9.55$$

The particle velocities in the soil/ground have been worked out for a few distances from the blowout site:-

Table No. 9.8: Ground Particle Velocities due to Vibrations Induced by Baghjan Explosion (25 km)

Distance (Km)	V (cm/s) Dry Alluvium	V (cm/s) Wet Alluvium	V (cm/s) Water body
1	1.95	8.0	8.95
2	0.4	1.7	1.9

Distance (Km)	V (cm/s) Dry Alluvium	V (cm/s) Wet Alluvium	V (cm/s) Water body
5	0.07	0.27	0.3
10	0.02	0.08	0.09
20	0.007	0.028	0.031
25	0.005	0.021	0.023

Since the soil was wet due to rains, the vibrations might have been felt upto at least 20-25 km from the blast site. A person can perceive ground vibration of magnitude 0.025 cm/s as already stated in the Methodology section.

9.10.3 Seismic magnitude and Velocity Due to The Flame

As explained earlier the mass flow rate of the flame at Baghjan has been estimated on average at 343.50 Kg/s and could also peak to 492 Kg/s at times. Assuming that once in a while about 500 Kg fuel could burn, this would amount to a pulse of explosion once in a while. 500 Kg of fuel would amount to causing a minor seismic activity of 1.29 magnitude on Richter Scale. AN Equivalent of the fuel would be 14307.5 Kg of AN. The ground velocities would be such as:

Table No. 9.9: Ground Particle Velocities due to Vibrations Induced by Baghjan Flame (5 km)

Distance (Km)	V (cm/s) Dry Alluvium	V (cm/s) Wet Alluvium	V (cm/s) Water body
0.5	0.87	3.59	4.0
1	0.16	0.65	0.72
2	0.033	0.135	0.15
3	0.01	0.058	0.065
5	0.005	0.022	0.024

It can be expected that there could be possibly minor explosions of 1.30 magnitude or more, and could cause perceptible ground vibrations even beyond 3-5 km of the explosion site.

9.10.4 Shock Response

Assuming that the velocities described in the previous two sub sections are pseudo velocities, let's work out the displacement and acceleration in the ground based on the two relationships given in the methodology section:-

$$D = V / 2 \times \pi \times f \quad \& \qquad \ldots\ldots Eq.No.\ 9.56$$

$$a = 2 \times \pi \times f \times V \qquad \ldots\ldots Eq.No.\ 9.57$$

It shall be assumed that there are objects on the ground such as houses and other structures having their natural frequencies 1 to 10 Hz. We shall take 3 representative frequencies namely 1, 5 & 10 Hz.

Table No. 9.10: Possible Displacement & Acceleration Impact on Structures

F (Hz)	A G & D	V (cm/s)					
		9	5	2	0.5	0.25	0.025
1	A	56.55	31.42	12.57	3.14	1.57	0.157
	G	0.058	0.032	0.013	0.0032	0.0016	0.00016
	D	1.43	0.80	0.32	0.08	0.04	0.004
5	A	282.74	157.08	62.83	15.71	7.85	0.79
	G	0.29	0.16	0.064	0.016	0.008	0.0008
	D	0.29	0.16	0.064	0.016	0.008	0.0008
10	A	565.49	314.16	125.66	31.42	15.71	1.57
	G	0.58	0.32	0.13	0.032	0.016	0.0016
	D	0.14	0.08	0.032	0.008	0.004	0.0004

[A is acceleration in cm/s^2, G is g value (=980 cm/s^2), D is displacement in cm]

The velocities represent the possible ground velocities generated due to the explosion and the perturbations in the fire from time to time, and normally could be 0.5 to 0.025 cm/s. Since the most probable natural frequencies are as above represented, and the fact that the ground motions get amplified upto 5 times, most of the vibrations would be felt by humans. Human beings can feel upto 0.001g. A force of 0.001g would feel like 0.005g.

9.10.5 Possible Vibrations from The Flame Acoustics in the Air

As we have already seen that the Acoustic Power of the flame comes to 160 dB or 10kW. This could be assumed to be vibrating as a point source at about 54 m high in the air. The pressure so created would be traveling to the ground. Part of the wave would get reflected, while part would penetrate the ground and travel.

Speed of Sound: Given the ground soil properties, as per EIA-ERM (2019), we can assume its bulk density (ρ) to be 1100 kg m^{-3}. We can also assume its bulk modulus (B) to be about 10 MPa. The speed of sound in such a medium is given by:-

$$v_g = \sqrt{\frac{B}{\rho}} \quad \text{..... } Eq.No.\ 9.58$$

Therefore, the speed of sound would be 95 m s^{-1} in the ground.

Sound Pressure: At 160 dB, it can be easily found that the sound pressure from the relationship:

$$L_P = 20 \times \log_{10}\left(\frac{P}{P_{Ref}}\right) \quad \text{..... } Eq.No.\ 9.59$$

where P_{Ref} is $2x10^{-5}$ Pa, and L_P = 160 dB. P turns out to be 2000 Pa.

Particle Velocity: Now, assuming that higher frequencies get reflected or attenuated faster in a denser medium, the sound frequencies 1-100 Hz would be able to penetrate ground and travel. While the wave velocity would be about 95 m/s, the frequency would remain the same, the wavelength would get shortened. The acoustic wave would impart a certain amount of particle velocity depending upon the pressure its carrying. The particle velocity and wave velocity relationship is given by

$$U = \frac{P}{\rho . v_g} \quad \text{..... } Eq.No.\ 9.60$$

Where P=2000 Pa, ρ=1100 kg m^{-3}, V_g = 95 ms^{-1}. This gives the value of particle velocity U=1.91 cm/s ~ 2.00 cm/s. We have already calculated the displacement and acceleration associated with 2 cm/s velocity at 1, 5 & 10 Hz in the previous sub section. These are reproduced here:-

Table No. 9.11: Possible Displacement & Acceleration Caused by the Baghjan Flame

Frequency (Hz)	Acceleration (cm/s)	Acceleration (g)	Displacement (cm)
1	12.57	0.013	0.32
5	62.03	0.064	0.064
10	125.66	0.13	0.032

Thus, it can be seen that the acceleration values of g are 13 to 100 times more than the minimum g value that humans can perceive, i.e. 0.001g. Therefore, the flame sitting at 54 m at 10kW is in itself a source of acoustic vibration that is capable of causing 0.013 to 0.13g acceleration in the ground.

9.10.6 Breach or No breach?

As of now, there does not seem to be any regulation that bans or limits ground motion/ vibration beyond certain limits or their impact on buildings beyond a point from

activities such as pile driving, large mechanical vibrations etc. This, however, as seen in the Methodology section, has been encoded in various laws and by-laws is some of the countries abroad. **Hence, no breach in India**.

9.10.7 COMMENTS ON THE IIT GUWAHATI REPORT

The findings as discussed above differ considerably from the report of IIT Guwahati. The findings/ conclusions of the IIT Guwahati in respect of noise and vibration emanating from the flame have not been accepted here. The findings of the IIT Guwahati in respect of vibrations are "*For, all the investigated structures, the time period will be below 5 s and natural frequency will be in well below 20 Hz. As the sound frequency from the gas blow out is much higher than the natural frequency of the structure, the resonance of the structure is not possible. Therefore, we conclude that the sound pressure intensities from the gas blowout has no significant influence on formation of cracks in the buildings.*" The natural period of the building were proposed to be worked out using the expression:-

$$T_a = \frac{0.09 \times h}{\sqrt{d}} \qquad \text{..... } Eq.No.\ 9.69$$

where Ta is the period of vibration of the building, h is the height of the building and d is the base dimension of the building at the plinth level along direction of the earthquake shaking. This is as per the IS 1893 (Part I) 2016 Code. However, there are no actual calculations of period of any building in the report of IIT Guwahati.

A Critical Assessment of the Report: The period of buildings have been assumed to be below 5 s, which, actually, is very high for the Baghjan and surrounding areas. As already stated, building in Guwahati, till 2008 had periods higher than 1 sec. The buildings in Baghjan area typically would be in 0.2-0.05 s period. The natural frequencies of the buildings could be between 5 to 20 Hz, and not 0.2 Hz (for a time period of 5 s or slightly lower). Secondly, the peak frequencies as can be discerned with ocular estimates from the frequency graphs of the IIT Guwahati report seem to be 220, 300, 340, 400, 550, 700, 1350, 1750, 3400, 4400 Hz. However, the spectra also show that the nature of the sound is broadband, and sound waves seen to be generated at or below 25 Hz with about values as high 30-55 as can be seen from the Table below constructed from the IIT Guwahati Report. This implies that the sound pressure at the origin (blowout site) could have been as much as the values estimated in Chapter 7. A few points alo tally with the predicted SPL values in the far field and direct field. [See Table 7.7]. Therefore, it can be said that the observations/ recordings of the sound levels are in agreement with the predictions made in Chapter 7.

Table No 9.12: Sound Levels Measured by IIT Guwahati

IIT G Sl. No.	Distance from Site (m)	SPL (dBA)	dBA @ 25 Hz
14	200	103.6	~ 55
17	550	76.8	~50
19	900	71	40
23	1700	87	~58
4	3000	46	30

What is amiss in the IIT Guwahati Report: The Report does not predict the possible acoustic power of the flame, i.e. how much noise the flame is creating near ground zero. This estimation would surely have led to possibilities of vibration from the fire. Secondly, taking the natural period of the building structures to be below 5 s, the frequencies point to about 0.2 Hz. The experts should have attempted to use equipment to measure infrasound (0-25 Hz). This should have been a more appropriate experiment to carry out if one is talking of vibrations and sonic booms. Thirdly, the sound levels at 10-25 Hz, as per the Report itself are higher than the levels beyond 16000 Hz. These levels are almost at half mark of the peak SPL as can be seen in the Table above. Thirdly, somewhere the fact that higher frequencies would get reflected back and only the lower frequencies would penetrate ground and water, has been grossly missed by the IIT Guwahati expert team. It is the attenuation of these lower frequencies that could cause possible vibrations as is the case for most of vibrating mechanical devices. Fourthly, if there are no regular seismic activities or any other source of vibrations such as fighter jets flying over Baghjan all the time, then why such vibrations were observed only around Baghjan, and nowhere else, say in Guwahati or Bongaigaon? Therefore, the report did not address the primary cause of the vibration and just said that "*sound frequency from the gas blow out is much higher than the natural frequency of the structure*", which is not completely a correct statement. The problem is that it is the peak frequency which is 10-100 times higher than the natural frequency of the buildings, but the spectrum also contains infrasound.

9.11 Conclusions

1. There is a breach in respect of permissible limits of noise in residential, industrial and silence zone during day and night. There is a violation of the various prescribed levels of noise pollution under the Environment (Protection) Act, 1986

and Environment (Protection) Rules, 1986.

2. The people affected from the noise are spread in a radius of 20-40 km of the blast site, but persons residing within 5 km radius have been acutely affected as the noise levels were more than 55 dBA on 24x7 basis.

3. Similarly, all those who worked or lived within 700m of the blowout site, were exposed to extreme noise of more than 75 dBA. These are all breaches of the permissible limits under the EPA, 1986.

4. The acoustic spectra of the noise emanating from the flame was examined. It was found that noise can be characterized as "Broadband Noise" radiating at almost all frequencies from 1 Hz to 20000 Hz.

5. The peak acoustic frequency was found centered around 100-200 Hz in the undisturbed flame at the original BGN#5 oil well site.

6. The characteristics of the sound and pressure levels of the emitted frequencies changed considerably after the new arrangement towards the end of September, 2020 till date. The acoustic radiation is almost equal in all frequencies from 50-7000 Hz.

7. It was estimated that the explosion on the 9th June, 2020 at 1.30 PM was 3.9 on Richter Scale. It caused vibrations in the ground that would have been felt upto 25 km from the blast site.

8. There are possibilities of some small explosions happening in the flame itself due to severe turbulence, and these could be of the order of 1.3 magnitude, and vibrations could be perceived even beyond 3-5 km distance from the blowout site.

9. All ground structures having natural frequencies from 1 to 10 Hz would resonate, as the low frequency waves would be travelling without much attenuation in the ground (and water).

10. The acoustic impact of the flame, assuming 160 dB power in the flame, on triggering ground vibrations was also examined. It was found that the acoustic power of the flame was capable of causing, independently of other factors, a velocity of 2 cm/s. This ground wave, while interacting with objects having natural frequencies 1-10 Hz could cause accelerations from 0.013g to 0.13g which are almost 10-100 more than the minimum of acceleration that a human being can detect, i.e. 0.001g.

11. As regard the various vibrations caused by the flame because of the large amount of fuel that it engulfs every second on 24X7 basis, and because of the inherent turbulence and noise that it creates thereon, the flame by its very nature generates ground waves in infrasound range (1-20 Hz). These frequencies match with the objects on the ground having natural frequencies in the similar range. This causes resonance resulting in vibrations in houses and dwelling units and other infrastructure, causing rattling sound to even cracking of walls, ceilings and floors. Since the vibrations could vary from 0.013g to 0.13g, these are strong enough to cause even difficulty in standing.

12. There are currently no prescribed limits of maximum permissible ground motion or vibration due to human induced factors such as pile driving, running of trains, heavy vehicle movement on the road, large mechanical rotating devices or even fire such as at Baghjan. Therefore, no breach. However, people affected may be awarded compensation for the damages caused to their properties. There is a need, as some other countries have done, to bring prescribed limits to ground vibrations in the environmental laws of the country.

13. The findings of IIT Guwahati in respect of vibration and noise have not been considered in this Report.

CHAPTER 10

10 THERMAL POLLUTION

10.1 Recapitulating The Findings So Far

So far upto the previous Chapter, all investigations possible, theoretically, using empirical relationships, have been completed. At this point, almost all variable required for the further enquiry have been frozen. Most importantly, the variation in the flame heights observed from time to time, has led to unearthing of all the associated parameters of the flame such as mass (fuel) flow velocities, turbulence, Heat Release Rates, Acoustic Powers of the flames, combustion characteristics based on fuels spewed from the well, stoichiometric burning of the fuel and associated emissions of pollutants and estimation of their quantities, levels of sound pollution, possible causes of vibrations and tremors and their estimated impacts on structures nearby, Power of the Flame and estimation of its radiative power called Radiant Heat Flux are the parameters estimated so far. Since most of these quantities are instantaneous (associated with the instant of photography of the flame), a lot of variation has been observed in these parameters, as already shown in the Chapter 9. However, in order to carry forward the damage assessment further, mean quantities, or maximum probable quantities shall be assumed. These quantities, in their mean or maxima, may be questioned or that questions may be raised about the adequacy of number of samples (say flame photography) taken. In this regard, it can only be said that these samples are well spread in the time space and are a good approximation of the facts and figures presented so far; and the empirical relationships used are based on the study of a large number of research papers/ publications. All throughout, a high level of scientific temper has been maintained while "unearthing" the mysteries of the fire purely based on empirical evidences and theoretical constructs.

Armed with considerable number of facts, figures and circumstantial evidences, now we can proceed to assess the thermal pollution. However, this Chapter is limited to the methodology deployed and the outcome of the assessment of the heat radiation in terms of its origin and spread and its validation by some measurements. In course of discussion, some parameters may have to be revisited.

10.2 Thermal Pollution: Context Explanation

Thermal pollution is normally defined as change in the temperature of a water body due to discharge of hot (or even very cold) waters/ liquids (or other substances) into the water body that alters the normal temperature of the water. This phenomenon is generally known as thermal water pollution, and we shall be covering the same in the next chapter.

Thermal pollution in the ambient air is scarcely studied, and no literature worth citing could be found other than thermodynamics text books and plethora of literature abuzz about "waste heat" or what we call the 2nd Law of Thermodynamics or even the much debated word "Entropy" coined by Rudolf Clausius in 1865. Though this Chapter is not meant for discussing change of entropy caused by the Baghjan Well fire since 9th June, 2020 (till 15th November, 2020), an attempt shall be taken towards the end of this Chapter to quantify ΔS i.e. how much "waste heat" has the well fire pumped into the surroundings, and whether its worth taking a note of. However, the key focus of this Chapter shall remain on heat generation and radiation and its impact on the surroundings. The principle of black body radiation would be also invoked along with the basics of heat and entropy.

Though the phrase "Thermal Pollution" in the literature means largely thermal pollution of water bodies, the word here has been used to mean "heat pollution" in the surrounding air, and its possible impact when such large quantities of heat would dissipate in the surroundings. Possibly, in literature, so far such a pollution has not been looked at only because we probably consider the atmospheric as a sink which is infinite in its capacity to absorb waste heat. If the fundamental principle of science that energy cannot be created, nor can it be destroyed, only it gets transformed from one form to another is considered to hold good, then, we must surely worry as to what could happen if large quantities of heat get pumped into the surroundings. This Chapter has been deliberately named as "Thermal Pollution" to focus on "thermal" or "heat" part of the pollution on "land", and not "thermal pollution" in "water".

10.3 Thermal Pollution And Law

Currently there is no law in India (and most other countries) that bars any entity or industry to pump quantities of heat below a given limit into the atmosphere. To givea hypothetical example:- if one were to light 100 such fires, as the Baghjan fire at Well No. 5, in the neighbourhood, and if these could be silenced by some "silencer mechanism" [to avoid any sound pollution] and if by some stratagem no house is burnt and nobody

dies, then, no crime would be committed, and no law would be breached, unless the water temperature in a surrounding lake rises by at least 5^0C.

Therefore, the Baghjan fire per se at Well No. 5 does not breach any law for pumping huge quantities of heat into the surroundings. This is the irony of our environmental laws.

10.4 Radiation

Heat radiation has been looked at here from three angles:

Black Body Radiation:

According to the Stefan Boltzmann Law, a body at temperature T would be radiating heat energy into the surroundings at a rate given by:-

$$\frac{P}{A} = \epsilon \sigma T^4 \qquad \text{..... } Eq.No.\ 10.1$$

where P is the radiating power in Watts (Joules m^{-1}). Temperature of the body is expressed always in Kelvin. The equation has already been used in Para 6.5.1.

The Entropy and Waste Heat:

If a system is at temperature T_{sys}, and throws ΔQ amount of heat into the surroundings at T_{surr} (< T_{sys}), then, the change in entropy of the system & surroundings are given by:

$$\Delta S_{sys} = \frac{-\Delta Q}{T_{sys}}$$

$$\Delta S_{surr} = \frac{\Delta Q}{T_{surr}} \qquad \text{..... } Eq.No.\ 10.2$$

$$\Delta S_{Total} = \Delta S_{Sys} + \Delta S_{Surr}$$

The entropy change in the surroundings is the waste heat, the non productive heat that dissipates into the surroundings. For a flame, ΔQ can be assessed from its Hear Release Rate, $\dot{Q}$. For a turbulent flame, ΔS would be changing constantly, as the $\dot{Q}$ would be fluctuating very frequently.

Absorption of Heat by nearby bodies:

If a body at temperature T_1 absorbs ΔQ amount of heat, its temperature would rise, by ΔT to T_2, which would be given by the relationship:-

$$\Delta T = \Delta Q / C_p \qquad \text{..... } Eq.No.\ 10.3$$

$$T_2 = T_1 + \Delta Q / C_p \qquad \text{..... } Eq.No.\ 10.4$$

However, it has to be noted that a body which would absorb heat at T_1 to reach to T_2, would also radiate heat at a higher rate at T_2 to become cooler, as a black body. However, the cycle of heating and cooling may produce thermal stress in the body.

10.5 Ill Effects Of Exposure To Heat Radiation

Some ill effects on human beings are illustrated here[152]:-

- Increased irritability.
- Loss of concentration and ability to do mental tasks.
- Loss of ability to do skilled tasks or heavy work.

Illnesses caused by Heat Exposure:-

- **Heat edema** is swelling which generally occurs among people who are not acclimatized to working in hot conditions. Swelling is often most noticeable in the ankles. Recovery occurs after a day or two in a cool environment.

- **Heat rashes** are tiny red spots on the skin which cause a prickling sensation during heat exposure. The spots are the result of inflammation caused when the ducts of sweat glands become plugged.

- **Heat cramps** are sharp pain in the muscles that may occur alone or be combined with one of the other heat stress disorders. The cause is salt imbalance resulting from the failure to replace salt lost with sweat. Cramps most often occur when people drink large amounts of water without sufficient salt (electrolyte) replacement.

- **Heat exhaustion** is caused by loss of body water and salt through excessive sweating. Signs and symptoms of heat exhaustion include: heavy sweating, weakness, dizziness, visual disturbances, intense thirst, nausea, headache, vomiting, diarrhea, muscle cramps, breathlessness, palpitations, tingling and numbness of the hands and feet. Recovery occurs after resting in a cool area and consuming cool drinks (e.g., water, clear juice, or a sports drink).

- **Heat syncope** is heat-induced dizziness and fainting induced by temporarily insufficient flow of blood to the brain while a person is standing. It occurs mostly

152 https://www.ccohs.ca/oshanswers/phys_agents/heat_health.html

among un-acclimatized people. It is caused by the loss of body fluids through sweating, and by lowered blood pressure due to pooling of blood in the legs. Recovery is rapid after rest in a cool area.

- **Heat stroke** is the most serious type of heat illness. Signs of heat stroke include body temperature often greater than 41°C, and complete or partial loss of consciousness. Sweating is not a good sign of heat stress as there are two types of heat stroke - "classical" where there is little or no sweating (usually occurs in children, persons who are chronically ill, and the elderly), and "exertional" where body temperature rises because of strenuous exercise or work and sweating is usually present. Heat stroke requires immediate first aid and medical attention. Delayed treatment may result in death.

10.6 Basics Of Thermal Radiation And Plant Life

Trees have two major components because of which we understand the form of a tree namely trunk and the leaves. Trunks not only provide the structural support that is needed to hold the food manufacturing assembly (i.e. the leaves), but also pass on water and nutrients from the soil through the root system to the leaves, and act as transportation channel and storage media for the food that is manufactured by the leaves. The leaves, on the other hand, carry out three principal functions: firstly the manufacture of simple C3 or C4 sugars by fixing atmospheric CO_2 through a mechanism of photosynthesis (about this, we shall be going in some more details subsequently), converting the simple sugars to complex carbohydrates such as glucose, starch and cellulose, and thirdly carrying out respiration (the process of breaking the sugars such as glucose and releasing energy required to carry out growth and repair works in the cells where mitochondria executes the process) and transpiration (the process of perspiration by plants by which they lose water through the stomata). Ambient air temperature impacts all these processes. While each of these phenomena are complex, a simple understanding is proposed to be developed here as to what could be the impact of heat on the plants and trees. However, before we do that, a basic definition of a few words and phrases is needed.

10.6.1 Key Thermal properties

There are a few of the thermal properties that we need to understand. When the plant is impacted with heat exposure from the surroundings, these parameters work in various directions and bring about a thermal equilibrium. If the plant can tolerate it, it

may survive with some injuries or damages or may die or even burn up. The discussion here has largely been borrowed from Jayalakshmi & Philip (2010)[153].

Thermal Conductivity: It is the ability of a material to transfer or conduct heat. It is denoted by Greek letter k, K or λ. The inverse of thermal conductivity is the thermal resistivity. Materials with low value of λ act as thermal insulators. The thermal conductivity follows Fourier's Law of Thermal conduction i.e. *the rate of transfer of heat ($\dot{Q}_c$) through a material is proportional to the negative of the temperature gradient (ΔT), to the area (A) through which the heat flows, and inversely proportional to the thickness of the material (Δx)*. Mathematically, it can be denoted as[154]:

$$\dot{Q}_c = \lambda A \frac{\Delta T}{\Delta x} \quad \text{..... } Eq.No.\ 10.5$$

Thermal resistivity or impedance is the inverse of thermal conductivity λ. The unit of thermal conductivity is W m^{-1} K^{-1}.

Volumetric Heat Capacity: This quantity is density (ρ, kg m^{-3}) times specific heat capacity at constant pressure (C_P, J kg^{-1} K^{-1}) of a material. It has units of J m^{-3} K^{-1}. It can be written as ρC_P.

Thermal Diffusivity: Thermal diffusivity denotes the speed or rate at which heat energy spreads through a material. It is denoted by α , and has the unit of m^2 s^{-1}. It is given by the following relationship with thermal conductivity and volumetric heat capacity:-

$$\alpha = \frac{\lambda}{\rho C_P} \quad \text{..... } Eq.No.\ 10.6$$

It is a bulk property of matter. It provides valuable information about the property of the material in which thermal conduction and storage of heat compete for each other[155]. It denotes the speed to reach thermal equilibrium under variable thermal conditions.

Thermal Effusivity: Thermal effusivity is a measure of ability of a material to exchange heat or thermal energy with its surroundings. It is denoted by *e*, and has the units of W $s^{1/2}$ m^{-2} K^{-1}. It is given by:

$$e = \sqrt{\lambda \rho C_P} \quad \text{..... } Eq.No.\ 10.7$$

153 Jayalakshmi M.S, Philip J., 2010, Int J Thermophys (2010) 31:2295–2304, DOI 10.1007/s10765-010-0877-7

154 Cengel Y. A. & Boles A, Thermodynamics, An Engineering approach, 7th Edition, Tata Mc Graw Hill, 2011

155 Dante Robert, 2016, Chapter 9, Metals, https://doi.org/10.1016/B978-0-08-100619-1.00009-2, Handbook of Friction Materials and their Applications, Woodhead Publishing, 2016

Effusivity is a surface property. The value of the thermal effusivity for a material determines the time taken by the material, if heated to a given temperature, to reach thermal equilibrium with the surroundings. If the material has lower value of the thermal effusivity, its surface temperature would be higher compared to another material having higher effusivity. Thus, a material with a low thermal effusivity, if immersed in an environment of a given temperature, it would take a longer time to reach the temperature of the surrounding environment compared to another material with a high thermal effusivity immersed in the same environment. Thermal effusivity explains as to why when we touch a metal piece it seems colder than other bodies at the same temperature. This is because the heat transfer from the skin to the metal is very fast. Metals such as copper, iron and aluminum have high effusivity. While diffusivity is related to heat penetration within the material, effusivity is related to surface heat exchange. Another example to understand effusivity, is frictional heat generation. During friction a lot of heat is created at the interface, and this heat must be dissipated; thus the most effective friction material is that which can dissipate more heat without raising its own temperature.

Measuring Thermal Properties of Plants: Thermal properties such as conductivity, diffusivity or effusivity of plant materials such as leaves are very difficult to measure as because the process involves heating and in the process the samples get damaged. According to Jayalakshmi & Philip (2010), very few direct measurements of thermal properties such as conductivity and specific heat are available in literature. There lies the challenge in understanding interaction of plants and trees with heat radiation. The authors have used photopyro electric (PPE) techniques to estimate these quantities.

10.6.2 Interaction of Leaves with external heat

Plants interact with external heat by way of:- 1. Conduction and convection with the air in immediate surrounding, 2. Heat loss due to transpiration in form of latent heat, and 3. Radiative heat loss. Specific heat capacity is one fundamental thermal property which tells a lot about thermal interactions. According to Jayalakshmi & Philip (2010), leaves have C_P values close to that of water (4186 J kg^{-1} K^{-1}) and range for fresh leaves varies from 1287 – 2267 J kg^{-1} K^{-1} and for dry leaves varies from 1514 – 5174 J kg^{-1} K^{-1}. In general, it is found that the value of C_P increases for dry leaves for most species, but may decrease for some. On the other hand, thermal conductivity of leaves is much less than that of water (=0.60 W m^{-1} K^{-1}), and seem to range from 0.20 – 0.50 W m^{-1} K^{-1}. As regards thermal effusivity, the value for water is 1600 W $s^{1/2}$ m^{-2} K^{-1}, while that for plant

leaves is 600 – 750 W $s^{1/2}$ m^{-2} K^{-1} which is less than half the value of water. Similarly, as regards the thermal diffusivity, its value for water is 0.14 m^2 s^{-1}, and that for plant leaves varies from 0.12 – 0.58 m^2 s^{-1}.

As can be understood from the parameters above, the specific heat of plants is very high, and this implies that the plant community can absorb a lot of heat and still remain cool, or there is very little change in their own temperature. It is just like water, in character, in trapping heat. There is another significance of very low thermal effusivity of the leaves. Water surface would lose heat much faster, and sand surface a little slower (e=1400 W $s^{1/2}$ m^{-2} K^{-1}). However, the leaves would release the heat at almost half of that rate. This implies that leaves of plants and trees act as large heat sinks (just as chunks of metal used in electronics & sea and sand, in general, are the biggest heat sinks in nature), and, thus, can effectively regulate temperature in the surroundings. This is how plants keep their surroundings cool. It can be said that tree canopies are like naturally built elevated sea water tanks to absorb heat radiation from the surroundings. [*This is how one can calculate the cost of damages from heat radiation to flora & also fauna*]. However, plants have to pay a heavy price if the quantity of heat is very high, such as in case of Baghjan fire, or the temperatures in the surroundings go beyond the optimal growing temperature. This part shall be discussed subsequently in a more appropriate section of this Chapter.

10.6.3 Tree trunks and Thermal radiation

The discourse here is based largely on the research publications of Derby & Gates (1966)[156], Nicolai (1986)[157], and Vines (1968)[158]. The temperature of a tree trunk is very important as it influences the physiological processes of the tree and influences the microclimate for many microflora, microfauna, insects, lizards, parasites, anthropods, spiders, psocoptera (bark lice), hemiptera (plant bugs), coleoptera (beetles), diptera (flies) and many other species, together with influences on their life cycle, eggs, larvae, young ones and the entire food web built around the tree trunk. Not only this, but also, it is to be noted that the tree trunk surface provides the requisite space for pairing, mating, resting ground, wintering, hunting, competitions for mates etc. A study by Nicolai (1989)[159] dwells on tree bark fauna relationships in African ecosystems. It is the tree trunk temperature that would play a crucial role in these activities of the communities dependent and resident upon it. Trunk temperature is largely dependent

156 Derby R. W, & Gates D. M, 1966, Amer. J. Bot. 53(6): 580-587. 1966.
157 Nicolai Volker, Oecologia (Berlin) , 1986, 69: 148-160
158 Vines R.G. Aust. J. Bot, 1968, 16, 499-514
159 Nicolai Volker, Oecologia (1989) 80:421~430

upon air temperature, wind speed, solar radiation (short wave), reflected radiation (long wave), other thermal radiation sources such as fires in the vicinity, heat islands etc. Therefore, the temperatures of the surrounding objects dictate the trunk temperature.

While the tree trunk external surface which largely consists of bark would respond most immediately to the external temperature changes, the cambium responds rather slowly. Several studies have been undertaken to understand the response of the trunk to external temperature. These studies are largely computer based models of the tree trunk as a heterogeneous and anisotropic (say varying properties along radial and axial directions) object. Derby & Gates (1966) studied the temperature variations by dividing the trunk into 12 radial sections and 5 concentric rings giving 60 elements. They worked out the following equation to study the temperature rise in each of the sections:-

$$T_i = F_a T_{i-1} + F_b T_{i+1} + F_c T_{i-12} + F_d T_{i+12} + F_e T_i \quad \text{..... } Eq.No.\ 10.8$$

where F's are constants derived for each element, and the subscript a denotes "from i-1 to i, b "from i+1 to i", c "from i-9 to i", d "from i+12 to i" and e "from i to i i.e. current element". The study found a gradient of almost 13^0C from the core of the cambium to the surface, temperature increasing from the core to the bark. Vines (1968) also found that when the tree trunk gets heated, the cambium temperature does not increase at once. It is the bark that responds first and the response time depends upon the bark thickness. For example, Vines found by experiment that a bark of quarter inch thickness took just 4 min to reach a temperature of 40^0C, when heated, and the bark with one inch thickness took 19 min.

The study found that the bark behaviour is almost independent of the tree species. Nicolai (1986) measured global radiation in 300-3000 nm range, and studied the response of the tree bark and cambium. He divided the barks into four different types for the study:- smooth, white, fissured & scaly. He found that temperature of small plant parts such as leaves was tightly coupled to air temperature due to large convective heat transfer coefficients. On the other hand, the temperature of large parts of a plant such as tree trunk (and also large leaves) may be quite at variance with air temperature, especially when wind speeds are low, in a strong radiation field, as they have small convective heat transfer coefficients. He generated curves of the global radiation as well as bark surface and cambial temperatures. These charts show that these temperatures are likely to shoot up to 30-40^0C during peak insolation. The charts for the 4 types of the bark studies are produced below:-

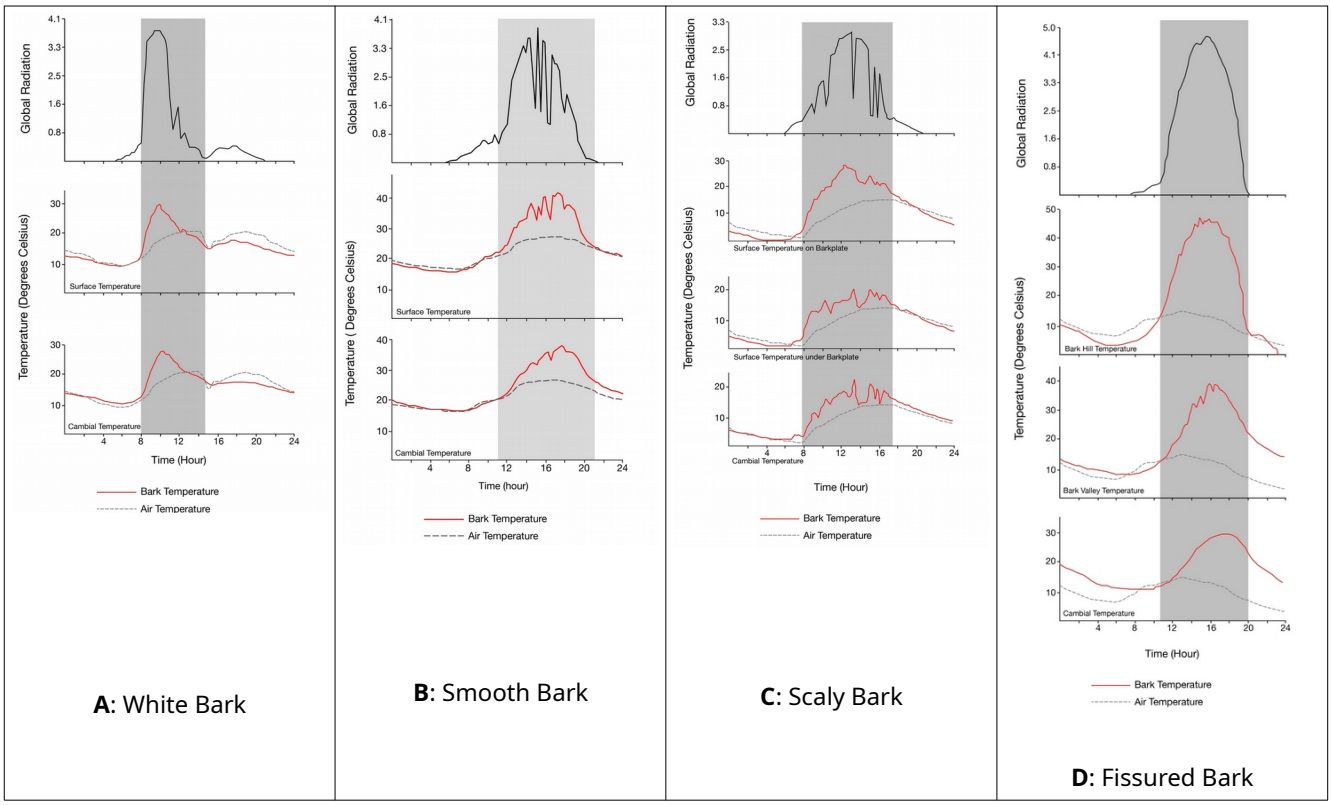


Fig. No. 10.1: Impact of Heat Radiation on Bark & Cambium

The study of Nicolai (1986) shows clearly that there is considerable impact of radiation on the bark surface and cambial temperature. Vines (1968) also demonstrated that thermal diffusivity of bark can be taken approximately at a constant value of ~0.13x10^{-6} m^2 s^{-1}, and it is largely independent of temperature and appears to remain same across all types of barks. Therefore, barks can be treated as slabs of uniform thickness subject to a constant heat flux. The temperature rise is related to $\frac{\dot{Q}}{\alpha}$. This factor for the Baghjan flame at a distance of 1000m from the flame would work out to be 2.5 [GW m^{-4} s] for an average heat flux of 0.33 kW m^{-2}. However, the author of this Report does not want to divert to heat transport phenomenon, as no field experiments were conducted in this respect. ***It suffices to conclude here that the tree canopies and the tree trunks behave differently to the bombardment of heat radiation, and the tree trunks are more vulnerable to heat shocks, and so are the faunal diversity dependent upon the tree bark ecosystem***.

10.7 Methodology

Heat measurements and assessment of radiation from the flame were carried out by only a few agencies. These are AMTRON, IIT Guwahati and ERM. In all, three broad type of measurements were done. These are described briefly below along with associated theoretical background, in brief, as applicable.

10.7.1 Flame Temperature Measurements

Flame temperature measurements/ studies were only done by AMTRON. They used Testo885 Thermal Imaging Camera temperature range -30^0-1200^{0}C, spectral range 7.5-14 µm, pixel resolution 320x240, thermal sensitivity <30 mK @ +30^{0}C, and measurement accuracy ±2^{0}C. Vertical and horizontal sectional temperature profile of the flame were drawn to see the minima and maxima at various points in the flame, and also to identify hot and cold zones. Thermal photographs of the flame were also taken from various angles. However, as there were objects in the surround of the flame, most thermal photographs were criss-crossed with "cool" lines from objects between the flame and the lens.

10.7.2 Temperature Profile of Surrounding Objects

AMTRON used NUTEC Fever Block to capture thermal profiles of objects, especially the vegetation (in absence of any better equipment at that point of time). When the Testo885 arrived, floods started, and photographs of surrounding objects/vegetation could not be taken, as it became difficult to approach the National Park and other sites. Of course, in a "Wet UMBRELLA" experiment, a black wet umbrella was kept positioned facing the flame site (from the National Park side) to see the impact of the incoming hot winds on the umbrella surface, and how fast it dried. Experiments were also done by measuring body temperature of a person facing the hot draft of air on the National Park side.

The IIT Guwahati used a camera similar to that used by AMTRON, but lower in temperature range, -20^0 to +650^{0}C. Rest of the parameters of the camera are almost same as that of AMTRON thermal camera (as is evident from the IIT Guwahati Report). IIT Guwahati carried out thermal scanning of the wall, housing structures and associated objects to find out the range of temperatures to which these objects got heated. The study by IIT Guwahati was conducted from 16th to 21st July, 2020.

10.7.3 Empirical Assessment

M/S EMR carried out ALOHA simulation (see Para 7.2.9) to arrive at the radiative power of the flame. The OMEC also carried out ALOHA simulation which is also presented in the Para 7.2.9, and shall not be repeated here. However, these are part of the methodology to assess heat radiation from the flame. Based on the the Power of the flame, radiated power at any point away from the flame, based on the Inverse Square Law, was computed. These findings have already been presented in Para 7.2.9.

10.7.4 Breach or No breach?

The issue of breach of any provision under law for radiated power does not arise, as there is no provision of law that radiated power (heat) beyond a limit is punishable. Therefore, **NO BREACH BY *M/S OIL INDIA LTD***.

10.7.5 If No Breach, Then Why This Chapter?

This Chapter has been purposefully inserted to highlight the gap in the existing environmental legal framework. The laws are mostly based on visible and immediately quantifiable quantities/damages. Radiation of heat does not fall in this category, unless it causes death due to burn injury or blisters at a close encounter. Waste heat emerges out of the Second Law of Thermodynamics, and has remained very tightly coupled with "Efficiency" of systems. Now, there are several studies, numbering almost 1000, pertaining to the South Asian urban settlements of "Urban Heat Island Effect"[160]. The purpose here is not to review UHI effect, but stress on the fact that local and rural heat island has been created by the Baghjan fire for past several months on 24X7 basis. Therefore, waste heat matters, it has negative impacts on health and air quality, and waste heat is a form of pollution (but actually not recognized legally). If heat islands are created, either localized (say between rows of buildings where the air conditioners are spewing hot aid blasts during office hours) or within a city limit or in any rural landscape, then it is surely a case of heat pollution.

Breach or no breach in respect of creating a Local Landscape Level Heat Island (3LHI) in the surrounds of the Baghjan fire shall be dwelt upon, even though there is no legal bar on it. This assessment shall be based on the measurements and thermal images available from the field measurements by AMTRON and IIT.

10.8 The IIT Report On Thermal Imaging Of Structures

The IIT Guwahati was entrusted by M/S OIL to investigate whether the fire by way of sound or heat caused any sonic booms or caused such vibrations that might have led to observations of shaking of ground and appearance of cracks in building structures/ houses in the nearby areas. To test the hypothesis, the experts of IIT Guwahati conducted thermal imaging of house structures, especially the damaged parts such as cracks etc, and carried out thermal imaging of some affected structures. In a 120 page long report covering sound and heat, the experts of IIT Guwahati opined that "*Based on thermal maps, we conclude that there is no significant effect of fire in blow out well in*

160 Kotharkar R, Ramesh A, Bagade A, Urban Island heat Studies in South Asia: A Critical Review, Urban Climate (2018), https://doi.org/10.1016/j.uclim.2017.12.006

Baghjan well 5 on the formation of crack in structures". The conclusion of IIT Guwahati has been contested here, as because the premise of the conclusion or the starting hypothesis appears questionable. The focus of the expert team of IIT Guwahati would have been on thermal and sonic properties of the flame, and whether the flame was capable of causing such vibrations and sonic boom that could shake the ground and cause cracks in walls, ceilings and floors of houses in the surrounding areas, as a vibrating thermo-mechanical device. The IIT experts should have looked at the thermal properties of the flame (for it is the flame's thermal properties that would cause sound and vibrations, as has been established in detail in the previous Chapter of this Report). The thermal maps of the houses definitely would not tell the story of vibration and sonic booms. The highest observed temperature was 41.3^0C in the IIT Report. In order to have thermal vibration effects, according to the IIT Guwahati experts, the temperature of the walls, floors and ceilings should be atleast 140^0C, and concrete would not yield below 400^0C. The question that one needs to ask is what are the conditions under which a dwelling house can attain temperatures ranging from 140^0-400^0C? Surely, there is only one answer- *the house is on fire*!!! Therefore, the IIT Guwahati Expert team was looking for evidence of such temperatures as would put the whole house on fire, by taking thermal images, and having not found such high temperatures, they concluded that the highest temperature being only 41.3^0C, there is no reason for the house to vibrate and shake. Therefore, the whole premise of the thermal experimentation on structures to establish temperatures as high as 140^0-400^0C to account for vibrations in houses due to heat energy cannot hold ground. Whereas, starting from the thermal properties of the flame was a sine qua non for this investigation, and this part was not touched at all. The expert team of IIT Guwahati has attempted to investigate a far field phenomenon with far field symptoms, rather than first deducing the near field parameters from the far field and then examining the consequences of the near field to see whether such far field impacts can be caused by the near field. While the measurements are correct, the conclusion drawn is not correct. To say that the there is no "significant impact of fire" on the "*formation of crack in the structures*" is wrong and scientifically untenable. Not only that the conclusion is wrong (as has been established in great detail in the previous Chapter that it was the fire that has been causing the vibrations and tremors that led to appearance of cracks in housing structures), but also the methodology chosen to come to a conclusion was not correct. Therefore, in opinion of the author, the conclusion of the IIT Guwahati Expert Report on Thermal investigation of the fire and its consequent reflection on the formation of cracks in structures located in the far field cannot be upheld.

10.9 Results And Discussion

Thermal measurements of the flame would be discussed first. It would be followed by far field assessment of temperature. The plume and the vertical temperature profile has already been discussed at Para 7.2.10. The radiant heat flux for an average Heat Release Rate of the flame has also been already shown at Para 7.2.9 along with values provided by M/S ERM. These values and parameters would be brought in the discussion as and when required.

10.9.1 Flame Temperature & Flame Height Relationship

Flame temperature has been a topic of discussion in the last three Chapters. So far the discussion on the flame temperature was based on empirical relationships. In this para we shall be having at actual measured flame temperature profiles. However, there are two serious limitations of the measurement- firstly, the maximum measurable temperature by the Testo885 was 1200^0C. The results are likely to white off at values more than 1250^0C. Therefore, it cannot be said that the maximum temperature of the flame was **1223.9^0C**. This is the highest value observed by the equipment. As already discussed in the Chapter 7, using the various empirical relationships, it is now possible to link flame temperature to flame height using the following algorithm:-

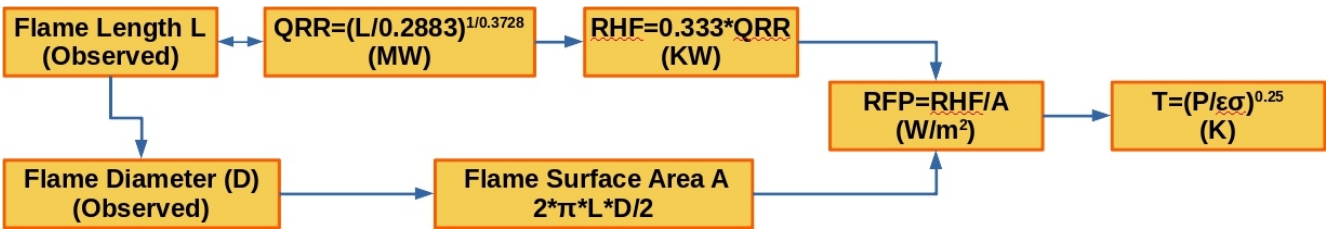


Fig. No. 10.2: Algorithm of Deriving Flame Temperature from Flame Length

Using the algorithm above, a best fit for a set of values of flame height varying from 20m to 150m and the maximum flame temperature was obtained. As the data are all deduced for natural gas, and it was blow out study, there was no way to vary diameter of the orifice. Therefore, the Flame diameter was taken as 12m fixed for all the cases. A linear best fit was obtained with fairly high R^2, indicating that there is quite a good possibility of having an interrelationship between flame length and flame temperature, even while the two are critically linked through the mass flow rate and the diameter of the orifice. It was found that if T is the temperature in K and L is the flame length in m, one can link them through the following simple relationship:-

$$T = 10*L+1050 \quad \text{..... } Eq.No.\ 10.9$$

The graph plotted with the best fit is reproduced below:-

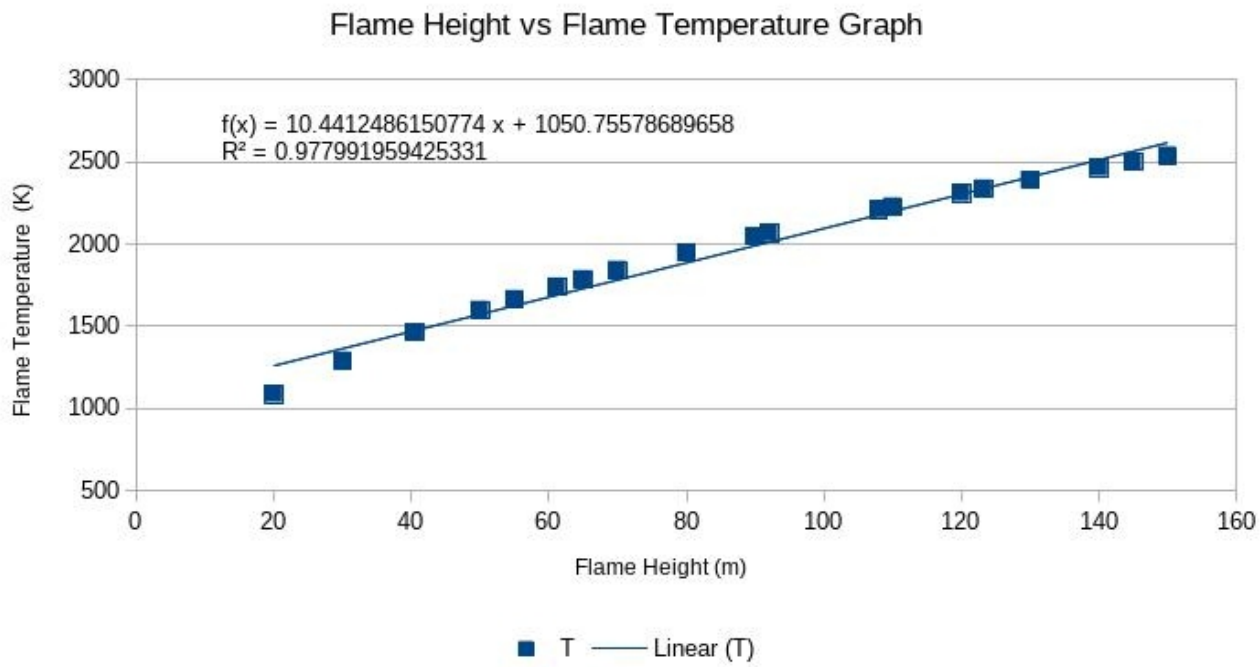


Fig. No. 10.3: Flame Length and Flame Temperature Correlation

Therefore, for natural gas, the minimum temperatures attained in the flame at the least possible height may not fall below ~1050K (~800^{0}C). From the above relationship, it can be easily deduced that the value of M/S ERM of 260 KW m^{-2} Radiating Fire Power (RFP) most likely pertains to a flame height of 40.5 m and a mass flow rate of ~25 kg s^{-1}.

The flame has been observed to vary in length from 55m to 145m, and thus the ***flame temperature could vary from 1600^0 to 2500^{0}C and the mass flow rate could vary from 56 to 760 kg s^{-1}***.

The correlation, in power equation, between flame length and flame is found to be:

$$T=308.403xL^{0.4206} \quad \text{..... } Eq.No.\ 10.10$$

If we go by the exact translation of the relationship as given in the flow chart, we shall be getting:

$$T=\frac{0.37299318\,L^{0.39377682}}{\left[2\pi L\frac{D}{2}\epsilon\sigma\right]^{0.25}} \quad \text{..... } Eq.No.\ 10.11$$

where T is flame temperature in Kelvin, L is flame length in m and D flame diameter in m. Usually, as observed in case of the Baghjan flame, the diameter of the flame can be assumed to be 1/10th of the flame height.

10.9.2 Measured Flame Temperature Profiles

As already stated in the paragraph above (and also elsewhere earlier), the observed maximum temperature of the flame was 1223.9^{0}C; and as 1200^{0}C was the maximum temperature that the measuring equipment could measure, it cannot be said that the highest temperature of the flame was 1200^{0}C. However, for all measured values below 1200^{0}C, one can confidently say that it represented actual values. The flame surface was observed to present a variety of temperature profiles, and the temperatures below 1200^{0}C could be measured very accurately.

10.9.3 Waste heat Generation Or Entropy Change in the Surroundings

Assuming an average height of 108 m and accordingly an average Heat Release Rate (HRR) of 16450 MW, and further assuming that this rate of release continued on a average from 9th June to 13th September, 2020. After that the flame was diverted to two flare headers in the flare pit in a bid to control the fire.

The total number of seconds during this period, S=(95 days*24 hours+22.5 hours)*3600=8289000 s. This amounts to **136 PJ** of energy, taking the HRR to be 16450 MW, released into the surroundings. This energy is almost half of the total energy consumption of Delhi (mobile+stationary) for the whole year in 2011[161]. Therefore, all the energy released around Baghjan, between 9th June to 13th September, 2020 in the blowout, would be sufficient to run a whole city of size of Delhi for a year. If this energy were to be purchased @ Rs. 1 per unit (kW hour)[162], assuming abundant supply of natural gas, it would cost ~**Rs. 3800 cr**. With a population of 1.68 cr (Delhi, 2011), the per capita energy cost comes to ~Rs. 2250 per annum. The other way to look at the the lost CH_4 is how much electrical energy it could have produced through a working Solid Oxide Fuel Cell (SOFC). 1 kg of CH_4 can produce 1.2 MJ of energy[163] taking ~70% efficiency. Therefore, ~ 3.4 PJ of electrical energy could have been produced through the CH_4 SOFC Fuel Cells during this period.

The entropy change in the surroundings (assuming ambient temperature to be 28^{0}C):-

$$\Delta S = Q/301 = 0.46 \text{ PJ K}^{-1} \quad \text{..... } Eq.\,No.\ 10.12$$

161 https://sites.ontariotechu.ca/sustainabilitytoday/urban-and-energy-systems/Worlds-largest-cities/energy-and-material-flows-of-megacities/delhi.php

162 1 kWh = 3.6 MJ

163 https://pubs.rsc.org/no/content/articlelanding/2017/ra/c7ra05245f#!divAbstract [Eq 2: $CH_4(g) = C(s) + 2H_2(g)$, $\Delta H_{298\ K} = 74.6$ kJ]

10.9.4 Impact of Heat on the Surrounding Objects

In order to see the impact of waste heat in the surrounding, knowledge of heat capacity values is essential. The table below provides heat capacity of some common objects:-

Table No. 10.1: Thermal Properties of Certain Materials

Sl. No.	Object	Heat Capacity[164] J kg^{-1} $^0C^{-1}$	Thermal Conductivity[165] (W m^{-1} $^0C^{-1}$)	Density (Kg m^{-3})
1.	Air	1005	0.062	1.20
2.	Brick	840	0.6-1.0	2000
3.	Clay	1381	1.5	1800
4.	Concrete	880	0.4-0.7	2000
5.	Iron	449		7800
6.	Soil (Dry)	800	0.5	2000
7.	Soil (Wet)	1480	1.0	2300
8.	Timber	~1400-2500	0.12-0.19	~600-950
9.	Water	4182	0.6	1000
10.	Wood	~1300-2400	0.17	~800

With the table above, one can roughly predict temperature rise if a specified volume of any of the above materials is exposed to heat radiation expressed in kW m^{-2}. Therefore, first it is necessary to get the rough values of far field heat radiation flux.

10.9.5 Far Field Radiated Heat Flux

Assuming maximum flame height to be 145 m and minimum 70 m, and average flame height to be 108 m, the associated HRR comes to 36400 MW, 5200 MW & 16450 MW respectively for these heights. Using inverse square law, the values of the radiated heat flux at various distances is worked out below:

Table No. 10.2: Heat Flux from Baghjan Flame (Peak, Minimum & Average)

Distance (m)	P_{MAX} (kW m^{-2})	P_{MIN} (kW m^{-2})	P_{AVG} (kW m^{-2})
100	73.40	10.43	33.18
200	18.35	2.60	8.30
300	8.16	1.16	3.70

164 https://www.engineeringtoolbox.com/specific-heat-capacity-d_391.html
165 https://www.engineeringtoolbox.com/thermal-conductivity-d_429.html

Distance (m)	P_{MAX} (kW m^{-2})	P_{MIN} (kW m^{-2})	P_{AVG} (kW m^{-2})
400	4.60	0.65	2.00
500	2.90	0.42	1.33
1000	0.73	0.10	0.33
1500	0.33	0.05	0.15
2000	0.18	0.03	0.08
2500	0.12	0.02	0.05
3000	0.08	0.01	0.04

10.9.6 Far Field Impacts Of Radiation On Certain Objects

Heat transfer is a complex subject, and radiation absorption by a body depends upon so many factors including wavelength of the incoming radiation, specific heat capacity, thermal conductivity, thermal inertia, emissivity etc, as well as impact of local ambient temperature, humidity, wind velocity and direction. It would require a complete computational model to do justice to the subject. Therefore, a simplification of the problem at hand is proposed. It is assumed that the object in question is facing the radiation normally by exposing a surface area of $1m^2$, its total volume is 1 m^3, and the object is able to absorb the heat uniforming within the given volume. Based on these assumptions, a Table of rise in temperature of some common objects has been generated and produced below:-

Table No. 10.3: Possible Rise in Temperature in Degree Celsius (Peak, Min & Avg)

Dist (m)	Brick	Clay	Concrete	Soil -D	Soil-W	Timber	Water	Wood
100	157,22,71	106,15,48	150,21,68	165,23,75	78,11,35	173,25,79	63,9,29	184,26,83
200	39,6,18	27,4,12	38,5,17	41,6,19	19,3,9	43,6,20	16,2,7	46,7,21
300	17,2,8	12,2,5	17,2,8	18,3,8	9,1,4	19,3,9	7,1,3	20,3,9
400	10,1,4	7,1,4	9,1,4	10,1,5	5,1,2	11,2,5	4,1,2	12,2,5
500	6,1,3	4,1,2	6,1,3	7,1,3	3,0.5,1.5	7,1,3	2.5,0.4,1	7,1,3
1000	1.5,0.2,0.7	1,0.1,0.5	1.5,0.2,0.7	1.6,0.2,0.7	0.8,0.1,0.4	1.7,0.2,0.8	0.6,0.1,0.3	1.8,0.3,0.8
1500	0.7,0.1,0.3	0.5,0.1,0.2	0.7,0.1,0.3	0.7,0.1,0.3	0.4,0.1,0.2	0.8,0.1,0.4	0.3,0,0.1	0.8,0.1,0.4
2000	0.4,0.1,0.2	0.3,0,0.1	0.4,0.1,0.2	0.4,0.1,0.2	0.2,0,0.1	0.4,0.1,0.2	0.2,0,0.1	0.5,0.1,0.2
2500	0.3,0,0.1	0.2,0,0.1	0.3,0,0.1	0.3,0.1,0.1	0.1,0,0.1	0.3,0.1,0.1	0.1,0,0	0.3,0.1,0.1
3000	0.2,0,0.1	0.1,0,0.1	0.2,0,0.1	0.2,0,0.1	0.1,0,0	0.2,0,0.1	0.1,0,0	0.2,0,0.1

Further, assuming that there was no fallen oil and condensate on the ground, and the flame was a stand alone phenomenon, it can be seen from the table above that within 100m, almost every structure would catch fire on an hour's exposure to the fire. The same level of temperatures are attainable at about 5 hours exposure at 200m, and at about 8 hours exposure at 300m. Structures at such distances of the flame are liable to catch fire. For structures situated at 400 to 1000m, there would be a gain of almost 5^0C or more depending how close the structure is to the flame (after discounting losses from black body radiation and diurnal changes) and its own temperature above the ambient temperature. For structures within 2000m, a rise of 1-2^0C may be felt. Beyond 2000 m there would be only marginal changes in temperature.

These findings may be collated from the thermal images taken by the IIT Guwahati team. Of the 50 images, about 15-20 images were found to be showing temperatures of wood (41,35.2, 33.5,30.2 ^{0}C), brick (36.5, 36, 31 ^{0}C), and concrete (34.1, 31, 30.6 ^{0}C), the ambient temperature being 28^0C.

10.9.7 Impact of Thermal Radiation on Ambient Air Temperature

As can be seen from the thermal properties chart, air has a very low heat capacity, and is likely to attain high temperatures with relatively low intake of heat from the surrounding. However, hot air would soon rise up, bringing in a fresh supply of air to be heated up again, and, thus, air cannot be heated "hot" enough in the open. One could look at it with "Local" or "Global" view. Both the views are presented below:-

Local View of the Radiation: Let us assume that there is a rectangular invisible airtight box 1000m high, 100kmX100km square base placed at the centre of the flame. The Volume V of the box: V=10^{13} m^3. Since 1206 J of energy is required to raise temperature of 1 m^3 air by 1^0C, The amount of heat needed to raise temperature of the box by 1^0C would be 43.416 TJ. Now we already know that 137 PJ of energy has been released so far from the flame. Therefore, possible temperature rise inside the box would be 11^0C. People inside the box would feel a lot warmer, but If we reduce the size of the box 10 times, everyone and everything would start boiling inside in an area of 100 km.

Global View of the Radiation: Assuming the mass of the whole atmosphere of the earth to be 5.1480x1018 kg, and specific heat being 1206 J kg^{-1} $^0C^{-1}$, the heat radiated from the Baghjan can change the temperature by 2.2x10^{-5} ^{0}C only. Therefore, the fire is globally insignificant, but locally very important as it has all the capacity to create local heat islands, which can easily impact the local conditions. This now brings us to the next topic of discussion.

10.9.8 Local Thermal Impacts of the Fire

The field visit to the Baghjan fire from the Dibru/Lohit river side made me realize that wherever there was direct exposure to the flame, two phenomena were noticeable. Firstly, a very intense hot current of wind from the fire side would blow, and secondly a cold gush of wind would follow it. This hot and cold fluctuation would invariably be noticed by me in all my field trips. This phenomenon was not noticeable on the land side, as there were many obstructions between the flame and the observer. Two experiments were done. NUTEC Fever Block camera was used to measure, from inside of the Dibru-Saikhowa National Park boundary, the face temperature of persons facing the hot draft. The results are presented hereunder with a series of images having human body temperature upto 111.2^0F. A person with such a high body temperature would be diagnosed with a very serious illness. Several such takes with hot blast showed high face temperature invariably. This establishes that even at 2 to 3.5 km away from the flame, and in direct line of sight, the hot blast could raise temperature of a person's body by 2-12 ^{0}C [or ^{0}F].

The second experiment was done to see if a wet black umbrella could get dried up in the blast. It was successfully demonstrated that the areas where the hot blast fell on the umbrella, it dried up fast. The experiment could not be fully completed due to appearance of bright sun that spoiled the experiment midway Some screenshots are presented later in the Chapter.

10.9.9 Impact Of Heat on Plant Life

All organisms (plants and animals) have a temperature range beyond which they cannot survive. Higher temperatures lead to more respiration, leading to loss of water from body and dehydration. In order to understand impact of heat on plants, a basic understanding of the underlying plant physiology is important. Plants can be divided into three types based on the photo-respiration mechanism: C3, C4 and CAM Plants. Photosynthesis is a two step process, as we all know from our school days botany text books. Firstly, light dependent reaction where the energy from photons is captured by the chlorophyll molecule to reduce NADP to NADPH and synthesize ATP. In the process one electron is lost, which is regained again in hydrolysis of water whereby O_2 is produced as by-product. The light dependent reaction is shown below:-

$$2\,H_2O + 2\,NADP^+ + 3\,ADP + 3\,P_i \xrightarrow{h\nu} 2\,NADPH + 2\,H^+ + 3\,ATP + O_2 \quad \text{..... } Eq.No.\ 10.13$$

The main aim of photosynthesis by plants is not the production of O_2 (*and that's why we call it a by-product. One can imagine how useful a wasteful exercise by nature is to humans who cannot survive without oxygen, but our wasteful exercises are so harmful to nature!*), but to fix carbon from the atmosphere into energy giving sugars. The carbon fixation happens in the stomata of the plants in absence of light, also called dark reaction, through Calvin Cycle. It is in this process that actually the atmospheric CO_2 is captured by a protein called RuBisCo (Ribulose-1,5-bisphosphate carboxylase/oxygenase) and converted to a C3 sugar. The overall reaction is given below:-

$$3\ CO_2 + 9\ ATP + 6\ NADPH + 6\ H^+ \rightarrow C_3H_6O_3\text{-}PO_4 + 9\ ADP + 8\ P_i + 6\ NADP^+ + 3\ H_2O$$

..... $Eq.No.$ 10.14

The C3 sugar is finally combined to make bigger sugars called carbohydrates such as glucose, starch and cellulose. CO_2 as substrate gets captured by the RuBisCo and triggers a carboxylase reaction to produce an unstable six-carbon phosphorylated intermediate known as 3-keto-2-carboxyarabinitol-1,5-bisphosphate, which decays rapidly into two molecules of glycerate-3-phosphate. The 3-phosphoglycerate is, then, used to produce larger carbohydrates such as glucose. The CO_2 and O_2 molecules compete for the RuBisCO active site causing the carboxylation or oxygenation process. The fist one produces sugars, while oxygenation process is actually photo-respiration, and it burns up the stored sugars, and produces CO_2 instead. The oxygenation reaction is considered wasteful[166].

C3 Plants: The C3 plants are those that solely depend upon the Calvin Cycle to generate sugars, and have no control over the CO_2/O_2 competition at the RuBisCo active site. Most plants in the world are C3 plants. As the temperature rises and dryness increases, O_2 starts competing heavily for the RuBisCo sites, and photo-respiration takes over in the stomata of the leaves. While respiration is important for the plants to grow, maintain themselves and ion uptake by roots, it is not the same as photo-respiration. Photo-respiration is a wasteful activity and reduces the efficiency of photo-synthesis. Further, respiration and photo-respiration mechanisms are different and well separated in the plants[167]. Further, in C3 plants, when stomata are open to let CO_2 in, they also let water vapor out, leaving these plants at a disadvantage in drought and high-temperature environments. The C3 plants are most common in wet evergreen, moist deciduous and temperate formations.

166 https://en.wikipedia.org/wiki/Photosynthesis

167 Yamori, W. (2016). *Photosynthesis and respiration. Plant Factory, 141–150.* doi:10.1016/b978-0-12-801775-3.00009-3

C4 Plants: C4 plants occur in relatively drier areas, and they need to control the wasteful photo-respiration in order to conserve water. In such plant species, a novel method has evolved by which plenty of CO_2 is released around the RuBisCo active site, so that chances of oxygenation get reduced. The enzyme used in the process is PEP (Phospho-Enol-Pyruvate) carboxylase enzyme that produces CO_2 from the inorganic CO_2 that diffuse into the stomata region of the leaves. PEP fixes carbon dioxide into a four-carbon molecule, called malate (or oxaloacetate and aspertate)[168], which is transported to the active RubiCo sites. The malate is then broken down into a compound that is recycled back into PEP and carbon dioxide that RuBisCo fixes into sugars[169]. Maize and sugarcane are to most common C4 plants. The most common families having C4 photosynthesis mechanism are *Euphorbaceae* and *Poaceae*. The grass family plants are mostly C4 category. These category of plants can bear higher temperatures and drier conditions.

CAM Plants: In extreme dry conditions such as deserts, water conservation would become top most priority, and any wasteful exercise that loses water or food can be dangerous to plant's survival. Crassulacean acid metabolism (CAM) is the photosynthesis pathway that achieves this feat. Most common plants are bryophyllum, cactus and pineapple. Epiphytes, jade plant, passion flower and cucurbits.

Temperature Effects on Photosynthesis Rates: As is clear from the discussion above, plants have developed distinct mechanisms to cope with climatic conditions such as higher temperatures, drier conditions and ways to conserve water. ***The plants in different climatic conditions have adopted differently over millions of years, and cannot suddenly change to new stimulus beyond their assimilation capacity***. Cunnimgham & Read (2002)[170]studied impact of temperature on photosynthesis rates on tropical and temperate plants in Australia. They found that the photosynthesis rate P (in μmol m^{-2} s^{-1}) can be correlated well with air temperature T (in Kelvin) through the following regression equation[171]:

$$P=b(T-T_{min})x[1-e^{C(T-Tmax)}] \quad \text{..... } Eq.No.\ 10.15$$

While b and c are constants derived from the regression, T_{min} and T_{max} are temperatures (minimum and maximum) at which photosynthesis totally stops. [T_{max} , for example,

168 https://csiropedia.csiro.au/the-discovery-of-c4-photosynthesis
169 https://ripe.illinois.edu/blog/difference-between-c3-and-c4-plants
170 Cunningham S.C, & Read J, Oecologia (2002) 133:112–119
DOI 10.1007/s00442-002-1034-1
171 Ratkowsky D A, Lowry RK, McMeekin TA, Stokes AN, Chandler RE (1983) Model for bacterial culture growth rate throughout the entire biokinetic temperature range, J. Bacteriology 154:1222–1226

some species could be just at 35^{0}C or for some at 45^{0}C.] The studied species in the tropical climate were *Alstonia scholaris*, *Heritiera trifoliata*, *Sloanea woollsii* and *Castanospermum australe*. While *A. scholaris* is a species very commonly found in the North East India and Upper Assam, the families of the other species studied also occur commonly in the region such as *Malvaceae, Fabaceae, Elaeocarpaceae*. The temperature vs photosynthesis rate graphs (in Australian tropic conditions) for the four above mentioned species is presented below. On the X-Axis rests temperature, and on Y-Axis is rate of photosynthesis.

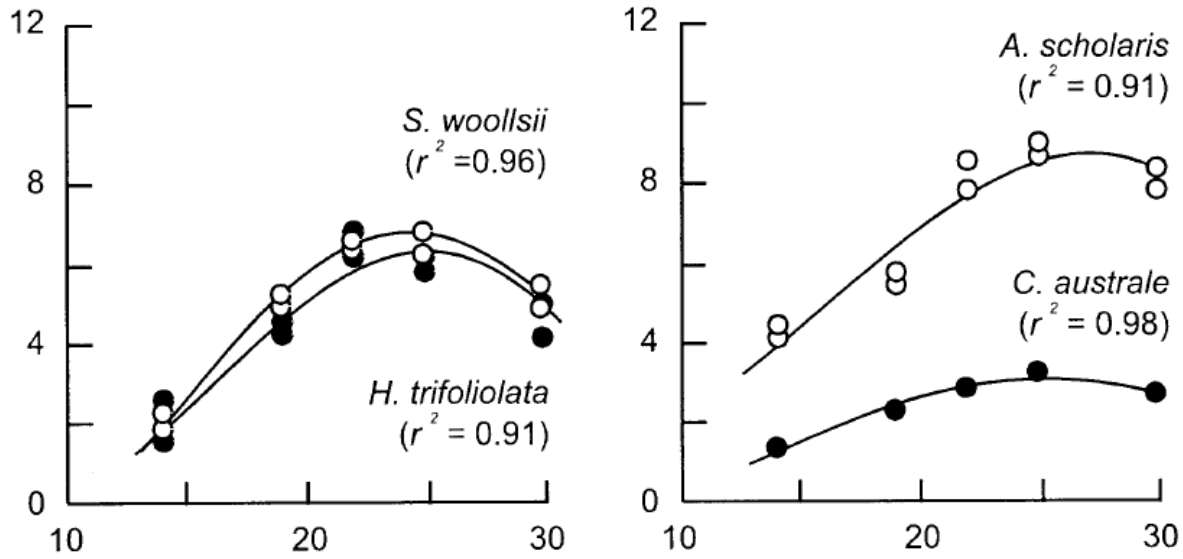


Fig. No. 10.4: Photosynthesis & Its Relation to Ambient Temperature

It is clearly seen at for all the four species, maximum photosynthesis rates are at about 25^{0}C. The photosynthesis rate declines after 25^{0}C. A team of researchers published data on ecosystem respiration rate (N_{EE}) and impact of air temperature (T K) on it as well as dependency of the rate on ecosystem water vapor deficit (D_E)[172]. Since the tropical forests grow almost round the year, the authors opined that the mean annual temperature could be treated as growth temperature. Accordingly, the ecosystem optimal temperature for growth (T_{optE}) would be higher, if the mean annual temperature was higher. However, the fall in the rate of ecosystem level photosynthesis rate with increase in temperature was very sharp as can be observed from the following charts taken from Fig. No. 1 of the study. Irrespective of the fact that whether the site is in South East Asia or Amazon, it is seen that there is steep fall in rate of photosynthesis by almost ½ to ¾ for a rise of 5^{0}C in air temperature.

172 Zheng-Hong Tan, Jiye Zeng, Yong-Jiang Zhang, Martijn Slot, Minoru Gamo, Takashi Hirano, Yoshiko Kosugi, Humberto R da Rocha, Scott R Saleska, Michael L Goulden, Steven C Wofsy, Scott D Miller, Antonio O Manzi, Antonio D Nobre, Plinio B de Camargo and Natalia Restrepo-Coupe, 2017 Environ. Res. Lett. 12 054022

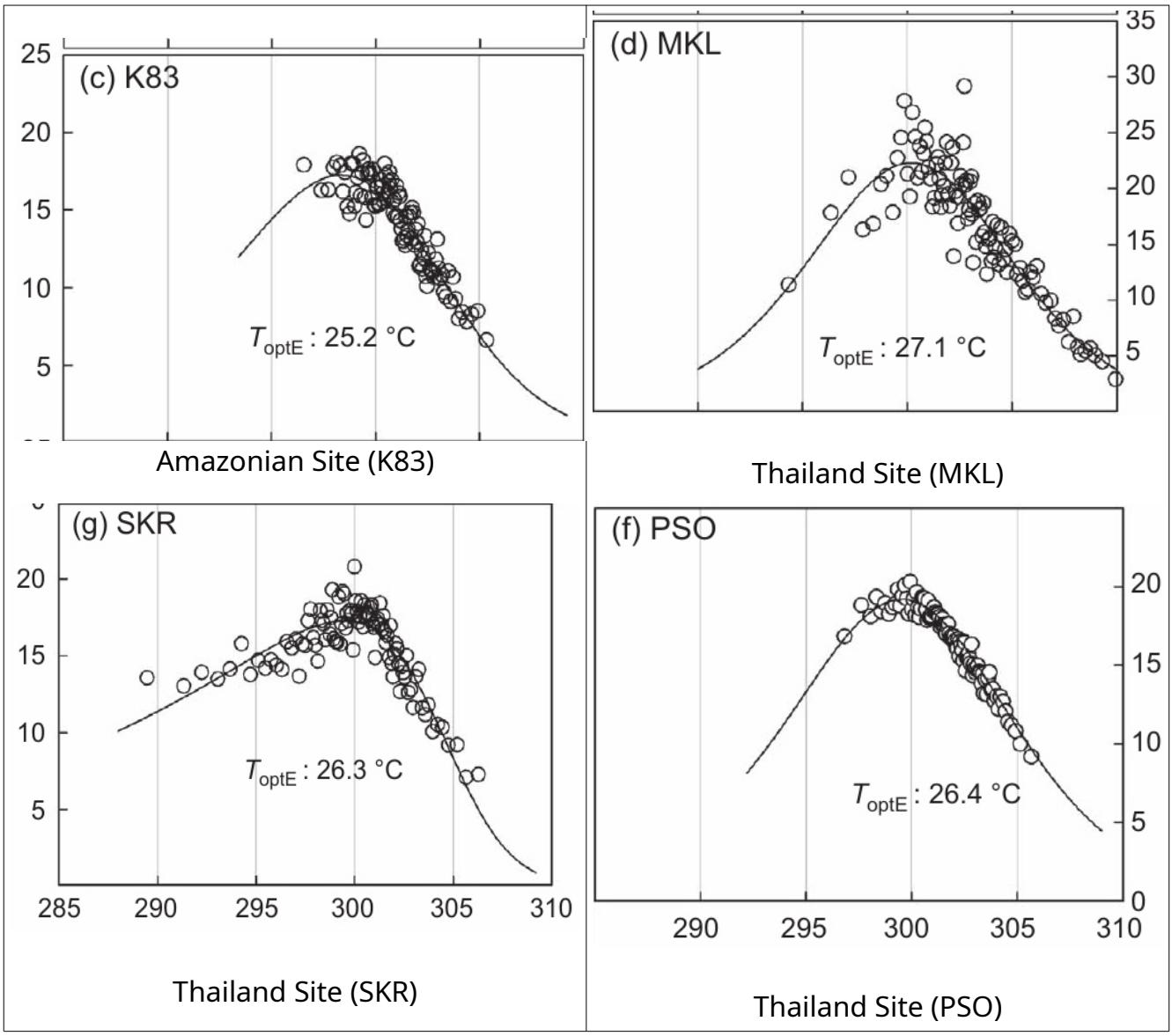


Fig. No. 10.5: Rate of photosynthesis & Temperature (K)

The x-axis temperature scales of the diagram above are as shown at bottom of each column, and divisions are all 5^0 apart.

From the above discussion it can be concluded that one can safely assume a drop of 50% in the rate of photosynthesis for a rise in temperature of about 5^0C above the optimal growth temperature. A drop in photosynthesis rate implies reduced carbon sequestration. Therefore, rise in temperature has direct consequences for climate change and climate related variability. Therefore, thermal radiation does have negative impact on the surrounding vegetation.

10.9.10 AIR TEMPERATURE AND THE FLAME - TESTING A HYPOTHESIS

Air temperature itself is a complex function of so many parameters such as rainfall, humidity, wind, insolation, cloud cover, vegetation cover etc. However, how can one say with certainty that the Baghjan flame had some impact on the local air temperatures? While so much heat is released in the surroundings of the flame, can we say that the ambient temperature in the area in a 3-4 km radius would be showing a very high maximum temperature during the day and also during the night? While one may be inclined to accept this argument, but in reality air temperature is neither just a function of heat alone, nor the space around the flame fully insulated from outside. However, is it still possible to test one hypothesis i.e. since the radiation from the flame is on 24X7 basis, is there a possibility that the difference between the day and night temperatures be "reduced" compared to the times when the flame did not exist? If yes, then it would imply that the radiated heat acted as a buffer or a kind of "green house chamber" by not allowing temperature to rise too much or fall too much within its zone of influence.

To test this hypothesis, temperature data from 2016 to 2020 was obtained from the Dighalturrung TE which is about 3.5 Km away from the site, for the months of March to September for all the years. The data was collected in form of maximum temperature (day max) and minimum temperature (night minimum) to give the maximum variability to the thought experiment (Gedanken experiment in German). The temperature data set of max and min was collected for each day of the month for March to September from 2016 to 2020. The difference of maximum and minimum for each day was averaged for the month and plotted. The Chart is produced below:-

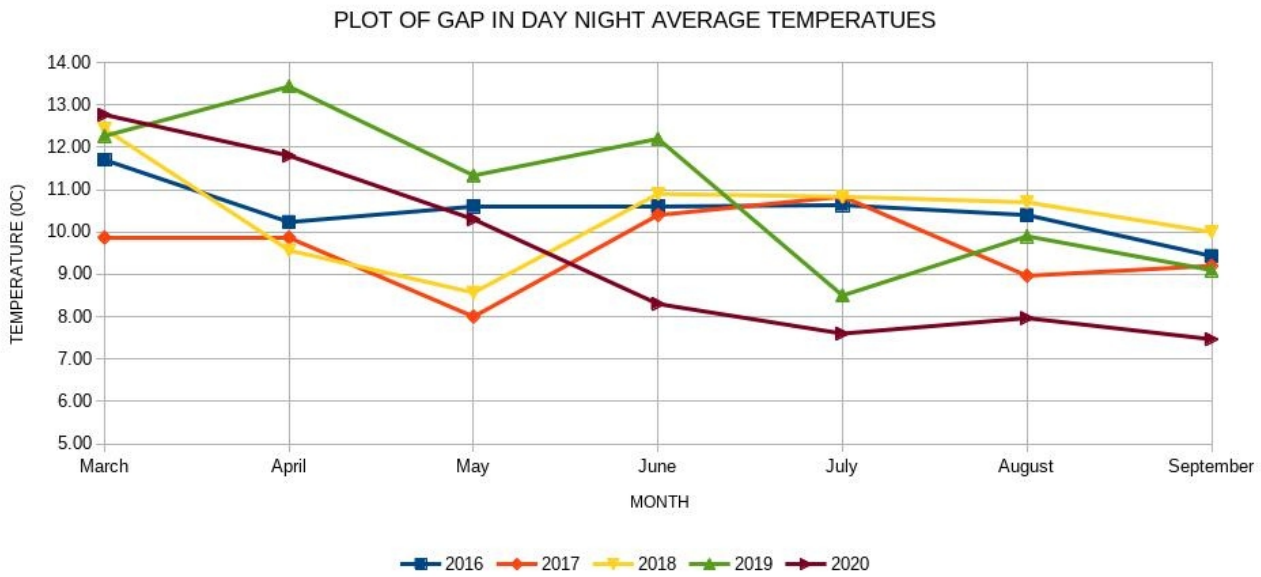


Fig. No. 10.6: Reduction in Diurnal Gap in Temperature due to Flame

As can be seen from the Chart above, from the month of June to September, 2020, in comparison to the same period for 2016 to 2019, the gap between maximum and minimum temperatures is 7.60 – 8.30 ^{0}C. This gap for the months March to May, 2020, when there was no fire, is 10.30 – 12.77. The mean gap for June to September, 2020 is only ~8^{0}C with a variation of ~±0.3^{0}C. This proves, to quite an extent, that there is an invisible blanket of heat over an area of about 3.5-4 km radius from the fire, which is regulating the temperature in its surrounding. Further, it is seen from the data that average gap between day and night temperature from 2016 to 2020 (barring June onwards) was 10.6^{0}C, which got reduced to 7.9^{0}C, reducing the gap by 2.7^{0}C. This reduction in gap could possibly be attributed to the thermal radiation from the flame.

10.9.11 BREACH OR NO BREACH

The thermal pollution has two parts. The water part has been dealt with in the next Chapter. Here, we had an opportunity to examine heat radiation emanating from the flame and its possible impacts in the surrounding areas. Four major concerns have emerged:-

1. From measurements of heat radiation/convection currents, it is clearly established that hot air flows in the surrounding areas carrying temperatures as high as 43^{0}C have been witnessed and recorded beyond 3 km line of sight of the flame. This is as high as ~15^{0}C over the ambient air temperature in the area.
2. The photosynthesis rate in the plants surrounding Baghjan (including plants in the Dibru-Saikhowa National Park) within a radius of 3-4 km would have possibly been reduced to almost 50% (or more). Most of the flora of the region belongs to the C3 photosynthesis pathway category, and has no inbuilt mechanism to counter rise in temperature, leading to fall in carbon fixation. Though no field verification could be done due to want of equipment, the leaf thermal stress study is required to be conducted at the earliest. This is an **ECOLOGICAL BREACH** and does not seem to be defined anywhere in any statute.
3. Due to drop in photosynthesis rate in the plants, the carbon fixation (or sequestration) process also would have dropped to 50%. The sequestration loss is an ecological damage and environmental loss.
4. There is a visible heat impact in the 3-4 km radius within which there is an invisible HEAT BLANKET operative which has clearly reduced the gap between day and night temperatures. Though low variability in temperature is a hall mark of the wet evergreen forest ecosystem, for humans such a system created artificially

may cause heat stress, dehydration and similar symptoms. Additionally, constantly living for months in a thermally stressed system may lead to fatigue. In all in about three months time 137 PJ of waste heat or entropic heat has been unleased in the area; and its ill effects are probably least studied. It is also not counted into any pollution category. However, an estimate of the kWH cost of this waste heat was estimated to be Rs. 3800 cr at a rate of Rs. 1 (one) per kWH penalty. This waste heat generation may be likened to an 100% inefficient engine, as 0 (zero) work could be extracted from it from the 9th June, 2020 till 13th September, 2020 [*Thereafter, part of the flow was tapped for production- could be 9 million metric cubic meter per day*].

5. As the diurnal impact of the heat radiation has been estimated to 2.7 ^{0}C, it can be assumed that the plant diversity around the Baghjan well No. 5 and upto the Dibru-Saikhowa National Park. Assuming specific heat capacity of sea water at 3850 J kg^{-1} K^{-1}, and its density to be 1025 kg m^{-3}, we can estimate the volume of sea water needed to capture all the 137 PJ of heat thrown by the Baghjan Flame so that water temperature rises only by, say, 5^{0}C. This comes to 7x10^{9} Billion cubic meters. This is the heat capacity that the trees around Baghjan have provided to M/S OIL India without any cost while acting as natural sink. This is approximately the size of the sink needed to absorb the heat radiated by the Baghjan flame. The cost of such as a hypothetical sink if one was required to build would cost, at Rs. 5 per litre, Rs. 3,50,000 Cr.

6. Therefore, M/S OIL and their owners deserve a heavy penalty on account of thermal radiation not withstanding that there is no such penal provision for heat radiation leakage; and one could levy a charge of 1% cess on the value of the services performed by the ecosystem for rendering heat remediation services on 24X7 basis non stop and without demur. It comes to Rs. 3500 cr.

10.10 Thermal Profiles

As already discussed in previous sections of this Chapter, thermal profiling of the flame, nearby objects/ landscape and human beings was carried out using thermal cameras. The results have already been discussed. Some of the image profiles are presented here as a record of proof of the studies carried out.

Thermal Profiles of the Flame: As can be seen from the images, thermal profiles have been worked out, additionally, in vertical and diagonal directions. Wherever flame was obstructed by an object, its thermal imprint got blocked to that extent.

Thermal Profile of Landscape: Due to floods, measured temperature profile could not be taken of all the sites. However, several profiles were taken earlier, till the time the Testo885 device did not arrive, without the temperature scale. However, face temperatures recorded by the system show the impact of the hot blast in the Dibru-Saikhowa National Park at 2-3 km distance from the blow out site.

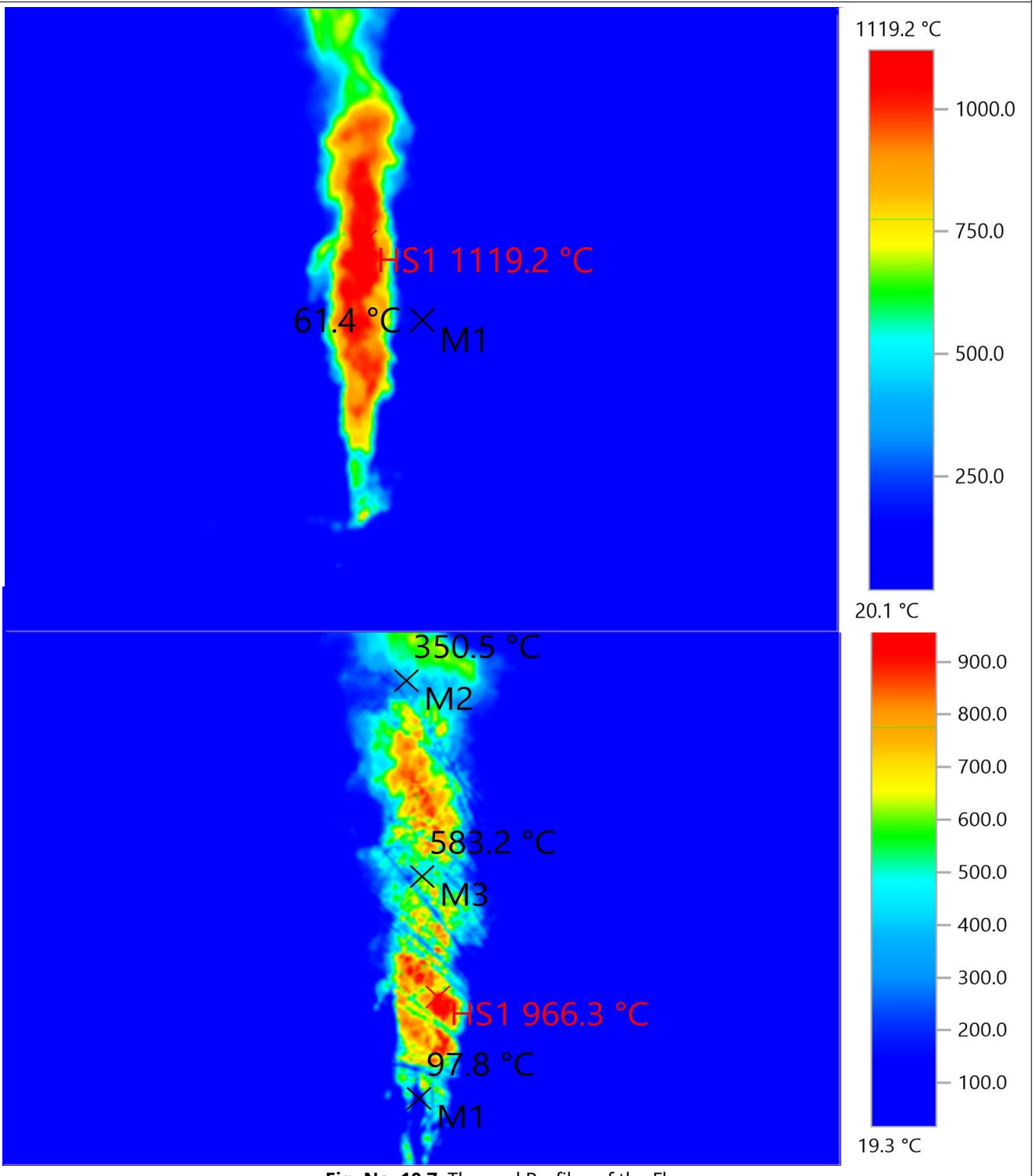


Fig. No. 10.7; Thermal Profiles of the Flame

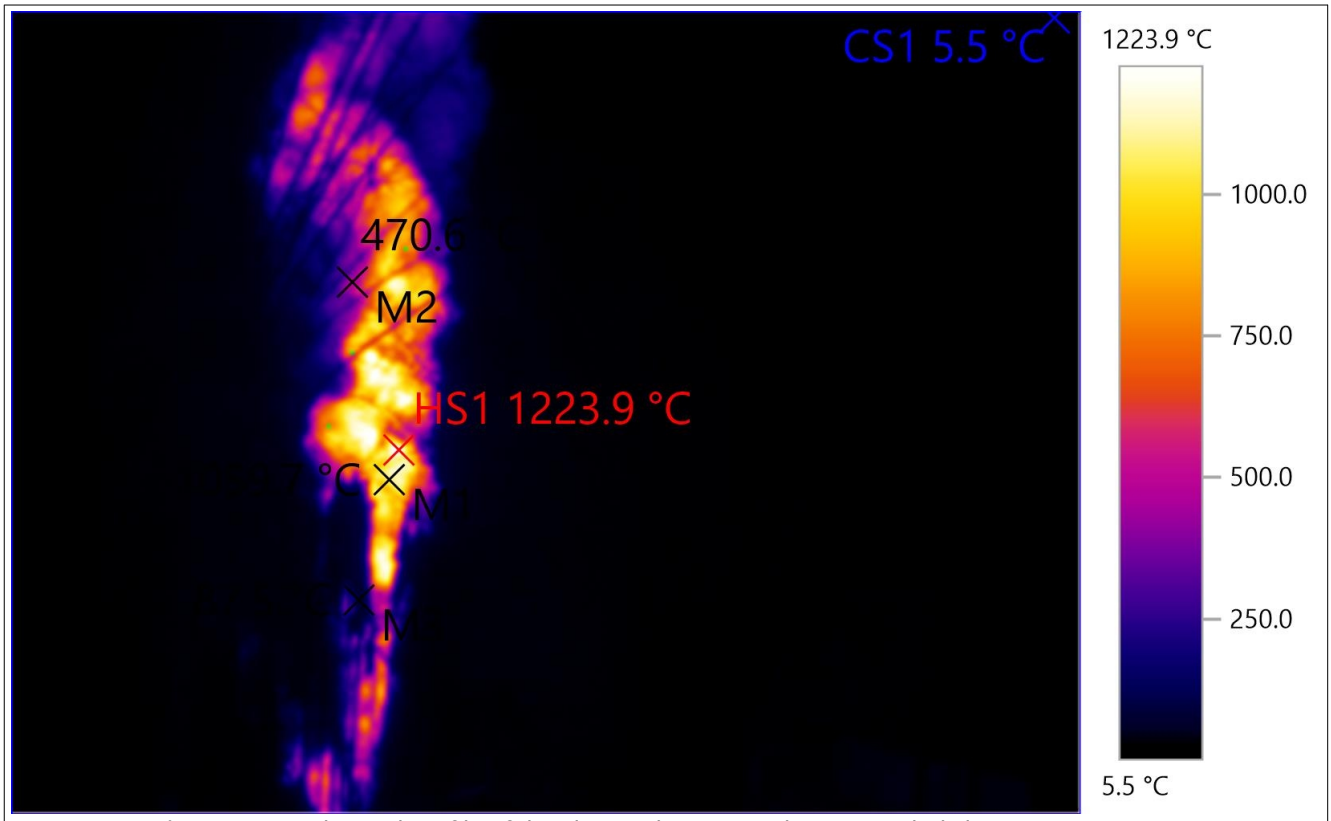


Fig. No. 10.8: Thermal Profile of the Flame (Showing Highest Recorded Flame Temperature)

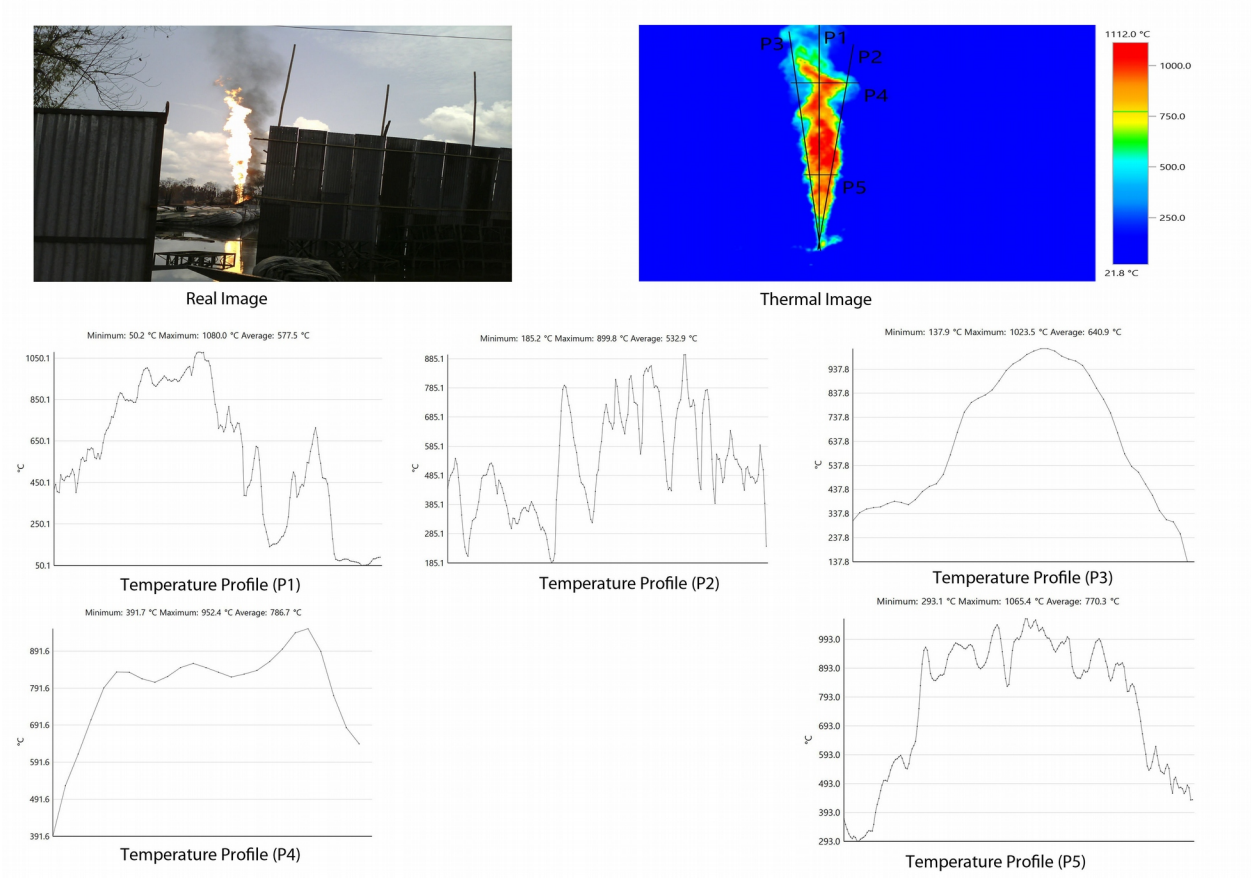
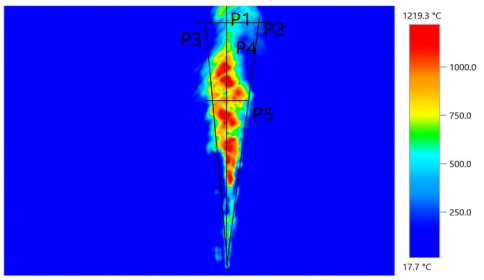


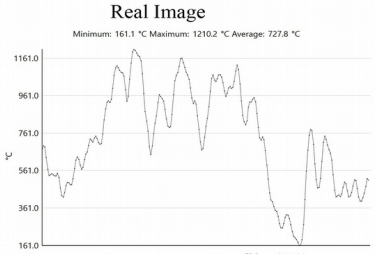
Fig. No. 10.9: Temperature Profiles of the Flame



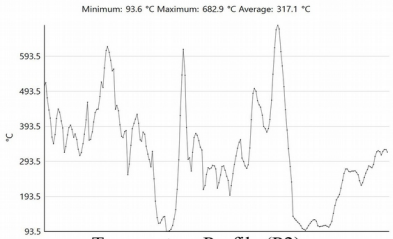
Real Image



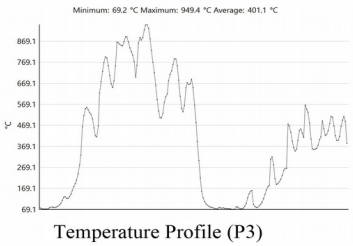
Thermal Image



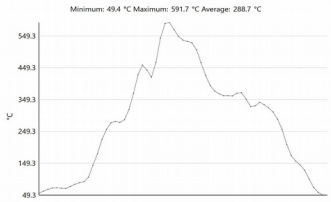
Temperature Profile (P1)



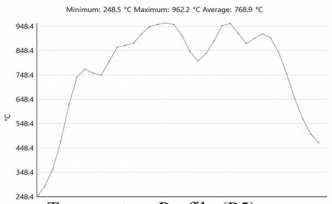
Temperature Profile (P2)



Temperature Profile (P3)



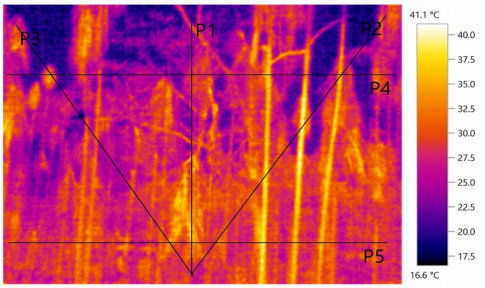
Temperature Profile (P4)



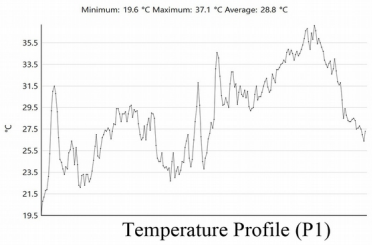
Temperature Profile (P5)



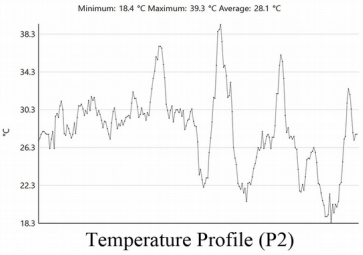
Real Image



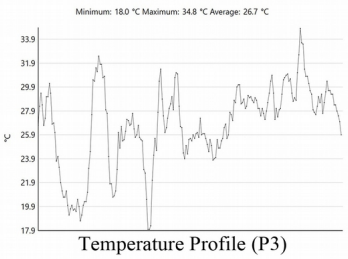
Thermal Image



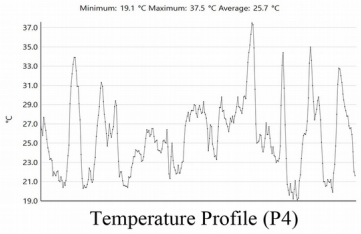
Temperature Profile (P1)



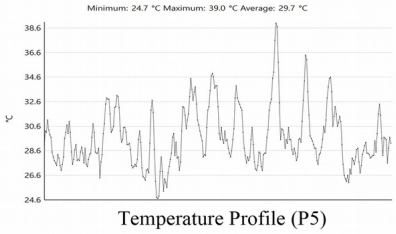
Temperature Profile (P2)



Temperature Profile (P3)

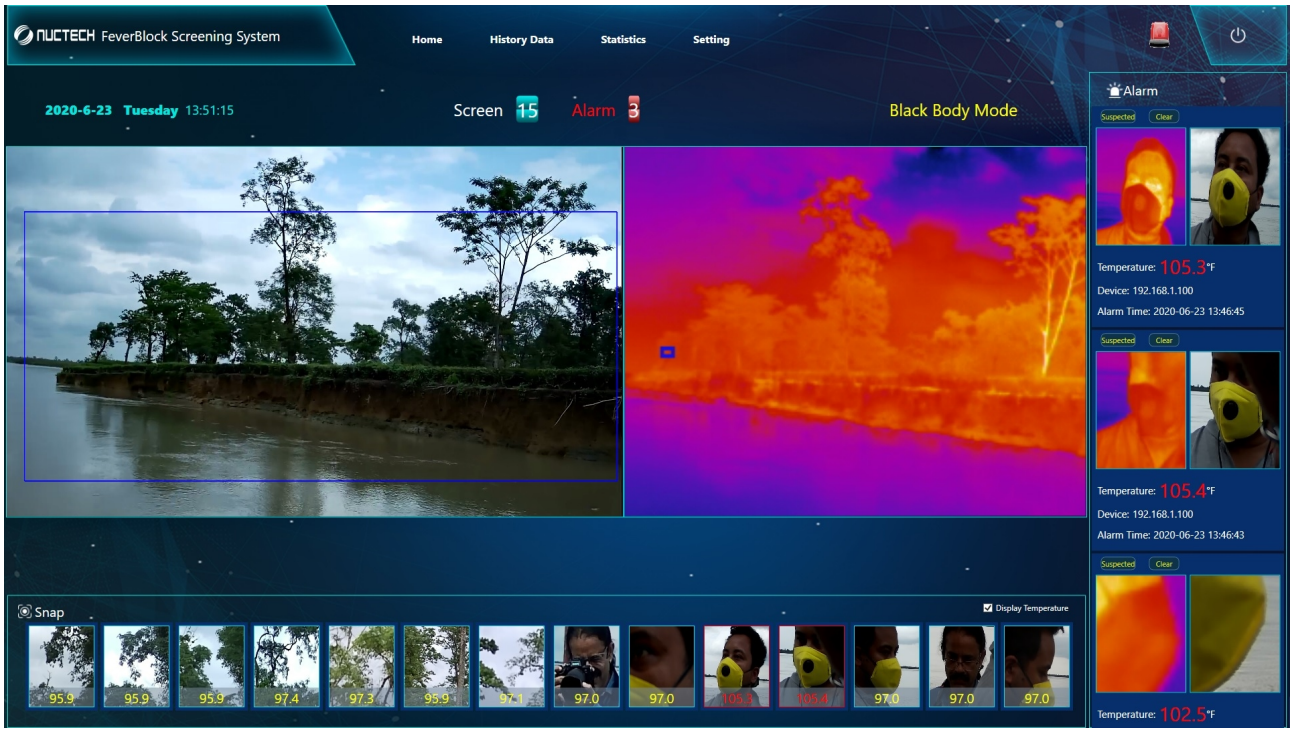


Temperature Profile (P4)

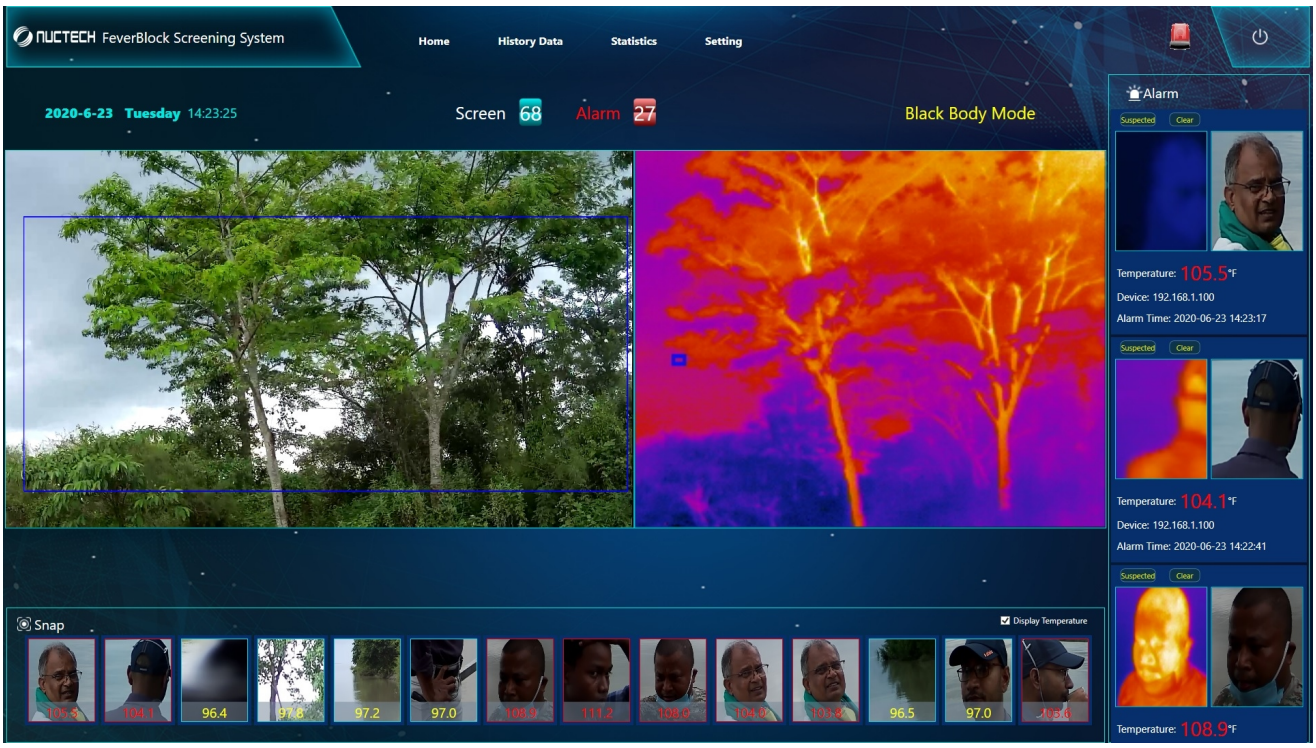


Temperature Profile (P5)

Fig. No. 10.10: Temperature Profiles (More)



A: DSNP River Side and Vegetation

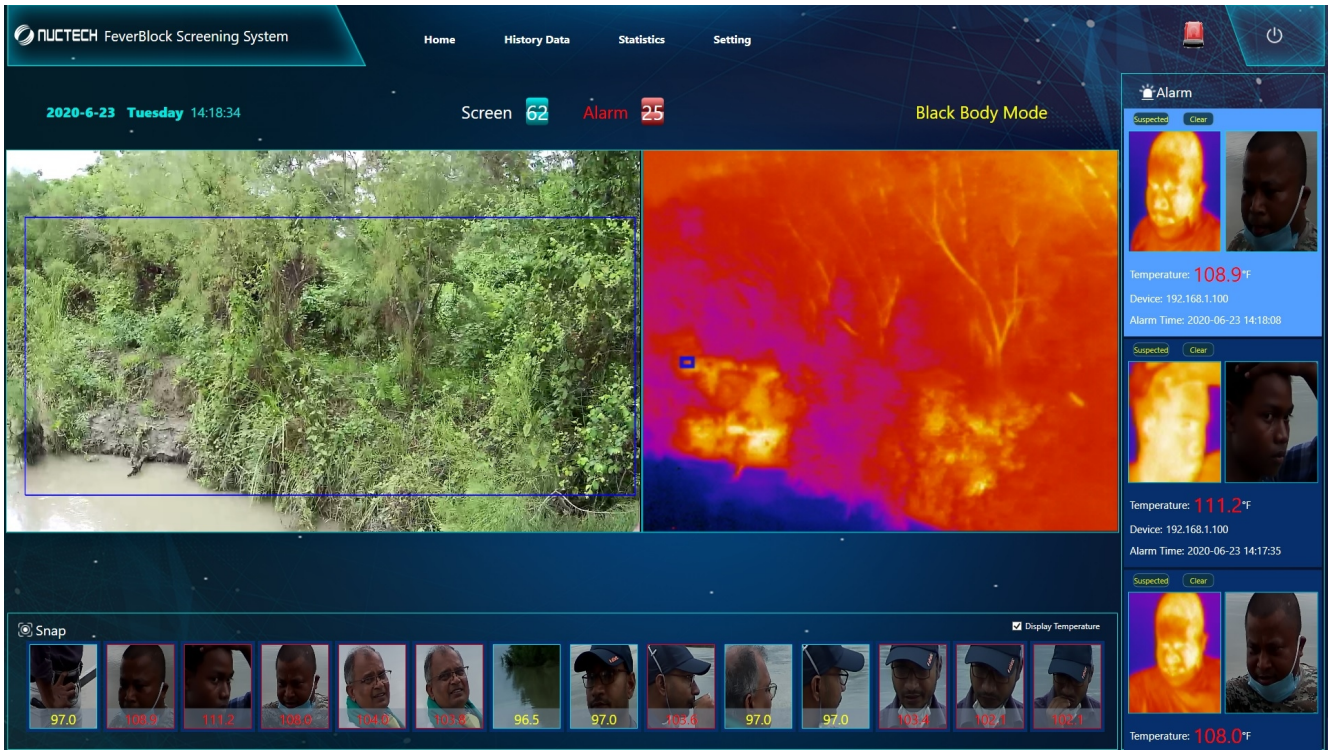


B: Tree Trunk Thermal Profiles

Fig. No. 10.11-1: Thermal Profiles of Surroundings and Face Temperature Images

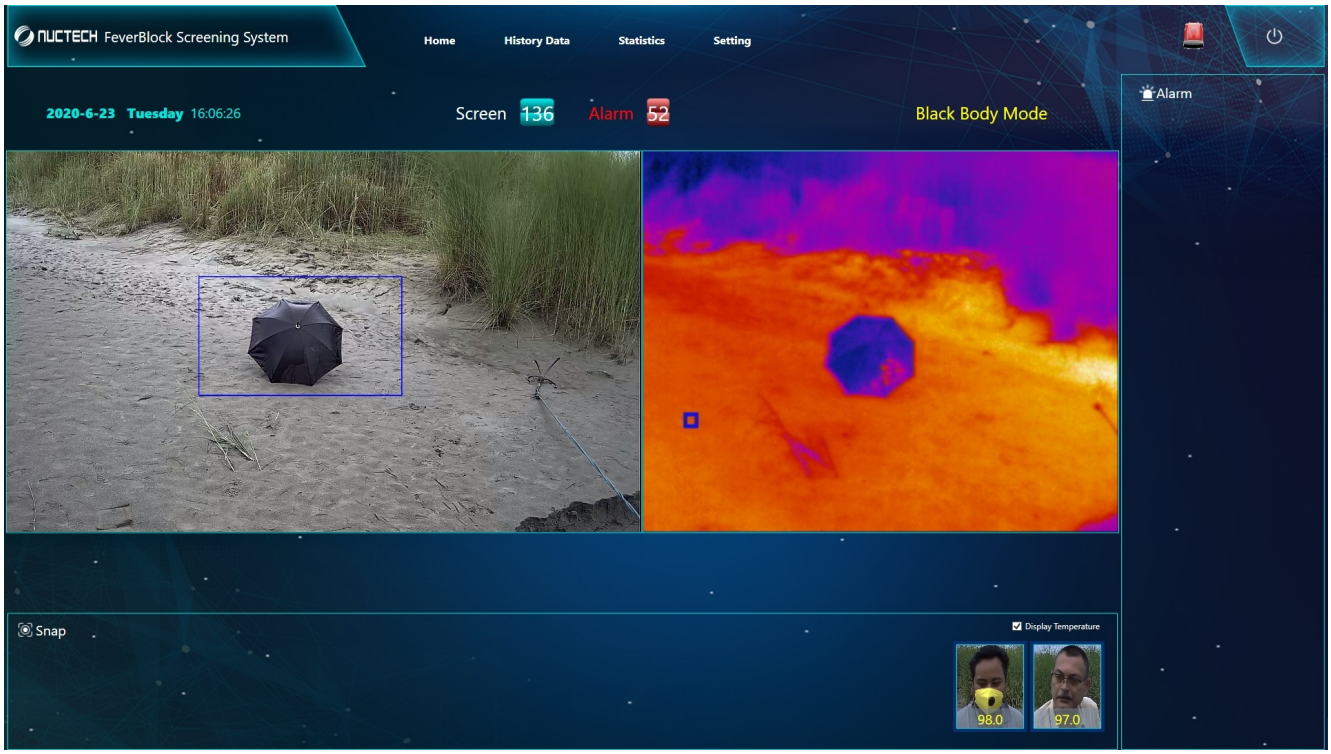


A: facing the Hot Blast from the Flame

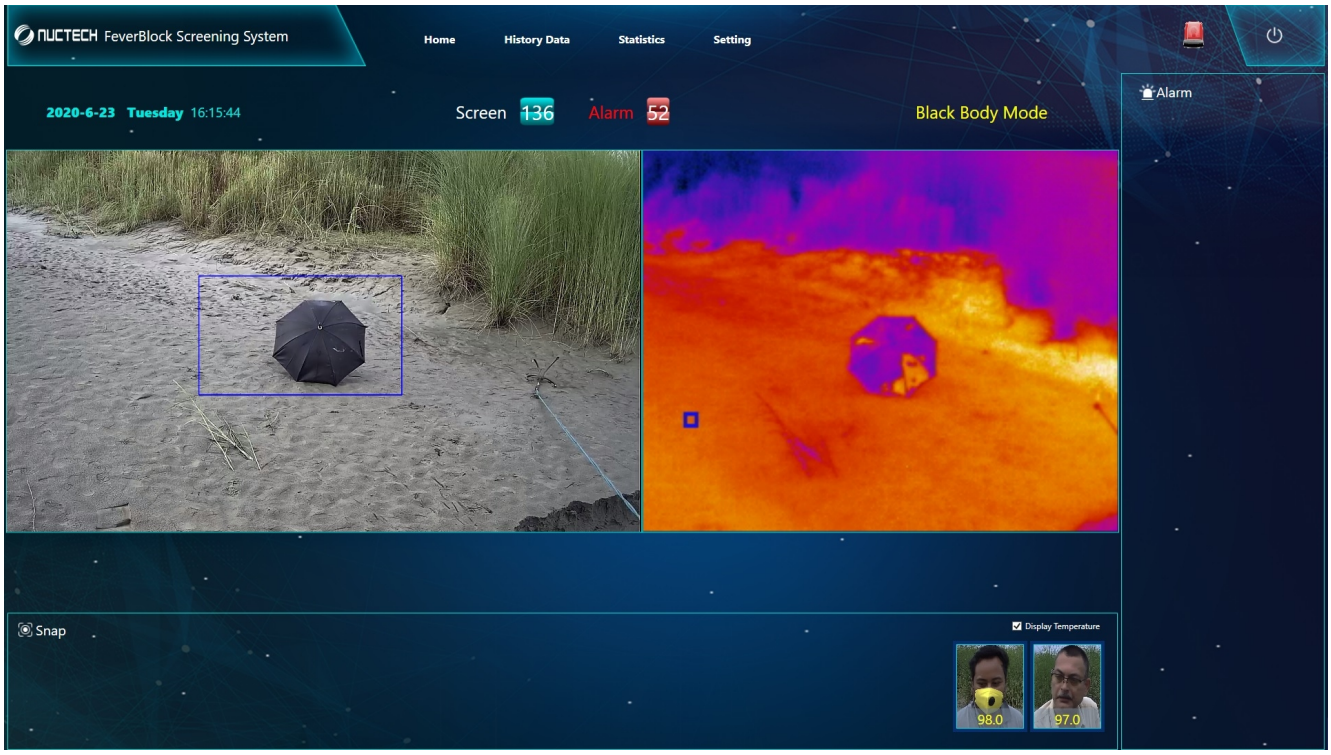


B: Face Temperature of 111.2^0 F

Fig. No. 10.11-2: High Fever Face Profiles on Facing the Flame



A: Wet Umbrella



B: Drying Umbrella

Fig. No. 10.12: The Umbrella Experiment

[*As can be seen, the highest facial temperature recorded is 111.2^{0}F (≡ 44^{0}C)*[173]*.*]

173 How many human beings can survive such a high temperature?

10.11 Conclusions

1. It is high time that we redefine Thermal Pollution as also pollution of the air if air temperature outside of an industrial installation or any usage of power or energy gets impacted and creates a heat island.
2. The tree ecosystem components respond differently to rise in air temperature. The leaves would try to absorb as much heat as possible without impacting their temperatures, and the trunk, on the other hand, may get impacted by high levels of heat radiation and the bark and cambium temperatures may rise to levels where the tree may even die.
3. The response of photosynthesis rate to temperature shows that at temperatures higher than the optimum growth temperature (25-30^{0}C), the photosynthesis rates would drop to more than half. This adversely impacts the food production in the plant, and also cuts the sequestration rates by more than half.
4. The total heat generated by the Baghjan flame is estimated at 137PJ. It is also estimated that the diurnal temperature gap has been reduced to 7.9^{0}C from the observed usual average of 10.6^{0}C.
5. The various measurements show that temperatures have risen by 5-10^{0}C depending upon the distance at which the structures (houses) are located.
6. Hot wind gusts that are capable of raising human face temperature by almost 12^{0}C from the normal body temperature have been observed.
7. The valuation of the waste energy of 137PJ in terms of a 100% inefficient heat engine (that the flame is), in terms of energy price, is equivalent to the total energy consumption of Delhi in 2011, and can be priced at Rs. 3800 cr @ Rs. 1.00 per kWH value. Further, in terms of the heat sink services that the tree ecosystem around Baghjan flame has offered, comes to a staggering Rs. 3,50,000 cr. Just about 1% cess on these services which could actually be charged to M/S OIL would come to Rs. 3500 cr.
8. Therefore, the heat that the Baghjan flame has been spewed appears to have marked footprint on the local microlimate. Though, there are no legal bars on creating and propagating such a big naked flame, ecological considerations discussed and circumstantial evidence presented warrant levy of penalties on the owners of the flame; and furthermore, heat radiation beyond certain radiative power should be strictly prohibited, and it should be made a part of the environmental regulation of the country.

CHAPTER 11

11 SOIL AND WATER POLLUTION

11.1 Prelude To Chapters 11, 12, 13 & 14

This Prelude was necessitated from the fact that while the findings of Chapters 6 to 10 were largely churned out by the author (who researched through a labyrinth of scientific literature, books and publications. One may refer to the footnotes, as well as an exhaustive list of references that have been appended at the end of this Report), but the findings of this Chapter and the Chapters that will follow, were meticulously researched by way of extensive field work, sample collection, testing and measurements, exhaustive literature reviews and research by several groups of experts. The works that are going to be presented in this Chapter, and Chapters 12, 13, 14 & 15, are largely, directly and indirectly, outcome of actions initiated by the undersigned as Chairman of the Expert Committee that was notified by the PCCF & HoFF, Assam vide Office Order No. 100 dt. 2nd June, 2020, after a few days of the Baghjan blowout. The Expert Committee (EC) started its work in right earnest from the 6th of June, and first field visit started in the morning of the 9th June, 2020. However, as ill luck would have it, mid way the big Baghjan explosion at Well No. BGN#5 happened and the rest is history. The findings in these Chapters are those of the experts and their respective teams that have worked extensively on the ground. The undersigned guided the team led by Dr. Narayan Sharma, as he and his team were at the core of the Expert Committee. Several rounds of discussions were also held with the other teams. In course of field work, looking at the vastness of assessment, other teams such as Wildlife Institute of India (WII), BNHS and other local experts were roped in. As regards WII, the Gangetic Dolphin work originated from the Expert Committee's mandate for WII. However, the WII did more than what was asked for (and also the MoEF&CC had desired an assessment of the situation from WII); but yes, the sample testing for Polycyclic Aromatic Hydrocarbons (PAH) was part of the Expert Committee work, very well coordinated by Sri Rajendra Bharti IFS, DFO, Tinsukia Wildlife Division and WII. Other experts included a team from Assam Agriculture University for soil study, from College Fisheries, Raha for study on fishes; and some of these works were guided by Dr. Apurba Chakrborty, Retired Professor, and Ex-Director, Research, College of Veterinary Science, Khanapara, Guwahati. Though he desired very much, COVID19 prevented him from visiting the site. Field works were also carried out by the DFO, Tinsukia Wildlife and the DFO Dibrugarh Forest Division. A brief description of the expert members and teams is necessary

before we begin the ecological assessment work of the Baghjan blowout. This is, in a way, an acknowledgment of the contributions made by each of the team members. Extensive field works were carried out from 10th June to the 1st week of August, 2020, and several ground rechecks were also done. Several control plots were laid in October and November, 2020. There were several expert groups that worked majorly and independent of each other:

1. Dr. Narayan Sharma, Deptt. Of Env. Biology & Wildlife Sc, Cotton University, Guwahati-781001, 2020, EC Final Report, Rapid Biodiversity Assessment Following a Blow Out and Oil Well Fire at Baghjan, Tinsukia [Referred to as Sharma et al, (2020)[174]]
2. Dr. Girish Jathar, Asstt. Director, BNHS, 2020, Preliminary Assessment of Impact of Baghjan Oil Field Disaster on Dibru-Saikhowa National Park and Maguri-Motapung Beel IBA, Tinsukia, Assam [Referred to as BNHS (2020)[175]]
3. Dr. Qamar Qureshi, Wildlife Institute of India, 2020, Impact of Oil Well Blow Out at Baghjan Field Oil Field, Assam and Resulting Oil Spill, on Surrounding Landscape [Referred to as WII (2020)[176]] as well a subsidiary report on the Dolphins.
4. Other Reports:
    - **(a)** Dr. Imtiaz Ahmed, Asstt. Professor, College of Fisheries, Rapid Assessment Report on Oil spill at Baghjan and its Impact on aquatic biodiversity of Dibru River and Maguri Motapung Beel (Wetland), Tinsukia district, Assam [Referred to as Ahmed I (2020)]
    - **(b)** Dr. Deborshee Gogoi, Asstt. Professor, Department of Commerce, Digboi College, 2020, Survey of Avifauna in Maguri-Motapung Beel Area Aftermath of Eruption and Subsequent Burnout of Baghjan 5 Oil Well [Referred to as Gogoi D et al (2020)[177]]

174 With Technical Experts: Teriang Rajib Rudra, Rahman Shamim, Arandhara Subhsish, Bhaduri Rupam, Deka, Bitupan, Darji Chanra, Gogoi Ghanashyam, Nayak Niranjan, Moran Papu, Gogoi Neeharika & Research Scholars: Hazarika Violina, Das Dhiraj, Bishaya Puja, Choudhury Pramod, Debnath Titir, Das Aditya, Saikia Anouska

175 Team Lead: Dr. Jathar Girish, Team: Chakdar Biswajit, Gogoi Monsoonjyoti, Khongsai Ngulkholal

176 Scientists: Quershi Qamar, Kolipakam Vishnupriya, Wakid Abdul; Researchers: Jacob Merin, Gayathri Aaranya, Singh Vineet, Rokade Anurag, Negi Ranjana, Sharma Hiyashri, Konwar Abhijit, Kalita Jitul, Tasfia Syeda Tabassum, Roy Gargi, Jhala Harshini, Deori Sunny, Rao Vishrutha, Roy Kanad, Gupta Karuna, Dutta Ayan, Kumari Madhavi, Mane Sneha, Das Subhasree, Mitra Archisman ; Collaborators: Dr. Ahmed Firoz (Herpetofauna, Aranyak), Phukan Mridu Paban (Birds); Field Assistants: Das Manoj Kumar, Hoque Nurjamal

177 PI: Dr. Gogoi Deborshee, Co-PI: Hatibaruah Binanda, Phukan Palash, Dutta Jivon

(c) In addition to all above, the two EIA Reports of M/S OIL were also considered. The one done by Gauhati University would be referred to as EIA-GU (2009), and that by ERM as EIA-ERM (2019).

(d) Dr. Ranjita Bania, Fisheries Biologist & Head, Aquaculture, Wetland & Livelihood Division, Jeeva Suraksha, Sibsagar, Assam, 2020, Preliminary Report on Baghjan Gas Oil Leak of Tinsukia District, Assam and its impact on aquatic biota (referred to as Bania R (2020)[178]]

(e) Dr. Kishore Kumar Sharma, Professor, Department of Plant Breeding and Genetics, AAU, Jorhat, & Dr. Samiran Dutta, Professor, Department of Soil science, AAU, Jorhat, 2020, Status Report on Soil and Water Analysis in Baghjan Well Explosion Affected Area [Referred to as Sharma K. K & Dutta S (2020)]

(f) Mr. B. Gogoi AE and Mr. J K Gogoi AEE, PCBA, 2020 Air, Soil, Water and Noise Sample Data [Referred to as PCBA (2020)]-already discussed variously in previous Chapters.

(g) Mr. Rajendra Bharti IFS, DFO, Tinsukia Wildlife Division, 2020, Report on Impact of Baghjan Blow Out on Dibru-Saikhowa National Park and Mr. Pradipta Barua, DFO, Dibrugarh Forest Division.

5. Dr. Ujjal Deka Baruah Asstt Prof, Department of Geography, Gauhati University & Dr. Kuleswar Sinha, Asstt Professor, Department of Geography, Abhyapuri College initially joined the Expert Committee bandwagon but later decided to de-link. No report was submitted by this group.

6. In addition, a team of photographers, videographers, Drone team and GIS survey and thermal imaging teams from AMTRON assisted in the entire operation on behalf of the Expert Committee.

Further, no separate Report of the Expert Committee was prepared. Each group submitted its own report. All the reports submitted by the various groups including data, photo and analysis were extensively used in this Report. In addition, some reports passed on by Justice B. P. Katakey, Chairman of the Committee formed by the Hon'ble National Green Tribunal were also considered.

Further, I must clarify that while elaborate chapters were written by the undersigned (especially Chapters 6 to 10), this Chapter and the other Chapters to follow have not

178 Lead: Dr. Bania Ranjita, Technical Assistants: Nayak Nipen; Field Assistant: Dutta Jivan

been elaborated in detail, as because the stand alone reports, as enumerated above, are taken to be part of this Report by default. Therefore, only the salient points, or critical comments or conclusions alone have been reflected in these pages. Further, the order of appearance of the reports is largely proportional to the work done on the topic under discussion. This does not mean that one report is more important than the other. The author of this Report has tried not to discriminate among the expert teams, rather these reports appear as per the theme of the Chapters and by way of a to-the-point presentation without prejudice to anyone. In case of difference of opinion or divergence of views or contradiction in findings, an attempt has been made to argue for the best possible point of view, keeping scientific temper in mind.

11.2 Introduction

After having unearthed, in some detail, the physical and chemical properties of the Baghjan blowout:- the subsequent explosion, fire and flame, we concentrated on emissions in the air, followed by noise and thermal pollution in the surroundings, impact of the blowout and fire on land, water and soil have been discussed. In this Chapter we shall briefly examine the effect of the Baghjan fire on the land (soil) and water (water bodies). Sharma et al (2020) and WII (2020) have dwelt in considerable detail on soil health and water quality, the pollution caused in the soil and waters of the surrounding areas of Baghjan. The present Chapter deals with soil and water from the pollution perspective, caused by the emissions from the fire. We also looking at thermal pollution (in water), and if the radiation of heat from the flame had any impact on the soil and water temperature. The impact on biodiversity indicator species etc. would be dealt with in subsequent chapters. Excerpts from various reports as mentioned above would also be provided in the findings section.

11.3 Plea Of M/S OIL In The Hon'ble NGT

In the Order Dt. 6th August, 2020 in the matter of OA no. 43/2020 (EZ) and OA No. 44/2020 (EZ), the plea taken by the M/S Oil India Ltd. is briefly outlined here. As per the said order, the plea of the OIL company is "*Report of the Wildlife Institute of India (WII) is based on post blowout incident. The OIL follows all safeguards and SoPs and has employed experienced contractuals. But the said contractor violated the laid down procedures… Contribution of Polycyclic Aromatic Hydrocarbons (PAH) is from tea gardens, forest land and insecticides/pesticides. With regard to environmental impact, it is stated that damage is on account of agricultural activities or other reasons in the area*".

The first plea of M/S OIL is that the Report of WII is post blow out, so shall be all reports considered here, including this Report itself. The question of a pre-blowout Report does not arise. Therefore, assuming that M/S OIL is not accepting any post blow out reports by others, it is not understood who would accept their post blowout reports, and who shall take the guarantee that all such reports would not be doctored? However, the question still remains which reports are pre-blow out and only these be considered to adjudicate on the matter? The only answer is any assessment report done by any third party engaged by M/S OIL prior to the blowout? Only two reports come to mind, and both the reports have been extensively used in getting answers to whether OIL had breached any provisions of law or not. These reports are the EIA by Gauhati University and by M/S ERM.

It must be again mentioned here, even at the risk of repetition, that there is no report by M/s OIL and MoPNG in public domain that speculates and predicts that such a disaster as Baghjan blowout can occur, and if any such incidents occur, such would be the fall out in terms of pollution, heat, tremors, fire, noise and ecological damages. If all these were not predicted in their assessment reports based on which Environmental Clearance was given, then M/s OIL and their owners have no justification in discarding reports of others by calling them post blowout.

Further, if PAH has been coming from tea gardens, forest lands and insecticides and pesticides, then the EIA reports by GU and M/S ERM ought to have found out in their EIA Reports, and if so then in what quantities. Let the expert team of M/s OIL show that higher quantities of contamination of PAH and other organic pollutants were already present in the soil and water prior to commencement of their operations. Also a comparison would have to be made in the quantities assessed by GU and M/S ERM vs WII to see what were the levels then and now. Further, if there are no PAH in the two EIA Reports, then, as because human habitations, forests and tea gardens predate the oil well by many decades, one would be forced to believe automatically that all PAH in the soils and water of the areas surrounding Baghjan are an outcome of the Blowout, and not any other activity prior to the blowout.

11.4 Ill Effects Of Soil And Water Pollution

The ill effects of soil and water pollution would make a separate book in itself, if one were to describe them. The sole point to drive here is that a polluted soil represents a polluted ecosystem where the smaller forms of life would be either dead and extinct or would undergo genetic mutations or would have malformed progeny or would impact

the coming generations of the flora and fauna in dangerous ways- and it would apply to humans, animals, avifauna, fish fauna and all other forms of life that depend on these ecosystems for their life cycle activities, food, shelter, nesting, roosting, reproduction and other life support activities. Serious health threat is also posed to mammalian wildlife, household cattle, domestic animals that might drink the polluted waters. The birds and almost entire avian family that would reside around polluted land and water sites are likely to get exposed to serious health hazards, risk of cancer, consuming poisoned and contaminated food. This would multiply across the food chain/ web dependent upon such polluted ecosystem environs.

Therefore, there are many ramifications of soil and water pollution that even do not exist directly for air pollutants that largely impact on inhalation of the impure air. The damage impact factor is also many degrees higher for soil and water pollution than for air pollution, especially the non-human populations that would inhabit such polluted sites.

11.5 Legal Provisions Pertaining To Soil And Water Pollution

The Water (Prevention and Control of Pollution) Act, 1974 is the mother Act in India that gave birth to the system of Pollution Control Boards in the country. The Act defines “pollution” as “(e) "pollution" means such contamination of water or such alteration of the physical, chemical or biological properties of water or such discharge of any sewage or trade effluent or of any other liquid, gaseous or solid substance into water (whether directly or indirectly) as may, or is likely to, create a nuisance or render such water harmful or injurious to public health or safety, or to domestic, commercial, industrial, agricultural or other legitimate uses, or to the life and health of animals or plants or of aquatic organisms”. Further the word “stream” has been defined in the Act to cover “(i) river; (ii) water course (whether flowing or for the time being dry); (iii) inland water (whether natural or artificial); (iv) sub-terranean waters”. Due to irrelevance of sea and tidal waters, this portion of the meaning of stream has been deliberately dropped here. The Central Pollution Control Board (CPCB) is empowered under Section 16(2)(g) to “lay down, modify or annul, in consultation with the State Government concerned, the standards for a stream or well”.

Under Section 24(1)(a), the Act prevents any person from causing any pollution into any stream or even land, and states that “*no person shall knowingly cause or permit any poisonous, noxious or polluting matter determined in accordance with such standards as may be laid down by the State Board to enter (whether directly or indirectly) into any [**stream***

*or well or sewer or on **land**]*" Thus, the Act covers pollution of the land and soil very well under this Section, as land and soil cannot be separated. Appeals under the Act, as per Section 28 lies with an Appellate Authority that the State Govt. may constitute, and under sub section (2) "An appellate authority shall consist of a single person or three persons as the State Government may think fit, to be appointed by that Government." Further, under Section 51 and 52 there is provision to set up Central Water Laboratory and State Water Laboratory.

As such there is no other legal provision exclusively for soil in India, other than that mentioned above for land. Coverage is, however, also available under the Section 9(1) of the Environment (Protection) Act, 1986, which states "Furnishing of information to authorities and agencies in certain cases- Where the discharge of any environmental pollutant in excess of the prescribed standards occurs or is apprehended to occur due to any accident or other unforeseen act or event, the person responsible for such discharge and the person in charge of the place at which such discharge occurs or is apprehended to occur shall be bound to prevent or mitigate the environmental pollution caused as a result of such discharge and shall also forthwith- (a) intimate the fact of such occurrence or apprehension of such occurrence; and (b) be bound, if called upon, to render all assistance to such authorities or agencies as may be prescribed". It further prescribes under sub-section (2) "On receipt of information with respect to the fact or apprehension of any occurrence of the nature referred to in sub-section (1), whether through intimation that sub-section or otherwise, the authorities or agencies referred to in sub-section (1) shall, as early as practicable, cause such remedial measures to be taken as necessary to prevent or mitigate the environmental pollution". Further under subsection (3) the Act mandates "The expenses, if any, incurred by any authority or agency with respect to remedial measures referred to in sub-section (2), together with interest (at such reasonable rates as the Government may, by order, fix) from the date when a demand for expenses is made until it is paid, may be recovered by such authority or agency from the person concerned as arrears of land revenue or of public demand".

Further, under the Environmental (Protection) Rules, 1986, the standards for emission or discharge of environmental pollutants specified under Rule 3(1) and (2) shall be complied with by an industry, operation or process within a period of one year of being so specified. The Rule under Schedule I, defines emission standards for Oil-refinery industry (Sl No. 3), Petrochemicals, basic and intermediate (Sl No. 38); and under Schedule VI prescribes general standards for discharge of effluent and environmental

pollutants. In addition, PCBA has issued several standards and guidelines from time to time. Let us look at some of the standards/ Guidelines.

11.5.1 Surface Water Quality Standards

As per the CPCB 1979 and BIS 1982 (IS:2296), there are five classes of surface water. These are: **Class A** – Drinking water without conventional treatment but after disinfection. **Class B** – Water for outdoor bathing. **Class C** – Drinking water with conventional treatment followed by disinfection. **Class D** – Water for fish culture and wild life propagation. **Class E** – Water for irrigation, industrial cooling and controlled waste disposal. Therefore, from water quality perspective, water bodies can be classified into the above five classes. It is expected that in normal conditions, the water-body should be Class A. Further, as per BIS (IS:10500), the drinking water quality has been defined by a set of parameters.

From the two standards, it is clear that odour and taste should be “agreeable” and “Unobjectionable”. The PAH limit is 0.2 mg/L for Class A, but zero for drinking water. The quantum of pesticides and insecticides has to be 0. Lead limit is 0.1 mg/L for Class A water body, but 0.05 mg/L for drinking water. BOD should be between 2-3 mg/L for Class A, B & C water bodies. Oil and grease quantity in water bodies has been prescribed at 0.1 mg/L for only C& D class water bodies. This implies that it should be 0 for Class A & B.

There are some effluent discharge standards that need mention here. N1 means discharged water shall not exceed 5°C above the receiving water temperature, N2 means all efforts should be made to remove colour and unpleasant odour as far as practicable from the effluent, N3 means 90% survival of fish after 96 hours in 100% discharged effluent.

11.5.2 Soil Quality Standards

Unfortunately, there are no soil quality standards in India (whereas some countries, such as some African countries have soil quality standards). Effluent discharge into land and water are the only parameters at hand to assess soil quality. Nevertheless, a few parameters can be attempted to be defined here. Soil quality has many facets, and we have limited applicability, we need to look at PAH, Lead and Oil & Grease in soil samples.

Lead (as Pb) levels in soils can be treated as safe upto 2-200 mg/Kg of soil as per published research[179]. PAH concentrations in soil have been graded differently depending upon land use. As per one research work[180], PAH of 1-3 mg/Kg is the maximum limit of PAH for background soil contamination, 10 mg/Kg for raising of forage crops and animal usage, 25 mg/Kg for settlement areas, and 100 mg/Kg for industrial areas. Oil and Grease (O/G) is a group of chemicals, mostly extracted from samples using Hexane, and hence these are also known as Hexane Extractable Materials (HEM). A very related terminology is Total Petroleum Hydrocarbon (TPH) which is also often used interchangeably. There are no standards for soil, as already stated. In research studies[181], the values are compared with control. Often heavy metals such as Cr, Cd, Cu, Zn, Pb and Ni also occur in oil spill sites.

11.5.3 HAZARDOUS SUBSTANCES DEFINITION

Though discussed earlier, natural gas and condensate do not fall strictly under the hazardous category, if one goes by the **Manufacture**, **Storage And Import Of Hazardous Chemical** (Amendment) **Rules**, **1989**. These are also not covered under the Explosives Act, 1884, but surely they can explode or cause explosion. The Section 4(d) of the Explosives Act, 1884 defines "Explosives" as "*... or any other substance whether a single chemical compound or a mixture of substances, whether solid or liquid or gaseous used or manufactured with a view to produce a practical effect by explosion or pyrotechnic effect; and includes fog-signals, fireworks, fuses, rockets, percussion-caps, detonators, cartidgcs, ammunition of all descriptions and every adaptation or preparation of an explosive as defined in this clause;*". Surely, no one produces natural gas for fireworks. However, under the EPA, 1986 definition of hazardous substances under Section 2(e), which defines "hazardous substance" as "*... any substance or preparation which, by reason of its chemical or physico-chemical properties or handling, is liable to cause harm to human beings, other living creatures, plants, micro-organism, property or the environment*". Thus, the natural gas and condensate fully fit the definition of hazardous substance under the Section 2(e) of the EPA, 1986. Persons handling hazardous substances are required to comply with procedural safeguards as prescribed under the Section 8 of the EPA, 1986.

179 Mukhraiya D, & Bhat J.L, 2017, DOI: 10.15515/abr.0976-4585.8.3.4753

180 Sonja Volk, Angelika Gratzfeld-Huesgen, Agilent Technologies, Inc., Waldbronn, Germany, 2011, Publication Number 5990-8414EN

181 Olufemi A.G, Titilaya E.A, Tunde E.O, 2012, Terrestrial & Aquatic Environmental Toxicology, 6 (1), 61-65 @2012, Global Science Books

Further under the Chemical Accidents (Emergency Planning, Preparedness And Response) Rules, 1996, Schedule I Part I (c) as "*Chemicals which may explode under the effect of flame, heat or photochemical conditions or which are more sensitive to shocks or friction than dinitro benzene*". For major chemical accidents, the Rule prescribes formation of various Crisis Groups at the Central, State, District and local levels and empowers the members of the Crisis groups under sub-section (1) of section 10 of the Environment (Protection) Act, 1986. In the backdrop of the Baghjan fire, it could not be ascertained if these provisions of law operate or are dormant.

11.6 Air-Soil-Water Temperature Relationships

As there are only a few standards and guidelines pertaining to water, and almost none pertaining to soil, relevant to the Baghjan blowout case, let us continue the continue the debate on "thermal pollution" further and see its impacts on air-soil-water ensemble.

Temperature is one of the most important indicators for suitability of the surrounding environment for sustenance and survival of organisms and ecosystems. Most species have their own temperatures beyond which it would be difficult for the individuals of that species to survive. Some organisms may also adopt to extreme temperature conditions. Land, soil and water provide the required habitat for various species to thrive by providing right kind of food, water and shelter suited to the species adopted in that environment. Land, especially soil and water differ in their characteristics wrt their response to radiation, especially the incoming short wavelength solar radiation. Soil being impervious and opaque to solar radiation, transforms the short wavelength into long wavelength scatter, and thereby gets hot in the process. Water, on the other hand, is transparent to short wavelength, and scatters incoming solar radiation at some depth, and thus, remains cooler than the ambient temperature.

A study by Zhan et al (2019)[182]examined relationships between air and soil temperatures in Monsoon Subtropical region of China from 1968-2018. The authors found that soil temperature was higher by about 2^0C or more than the air temperature. The top soil is the hottest. The figure below clearly demonstrates the relationship between air and soil temperature.

182 Zhan Ming-Jin, Xia L, Zhan L, Wang Y, 2019, Advances in Meteorology, Volume 2019, Article ID 6927045, 9 pages, https://doi.org/10.1155/2019/6927045

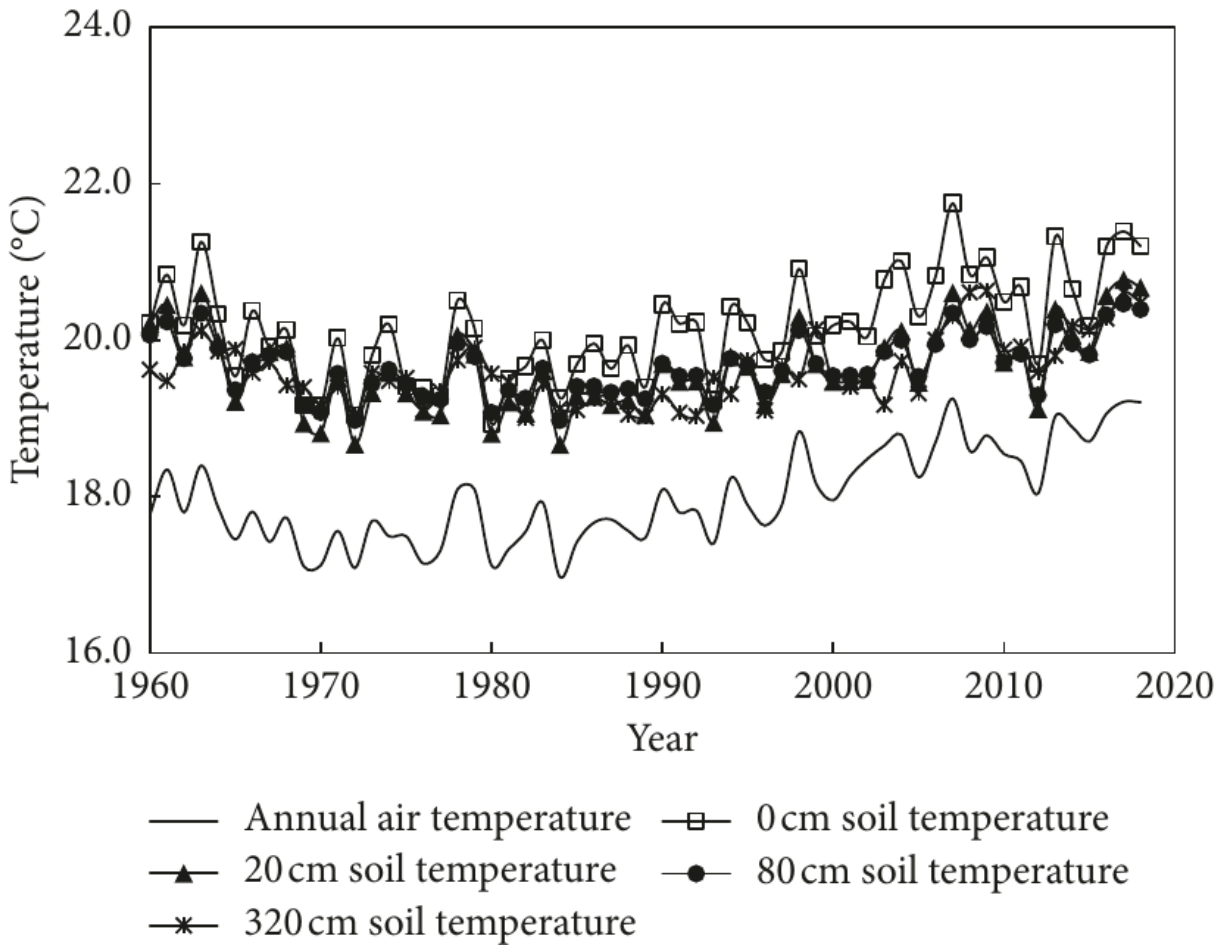


Fig. No. 11.1: Air and Soil Temperature

They found very high correlation among air temperature and soil temperature at various depths starting from topsoil to soil depths upto 3.2m. They proposed a direct linear relationship between air temperature and soil temperature at various depths. The equations are reproduced here.

Soil depth (cm)	Regression equation	Correlation coefficient
0	$y = 0.9787x + 2.5523$	0.914
20	$y = 0.748x + 6.181$	0.858
80	$y = 0.529x + 10.147$	0.798
320	$y = 0.4908x + 10.785$	0.700

Fig. No. 11.2: Regression Equations of Soil Depth and Temperature

In another significant study by Barman et al (2017)[183], of relationship between soil and air temperatures in the lower Gangetic plains from 1985-2014, it was found that soil temperatures were higher than the air temperature by 2.97^{0}C for soils at 5 cm depth, 4.51^{0}C for soils at 15 cm depth and 6.3^{0}C for soils at 30cm depth. They found that a good correlation existed between mean air temperature and soil temperature at various depths. The relationship at 5cm depth is shown below:

$$Y=0.284\ X^{1.358} \quad R^2=0.993 \qquad \text{..... } Eq.No.\ 11.1$$

where Y is the soil temperature in ^{0}C, and X is the mean air temperature in ^{0}C. However, it has to be noted that the surface soil cools down after sunset by radiating long wavelength radiation and attains equilibrium with air temperature in the morning before starting to get heated again.

A study by Minnesota University[184] found simple linear relationships between daily air temperature and weekly mean air temperatures and water temperatures (of water bodies). If T_a is the air temperature and T_w is the water temperature, then the two are related by the following equations:

$$T_w = 5.0 + 0.75xT_a \quad \text{(Daily)} \qquad \text{..... } Eq.No.\ 11.2$$

$$T_w = 2.9 + 0.86xT_a \quad \text{(Weekly)} \qquad \text{..... } Eq.No.\ 11.3$$

While the above equations look simple, heat exchange at the water surface of a water body is a complex phenomenon as depicted in the figure that follows [from Piccolroaz S et al (2013)[185]]. The authors proposed a semi-empirical lumped model for a relationship between T_a and T_w, which is given below:-

$$\frac{dT_w}{dt} = \frac{1}{\delta}\left\{p_1 \cos\left[2\pi\left(\frac{t}{t_{yr}} - p_2\right)\right] + p_3 + p_4\,(T_a - T_w) + p_5\,T_w\right\},$$

Where,

$$\delta = \exp\left(\frac{T_r - T_w}{p_6}\right), \quad (T_w \geq T_r)$$

$$\delta = \exp\left(\frac{T_w - T_r}{p_7}\right) + \exp\left(-\frac{T_w}{p_8}\right), \quad (T_w < T_r)$$

..... $Eq.No.$ 11.4

The above model is based on 8 physical parameters p_1 to p_8.

183 Barman D, Kundu D.K, Pal Souman, Pal Susanto, Chakraborty A. K, Jha A.K, Majumdar S. P, Saha R, Bhattacharyya P, 2017, Int. Agrophys., 2017, 31, 9-22, doi: 10.1515/intag-2016-0034

184 Preud'homme Eric B & Stefan Heinz G, Report No. 333, USEPA, Duluth, Minnesota, 1992

185 Piccolroaz S, Toffolon M, Mojne B, 2013, Hydrol. Earth Syst. Sci., 17, 3323–3338, 2013, doi:10.5194/hess-17-3323-2013

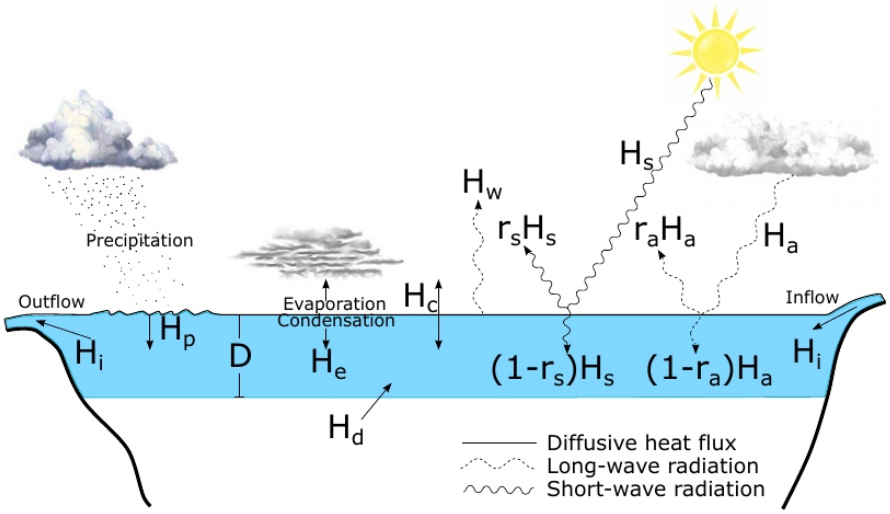


Fig. No. 11.3: Schematic of various Heat Radiations on Water Surface

The net heat flux H_{net} per unit surface [W m^{-2}] can be given by:

$$H_{\text{net}} = H_{\text{s}} + H_{\text{a}} + H_{\text{w}} + H_{\text{e}} + H_{\text{c}} + H_{\text{p}} + H_{\text{i}} + H_{\text{d}} \quad \text{..... } Eq.No.\ 11.5$$

where the indices at the bottom indicate: s→short wavelength incoming solar radiation, a→ long wavelength, w→long wavelength radiated from water, e→latent heat due to evaporation, c→sensible heat due to convection, p→heat flux due to precipitation, i→heat exchanged through inflows and outflows, d→ heat exchanged with deep water. When we introduce the perturbation of heat flux from the Baghjan flame, the equation would change considerably. However, no detailed treatment of the above has been attempted in this Report. It has been mentioned here only to emphasize that it was possible to work out the net heat flux on water and the impact of the Baghjan flame if sufficient resources were available. This is for future reference only.

Authors Morrill JC et al (2005)[186] also studied relationship between air temperature and stream temperatures by drawing water samples from 43 stream sites globally in 13 countries. They found that for every rise of 1^0C in air temperature, stream temperature rises by 0.6-0.8^{0}C. They also found that as water temperature rises, the Dissolved Oxygen value gets reduced. They used linear and non linear regression equations for the study, and found that the non linear models fitted better. The non linear model fitted was of the type:-

186 Morrill Jean C, Bales Roger C, Conklin Martha H, 2005, Journal of Environmental Engineering, Volume 131 Issue 1 - January 2005.

$$T_w = \mu + \frac{\alpha - \mu}{1 + e^{\gamma(\beta - T_a)}} \quad \text{..... } Eq.No.\ 11.6$$

where T_w is the predicted stream water temperature, T_a is the measured air temperature (for the period of interest), μ is the minimum stream temperature, α is the maximum stream temperature, γ is the function of the steepest slope (inflection point) when T_w and T_a are plotted, β is the air temperature at the inflection point. The non linear equation arrived in their research is given below[187]:-

$$T_w = 0.3 + \frac{22.9 - 0.3}{1 + e^{0.21(12 - T_a)}} \quad \text{..... } Eq.No.\ 11.7$$

11.7 Methodology For Assessment Of Soil & Water Pollution

As already stated, there is no comprehensive single point legislation to deal with soil and water pollution in the country. The broad legal framework has already been described in the earlier paragraphs in some detail. Now, lets gather together various methodologies that may be deployed to assess the various types of pollution possible in case of soil and water primarily keeping in view the nature of enquiry at hand i.e. natural gas and condensate spillage, explosion and burning flame.

11.7.1 Quality Indicator Measurements

Most measurements in case of soil and water have been quality indicators such as pH, BOD, COD, Dissolved Oxygen (DO), Oil & Grease, Pb, PAH, heavy metals such as Ni, Zn, Cu, Pb, Hg, As, Cr etc. However, not all of the measurements have been fully defined under the quality standards with tolerance limits. Therefore, some key measurements would alone be highlighted here, especially the ones which were actually measured in the field by the various expert teams.

pH Measurements: It was noticed that most pH value in lab show neutral water. It has been observed that in-situ pH measurements and subsequent lab measurements based on stored samples often do not match. The possible reason could be various reactions with the atmospheric air, or microbial activity in the sample or handling and transport. The differences in field and lab measurements could be substantial[188]. The authors observed that onsite pH measurements were to be considered to be a more accurate assessment of the chemical conditions than subsequent laboratory measurements. Most water sample pH values measured in the lab in the case of Baghjan ranged

187 One of the linear relations arrived at by the authors is: $T_w = 0.65 + 0.89 \times T_a$
188 Latysh N, Gordon J, 2004, Water, Air, and Soil Pollution 154: 249–270, 2004.

between 7 to 8, while onsite measurements showed highly acidic nature of the water. Therefore, all lab measurements of pH have been rejected in this Report.

Temperature: Very few measurements of onsite soil and water temperature were taken. In case of contamination by oil and condensate and blazing fire, the temperatures are expected to be higher than normal. Baseline studies need to be used. It is to be noted that temperature measurements are available for the water samples in the two EIA Reports of M/S OIL, but not for the soil samples. **The EIA Reports may be considered deficient in this respect**. Insitu measurements of water temperature were carried out by Sharma et al (2020), WII (2020) and PCBA (2020), while for soil temperature measurements were carried out by Sharma N et al (2020). Further baseline temperature data for water was available from the National Water Monitoring Program, from October, 2019 to March, 2020 from the Maguri Beel near Guijan.

DO, BOD, COD: The Dissolved Oxygen, Biological Oxygen Demand and the Chemical Oxygen Demand for various water samples were carried out by PCBA (2020) and WII (2020). Baseline data were available from the two EIA Reports by M/S OIL. Further under the National Water Monitoring Program, from October, 2019 to March, 2020 from the Maguri Beel near Guijan.

Heavy Metals: Heavy metal concentration measurements in soil and water samples were carried out by the PCBA (2020) alone. Baseline data are available from the two EIA reports.

Oil & Grease: Oil and Grease concentrations in the water and soil were measured by PCBA (2020) alone. Baseline data on O/G values for water samples are available from the two EIA Reports. However, for soil sample O/G, the values are available in only one Report i.e. that by the Gauhati University. T**he EIA report by M/S ERM is considered deficient in this respect**.

PAH & TPH: PAH measurements were carried out by WII (2020). Only a few TPH measurements were available from M/s ERM for dates 1st to 9th June, 2020 near the blowout site. However, none of the EIA Reports mention either of PAH or TPH at all. **To this extent, the two EIA Reports by M/s OIL are deficient**. ***This omission is not acceptable at all***. Now that OIL has no baseline data, on PAH, of their own for the area in question (despite the fact that PAH is a part of the water quality parameter set as defined by BIS as discussed in the previous section), they cannot claim that all the PAH and heavy metals found in the soils and water bodies is a contribution from agriculture and tea cultivation. Further, how can the two EIA reports be considered complete

without PAH assessment, whereas its well known that PAH has been associated with petroleum and crude oil. A study by Sarma H et al (2016)[189] show that PAH is common in oil field areas of Upper Assam, and PAH together with HM (Heavy Metals) has a strong tendency for uptake by rice plant (*Oryza sativa*) and thus would enter into the food chain by way of bio-accumulation.

11.7.2 Thermal Pollution

It was discussed in the previous Chapter that thermal pollution largely refers to rise in temperature of water bodies due to effluent discharge or other reasons. In the Indian context, the rise needs to be above 5^0C than the normal temperature of the water body in order to fall in the category of thermal pollution. Since, baseline temperatures are available, one can easily assess the temperature from the insitu measurements, and see if actually there has been some degree of thermal pollution or not. Now that there is an estimation for the heat energy already carried out in the previous Chapter, one can also easily assess possible rise in water temperatures.

11.7.3 Land Surface Temperature

The land surface temperature studies were carried out by Sharma N et al (2020) using Landsat 8 satellite images. They used Landsat bands 10 & 11 (Thermal bands) in combination with red band 4 & near infra red band 5. The formula used was:-

$$LST = \frac{BT}{\left[1 + \frac{10.8\,BT}{14388} \times \ln(\epsilon)\right]} \quad \text{.....} Eq.No.\ 11.8$$

where LST is the Land Surface Temperature in ^{0}C, BT is the Brightness Temperature in ^{0}C, and ε is the emissivity of each pixel point (i,j) in the image set. The detailed methodology can be seen at page 120-121 of the said Report. Using the methodology above, the surface temperatures were calculated for 26th April, 2020, 28th May, 2020, and 29th June, 2020. This was in a radius of 5 km from the blast site and covered the Dibru-Saikhowa as well as the Maguri Motapung Beel ecosystems.

11.7.4 MODIS Data for Baghjan Blow Out

The undersigned obtained MODIS VIIRS data surrounding the Baghjan blowout site from 28th May to 22nd June, 2020. It consisted of a mix of Terra, Aqua and VIIRS data. The "hot" pixel values, background pixel values as well as FRP were obtained from the MODIS & VIIRS data.

189 Sarma H, Islam N.F, Borgohain P, Sarma A, Prasad M. N. V, 2016, Emerging Contaminants, 2 (2016) 119-127

11.7.5 COSTANZA'S ECOSYSTEM SERVICES VALUATION

Robert Costanza[190] and his team evaluated the economic worth of the ecosystem services in their landmark research in ecological science in 1997. In words of the authors, "*Because ecosystem services are not fully 'captured' in commercial markets or adequately quantified in terms comparable with economic services and manufactured capital, they are often given too little weight in policy decisions. This neglect may ultimately compromise the sustainability of humans in the biosphere. The economies of the Earth would grind to a halt without the services of ecological life-support systems, so in one sense their total value to the economy is infinite. However, it can be instructive to estimate the 'incremental' or 'marginal' value of ecosystem services (the estimated rate of change of value compared with changes in ecosystem services from their current levels).*" They grouped all the services provided by the various ecosystems into 17 categories namely: Gas regulation (Regulation of atmospheric chemical composition), Climate regulation (Regulation of global temperature, precipitation, and other biologically mediated climatic processes at global or local levels), Disturbance regulation (Capacitance, damping and integrity of ecosystem response to environmental fluctuations), Water regulation (Regulation of hydrological flows), Water supply (Storage and retention of water), Erosion control & sediment retention (Retention of soil within an ecosystem), Soil formation (Soil formation processes), Nutrient cycling (Storage, internal cycling, processing and acquisition of nutrients), Waste treatment (Recovery of mobile nutrients and removal or breakdown of excess or xenic nutrients and compounds), Pollination (Movement of floral gametes), Biological control (Trophic-dynamic regulations of populations), Refugia (Habitat for resident and transient populations), Food production (That portion of gross primary production extractable as food), Raw materials (That portion of gross primary production extractable as raw materials), Genetic resources (Sources of unique biological materials and products), Recreation (Providing opportunities for recreational activities) and Cultural (Providing opportunities for non-commercial uses). The authors evaluated total 516.25 million sq km of ecosystems spread in the Marine and Terrestrial Biomes and estimated their annual flows of ecosystem services at 33.368 Trillion US $ per year. The valuation, according to the authors, of the four most relevant ecosystems to the enquiry at hand are:

190 Costanza Robert, d'Arge Ralph, de Groot Rudolf, Farberk Stephen, Grasso Monica, Hannon Bruce, Limburg Karin, Naeem Shahid, O'Neill Robert V, Paruelo Jose, Raskin Robert G., Suttonkk Paul, & van den Belt Marjan, 1997, Value of World's Ecosystem Services and natural Capital, Nature, Vol 387, 15 May, 1997

Table No. 11.1: Value of Ecosystem Services (1977)

Ecosystem	Value of Services, 1977 (US$ Ha^{-1} $Year^{-1}$)
Terrestrial Floodplain Wetlands	19580.00
Terrestrial Grasslands/ Range lands	232.00
Terrestrial Rivers/ Lakes	8498.00
Tropical Forest	2769

In a revisit to the previous study of 1997, Costanza[191] and team reworked the estimates of the ecosystem services at 2007 US$ prices, and gave a fresh valuation of the various services. The revaluation of the ecosystem services pertinent to our study is given below:-

Table No. 11.2: Value of Ecosystem Services (2011)

Ecosystem	Value of Services, 2011 (US$ Ha^{-1} $Year^{-1}$)
Terrestrial Floodplain Wetlands	25,681.00
Terrestrial Grasslands/ Range lands	4166.00
Terrestrial Rivers/ Lakes	12512.00
Tropical Forest	5380.00

The values mentioned in the table above are proposed to be used for valuation of the ecosystem services loss due to the Baghjan well blowout with additional following principles:-

1. The prices of 2007 to be scaled up at the rate of 6% per annum in compounding mode till 2019.
2. The exchange rate of US$ to INR to be on the 27th of May, 2020 [*Rs. 76.13 = 1 USD*][192]

The approximate quantum in terms of time period and extent of area shall be determined separately as outlines in the next section.

191 Costanza Robert, de Groot Rudolf, Sutton Paul, van der Ploeg Sander, Anderson Sharolyn J, Ida, Farber Stephen, Turner R. Kerry, 2011, Changes in the gloval value of ecosystem services, Global Environmental Change 26 (2014) 152–158

192 However, an Exchange Rate of INR 74.00=1 US$ has been assumed for all exchange rates in this Report.

11.7.6 Estimation of Extent using Drone Based Mapping

Drone services were requested from AMTRON for the estimation of the damages around the Baghjan blow out well site. The schematic of all the flight paths is given below:-

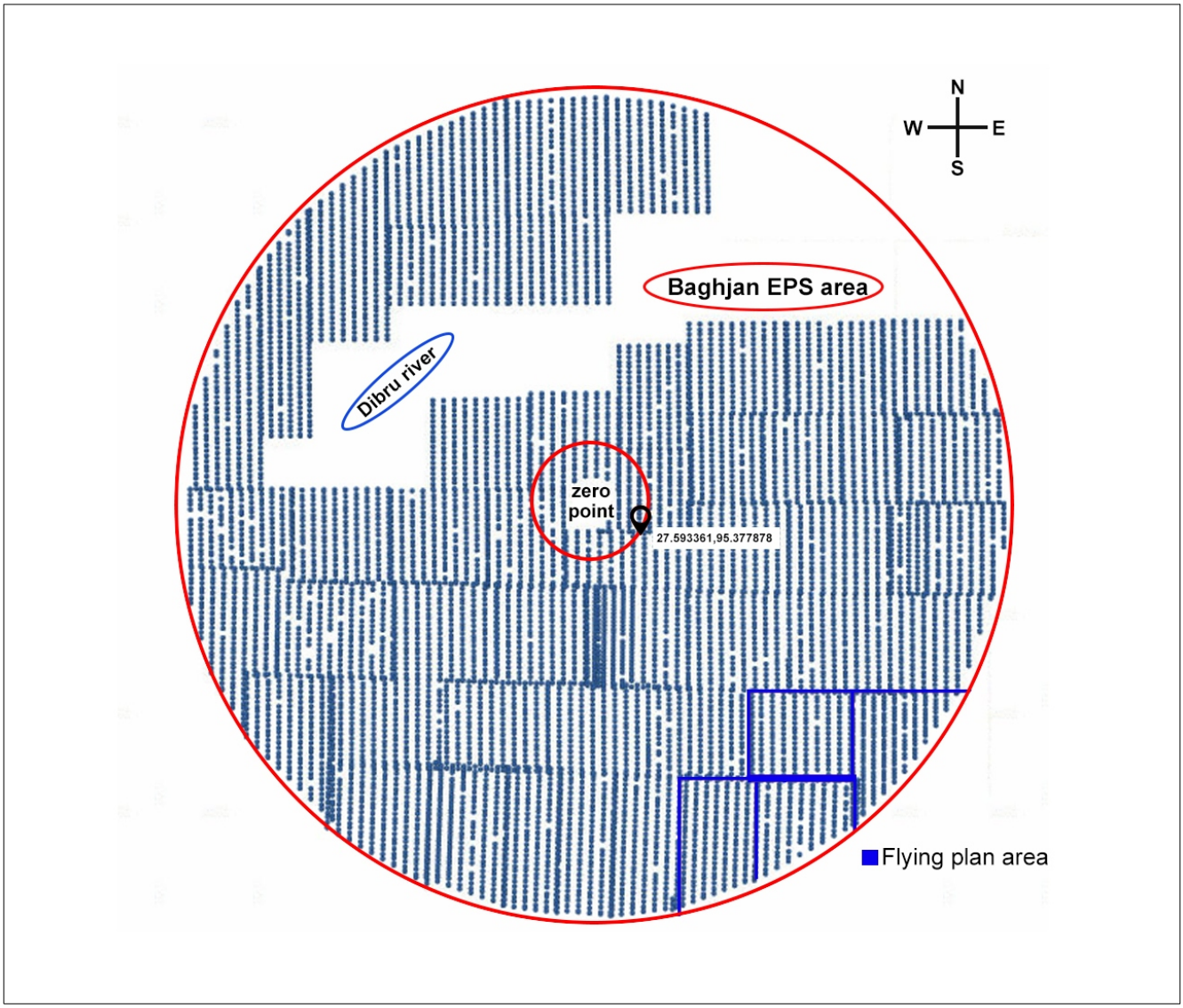


Fig. No. 11.4: Schematic of Drone Flight Path around Blowout Site

The matrix of blue dotted lines are the actual flight paths, taken within a radius of 3 km radius of the ground zero, represented by the outer red circle. The inner red circle (~ 200m radius) is the area out of bound due to barricading, and the position marker shown on the inner circle in the south east edge is the start of the drone flight path. The large white patches are the areas where the drone could not fly due to either "out of bound" restrictions such as the Baghjan EPS, and flooded river Dibru/ Lohit where no take-off/ landing point for the drone could be provided.

In the entire process approx. a total of 45 no of flights have been made covering a distance of 500-700 sq m with a flying time of 15-20 min in each flight of the tiles with the elevation of 200 m from the home point of the UAV. Overlapping of images is 80% (72 %), Mission Type : Polygon , Camera angle : 90^0. All the pictures captured from the UAV are of 20 megapixels with aspect ratio 4:3. Average Ground Sampling Distance 3.63 cm / 1.43 inch, 200 meter inner circle from the zero point is been left uncovered due to extreme heat. Nearest flight plan from the zero point is Lat 27.600103^0 N, 95.379505^0E.

Assumed Absolute Camera Position and Orientation uncertainties:

Mean X (m) 0.057, Y (m) 0.058, Z (m) 0.124.
Omega (degree) 0.018
Mean PHI (degree) 0.016, Kappa (degree) 0.006,
Sigma X (m) 0.013, Y (m) 0.014, Z (m) 0.030.
Omega (degree) 0.003, PHI (degree) 0.003, Kappa (degree) 0.002.

Camera: DJI model FC6310_8.8-5472 x 3684 (RGB). UAV: Phantom 4 Proceedings

Expected Estimates from Drone Mapping: The following quantities are expected to be evaluated from the drone based ortho-photography within the 3 Km radius of the flame:

1. Average flame height taken from different flights around the ground zero
2. Area and polygon of spread of the blow out condensate
3. Area and polygon of spread of fire
4. Approximate count of tea bushes damaged in the fire
5. Approximate count of coconut trees damaged in the fire
6. Approximate count of trees damaged in the fire

Estimating Extent of Agricultural Damages etc: Based on the drone mapping data, the extent of the damage to agricultural fields, damage to soil due to burning and or oil spill, extent of damage, in terms of area, to wetlands, grasslands and rivers due to the blow out. Also, the proportion of the condensate received by these various land forms would also be estimated. For example, if C was the total condensate spewed from the well before the explosion, and it was found to spread to total area A, then, c (=C/A) would be the per unit area quantum spread of condensate; and, the amount of condensate in a land-form I having area A_i, shall be given by:

$$c_i = cA_i \quad \text{..... } Eq.No.\ 11.9$$

$$c_i = C\ \frac{A_i}{A} \quad \text{..... } Eq.No.\ 11.10$$

Depending upon whether the land form i was agriculture/ grassland, and whether it got fully or partially burnt, or it was a water body, and there caused 100% damage to wildlife, or a flowing water such as river where it caused a temporary damage by cutting down oxygen and air supply or got deposited temporarily, and subsequently got washed in the rains/ floods. Based on the above characteristics, one could arrive at an approximate physical damage assessment to the ecosystem services already discussed in the previous section.

Detailed Damage Assessment & Analysis: While detailed damage analysis, plot by plot or house by house within the 3 km radius of the fire for which the drone ortho-photography has been carried out, would be possible; but the same has not been attempted in this Report. However, the drone mapping could be used to assess the actual compensation packages that would need to be determined at the time of final settlement of compensation claims for people/ properties falling within 3 km radius of the blow out.

11.7.7 Breach or No Breach?

Breach or no breach has been adopted as a methodology in this Report to ascertain, in case where legal or statutory provisions exist that restrict emission of certain pollutants or their transforms beyond the permissible limits, whether the provisions of the applicable statutes have been broken or not as arrived from the empirical research and/ or field measurements. However, in certain other cases, where no such bar on emissions exist, the matter has been examined from the point whether the emissions have impacted the surroundings significantly.

However, in case of land, soil and water, there are a few provisions which are either in the nature of emissions directly from the blow out, explosion and fire, or indirectly derived from the incident. For example, PAH is an indirect output of combustion of natural gas, and may not be established directly in the manner as one can do for CO_2 and CO from a combustion process, without going into quite a detailed research on the subject. Similarly, while one can directly correlate quantum of Oil and Grease (O/G) in soil and water, but higher presence of Pb, Cr, Zn may not be immediately derivable from the natural gas and condensate. If the measured data in the field is found to be higher than the prescribed limits, or the PCBA/CPCB say that the concentrations are not desirable, all such cases would be treated as breach. However, in case, none of these exist, but the values are higher than the base line data from the available reports, these shall be marked too, and considered as “breach”.

11.8 Assessment Of Damages To Land, Soil And Water

As already described in methodology, the assessment of pollution or damages would be based on certain parameters that were measured during the site surveys in the month of May, June and July and subsequent measurements to reverify the outcome. However, for several of these parameters, especially the soil and water temperature and Dissolved Oxygen (DO), control assessments or baseline data is required to see if there is any significant change in any of the parameters. To a certain degree, some amount of baseline data is available from the two EIA Reports of M/S OIL. However, these were found not sufficient enough to enable adjudication of "breach or no breach". Therefore, research data from the Internet was searched, and has been used, and also a few control samplings were also done. Now, we shall be discussing the polluting parameters one by one or in groups as the case may be in the paragraphs to follow.

11.8.1 Water Temperature Baselines

The water bodies in the Baghjan area are the Dibru River/ Lohit River, Maguri Motapung Beel, Brahmaputra river in the western end of the Dibru-Saikhowa National Park, Dangori river and Doomdooma river, and several other beels in between. We shall be briefly discussing water temperature issues in these water bodies in the paragraphs below:-

Water Temperature of Brahmaputra River: According to Ahamed et al (2014)[193], the water temperature profile of the Brahmaputra river in certain parts of Bangladesh was studied. The annual temperature variation is depicted in the figure below:

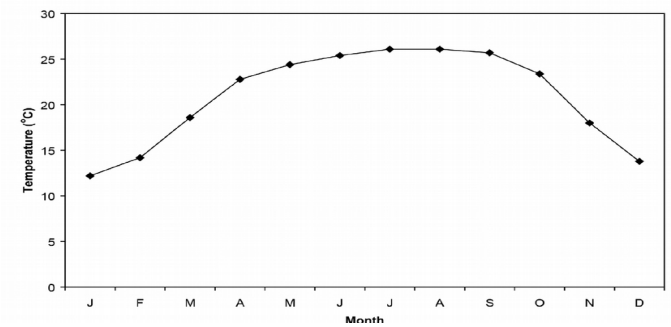


Fig. No. 11.5: Annual Water Temperature Profile of Brahmaputra River

According to CEC Water Quality Monitoring Report of June, 2019[194], the water temperature of the Brahmaputra river at Pandu monitoring station was found to be

193 Ahamed F, Ahmed Z. F. A, Hossain Md Yeamin, Ohtomi J, 2014, Sains Malaysiana 43(11)(2014): 1645–1655

194 CEC, Central Water Commission, June, 2019, Effect of Time and Temperature on DO Levels in River Waters, Ministry of Jal Shakti, Department of Water Resources, River Development & Ganga Rejuvenation, 2019

~25^{0}C (minimum 23.1^{0}C and maximum 27.2^{0}C) in the study period from 22/10/2018 to 29/10/2018. In another study of various parameters of the Brahmaputra river waters was done by Singh S K et al (2005)[195]. The authors carried out sampling of the river Brahmaputra waters and a few of its tributaries. Sampling was also done at Dibrugarh among other stations, and the river Lohit among other tributaries. The authors found that the river water temperature at Dibrugarh was 21.1^{0}C and at Sadiya for Lohit river was 18.6^{0}C during the October, 1999. The temperature at Guwahati was found to be 24.7^{0}C in October, 1999 and 31.2^{0}C in July, 2000. Therefore, both the research studies show similar temperatures for the river in the month of October from studies spaced over 15 years of time.

Water Temperature of Other Rivers and Water Bodies: Islam M R et al (2012)[196] worked on the water quality of Kulsi river, and took samples at three points. The minimum and maximum water temperature obtained was 16.4 to 28.2 ^{0}C., and the mean water temperature during Monsoon time was found to be between 27.5 to 28.2 ^{0}C. Another study by Deori et al (2015)[197] was conducted on Dihing river about 22 km before it joins the Brahmaputra river. The authors reported the water temperature of the Dihing river sampled at three points to be from 18.5 to 25.7^{0}C (average minimum during winter, and average maximum during summer). 26.8^{0}C was the highest temperature during summer. Another study by Sharma BK & Hatimuria MK (2017)[198] on the three water bodies of Majuli river Island namely Bhereki Beel, Holmari Beel and Ghotonga Beel. The water temperature of these beels were measured from September, 2010 to August, 2012. The average temperature for Bhereki Beel was 23.7 (21.5-27.5) ^{0}C, for Holmari Beel 23.6 (21-27.5) ^{0}C, and for Ghotonga Beel 23.9 (21.5-27.5) ^{0}C.

Baseline Data: According to the EIA-GU (2009), sampling was done at 10 sites for water quality, but the number of samples taken and time period is not recorded. However, the average water temperature shown for the 10 sites varies from 19-22.6^{0}C. According to the EAI-ERM (2019) Report, water quality for surface water was carried out at three sites only, but again the number of samples and time period is not known. As per this study, the surface water temperature varied from 20.4 – 22.1 ^{0}C. Looking at the various data

195 Singh Sunil K, Sarin M M, France-Lanord Christian, 2005, Geochimica et Cosmochimica Acta, Vol. 69, No. 14, pp. 3573–3588, 2005

196 Islam M. R, Bania R, Baruah D, Biswas S.P, Gupta A, 2012, European Journal of Experimental Biology, 2012, 2 (6):2451-2455

197 Deori D J, Abujam S, Biswas S. P, 2015, International Journal of Fisheries and Aquatic Studies 2015; 2(4): 190-197

198 Sharma B. K & Hatimuria M. K, 2017, Journal of Aquaculture & Marine Biology, Vol 6, Issue 1: 00144. DOI: 10.15406/jamb.2017.06.00144

obtained from research studies, these samples might have been collected during February to May. All the results, by and large, agree. However, due to lack of complete data on air temperature and water temperature in all the studies, it is difficult to establish any direct relationship. Nevertheless, it can be assumed that during June-July and August-September, the surface water temperature could vary from 25-28^{0}C. No direct calculation could be done, as month wise data was not available. Therefore, it would be not out of place to assume the lower end of this temperature to be 25^{0}C, as the cut-off temperature of the water bodies around Baghjan, above which we shall assume it to be a case of thermal pollution. The associated air temperature can be worked out, using one of the regression relation equations mentioned earlier, Further, the air temperature for 2016 to 2020 was also analyzed, and it was found that from June to September, the temperature varied as 27.37, 28.86, 30.00, 27.83 ^{0}C. The mean summer temperature can, therefore, be taken as 28.5^{0}C. Therefore, the average mean day time surface water temperature in these parts of the world is expected to be about 25^{0}C in summer / Monsoon (June to September), and the corresponding air temperature can be expected to be 28.5^{0}C.

WII Assessment of River Water Temperature: The WII team took 59 sample points from Dhola Sadiya Bridge to Guijan and Balijan in the Lohit River from 19th to 20th June, 2020. However, due to instrument error, the data of 47 points from the start was lost. The data from Guijan to Balijan (12 sample points) showed that the water temperature of the main stream varied from 21.3 to 23.7 ^{0}C. The average river water temperature comes to 22.89 ^{0}C.

11.8.2 WATER TEMPERATURE ASSESSMENT

Now that the baseline datum for the water temperature has been fixed at **25^{0}C** in summer, and air temperature at **28.5^{0}C**, we can examine the various assessments of water temperature (and also air temperatures wherever available) in the various assessments carried out by the expert teams.

Ahmed I (2020): The College of Fisheries team led by Dr. Imtiaz Ahmed had carried out sampling at three sites in the Dibru river on 22nd June, 2020. They measured mean air temperature and water temperature at the three sites. The air temperature at the three sites was 29, 28.03 & 28.07 ^{0}C. The average comes to 28.37^{0}C. As per the archived data of air temperature of Dighalturrung TE, the maximum and minimum temperatures on 26th June, 2020 were 32 and 23 ^{0}C respectively, giving an average of 27.5^{0}C. The water temperature at the three sites were found to be 28.96, 27.96 and 27.66 ^{0}C, giving an

average water temperature of 28.19^{0}C. Therefore, while the air temperatures agree, the water temperature is found to be above the baseline temperature by 3.19^{0}C.

PCBA (2020): PCBA carried out water quality monitoring under the National Water Monitoring Programme (NWMP) under which data was collected from Maguri Beel near Guijan every month. Data from October, 2019 to March, 2020 was made available by the PCBA, according to which water temperature of the Beel water was 29^{0}C in October, 2019 (*This data point is highly unlikely, and may be an error*!), it came down to 20^{0}C in January, 2020 and again risen to 23^{0}C in March, 2020. Post blow out, no measurement of surface water temperature or air temperature was taken by the PCBA Officials. Thus, it can be said that officially there was no monitoring of temperature (air, water and soil) by the PCBA post blowout. These could be the parameters which do not seem to gather the attention of the agencies assigned to monitor pollution levels.

Sharma N et al (2020): This group carried out three different set of water temperature measurements. One set was during the flood that occurred on the 26th June, 2020 and due to which all the oil that was left unburnt spread all over the Maguri Beel and the grassland causing widespread damage to the ecology:- A number of earthworms, molluscs, fishes died instantly. Insitu water temperatures were also measured at that point of time. The values of water temperature ranged from 28-31 ^{0}C. Air temperatures were also recorded at each location. The range of variation was 28-32 ^{0}C. There was very little to no difference between the air and water temperatures. Prior to floods, but after the blow out, 97 sites were surveyed around the blow out site where dead fauna were located. The water temperature at each site was taken. The water temperature was noted to be from 27-32 ^{0}C. The air temperature was also recorded at each site. It varied from 32–42 ^{0}C. The difference between the air and water temperature at the sites varied from 2^{0}C to 13^{0}C. It also needs to be noted that the Dighalturrung TE monitoring station recorded the whole of June, 2020 the maximum temperature (during the day) varying from 25-35 ^{0}C, and in the whole of July, 2020 the maxima varying from 29-35 ^{0}C.

Therefore, the phenomena of temperature variations captured in the assessment of Dr. Narayan Sharma et al team cannot be explained in ordinary terms. While it is clear that when flood came on 26th June, 2020, the spread of water might have lowered the air temperature in the grasslands surrounding the fire, but there was no reason for the water temperature to rise, except the fact that the film of oil on water did the trick. Further, since the recorded maximum temperature for both the months of June and July, 2020 was 35^{0}C, we need to look at the number of sites out of 97 sites surveyed by

the team where temperatures were higher than 35^{0}C. The Chart below shows the frequency of high temperature zones (beyond 35^{0}C) was more than 78%.

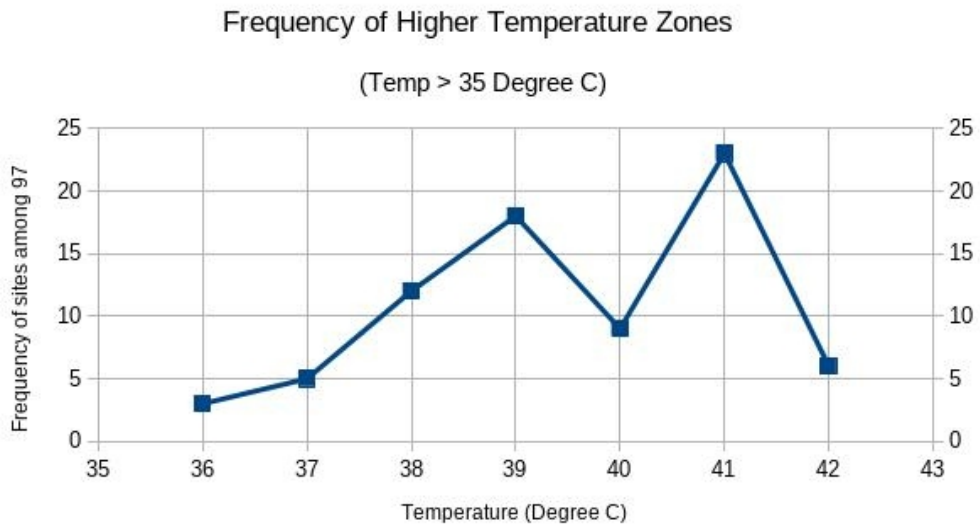


Fig. No. 11.6: Frequency of High Temperature Zones

The median temperature is clearly 41^{0}C and the mean is 40^{0}C. Thus, the only way the observations from the field can be reconciled is by theorizing that the microclimatic parameters around the fire have been different than those monitored by slightly remote fixed stations. This clearly establishes heat zones around the fire, where air as well as water temperatures are beyond the maximum limits.

WII Assessment: This assessment was done by WII, but does not form a part of the WII (2020) Report. The data was supplied by Dr. Abdul Wakid; and presented here exactly in the same format as supplied. The output is clear. Trend of high water temperature are clearly visible around the blow out site. As one goes towards the main stream Lohit/Dibru river, water temperature approaches to normality. The difference is clearly ~ 8.16 ^{0}C between the highest and lowest water temperatures. If one measures the difference from the average river temperature as arrived out of WII dataset (from the 12 sample points) to the highest water temperatures in Maguri Beel, there is clear cut difference of 7.46 ^{0}C which is higher than the mandated 5^{0}C under the EPA, 1986.

Table No. 11.3: River Water temperature Near Baghjan (WII-2020)

River	Date of survey	Reach No.	Temperature(°C)
Dibru	22-06-2020	R_01	29.3
Dibru	22-06-2020	R_02	29.6
Dibru	22-06-2020	R_03	25.9
Dibru	22-06-2020	R_04	22.7
Dibru	22-06-2020	R_05	22.4
Dibru	22-06-2020	R_06	22.8

River	Date of survey	Reach No.	Temperature(°C)
Dibru	22-06-2020	R_07	22.2
Maguri Beel	06-07-2020	S_01	30.16
Maguri Beel	06-07-2020	S_02	30.20
Maguri Beel	06-07-2020	S_03	30.20
Maguri Beel	06-07-2020	S_04	30.38
Maguri Beel	06-07-2020	S_05	29.66
Maguri Beel	06-07-2020	S_06	29.63
Maguri Beel	06-07-2020	S_07	29.75
Maguri Beel	07-07-2020	S_08	30.36
Maguri Beel	07-07-2020	S_09	29.81

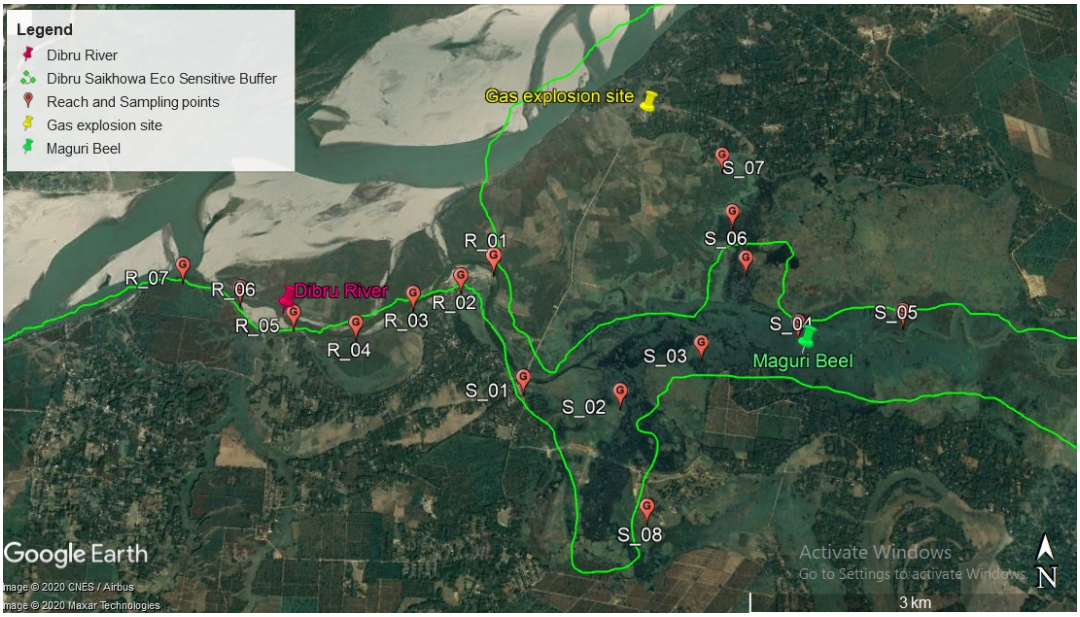


Fig. No. 11.7: Dibru River/ Maguri Beel Survey Points

Breach or No Breach?: Water temperature of the water bodies and rivers have been showing above normal behaviour. There is virtually no observation post blow out in a radius of 3 km of any water body showing baseline temperature of 25^{0}C. The air has also been warmer by 7^{0}C above the maximum ambient day temperature, and similarly, the water bodies too have shown a rise of ~ 7^{0}C from their normal expected temperatures, which is more than 5^{0}C, and hence comes in the category of "Thermal Pollution". Therefore, M/S OIL has breached the thermal pollution provisions of the EPA, 1986. In the tropics, the normal temperature for survival of aquatic fauna is considered to be 20-30^{0}C. Beyond 30^{0}C, only very hardy species can survive. Therefore, a temperature of 32^{0}C is not acceptable at all from ecosystem perspective.

11.8.3 Assessment of Dissolved Oxygen

Next to temperature, it is the dissolved oxygen which is the most important factor for survival of aquatic flora and fauna. Temperature and DO are intimately related (and inversely). Solubility of oxygen in water reduces as temperature rises. Therefore, at

higher temperatures, the DO value gets reduced. Beyond 3 mg/L of DO, only most tenacious of the species survive, and beyond 2 mg/L, the condition is treated as "Hypoxia", and it leads to death of large number of aquatic fauna/ fishes. Here, it must be recorded that most field measurements, other than that on 26th June, 2020 when the floods occurred, have been much after the incident of deaths of fauna have been reported. Therefore, the exact conditions at that point of time such as temperature, DO levels and presence of oil/grease films that would have cut the oxygen, or swallowing of polluted liquid, becomes difficult to judge. Also it may be noted that the dead specimens and viscera of the smaller wildlife tend to deteriorate much faster than a large mammal. If the investigation happens even a day or two after the reported incident. It is only "*Advantage OIL*", as it would become very difficult to prove the exact cause of death.

As is the methodology followed in the Report, we shall first look at established baseline data, and then the assessments of DO carried out in the field by various agencies, followed by the "Breach or No Breach" exercise.

DO Level Baseline Data: As per the CEC Report 2019[199], the Dissolved Oxygen at Pandu was found to be from 7.2 to 10.9 mg/L. The EIA-ERM (2019) Report carried out sampling at three sites in Dibru River and Dangori river. The DO was found to be varying from 7.6-8.8 mg/L. The EIA-GU (2009) Report had carried out sampling at 10 sites (but none of the sites seem to be of much significance!), and the DO values obtained varied from 3.5-5.3 mg/L. The state of these water bodies must have been pathetic, but no alarm or concern raised in the said EIA Report [*EIA reports seem to be highly automated & mechanically scripted instruments, which seem to have no active purpose to serve, and are voluminously produced without any intent or purpose - "khana-purty" type of documents*. *THIS MUST STOP FORTHWITH*]. It is not understood how aquatic fauna would have survived in all the 10 sampled water bodies. Therefore, the data of EIA-GU (2009) as regards its value as baseline is rejected. Deori D J (2015)[200] found DO in Dihing river varying from 6.3-8.4 mg/L. Similarly, Sharma & Hatimuria (2017)[201] found DO levels in three beels of Majuli to be 4.8-8.0 mg/L (Bhereki Beel), 5.6-8.0 mg/L (Holmari Beel) and 4.0-8.0 mg/L (Ghotonga Beel). Islam M R et al (2012)[202] measured DO in Kulsi river, and found values ranging from 7.0-7.6 mg/L at three different sites. Therefore, the data above reveals that the Brahmaputra river DO is about 9.0 mg/L on average; and for

199 See Footnote Reference 194
200 See Footnote Reference 197
201 See Footnote Reference 198
202 See footnote Reference 196

other "healthy" water bodies, the DO levels are expected to be about 5.5-8.0 mg/L. With mid value of 6.7 mg/L. Since DO is very critical for survival of aquatic fauna, **6.7 mg/L** should be taken as the value for judging breach or no breach.

DO Level Assessment by WII: Data was obtained from the WII (Dr. Vishnupriya Kolipakam) on DO levels in Lohit river for two seasons (February, 2020 and June, 2020, as well as for Dibru-Maguri Beel for July, 2020. This data is also not published in WII (2020). A chart made from the supplied data is produced below. It shows drastic reduction in DO levels in Lohit river (but still very good) during the blow out, and very drastic fall in DO levels in Dibru river - Maguri Beel water system. However, as already narrated, due to equipment error, data for Dhola-Sadiya to Guijan stretch was lost for June, 2020. These data sets were obtained during Dolphin survey exercises, and hence are different from the water samples taken by WII for water quality assessment (W1-W13).

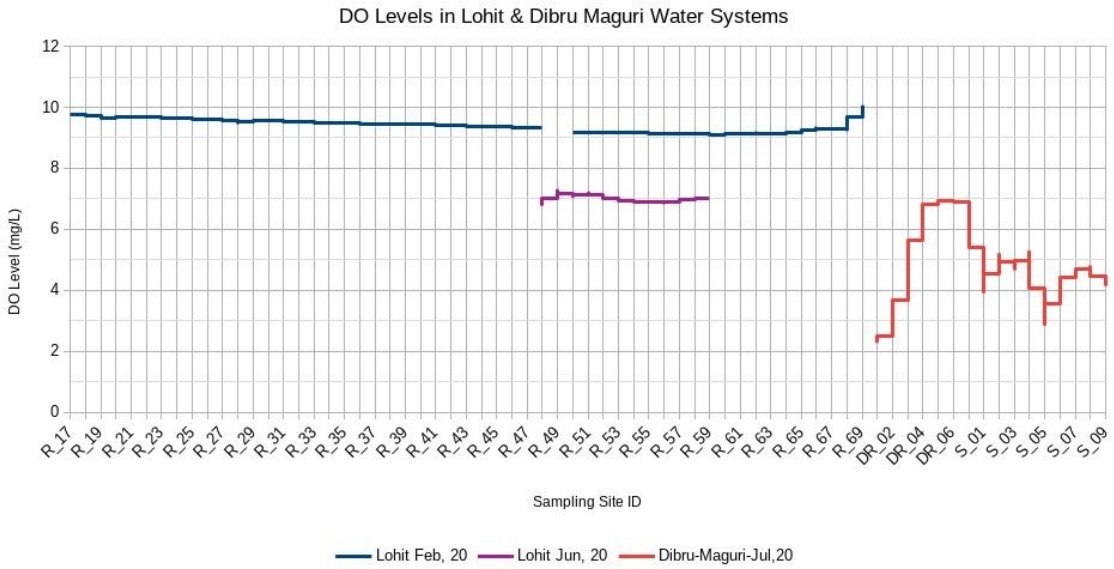


Fig. No. 11.8: DO Levels in Lohit and Dibru-Maguri Water Systems

DO LEVEL Assessment: DO level assessment were made by WII (2020) post blow out, and at places in a few sites by PCBA (2020). The PCBA measured DO at Guijan Ghat, upstream at confluence of Lohit & Dibru rivers, Kolomoni Nullah (DSNP), and Dibru river at Dighalturrung. The reported DO values are 7.0, 8.5, 8.8, 8.7 mg/L. While all values are within limits, the most impacted point of the Dibru river, i.e. Guijan Ghat is showing DO levels less by almost 1.7 mg/L from the remaining points which happen to be either upstream (meaning least impacted) or downstream (meaning "impacts" washed away by natural forces in operation). WII (2020) sampled water quality at 13 (thirteen) sites, W1 to W13, and recorded the DO levels. DO above 7 mg/L were observed only at two

sites (W1 & W7), >6.7 & <7.0 mg/L at five sites (W2-W5, W8), >5 & <6 mg/L at three sites (W6, W12, W13). The remaining three sites W9-W11 are actually "**AQUATIC HYPOXIA**[203]" sites, and the DO levels are murderous (≋*Day Light Murder*!) being at 0.94 to 1.74 mg/L. These can be very aptly termed as DEAD ZONES[204] or more aptly DEATH ZONES. As per BIS 1982 and CPCB 1979, DO below 4 mg/L is unfit for aquatic fauna.

Breach or No Breach: The outcome is for all to see without resorting much mathematical and statistical calculations. This is a clear breach on part of M/S OIL. We shall examine the "deaths" actually in the next chapter, but as of now, M/S OIL is guilty of converting the healthy Maguri Motapung Beel into a deadly beel, so much so that its impacts are also visible right upto Guijan in the main river system.

11.8.4 Oil & Grease Assessment

Unfortunately EIA reports are such an irony that these documents are written but never read. While the EIA-ERM (2019) carried out Oil/Grease assessment in the main river system at three sites, and found O/G quantities less than 1.4 mg/L, the EAI-GU (2009) carried out O/G assessment at 10 (ten) sites and found O/G at five sites varying from 6.5-9.1 mg/L (SW1-SW5), at two sites 4.8-5.1 mg/L (SW6 & SW10), and only three sites with values varying from 2.2-3.3 mg/L. Now, as per IS:2296.1982 Surface Water Quality Standards, the O/G maximum limit is of 0.1 mg/L and such surface water is classified as Class C & D. Above 0.1 mg/L it is not supposed to be fit even for wildlife as per the IS:2296. The O/G levels in the Dibru River system are already high, as per the EIA study, (*due to the oil well drilling activities in the area?*) and exceed the prescribed limits by 10 times at the time of EIA exercise itself. The O/G levels as reported in EIA-GU (2009) are almost 48 to 91 times higher than the prescribed limits in all water bodies, except 3 sites which are 20-30 times higher than the prescribed limits, in 2009. Yes, O/G in the waters of the oil town Digboi and other such areas could be the norm, and is the price one has to pay for economic development. However, when the EIA reports are showing categorically high numbers, ***why a detailed study to delve deeper into the matter, and also mitigation strategies was not put in place by OIL and or the Regulators i.e. the PCBA and the MoEF&CC?***. Let the management of M/S OIL spell out the steps taken in this regard even prior to taking up the industrial activity. All these sites are located in and around the "Rain Forests" of the Upper Assam. What an irony! How is the wildlife surviving under such conditions is a matter of detailed research - and many of them over long periods of time!

203 https://en.wikipedia.org/wiki/Hypoxia_(environmental)
204 https://en.wikipedia.org/wiki/Dead_zone_(ecology)

PCBA (2020) carried out post blow out sampling exercises at eight sampling stations with four repeats, totaling to 12 (twelve) sets of sampled data. The site wise values are reproduced below. The site codes are given by the author of this Report.

Table No. 11.4: Oil & Grease Levels in Waterbodies

Site Description	Site Code	O/G Value (mg/L)	O/G Value (mg/L)
Guijan Ghat	GG0	3.3	3.3
Confluence of Dibang with Dibru River	CDD	3.4	2.9
Maguri Beel	M01	4.5	
Kolomoni Nullah at Dibru Saikhowa NP	KDS	4.5	5.1
Dibru river at Dighalturrung	DDT	BDL	BDL
Maguri Beel Guijan	M02	5.1	
Baghjan near Blow out Site	BG1	11.5	
Baghjan near Blow out site	BG2	8.4	

The table above clearly demonstrates that O/G limits in surface water have been breached at all sites except one (which could be protected by “wind shield” for wind blowing south west from north east). The Dibru-Saikhowa National Park also received fair amount of condensate as can be seen from the table above. The breach ranges from 29 times to 119 times the prescribed limit for O/G.

Measurements of O/G were also done by ERM from 1st to 9th June, 2020 near the blowout site. Two sets of surface water tests at 15 locations were carried out. The O/G values recorded were very high in areas adjacent to the blowout site were 43706.4 mg/l, 48706.2 mg/l, 5388 mg/l, 33296 mg/l. At the drain at 200 m from the site, it was 38610 mg/l, and at the ditch next to the site, it was 160,000 mg/l.

Breach or No Breach: As demonstrated above, there has been clear cut breach on account of presence of Oil and Grease (O/G) in surface water beyond the prescribed limit of 0.1 mg/L as per the IS:2296.1982. However, this breach is just not post blow out, but appears to be there all along when production started at the Baghjan oil fields. Actually, there has been breach all along by all oil producing majors in the area ever since, and it never was highlighted, except in a couple of research works. One such recent study by Konwar D et al (2019)[205] carried out water quality tests on samples of

205 Konwar D, Borgohain Gogoi S, Barman Joyshree, Kallel M, 2019, Quantitative and Qualitative

"Produced Water" from the oil fields of Upper Assam at 10 (ten) oil well sites. They found the produced water having Oil/Grease content in the water samples at the discharge point varying from 1000-3500 mg/L as against the prescribed WHO limit of 10 mg/L for disposal.

11.8.5 PAH Assessment

With regards to PAH, there are no baseline studies in either of the EIA Reports produced by M/S OIL. This only can be treated as a grave "Act of Omission", especially when the IS:2296.1982 Surface Water Quality Standards mentions PAH for Class A water body and limits it to 0.2 mg/L (≅ 200 µg/L). Therefore, M/S OIL cannot take the plea of PAH coming from agriculture/ tea cultivation and use of insecticides and pesticides. It is assumed that concentrations above 200 µg/L shall be treated as direct violation. The only reported study for PAH in river water of Brahmaputra was found to be by Chakraborty P et al (2014)[206]. They reported a maximum of 31 µg/L PAH in the river system.

WII (2020) measured PAH at 12 (twelve) water sampling sites, and 12 (twelve) water sediment samples. PAH concentrations above 200 µg/L was found at site W9 and SS9 in the Lohit river with concentrations 691.31 µg/L and 395.8 µg/Kg respectively. Fluorene and Phenanthrene were found in highest concentrations followed by Acenapthene.

The PAH measurements were done by M/s ERM near the blast site from 1st to 9th June, 2020 in two sets at 15 locations. The PAH was found to be varying from 0.12 to 0.67 mg/l. The PAH values at Dangori river and at the confluence of Dangori and Dibru were 0.16 and 0.12 mg/l respectively. At Guijan Ghat it was found to be 0.21 and 0.34 mg/l. The Dibru and Dangori rivers are Class A water bodies, and hence such high levels of PAH discharge are unwarranted. TPH measurements showed a value of 155090 mg/l at the ditch near the blowout site, 357 mg/l near the Maguri Beel, 2.95 mg/l at Dangori river near Baghjan and 6.1 mg/l at Guijan Ghat.

Breach or No Breach: The PAH concentrations as reported above are in clear violations of the limits prescribed for surface water quality standards for Class A water bodies. The Lohit river, which is one of the main tributaries of the Brahmaputra river, and in fact together with Lohit only the river is called Brahmaputra, is a class A water body, and the

Characterization of Oil Field Produced Water of Upper Assam Basin (India), p113-116, S. Banerjee et al. (eds.), Advances in Petroleum Engineering and Petroleum Technology, Geochemistry, Advances in Science, & Innovation, https://doi.org/10.1007/978-3-030-01578-7_27

206 Chakraborty, P., Sakthivel, S., Kumar, B., Kumar, S., Mishra, M., Verma, V. V., Gaur, R. (2014). Spatial distribution of persistent organic pollutants in the surface water of River Brahmaputra and River Ganga in India. Rev Environ Health; 29(1-2): 45–48.

water of such a pristine water body should deliberately be never allowed to fall below the standards prescribed. Therefore, M/S OIL stands in clear violation of the prescribed PAH limits. PAH are highly carcinogenic substances.

Due to logistic bottlenecks arising out of COIVD19 and lock-down, only very limited tests could be conducted. The entire area needs to be systematically sampled for PAH and traces of oil and grease and heavy metals in water, sediments and soil. The cancer causing potential of PAH is very high, as total concentrations beyond 1000 µg/L in terms of BaP_{eq} can be significantly risky[207].

11.8.6 Pb and Heavy Metals Assessment

The IS:2296.1982 Surface Water Quality Standard mandates Lead (as Pb) in water to be not more than 0.1 mg/L. As per the EIA-GU (2009), the Pb concentrations found in the 10 water samples varied from BDL – 0.0400 mg/L. These are within limits as prescribed. The lead in the river water system that was tested in the EIA-ERM (2019) at three sites was found to be below 0.005 mg/L. Therefore, the baseline data clearly demonstrates that Pb has not been an issue in the waters of the area at least from 2009-2019. It has to be mentioned that the National Water Monitoring Program does not seem to mandate measurements of Pb and other heavy metals. Therefore, there is no baseline data available under this programme.

Post Blow Out Assessment: Post blow out assessments in terms of estimation of Pb and other heavy metals were only carried out by the PCBA. As per PCBA (2020), Pb, Cr, Zn, Ni, Hg, As & Cu were tested in seven water sampled sites. It is seen that for the heavy metals, other than Pb & Cu, either the measurements were all very much within the prescribed limits or no limits have been prescribed for some of them. Therefore, only the values found for Pb and Cu are being shown here:-

Fig. No. 11.5: Lead & Heavy Metal Assessment in Waterbodies

Site Description	Site Code	Pb Value (mg/L)	Cu Value (mg/L)
Guijan Ghat	GG0	0.17	
Confluence of Dibang with Dibru River	CDD	BDL	
Maguri Beel	M01	0.515	
Kolomoni Nullah at Dibru Saikhowa NP	KDS	0.17	
Dibru river at Dighalturrung	DDT	0.07	

207 Alawi M. A, & Aziz A. L, Toxin Rev, 2016; 35(3–4): 69–76, DOI: 10.1080/15569543.2016.1198379

Site Description	Site Code	Pb Value (mg/L)	Cu Value (mg/L)
Baghjan near Blow out Site	BG1	BDL	0.605
Baghjan near blow out site	BG2	0.255	

From the table above, it is seen that the Pb values are also abnormally high in the Dibru-Saikhowa NP area. As can be seen, the number of samples are very few to generalize the results, but the trends are clear that heavy metal presence in the surrounding waters have increased many fold. A systematic sampling is strongly suggested to cover this aspect fully. There are clear-cut breaches in terms of high concentrations of Pb and Cu in the water samples tested. PCBA should have done a better job of this sampling (but manpower and funding issues would have restrained them from taking big steps in a full scale investigation. [*If the Regulator institution itself is crippled, what more can one expect from such institutions? We often want Regulators to earn their own money too!*]

Breach or No Breach: Despite a very limited number of samples, it is seen that M/S OIL has breached the prescribed provisions of the IS:2296.1982 in respect of the limits of Pb and Cu in the water samples tested by the PCBA. While M/S OIL would still ask the proof as to how the blow out has contributed to the enrichment of Pb and Cu and other heavy metals in the waters without having a control sampling done. The argument against this would be, for all the cases of breach, that firstly either M/S OIL's EIA Reports show clear absence of such high concentrations in their EIA evaluations of the site, or even these EIA reports are totally silent on the matter (say in case of PAH). In either case, M/S OIL and their owners cannot escape the responsibility. However, if they have been measuring the water qualities regularly from the start of the project, they should have produced the same before the One Man Enquiry Committee, and which they did not do, except handing over to the Committee the two EIA reports, and a bunch of air quality monitoring reports.

11.8.7 BOD & COD Assessments

As per the IS:2296.1982, the prescribed standard for BOD is 3 mg/L or less. However, there are no such tolerance limits for COD for any class of water body. Effluent water to be discharged into a fresh water body should not be having more than 250 mg/L of COD. As per PCBA, they have kept a limit of 100 mg/L for COD for surface water quality. However, we shall consider only BOD here. As per the EIA-GU (2009), the water bodies, tested for BOD all seem to be very polluted already with respect to BOD. All the 10 samples sites show BOD levels 10-28 mg/L against the prescribed limits of 3 mg/L. The COD levels are more than 100 mg/L for at least three of the sites sampled. It means that the surface waters tested in the EIA assessment seem to be hall mark of polluted waterbodies, or must be getting discharges of toxic effluents from some source. ***If these sampling sites are randomly chosen in an unbiased manner, then the Tinsukia District Administration needs to actually worry about surface water quality in the district***. ***Most of such water bodies in the district would be highly toxic by now if not already cleaned***. A regular water body monitoring program is called for, if one not existing already. However, the EIA-ERM (2019) is quite in contrast and speaks that the health of the river system, at least prior to the blow out was in good condition wrt to these conditions. The BOD for all the three sites was found to be <2 mg/L. The COD values were found to be less than 4 mg/L. There is another very important baseline data i.e. from the NWMP at Guijan Maguri Beel point for which the PCBA data available shows BOD values varying from 2.0-2.4 mg/L. The COD values are 8.0 -10.5 mg/L.

Post Blow Out Assessment: The post blow out assessment of BOD and COD was carried out by PCBA. The values are listed below site wise as in the previous assessments of water quality carried out by PCBA.

Table No. 11.6: BOD & COD Assessment

Site Description	Site Code	BOD Value (mg/L)		COD Value (mg/L)	
Guijan Ghat	GG0	1.0	1.1	2.9	3.3
Confluence of Dibang with Dibru River	CDD	2.1	1.9	4.4	4.1
Maguri Beel	M01	2.8	1.7		

Site Description	Site Code	BOD Value (mg/L)		COD Value (mg/L)	
Kolomoni Nullah at Dibru-Saikhowa NP	KDS	2.6	2.4	7.4	5.5
Dibru river at Dighalturrung	DDT	1.8	2.2	4.4	4.8
Maguri Beel Guijan	M02	7.4	4.4		
Baghjan near Blow out Site	BG1	33.4	133.2		
Baghjan near blow out site	BG2	16.6	65.4		

It is seen that there are two observed violations of BOD and one of COD, both near the blow out site. However, as there are no other observations of BOD and COD, it is assumed that there are no issues of BOD beyond 500 m of the blast site. As per Sharma K K & Dutta S (2020) from AAU, Jorhat, the BoD near the exploded well was 71.5 mg/L. The Salibari beel within the DSNP showed BOD of 8.2 mg/L, another point in the interior of the Park showed a value of 3.5 mg/L, and in the opposite direction to the blow out site at the DSNP end, the BOD was found to be 2.6 mg/L.

Breach or No Breach: The BOD and COD values within 500 m of the blast site seem to be in violation of the IS:2296.1982 standards as proved by the PCBA measurements. There are other violations as well, and within the Dibru-Saikhowa National Park, as is evident from the AAU report, but in absence of control data, these are not considered.

11.8.8 In Situ Water pH

As discussed earlier, pH has been already discounted due to differences in the field measurements and laboratory measurements. Here a few measurements were made insitu using hand held pH meters. It needs to be stated here that pH related standards for surface water, as per IS.2296.1982, warrant the pH values should be within 6.5 to 8.5.

Three sets of in situ water pH measurements were taken by Sharma N et al (2020). A set of 62 measurements on the day of the flood (26th June, 2020), another set of 97 measurements, and an additional set of 91 measurements. The average pH value of the first 62 set was 5.96, for the second dataset, it was found to be 6.46 and for the third

dataset it was 5.57. All the average pH values are below 6.5 as mandated by the IS:2296 standards. Most data points are highly acidic. A chart for the first 62 data set is produced below:-

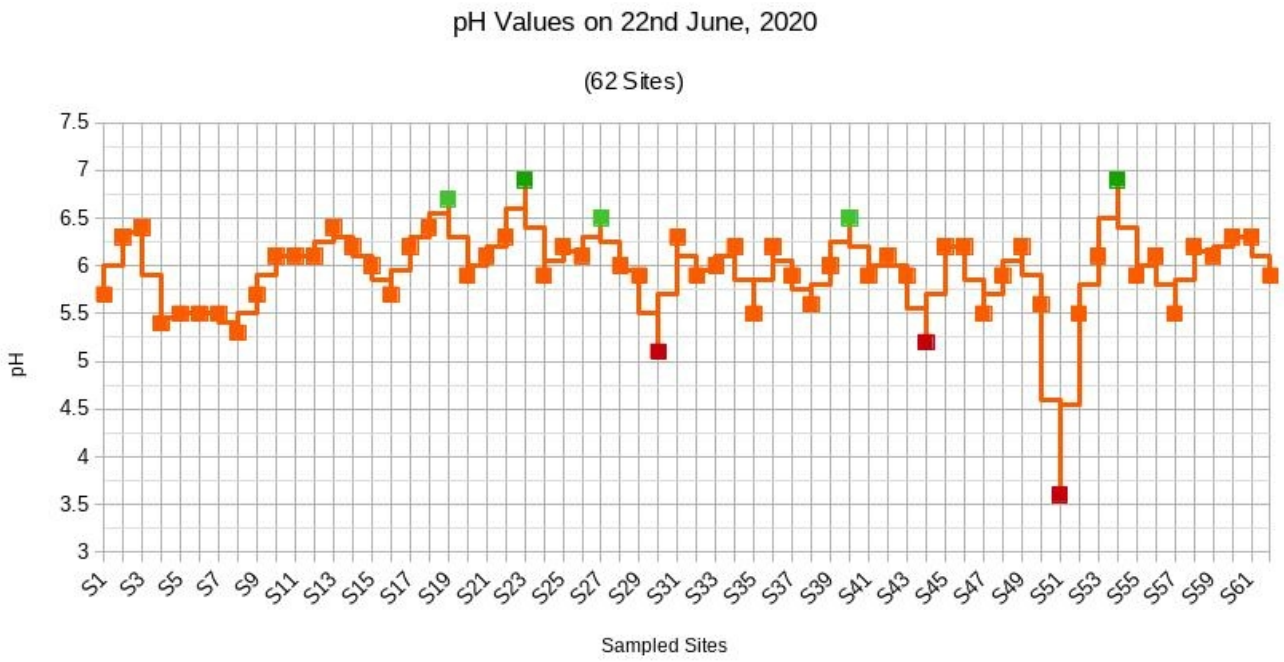


Fig. No. 11.9: In Situ pH at 62 Sampled Sites on 22nd June, 2020

Thus, of the 62 sample sites, only 5 sites conform to the standards (shown in green squares in the figure above), rest are below 6.5 pH value. At one site, the pH is as low as 3.6. Aquatic fauna are sure to die under adverse conditions.

Breach or No Breach: Of the total 250 sampled insitu points, 190 points were found to be below 6.5 pH value, and 46 points were found very acidic i.e. equal to or below 5.5. Of these 5 points were having equal to or less than 4 pH. Therefore, there has been violation of pH value in the water systems of the 250 points sampled. On average all these sites are acidic, as already explained and are below the prescribed pH value of 6.5 to 8.5. Hence, there is a definite breach by M/S OIL on account of low water pH values induced by the blow out. This also has resulted in, together with other accompanied factors of fallen DO and higher water temperatures, high number of deaths of aquatic fauna. Dead organisms in thousands were observed near the blow out site in the Maguri beel and other surrounding water systems.

11.9 Soil Quality Assessment

As already stated, there are no standards prescribed. Nevertheless, we shall go by the various assessments carried out on the ground using a variety of methodologies deployed by the assessing agencies. However, in these we shall be concentrating on soil temperature, soil pH, Pb and heavy metals, Oil & Grease and PAH.

11.9.1 Soil Temperature Assessment

Soil temperature is not recorded in any of the EIA reports provided by M/S OIL. Normally, as discussed, soil temperatures are expected to be about 2^0C higher than the air temperatures. This may, however, not be always applicable. The temperature could depend upon wind conditions, moisture content, presence of water body nearby etc. A test case of variation in air and soil temperature at 15 sampled points during the day is presented below to drive the point home. (Courtesy Dr. Narayan Sharma & Ms. Neeharika Gogoi who carried out the experiment exclusively) .

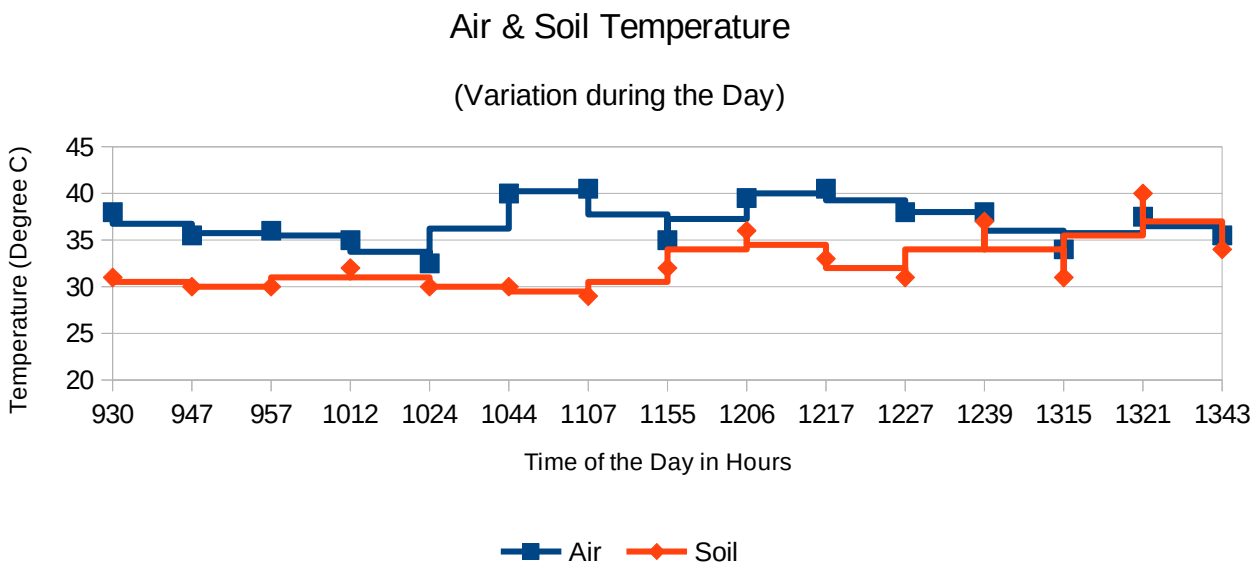


Fig. No. 11.10: Air & Soil Temperature at a Control Site

As the day moves ahead, the soil gets heated (and gets cooled later); and temperature picks up by middle of the day. Some other external factor such as light shower cools the air and soil; and it goes on and on. The samples were taken in Tinsukia district near Makum. The difference between air and soil temperatures is 4.6 ^{0}C for the 15 sampled sites. This experiment was treated as a "control" and carried out in October, 2020. Against the above "control" backdrop, an assessment of soil and air temperature was done near Baghjan for 62 points on 22nd June, 2020. The chart is produced below.

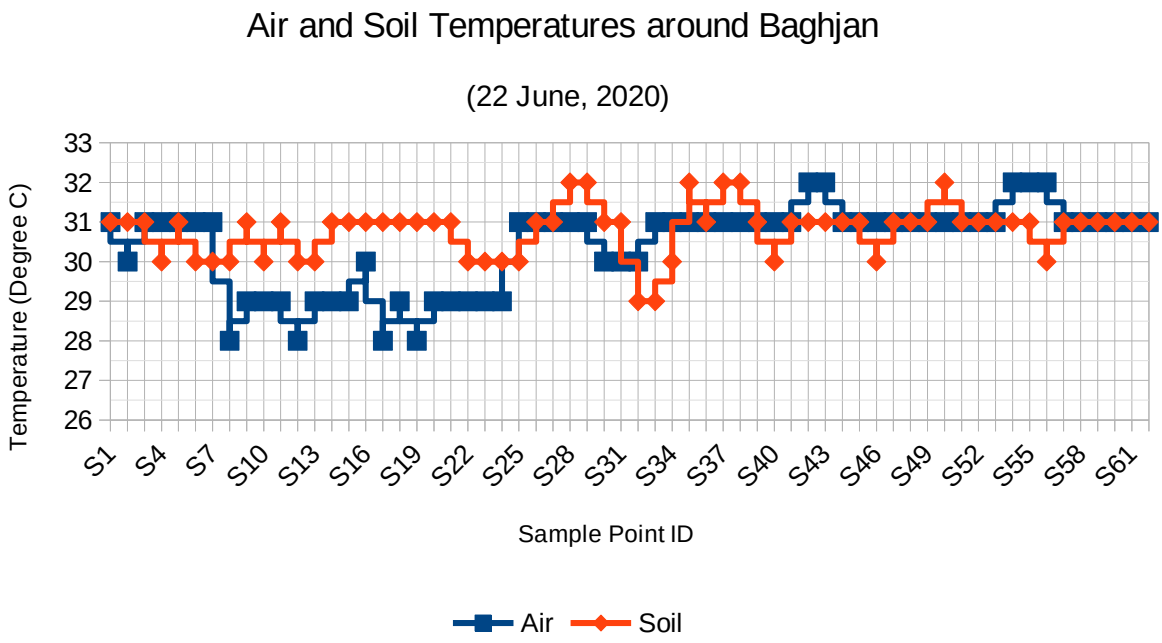


Fig. No. 11.11: Air & Soil Temperature around Baghjan on 22nd June, 2020

At Baghjan, in contrast to the behaviour at Makum shown in the previous chart, the heat from the flame keeps the air and soil mostly at the same temperature. The air-soil system temperature at most of the 62 sampled points are fixated at 30-31 ^{0}C by the inflow of constant heat that keeps the system in equilibrium. The average difference between the soil and air temperatures is only 0.4 ^{0}C, and for 22 sample points out of 62, the difference is 0. As already proved earlier, this mechanism also would keep the day and night temperatures within a narrow range of variation.

Breach or No Breach: Having gone through the details of temperature variation and patterns, it is difficult in absence of baseline data to say that there is a breach on the soil temperature point. Nevertheless, the virtual equality of air and soil temperatures around the Baghjan blow out site appears un-natural. This phenomenon has been happening for all the time during the period of the blow out; and hence, this is a kind of heat island effect. This is to be treated as a breach, though not defined in any statute.

11.9.2 Soil pH

The available baseline for soil pH from EIA-GU (2009) shows that from a sample of 10 data points, the pH varies from 4.4 to 6.3. As per the EIA-ERM (2019), the pH for five sampled point varied from 4.94 to 6.27. The PCBA (2020) assessment of the soil pH after the blow out shows that from 6 samples tested, the pH varies from 5.4 to 5.9. The range has narrowed considerably. No breach is considered on this parameter.

11.9.3 Oil & Grease in Soil

As per the EIA-GU (2009), the 10 sites, sampled for soil quality, show presence of oil and grease, and the values range from 3.3-8.2 mg/kg. The EIA-ERM (2019) does not mention any oil and grease component in the soil quality checks. In this respect, the EIA-ERM (2019) report is defective. The PCBA carried out soil samples at 6 sites. The oil and grease concentrations in the tested soils as per the PCBA (2020) appear to be very high. The recorded values by PCBA show that the O/G quantities vary from 1110 to 17150 mg/kg (~ 1.11 to 17.15 gm/kg) with a mean of 9130 mg/kg (~ 9.13 gm/kg). These values are 300 to 2000 times more than the baseline value; and must surely be attributed to the blow out incident. The maximum allowable discharge of oil and grease as per the EPA, 1986 does not exceed beyond 20 mg/L (~ 20 mg/kg). This is a clear cut breach of the prescribed provisions under the law. **Therefore, M/S OIL has committed a clearcut breach here.**

11.9.4 PAH and Soil Quality

A total of 16 PAH species were targeted for testing. The 16 priority PAH species among many possible PAH are: Naphthalene (NaP), Acenaphthylene (Acpy), Acenaphthene (Acp), Fluorene (Fl), Phenanthrene (Phe), Anthracene (Ant), Fluoranthene (Flu), Pyrene (Pyr), Benz[a]anthracene (BaA), Chrysene (Chr), Benzo[b]fluoranthene (BbF), Benzo[k]fluoranthene (BkF), Benz[a]pyrene (BaP), Dibenzo[a,h]anthracene (DbA), Benzo[g,h,i]perylene (BghiP), Indeno[1,2,3-cd] pyrene.

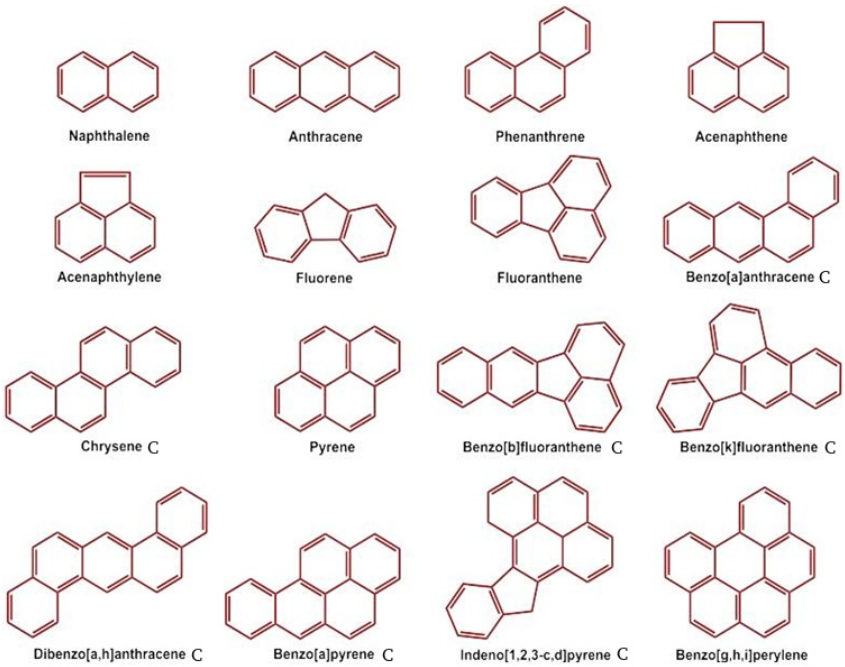


Fig. No. 11.12: PAH Chemical Formulae (16 Nos)

The USEPA (2004)[208] has identified 7 (seven) of the 16 PAHs as carcinogenic. A family of 16 PAHs is shown in the figure above. The ones marked with C in the chart above are the carcinogenic PAHs. The sum of concentrations of all PAHs is denoted by ΣPAH. The sum of concentrations of the carcinogenic PAHs is denoted by ΣCPAH. A study by Alawi & Azeez (2016)[209] in the Iraqi oil fields showed soils with 13 PAH concentrations varying from 19-855 µg/kg, with mean value of 320 µg/kg. They also worked out the Toxicity Equivalent (TEQ)[210] by summing up all concentration to BaP_{eq}. The authors found the BaP_{eq} to be 102.14 (0.10-473.08) µg/kg. The authors also reported that range of total PAHs concentrations found in their study was much lower than those reported by Song et al (2006)[211] from Shenyang, China, the values being 950-2790 mg/kg. The authors also worked out the risk of cancer from the PAH exposures to humans, and found that the risk varied from 0 to 5 per million population.

The assessment of PAH, which was carried out at the behest of the DFO, Tinsukia Wildlife, by WII for water, sediment and fish samples, reveal that in water samples, the PAH concentration ranged from 0.21 to 691.31 µg/L with a mean of 31.11 µg/L. The carcinogenic PAH ranged from 0.27 to 14.82 with a mean of 5.28 µg/L. The sediment PAH showed presence of 3 PAHs with a variation from 37.6 to 395.8 µg/kg with a mean of 195.23 µg/kg. The ΣPAH in fish samples ranged from 104.3 to 7829.6 µg/kg, and the ΣCPAH concentrations were found to vary from 145.1 to 169.3 µg/kg. Another study by Sarma et al (2016)[212] showed that in the 10 (ten) oil fields from Digboi to Borholla in Upper Assam, the ΣPAH concentrations of all 16 PAHs was found to be 21.22 to 86.3 mg/kg. ***This shows that PAH is already a serious concern in Upper Assam, and the issues raised by WII in the present investigation is only tip of the iceberg, as mean background concentrations of PAH appear to be already as high as 53760 µg/kg in the entire belt***. These concentrations appear to be highly carcinogenic, posing a serious risk to the populations around the oil well sites. Therefore, these facts call for a detailed investigation.

208 USEPA. (2004) Risk Assessment Guidance for Superfund, Volume 1, Human Health Evaluation Manual (Part E, Supplemental Guidance for Dermal Risk Assessment EPA/540/R/99/005 OSWER 9285.7-02EP PB99-963312.

209 Alawi Mahmoud A. & Azeez Abbas L. (2016), Study of polycyclic aromatic hydrocarbons (PAHs) in soil samples from Al-Ahdab oil field in Waset Region, Iraq, Toxin Reviews, 35:3-4, 69-76, DOI: 10.1080/15569543.2016.1198379

210 US EPA, (1993) Provisional Guidance for Quantitative Risk Assessment of PAHUS Environmental Protection Agency (1993) EPA/600/R-93/089.

211 Song YF, Wilk BM, Song XY, et al. (2006). Polycyclic aromatic hydrocarbons (PAHs), polychlorinated biphenyls (PCBs) and heavy metals (HMs) as well as their genotoxicity in soil after long-term wastewater irrigation. Chemosphere 65:1859–68.

212 See Footnote Reference 189

Therefore, while M/S OIL is guilty of excess PAH beyond the prescribed limits of 0.2 mg/ L (~ 200 µg/L) in the water bodies of Maguri Motapung Beel and Lohit River, it also warrants the examination of the mechanism of contamination.

While M/S OIL in the name of emergency since 10.30 AM of 29th May, 2020 have been using large quantities of water to cool the blow out and the fire; and none of this water has ever been treated prior to discharge in the nearby water bodies, and there is no provision to treat these waters. Neither has M/S OIL made any provisions to segregate and treat this copious volumes of water, nor attempted to address the issue of at all. All the "effluent" water which comes out/ falls directly after getting in touch with the blowout gases, condensate and fire, gets directly drained into the river Dibru and Lohit untreated, and also flows to the Maguri Motapung Beel. On flooding, these waters, heavily laden with condensate and other lethal chemicals, get spread over the entire landscape, and seep into the soil. However, it has to be noted that concentrations get diluted in the process. If we ignore the low concentrations at some distances from the blow out site, we shall be undermining a whole range of health hazard and other factors that may jeopardize the health of the surrounding ecosystems in the long run.

11.9.5 Pb and Heavy Metals in Soil

As per the EIA-GU (2009) and EIA-ERM (2019), the Pb and other heavy metals, other than Fe and Mn, are in the order of units and tens of mg/kg. As per PCBA (2020), Pb and Cr are at some places in the 1-300 mg/kg range, or Below Detectable Limit (BDL). Therefore, on account of Pb and heavy metals in soil, there is no substantial presence indicated in the tests by PCBA. While quantitatively there is clear cut 10 fold increase in heavy metals in the soil, but there are no definite thresholds defined. Therefore, "breach or no breach" assessment on account of this parameter is dropped.

11.10 Revisiting The Blowout & The Explosion

This is the right time to revisit the explosion, as we left a question unanswered in Chapter 6 as to how much gas would have caught fire and where from did it come, for the quantity exploded appeared to be almost 66% of the day's production, if we go by the estimates of M/s OIL. Now we know that the mass flow rate of the fuel would average on 343.50 kg/s based on a mean flame height of 108m confirmed from multiple calculations including drone based estimations. Assuming that the calculation of the mushroom cloud was right, the yield of the explosion was estimated at 0.833 kT of TNT, which translates to 3485 GJ of energy. At the flow rate of 343.50 kg/s, the accumulation of natural gas to give that much amount of energy is just 3.53 min, and not 12 hours, if

we go by Oil India's estimates. In just 3 to 4 min, there was enough explosive material around to detonate to 0.8 33 kT levels [*Could be higher too!*].

11.10.1 Estimates of Natural Gas During Explosion

The flow rate of 343.50 kg/s provides us quickly an estimate that about 82.44 tons of natural gas would be spewed from the well in 4 min time, which is equivalent to 3.95 TJ of energy (which is more than what the explosion actually consumed). Infact, here we are totally discounting the deposited condensate around the well site since the time of blow out.

11.10.2 Estimation of Condensate during the Blowout

After the blowout and just before the explosion, condensate was also coming with the natural gas from the blowout well, and it was getting liquefied and settled around. Assuming that the pure blowout lasted for 1134000 s, as explained in the Chapter 8, this should give rise to release of 389529 tonnes of natural gas from the well just prior to explosion. Also assuming NG:Condensate ratio to be 6136:1, the total condensate quantity comes to ~63.50 tonnes during that period. Assuming 50% of it settled within 300m of the well, and the rest drifted with the wind to surrounding areas, the quantum of condensate available at the site would be ~ 32 tonnes. This would amount to almost 1500 GJ or 43% of the total explosive material.

11.10.3 Estimation of Natural Gas in the Explosion

If 43% of the fuel to the explosion came from the condensate, what remained was supply of 1985GJ of energy, which could be just supplied in 2 minutes by the spewing well. Thus, about 42 tons of natural gas could have been involved in the explosion.

11.10.4 Amount of Drifted Condensate

Having assumed that 50% of the condensate got burnt, it leaves us 32 tons of condensate that would have drifted with the winds. It would require quite a bit of computer modelling and simulation to predict the actual gradients and contours of the drift. From the drone orthophotography, we find that core burnt area comes to a radius of almost 277 m. The drifted condensate would have crossed more than 300m to reach other land parcels with the wind. **Therefore, we shall be assuming 32000 Kg of condensate that would have polluted the ecosystems beyond 300 m**.

11.11 Surface Temperature

Landsat 8 Imageries: Images of 26th April, 2020, 28th May, 2020 and 29th June, 2020 show the land surface temperatures around 5 Km of the Blowout site. The images must be interpreted with increasing extent of wet period as we move from April to June. While the temperature pattern of the land cover would have largely been same in all the images, it is seen that while temperatures have fallen due to wetness, but hot areas have steadily increased. The difference in minimum and maximum temperature of the objects (say water body to scrub land) seems to have increased post explosion and fire: 26 Apr→ 11.75^0 C, 28 May→ 12.74^0 C & 29 June→ 13.39^0 C. Increased heat in the Dibru-Saikhowa NP area can be easily discerned from the maps.

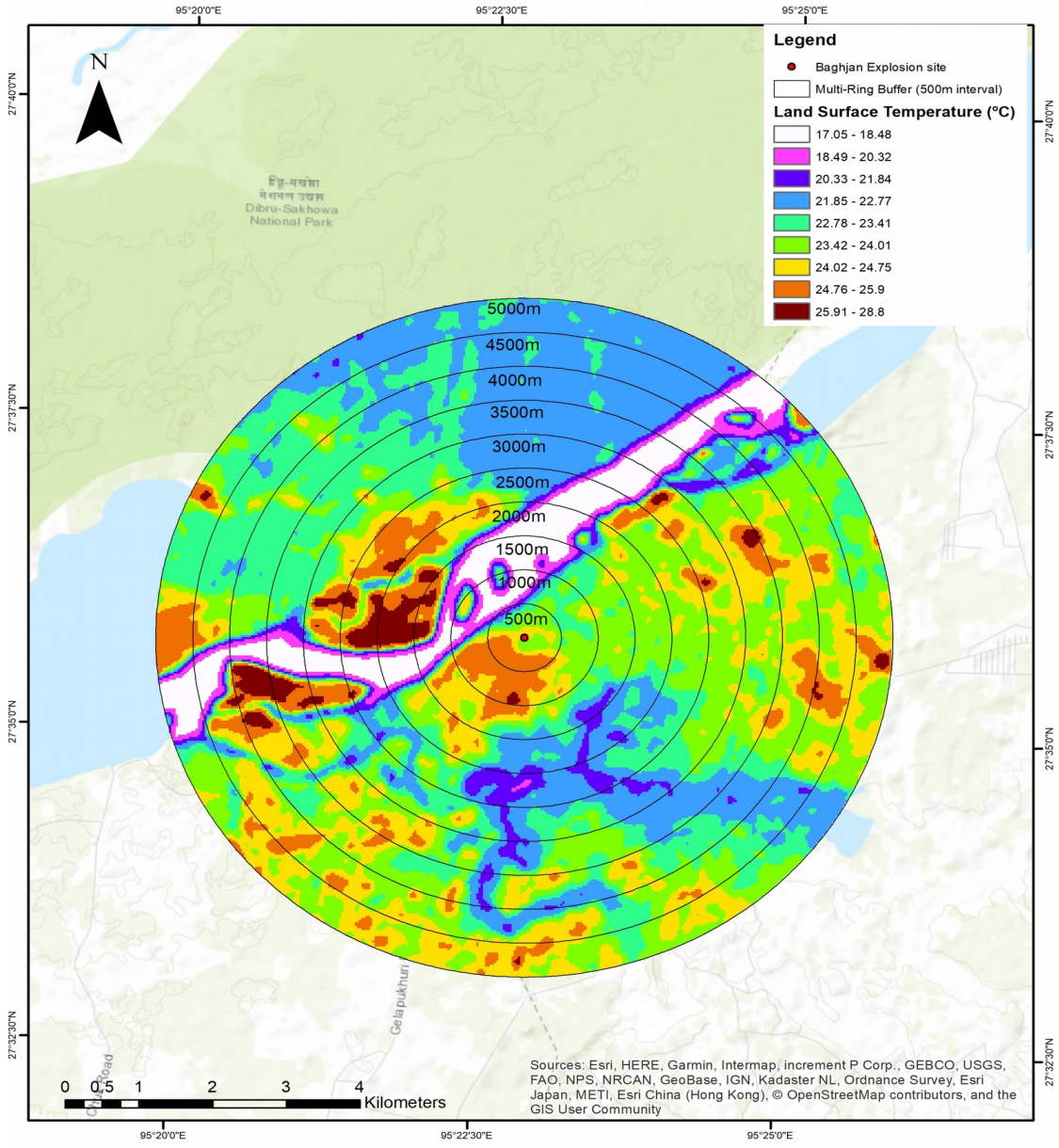


Fig. No. 11.13: Land Surface Temperature Profile (26th Apr, 2020)

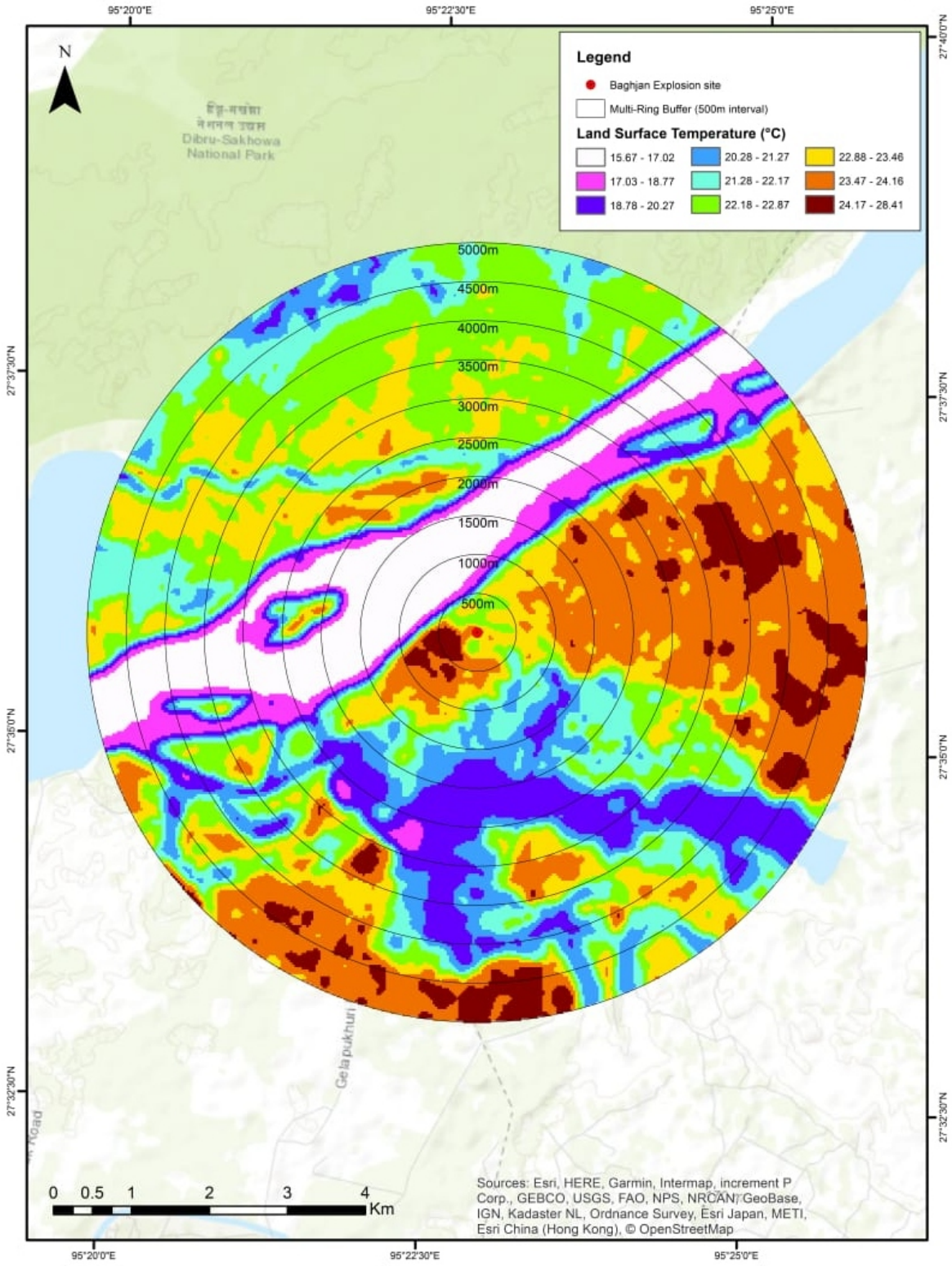


Fig. No. 11.14: Land Surface Temperature Profile (28th May, 2020)

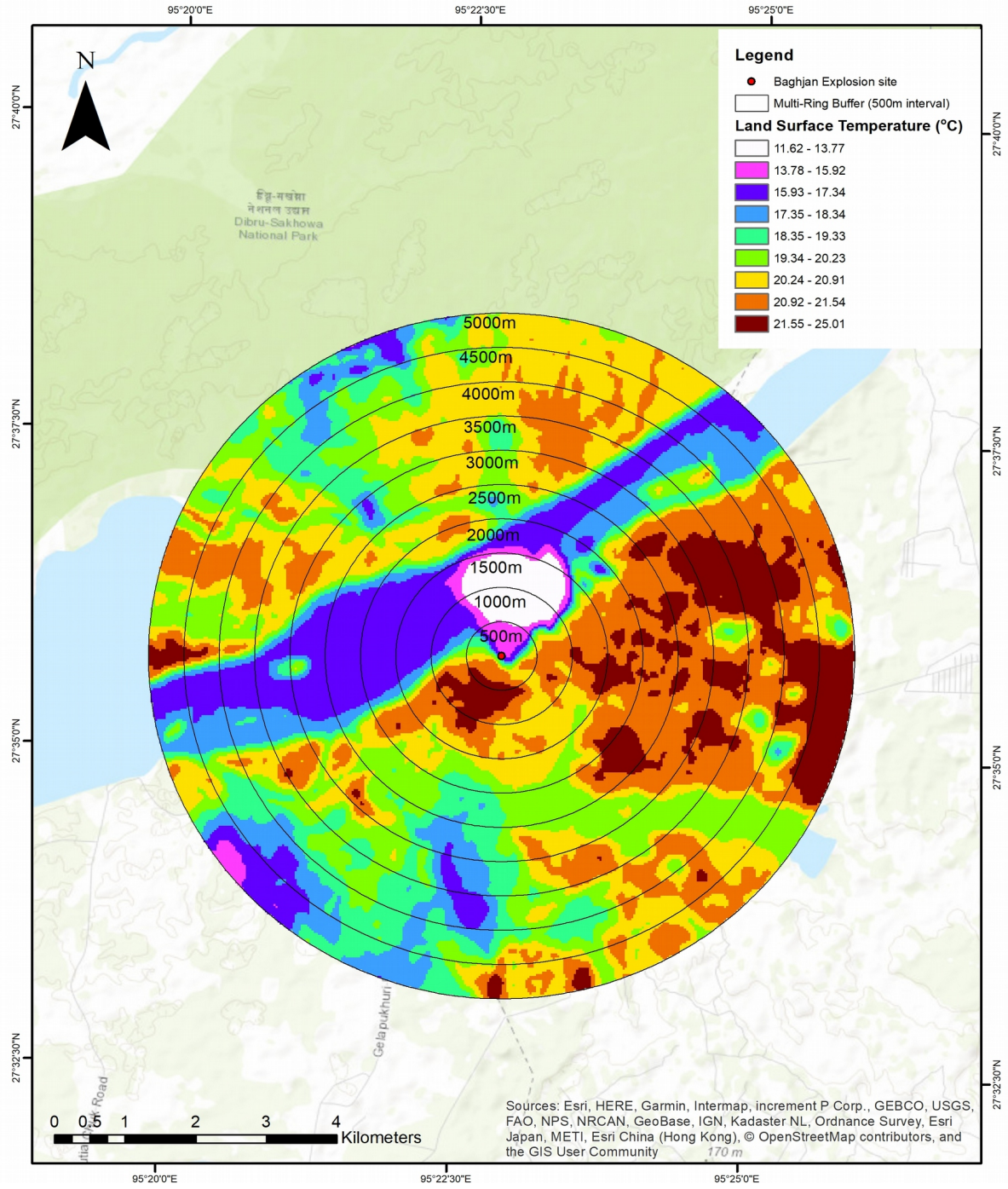


Fig. No. 11.15: Land Surface Temperature Profile (29th Jun, 2020)

MODIS Records the 9th June Fire: The Chart below shows how MODIS recorded the 9th June, 2020 fire incident from MODIS & VIIRS satellite platforms. One peak with a value of 100 FRP (Fire Radiative Power) can be clearly seen on the day of the explosion.

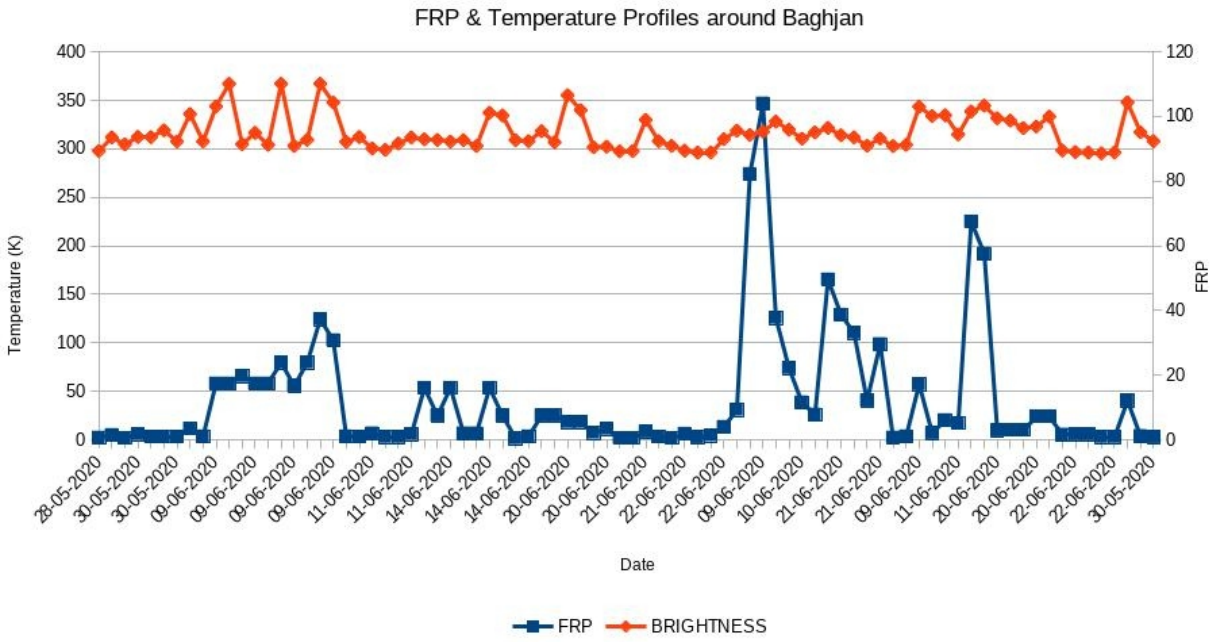


Fig. No. 11.16: MODIS & VIIRS Peaks in May-June, 2020

11.12 Drone Based Assessment Of Damages

A radius of 3 km was taken around the blowout well in a staggered manner, avoiding photography of EPS, and the river as these were either not possible or not allowed by the security agencies. The drone based assessment revealed the following damages in the immediate vicinity of the well:-

Table No. 11.7: Damage Area Statement

Sl. No.	Description of Landuse/ Damage	Area (in Sq m)	Remarks
1.	Severely Burnt Area	242,682.0	
2.	Partially Burnt Area	1,021,653.0	After subtracting Sl. No. 1
3.	Condensate Spread Area	5,889,874.0	After subtracting Sl. No. 1

A damage map has been prepared based on the Drone orthophotography within the radius of 3 km. showing the above three categories of land parcels around the blowout site. The various categories of damages and the existing land use has been attempted in one map itself. Based on the previous Google images and Drone photographs, a total of 23 houses have been identified as totally burnt within the severely burnt area around the flame. A few maps and images pertaining to this assessment have been presented here:-

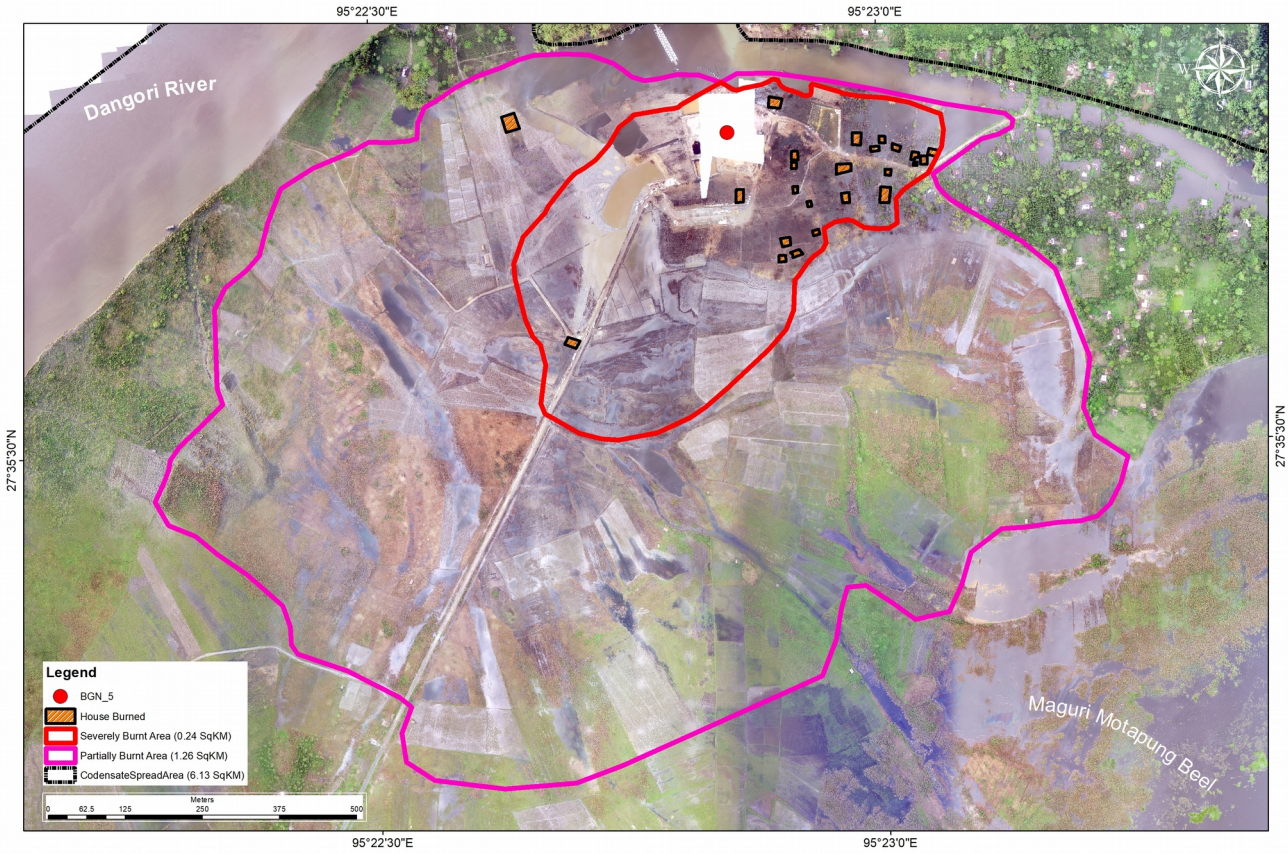


Fig. No. 11.17: Map of Severely Burnt Areas



Fig. No. 11.18A: A Drone Shot of Flooding around the Blowout Site



Fig. No. 11.18A: Another Drone Shot of Flooding around the Blowout Site

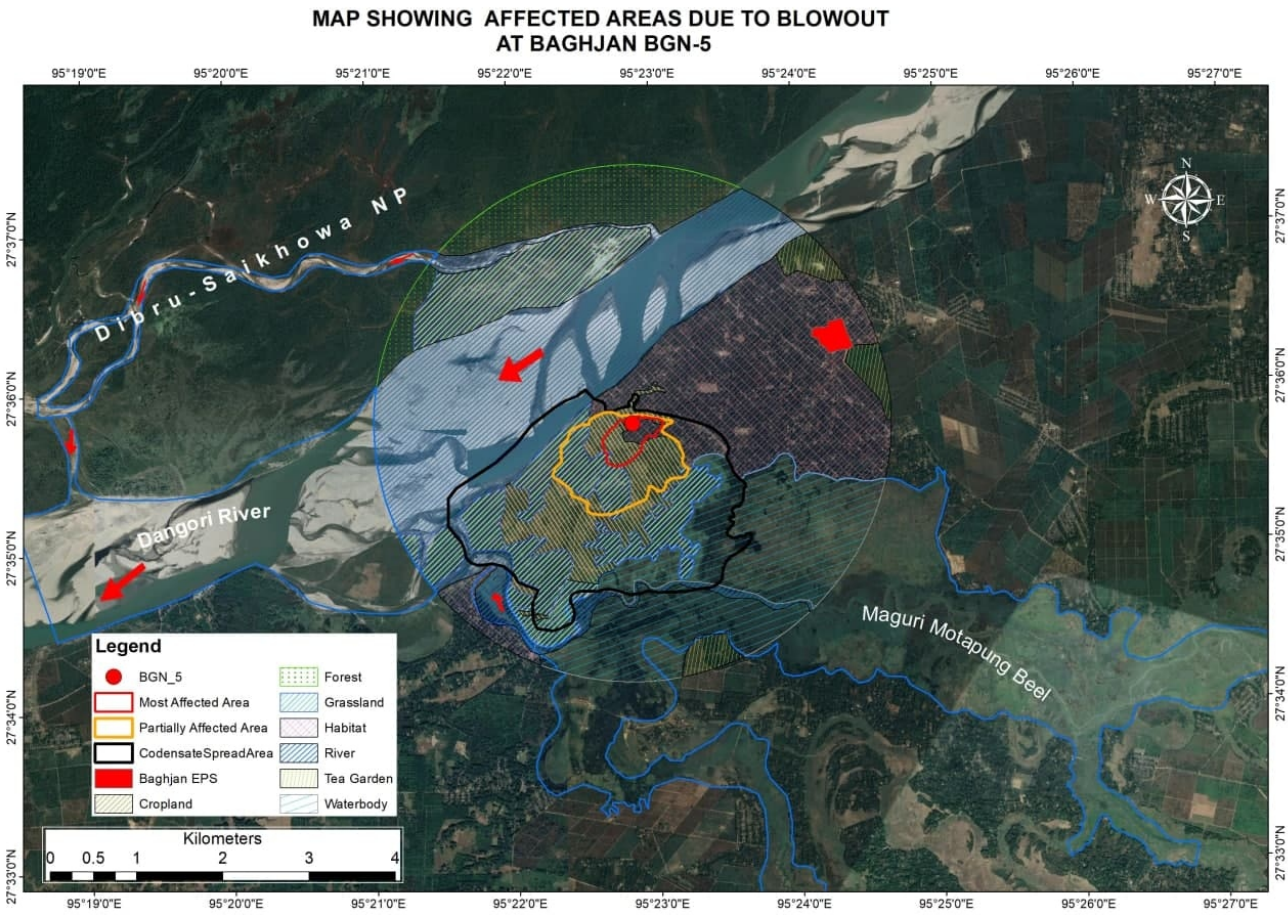


Fig. No. 11.19: A Map of the Condensate Affected Areas around Baghjan Blowout Site

11.12.1 THE AFFECTED LAND USE

As per the drone based assessment of the area covering a radius of 3 km, it is seen that roughly the condensate has affected areas falling within the 3 km radius. However, due to water and rains, the condensate has spread to other areas, water bodies and river channels. Majorly the following areas have been identified:-

1. Severely burnt area
2. Partially damaged area
3. Condensate spread area
4. Secondary affected area

Within each of these areas, other than the totally burnt area, further sub division of land use in the following categories have been done:-

1. Habitation
2. Cropland
3. Grassland
4. Tea bushes
5. Waterbodies
6. River/ Streams

The table below provides the areas as per land use as mentioned above:-

Table No. 11.8: Land Use Wise Damaged Area around Baghjan Fire

Sl. No.	Land Use Type	Severely Burnt Area (m^2)	Partially Burnt Area (m^2)	Condensate Spread Area (m^2)	Secondary Affected Areas (m^2)	DSNP (m^2)	Areas Outside 3 Km Radius (m^2)	TOTAL (m^2)
1.	Habitation	5368109	17339	276860	5340488			11002796
2.	Cropland	1801753	528493	1108568	61257			3500071
3.	Grassland	776286	475821	1745770	504676	1728701		5231254
4.	Tea Bushes				701319			701319
5.	Water bodies			1002149	4089863		11225570	16317582
6.	River/ Stream			734875	2935099	8209143	7880808	19759925
7.	Forest land					2127337		2127337
8.	Bagjhjan EPS				117293			117293
9.	Well Area	16634						16634
	TOTAL	**7962782**	**1021653**	**4868222**	**13749995**	**12065181**	**19106378**	**58774211**

11.12.2 Spread of Condensate Per Unit Area

In absence of a computer model and simulation, there is no option but to assume that the condensate fell uniformly all over the remaining area (which were not fully burnt). This area comes to, as per the drone assessment, 5.9 sq km. The density of spread of the condensate of quantity 32000 kg would be ~5.4 gm/m^2. This is a very high value even for a thin spread. Typically, wind directions would have ensured that only one third of the whole area received all of it, taking the actual values possibly to 16 gm/m^2.

11.12.3 Possible Concentrations of Condensate in the Soil

As per the EIA-ERM (2009), the average bulk density of soil comes to 1.1 gm/cc or 1100 kg/m^3 in the Baghjan area. Further assuming that the oil would percolate 10 cm down the soil (Vol=0.1 m^3), the possible concentration of the condensate in affected soil would be on these lines:-

Table No. 11.9: Estimated Spread Density & Concentration of Condensate

Spread Density (gm/m^2)	Concentration (mg/Kg)
5.4	49 mg/Kg
16	145 mg/Kg

The field tests by PCBA has suggested presence of Oil and Grease to the levels of 1.11 to 17.15 gm/kg in the affected soils. These levels can be theoretically achieved by reducing the depth of the penetration of the condensate in the soil. If the penetration is just 1 cm deep, the predicted values would meet the values as reported from the ground measurements by the PCBA. Therefore, the theoretical and field observations can be said to be matching. These may require further experimentation to simulate the field conditions and arrive at more accurate theoretical values from the blow out oil spill.

11.12.4 Concentration of Condensate in Water

While from the assessment of drone, the area of water that would have directly received the condensate is available, it would not be practical to guess values randomly, as water is flowing, and rains have been there for several days.

11.13 Assessment Of Ecosystem Services Loss

At this juncture, let us proceed to the most significant part of the assessment of the ecosystem damages. The valuation per ha of the ecosystem services has already been provided in the methodology part of this Chapter. We wish to take it forward from here.

11.13.1 Valuation of the Ecosystem Services at Current Prices

The valuation presented in the methodology section for the monetary value of the ecosystem services was based on Costanza et al (2014) in which the basis of the cost was in dollars as of the prices of 2007. Therefore, by using the compound rate of interest of a minimum of 6% per annum, we need to bring the prices to the level of 2020. It would be 13 years @ 6% pa compound interest on 1 US$. A simple mathematics tells that the value of 1 US$ would be ~2.13 US$. The current rate of exchange can be taken as US$1=74.00 INR. With these parameters, the valuation of the ecosystem services for 2020 in Indian Rupees becomes:-

Table No. 11.10: Ecosystem Services Valuation in 2020

Sl. No.	Ecosystem	Valuation in 2011 (US$/Ha/yr)	Valuation in 2020 (INR/Ha/yr)
1.	Terrestrial Flood Plain Wetlands	25,681	4,047,839
2.	Terrestrial Grasslands	4,166	656,645
3.	Terrestrial Rivers/ Lake	12,512	1,972,141
4.	Tropical Forest	5,380	847,996

11.13.2 Estimation of Loss of Ecosystem Services

In order to assess the loss of ecosystem services, we need to first assume as to how much time it would take for rejuvenation or restoration of the ecosystem to get it back to the original state. Such restoration of a natural system to its original state may not be possible. However, we can roughly estimate. It may take at least 10 years for the most damaged ecosystems to come back to 70-80% of the original value. Thereafter, this could be left to heal on its own. Flowing river systems may get restored faster, say a 5 years time period, unless the bottom of the river is very badly impacted. Forest/Grassland and soil ecosystems also would take 7-10 years to heal fully to get back the old productivity level of the natural system. In agricultural/plantation systems, which are artificial, it may take 3-5 years only. Therefore, two slabs for time period of restoration, during which, it is assumed that the ecosystem services would be not fully available [*and actually a positive feedback may be killing it more, who knows?*], i.e. 10 years for wetlands and grasslands, and 5 years for rivers and streams. Based on these, the loss of ecosystem services in the Baghjan blow out ecological disaster is shown below:-

Table No. 11.11: Valuation of Loss of Ecosystem Services at Baghjan

Sl. No.	Ecosystem	Valuation in 2020 (INR/Ha/yr)	Area (Ha)	Time (Years)	Valuation (In Cr Rupees)
1.	Terrestrial Flood Plain Wetlands	4,047,839	1632	10	6606.07
2.	Terrestrial Grasslands	656,645	523	10	343.43
3.	Terrestrial Rivers/ Lake	1,972,141	1976	5	1948.48
4.	Tropical Forest	847,996	213	10	180.62
	TOTAL		**4344**		**9078.6**

11.13.3 Realistic Timelines for Restoration of Ecosystem Services

While we have, for arithmetical simplicity, assumed restoration time of ecosystem as 10 years for wetlands, grasslands and terrestrial forest ecosystem, and 5 years for rivers, justice would be denied to the mute and voiceless ecological systems, if we do not deliberate as to what the contemporary research speaks about restoration of various ecosystems. The time taken for an ecosystem to return from a state of disturbance to a state of normalcy would depend upon so many factors including the nature of disturbance, level of disturbance to the habitat and degree of disruption of the various communities living within the ecosystem, including the number of species pushed locally on the path of extinction.

Factors Impacting Ecosystem Recovery: Recovery of any ecosystem, following a disturbance such as the one caused by Baghjan blowout, is a complicated process. The rate and time taken by the ecosystem to recover probably depends on its resilience and degree of the damage: damage caused to the habitat and damage caused to the populations of the various communities living therein. A grassland ecosystem, when exposed to such disturbance will take a long time to recover, as in addition to the root cause of disturbance, the land is, additionally, subjected to varying weather conditions over time, which in turn result in runoff and erosion, faunal disturbance and invasion by non-native species [Desserud and Naeth, (2013)[213]]. These moreover, intensifies with the loss of genetic diversity of grassland flora and fauna, and inability to include some of

213 Desserud Peggy A., Naeth Anne M, 2013, "Natural Recovery of Rough Fescue (*Festuca hallii* (Vasey) Piper) Grassland After Disturbance by Pipeline Construction in Central Alberta, Canada," Natural Areas Journal, 33(1), 91-98, (1 January 2013)

the drivers that were historically important in shaping grasslands, such of landscape-level patterns of fire and grazing [Blair et al (2014)[214]]. In case of wetland, the restoration can be constrained by landscape setting, habitat type, hydrological regime, soil properties, topography, nutrient supplies, disturbance regimes, invasive species, seed banks and declining biodiversity [Zedler Joy B. (200)[215]].

The final goal of restoration is to recover or re-establish ecosystems such that they approach the original natural ecosystem state, prior to the disturbance, and are maintained at relatively stable states. Natural restoration of ecosystems such as grassland or wetland is, hence, similar to secondary succession. Thus, one of the way of evaluating various stages of restoration, much like succession, is assessing changes in vegetation parameters over time. This might be achieved through utilization of Space for Time Substitution (SFT) method. This method uses sites of different stages and ages of succession at separate locations to infer vegetation succession characteristics [Renhui Miao et al (2018)[216]]. This is useful in terms of restoration studies as it can predict the variation in vegetation and community states over a long period, while providing information on contemporary community characteristics. The success of restoration is not only determined by the time taken to recover the original species assemblages, but also on how long it takes to restore other parameters such as ecosystem processes and cycles. ***It takes 1000 years, for example, to regenerate three centimetres of top soil*** [Arsenault Chris (2014)[217]]. Thus, one has to consider all these aspects before estimating whether the complete recovery of the ecosystem is achieved or not.

Recovery Time for Damaged Wetlands: In case of wetlands, the time taken to restore the ecosystem depends on the type of wetland. For example, while it may take only three to four years to restore a marsh with a lush stand of marsh vegetation, yet it might take more than 30 years for restoration of a red maple swamp. When it comes to

214 Blair John M, Ratajczak Zak, Nippert Jesse B, Briggs John M, 2014, Fire dynamics distinguish grasslands, shrublands and woodlands as alternative attractors in the Central Great Plains of North America, Journal of Ecology, 2014, Vol 102, Issue: 6, Pages: 1374-1385

215 Zedler, Joy. B, 2000, Progress in Wetland Restoration Ecology. Trends in ecology & evolution. Vol 15, Issue 10, Pages 402-407. 1Zedler, Joy. (2000). Progress in Wetland Restoration Ecology. Trends in ecology & evolution. 15. 402-407. https://doi.org/10.1016/S0169-5347(00)01959-5

216 Renhui Miao, Qiu Xueli, Guo Meixia, Musa Ala, Jiang Deming, Accuracy of space-for-time substitution for vegetation state prediction following shrub restoration, *Journal of Plant Ecology*, Volume 11, Issue 2, April 2018, Pages 208–217, https://doi.org/10.1093/jpe/rtw133

217 Arsenault Chris, 2014, http://www.scientificamerican.com/article/only-60-years-of-farming-left-if-soil-degradation-continues/, Scientific American, December 5, 2014

wetland functions dependent upon mature soils, this duration may go beyond hundreds or thousands of years [Kusler et al (1990)[218]]. In fact, ***even if a wetland continues to evolve, as sediments are trapped and deposited by the vegetation, it might take another 50 years for the restored wetland to regain its original form*** [Frenkel and Morlan (1991)[219]].

Recovery Time for Damaged Grasslands: The self-recovery of a grassland, i.e. the point until which recovery can take place without assistance, is high if the restored species belong to the original characteristic species pool of the region. The self-recovery becomes difficult when the changes in the composition and structure of the system are mediated by changes in soil conditions [Andrade et al (2015)[220]] and other ecosystem processes. Grassland recovery after any kind of degradation, hence, depends on the intensity and frequency of management [Winter et al (2012)[221]].

11.14 Remediation Measures For Soil And Water

The remediation measure suggested for soil and water bodies is bioremediation. A detailed write up on bioremediation[222] is provided in the Volume II of the Report. The important issues with respect to bioremediation are listed below:-

1. The soil/ water samples must be tested prior to bioremediation as well as during the process and post remediation
2. All the sample tests must be under strict supervision of the public. It is suggested that an expert group with public members and members from the affected people be included in that watch group.
3. All bacteria must be fully certified to be local. M/s OIL must be able to satisfy this condition.

218 Kusler, J. and M. Kentula (eds.), 1990., Wetland Restoration and Creation: Status of the Science, Vol I: Regional reviews, Island Press

219 Frenkel, R.E., and Morlan, J.C., 1990, Restoration of the Salmon River salt marshes--Retrospect and perspective: U.S. Environmental Protection Agency, Region, February, 1990, Department of Geosciences Oregon State University Co,vaIIls, Oregon 97331

220 Andrade Bianca O, Koch Christiane, Boldrini Ilsi I, Vélez-Martin Eduardo, Hasenack Heinrich, Hermann Julia-Maria, Kollmann Johannes, Pillar Valério D, Overbeck Gerhard E., Grassland degradation and restoration: a conceptual framework of stages and thresholds illustrated by southern Brazilian grasslands, Natureza & Conservação, Volume 13, Issue 2, 2015, Pages 95-104, ISSN 1679-0073, https://doi.org/10.1016/j.ncon.2015.08.002.

221 Winter, S.L., Fuhlendorf, S.D., Goad, C.L., Davis, C.A., Hickman, K.R. and Leslie Jr, D.M. (2012), Restoration of the fire–grazing interaction in *Artemisia filifolia* shrubland. Journal of Applied Ecology, 49: 242-250. https://doi.org/10.1111/j.1365-2664.2011.02067.x

222 Piraisudan B. IFS, ACF, KNP, Bokakhat, 2020, [Unpublished]

4. Control experiments must be taken with respect to the process to ensure that the process is working actually.
5. The works must be published in a peer reviewed open access journal of international repute with high impact factor for scientific scrutiny.
6. The cost may be met from the compensation package or from M/S OIL or MoPNG.

11.15 Sink Is A Sink

In nature all waste congregates into the air, water and land. These are the sinks and are connected with the overall ecosystems in the surroundings and appropriately interact with the various cycles such as nitrogen, water and carbon. It is seen that while we have standards for "effluents" into water, but the parameters defined are at variance with one another, and differ considerably from industry to industry as stated in the Environment (Protection) Rules, 1986. The variance of pH is seen from 5.5 to 7.5, for example. pH below 6.6 could be harmful to aquaflora and fauna. ***Therefore, the plea here is that there must be a single standard for all effluents/ emissions into air, water and land. Before emitting anything into the environment, it should be the responsibility of the industry to ensure that all parameters are met, irrespective of the industry. Further, we do not have any standards for emissions into soil or limits to pollution in soil. It is time that we made one, and a uniform standard that should be***.

11.16 Conclusions

1. There are no soil quality standards in the country. The water quality standards are there, but they differ considerably from context to context. In all these standards are very clumsy for application in the field.
2. Baseline for water temperature and water quality was difficult to obtain for the main water bodies, and even for the river Brahmaputra. A very few research studies were found on the subject.
3. Water temperature was found to be, at places, higher than 5^0 C, which falls in the category of thermal pollution. This is a contravention of the provisions of the Environment (Protection) Rules, 1986. A breach was found in this regard by M/s OIL.
4. The DO levels was found dipped to dangerous levels of below 4 mg/L, which is dangerous for aquatic fauna. At places DO levels were found to be as low as 0.94 mg/L. This is a breach of water quality on the part of M/s OIL.

5. Breach was also found in respect of amount of Oil and Grease in the water as well as soil.

6. There was neither any baselines studies done by M/s OIL in the EIA, among so many other shortcomings, nor any study by regulators. However, assessments showed very high amounts of PAH in water, soil and organic samples of fauna. As regards breach, PAH limits were clearly breached for water, as per the existing standards. There being no standards for PAH in soil and organs of fauna. However, one needs to consider these as breach too.

7. There was breach in respect of Pb and Cu in water samples tested by PCBA.

8. The BOD and COD were found to be in violation of the standards within 500m of the blast site. This constitutes a breach in the water quality.

9. In the assessment, 250 points were found showing pH below 6.5. Low pH in combination with low DO became a fatal combination for the wildlife in the wetlands and the grasslands. All lab tested pH values were rejected, as the standards followed could not be determined, and pH values of stored water in contact with air would tend to move to 7 or 7.5 over a period of time. There was a breach in respect of pH in the water.

10. It was also found that a “Heat Island Effect” was created by the flame in the surrounding areas. However, since, there is no such regulatory prohibition, we cannot call it breach technically. It is a kind of heat pollution (as dealt with in the previous Chapter), and accordingly, should be brought under environmental regulatory regime.

11. Drone-based assessment of damages on land and water was evaluated in a 3 km radius along with other adjoining areas. The total affected area came to 58.8 sq km.

12. The total quantity of natural gas and condensate that would have flown out of the well during the blowout prior to the explosion was estimated. It was found that the amount of fuel needed to explode (equal approximately to 0.833 kT) could effectively have been emitted in just about 2 to 4 minutes time alone.

13. It was assumed that about 50% of the condensate would have fallen within 300 m radius (as is seen from the drone assessment, which shows an average of 277 m radius). The total condensate has been estimated at 64000 Kg during the blowout period prior to the explosion.

14. The amount of condensate that would have fallen in the surrounding areas, and was left unburnt by the fire was estimated for the affected site. The generic estimate yielded values from 5.4 to 16 mg/m^2 of land surface assuming a uniform penetration depth of 10 cm. However, this is a very generic supposition. Therefore, it was seen that the field values observed (1.11 to 17.15 gm/Kg) could be justified easily from the above generic values.

15. The valuation of loss of ecosystem services for 4 ecosystems namely 1. Flood plain wetlands, 2. Grassland, 3. River and streams and 4. Tropical forest was evaluated based on the work by Costanza et al (2014). The valuation was recast to 2020 prices and in INR. The time period was considered 10 years for land based systems, and 5 years for river/streams. The total loss, accordingly, came to Rs. 9078.60 cr.

16. Bioremediation was suggested as a method of recovering the land and water. A detailed writeup on bioremediation has been produced. However, certain precautions have been suggested while carrying out the bioremediation.

17. Sink is a sink, and is to be treated equally everywhere. All emissions to air, water, soil and land must follow a single set of standards. The current provisions under the Environment (Protection) Rules, 1986 are quite difficult to work with on the ground. Sink standards should be uniquely and universally defined.

CHAPTER – 12

12 ASSESSMENT OF BIO-DIVERSITY LOSS

12.1 Introduction

This Chapter is different from the Chapters 8 to 11, as it does not deal with "Breach or No breach"; rather this Chapter is all about "Breach", as this blow out and subsequent fire has left a large number of wildlife dead; many animals deserted the area; and several parts of the habitat were destroyed, which has already been dealt with in some detail in the previous Chapter. We shall be dwelling upon the damages done to the key biodiversity indicator and niche species, and consequences thereof.

The habitat considered here are Dibru-Saikhowa National Park, Lohit/ Dibru rivers, Maguri Motapung Beel and adjoining grasslands, parts of Bherjan Borajan Podumoni WLS and other wildlife areas such as Barekuri. Furthermore, there has been considerable damage by way of burning, dying due to excessive heat or full/partial damage caused by spread of the condensate in the surrounding areas applicable to both flora and fauna. However, we shall restrict the findings to faunal species only in this Chapter. It was not possible to do full justice to the biodiversity loss assessment, as the connotations of biodiversity are very large, and cover all living organisms including plants and microorganisms. Further, it needs to be mentioned here that assessment was carried out by multiple agencies, and hence, the individual reports from various agencies may overlap in content, assessment and area of operation. Most species that were identified to be falling under the provisions of the Wildlife (Protection) Act, 1972 were directly handled by the DFO, Tinsukia Wildlife Division and/ or the DFO, Dibrugarh Division. These two divisions have also submitted detailed reports.

12.2 An Understanding Of Wildlife And Habitat As Per WPA, 1972 And Other Acts

We shall be discussing a few minor criminal laws here:

12.2.1 WILDLIFE (PROTECTION) ACT, 1972

The Wildlife (Protection) Act, 1972 is the most comprehensive legislation in India in matters of wildlife and habitat. Under Section 2 (1) "animal" is defined as "*includes mammals, birds, reptiles, amphibians, fish, other chordates and invertebrates and also includes their young and eggs*". This is indeed a very comprehensive definition of the animal kingdom in a few words. Under Section 2(36) "wild animal" is defined as "*means any animal specified in Schedule I to IV and found wild in nature*". Under Section 2 (37)

"wild life" is defined as "*means any animal, aquatic or land vegetation which forms part of any habitat*"; and under Section 2(15) "habitat" is defined as "*includes land, water or vegetation which is the natural home of any wild animal*". Under Section 2 (17), "land" is defined as "*includes canals, creeks and other water channels, reservoirs, rivers, streams and lakes, whether artificial or natural, marshes and wetlands and also includes boulders and rocks*". Under Section 2 (18A) "livestock" is defined as "*means farm animals and includes buffaloes, bulls, bullocks, camels, cows, donkeys, goats, sheep, horses, mules, yaks, pigs, ducks, geese, poultry and their young but does not include any animal specified in Schedules I to V*". It is also interesting to look at the definition of "Weapon" which is defined under under Section 2 (35) as "*includes ammunition, bows and arrows, explosives, firearms, hooks, knives, nets, poison, snares and traps and any instrument or apparatus capable of anaesthesizing, decoying, destroying, injuring or killing an animal*".

Concerning criminal activities pertaining to wildlife, the Section 2 (16) defines "hunting" which says, "*with its grammatical variations and cognate expressions, includes – (a) killing or poisoning of any wild animal or captive animal and every attempt to do so; (b) capturing, coursing, snaring, trapping, driving or baiting any wild or captive animal and every attempt to do so; (c) injuring or destroying or taking any part of the body of any such animal or, in the case of wild birds or reptiles, damaging the eggs of such birds or reptiles or disturbing the eggs or nests of such birds or reptiles*".

While everything about the provisions above fits into the crime scene of Baghjan oilfields, the Section 9 of the Wildlife (Protection) Act, 1972, which prohibits the act of "hunting" can only be applied if any wild animal specified in Schedules I, II, III and IV is killed or hunted. For the rest, one has to look elsewhere.

Under the WPA, 1972, there is provision of penalty of imprisonment under Section 51, for a period of three to seven years if offence is committed in relation to any animal specified in Schedule I or Part II of Schedule II, and for any other animal falling in any other Schedule, the imprisonment is for three years. If the offence is committed in respect of an animal not defined in the Schedules but is a wild animal, such an offence cannot be taken cognizance under the WPA, 1972.

12.2.2 ASSAM STATE AMENDMENT TO THE WILDLIFE (PROTECTION) ACT, 1972

The Govt. of Assam, in 2009, with the assent of the President of India has enacted an Act further to amend the Wildlife (Protection) Act, 1972 in its application to the State of Assam. This Act may be called the Wildlife (Protection) (Assam Amendment) Act, 2009 that extends to whole of Assam. As per the said amendment there is provision of

penalty of imprisonment under Section 51 (1) for a period of minimum seven years but may extend to ten years and also with fine which shall not be less than fifty thousand in relation to any animal specified in Scheduled I or part II of Schedule II where the offence relates to hunting in or outside the boundary of a Sanctuary or a National Park.

Further on, in case of second or subsequent offence of nature mentioned above the term of imprisonment shall not be less than seven years but may extend to "life imprisonment" and also with fine which shall not be less than seventy five thousand. As per Section 51 B (1) of the Wildlife (Protection) (Assam Amendment) Act, 2009 "*Every offence punishable under this Act shall be cognizable and non-bailable within the meaning of the Code of Criminal Procedure, 1973*".

12.2.3 ASSAM FOREST REGULATION, 1891

Under Section 3(4)(b)(iii) of the Assam Forest Regulation, 1891 (AFR 1891), "forest produce" is defined as "i*ncludes – the following when found in, or brought from a forest, that is to say, – wild animals and skins, tusks, and horns, other than rhinoceros horns, bones, silk, cocoons, honey and wax and all other parts or produce of animals, …*". Further, the Section 34 of the Act categorically states, "*Protection of unsettled forests belonging to the Government-- (1) No person shall make use of any forest produce of any land at the disposal of the Government and not included in a reserved forest or village forest, except in accordance with rules to be made by the State Government in this behalf, or as provided by the last section of this Chapter. (2) Such rules may, with respect of such land, – …..(f) prohibit the poisoning of water, and regulate or prohibit hunting, shooting and fishing, and the setting of traps or snares…*". However, Rules in respect of Section 34 (2) (f) have not been made [but for 34 (2) (c), (d), (g) & (h) Rules have been made]. Therefore, in absence of any Rules, the last line of the Section 34 (1) would apply, and it reads, "… *or as provided by the last section of this Chapter*". The last Section of the **Chapter IV, General protection of Forests and Forest produce**, of the AFR, 1891 is Section 36, which reads "*36. Nothing in this Chapter to prohibit acts done in certain cases-- Nothing in this Chapter, or in any rule under this Chapter, shall be deemed to prohibit any act done in exercise of any right or with permission in writing of a Forest Officer specially empowered to grant such permission*". This clearly implies that prohibitions imposed under Section 34(2)(f), in absence of a rule, are absolute, and cannot be committed without permission in writing of a Forest Officer specially empowered to grant such permission.

Therefore, all Government lands surrounding the Baghjan blow out site, such as the Maguri Motapung Beel, the surrounding grasslands, river Lohit and Dibru etc., are all protected under the Section 34 (1), (2) (f) and 36 of the AFR, 1891; and any

contraventions of the provisions of the AFR, 1891 such as poisoning and hunting are "forest offences" punishable under the AFR, 1891.

The only issue now remains to be deliberated upon is the "*Seizure of property liable to be confiscation*" under Section 49(1). The Section 49 provides for seizure of property, "*(1) When there is reason to believe that a forest offence has been committed in respect of any forest produce, such produce together with all tools, boats, carts and cattle used in the commission of such alleged offence may be seized by any Forest Officer or Police Officer*". The emphasis on seizure of forest produce, and in case of perishable goods, the Section 54 applies. Under Section 49A, any Forest Officer of a rank not inferior to that of a Forester who or whose subordinate has seized any tools, boats, carts or cattle under section 49, may release the same to the owner on execution of a bond.

12.2.4 INDIAN PENAL CODE, 1860

Under the IPC, under Section 428 and 429, there is a provision of Mischief (killing or maiming) against animals, and if the value of animal(s) is Rs. 10.00, the imprisonment can be upto two years or fine or both. In case the value of animals (s) is Rs. 50.00 or more, the punishment for Mischief is imprisonment upto five years, or fine, or both. Therefore, under the IPC Section 428/429, imprisonment can be imposed for killing or maiming any animal.

Table No. 12.1: Provisions under IPC

IPC 428:

Mischief by killing, poisoning, maiming or rendering useless any animal of the value of 10 rupees or upwards	2 Years or Fine or Both	Cognizable	Bailable	Any Magistrate

IPC 429:

Mischief by killing poisoning maiming or rendering useless any elephant, camel, horse, etc., whatever may be its value or any other animal of the value of 50 rupees or upwards	5 Years or Fine or Both	Cognizable	Bailable	Magistrate First Class

The only question is how to decide the value of wild animals. Values can be fixed by many modern methods available to economists, and recourse to IPC section 428/429 may be taken against offenders who cannot be either booked under the Wildlife (Protection) Act, 1972, or the Assam Forest Regulation, 1891. However, the Wildlife (Protection) Act, 1972 needs further amendments to cover all wildlife, and include destruction of habitat as a wildlife crime.

12.3 Indicators Of Bio-diversity Richness And Health Of Habitat

There are several indicators of biodiversity richness index, and it is important that some of these be briefly described here, as the various reports on biodiversity assessment would referring to some of these indices.

12.3.1 Species Richness Curve

This is the simplest, yet most indicative of the efforts in sampling and "encounter" of new species in a sampling exercise. It is a plot of no. of individual detected (N) or even no. of samples (n) taken vs encountered number of species. As the number of samples increase, chances of discovering/ encountering new species declines, and the curve typically becomes flat. At that point additional sampling efforts are less likely to throw up more species, and one can safely say that no more sampling is needed. A representative species richness curve is depicted below for illustration purposes. These curves are also called species accumulation curve, or species effort curve.

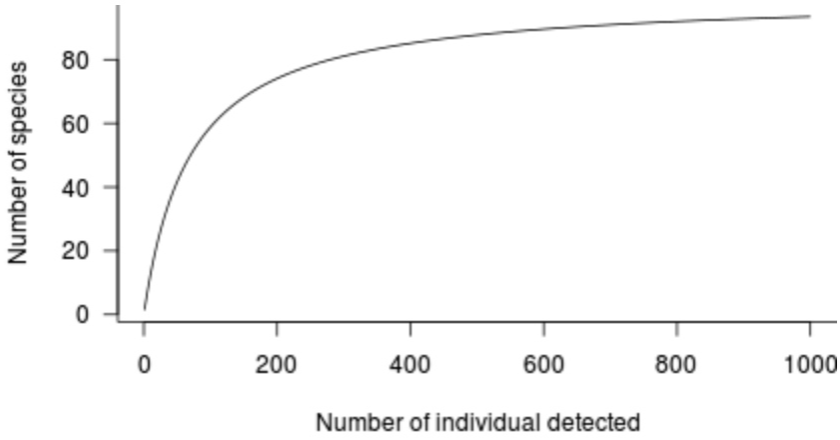


Fig. No. 12.1: Species Accumulation Curve

At this point one is tempted to discuss α, β, and γ diversity measurements[223,224],[225] as proposed by Whittaker R.H, one should refrain from doing so, except simply stating one line about each avoiding all controversies, as each ecologist sees these diversity measures as differently. Here, α is simply a measure of number of species (S) in a sample or a standard sample of or a quadrat (generally defined as each of a number of small areas of habitat, typically of one square metre, selected at random to act as sample for assessing the local distribution of flora and fauna). Y is a landscape level diversity, or the total diversity summed over all the quadrats. Average α could be seen

223 Whittaker R. H, 1972, TAXON 21 (2/3): 213-251, May 1972
224 Jurasinski G, Retzer V, Beerkuhnlein C, 2009, Oecologia (2009), 159:15-26
225 https://www.flutterbys.com.au/stats/tut/tut13.2.html

as $\bar{\alpha}=S=(\sum S_i)/n$ where S is the number of species, and n is the number of quadrats. Y is the total number of all species encountered. Thus, one can define β as $\frac{\gamma}{\bar{\alpha}}$. Therefore, it is a measure of common diversity between the quadrats.

Species diversity is often measured by way of a number of indices. We shall be discussing some of these indices, mainly because, some of the assessments carried out in the field happen to refer to one or more of these indices.

12.3.2 SHANON-WEINER INDEX

Shannon-Wiener Index is typically denoted by H' and is defined as

$$H^{'}=-\sum_{i=1}^{S}\frac{n_i}{N}\times\ln\frac{n_i}{N} \quad \text{..... } Eq.No.\ 12.1$$

where of a total of n quadrat samples, the total number of individuals encountered is N, total number of species encountered S and n_i is number of individuals of species i_i. The values of H' can range from 0 to 5. A value of 3.5 is supposed to be a good index.

12.3.3 SIMPSON'S INDEX

Simpson's Index is a kind of probability of finding two different individuals of two different species drawn randomly from the landscape, and is denoted by symbol λ. Usually, its inverse as defined below is taken as a measure of diversity (D^S).

$$\lambda=\frac{\sum n_i(n_i-1)}{N(N-1)} \quad \text{..... } Eq.No.\ 12.2$$

$$D^S= 1 - \lambda \quad \text{..... } Eq.No.\ 12.3$$

The value of Simpson's index ranges from 0 to 1.

12.3.4 MARGALEF'S INDEX

Margalef's index (D_{MA}) is a simple index or a measure of α diversity, and is given by:

$$D_{MA}=\frac{S-1}{\ln N} \quad \text{..... } Eq.No.\ 12.4$$

12.3.5 MENHINICK'S INDEX

Menhinick's Index (D_{ME})is yet another measure of α diversity, and is given by

$$D_{ME}=\frac{S}{\sqrt{N}} \quad \text{..... } Eq.No.\ 12.5$$

12.3.6 Measure of Evenness or Equitability (J)

Evenness is how homogeneous (even) a ecosystem is in terms of the abundances of species inhabiting it. An ecosystem in which all species are equally common is said to be highly even. Measure of evenness or equitability (J) is given as

$$J = H' / \ln S \quad \text{..... } Eq.No.\ 12.6$$

The value would typically vary from 0 to 1.

12.3.7 Chao1 Index

Chao1 is a nonparametric estimator based on Capture-Mark-Recapture (CMR) method which considers the proportion of species that have been observed before ("recaptured") to those that are observed only once. In a very diverse community, the probability that a species will be observed more than once will be low, and most species will only be represented by one individual in a sample. In a depauperate community, the probability that a species will be observed more than once will be higher, and many species will be observed multiple times in a sample. Chao1 uses this CMR like ratio to estimate richness by adding a correction factor to the observed number of species. Chao1 estimates total species richness as

$$S_{Chao1} = S_{obs} + \frac{n_1^2}{2n_2} \quad \text{..... } Eq.No.\ 12.7$$

where S_{obs} is the number of observed species, n_1 is the number of singletons (species captured once), and n_2 is the number of doubletons (species captured twice). This index is particularly useful for data sets skewed toward the low-abundance classes. However, Chao1 underestimates true richness at low sample sizes.

12.4 Approach And Methodology For Biodiversity Loss Assessment

As stated elsewhere already, several research groups of experts were engaged to carry out various types of assessments. The WII (2020) carried out biodiversity survey of the Gangetic Dolphins, fishes, butterflies & odonates and herpetofauna. Sharma (2020) et al carried out surveys of earthworms, Mollusca, Lepidoptera, Odonates, Herpetofauna, fishes, birds, aquafauna and Hoolock Gibbons. BNHS (2020) carried out surveys of avifauna (restricted to Dibru-Saikhowa NP), Ahmed I (2020) carried out assessment of fishes in Dibru river and Maguri-Motapung beel. WII (2020) also submitted an exclusive report on Gangetic Dolphins survey to the OMEC, together with other data in form of replies to in-between queries by OMEC, which are reflected in these Chapters (11-14). Gogoi D (2020) carried out survey of avifauna exclusively in Maguri-Motapung beel.

Bania R (2020) studied ichthiofauna (fish fauna), aquatic macrophytes, molluscs and planktons. Another work that has been referred is the PhD work of Dr. Ranjan Kumar Das on avifauna of grasslands of Dibru-Saikhowa.

Many specimens of dead fauna were collected by the DFO Tinsukia Wildlife and DFO Dibrugarh Divisions through the various research teams and the local people. Many samples were sent for testing to Delhi (courtesy WII), others to the Forensic Laboratory (FSL), Guwahati, laboratories at College Veterinary Science, Khanapara, IASST, Guwahati, IIT Guwahati etc. Some labs received the samples and tested them despite COVID19, and sent reports too, some labs refused or had no such facilities, some were completely shut down due to COVID19. As a result, very comprehensive lab test reports on a large number of samples could not be obtained. These were very circumstantial and, on top of that, one had to face field limitations imposed by restricted entries to the Baghjan, compounded by a series of wave of flood, and restrictions in movement due to COVID19 strict protocols and lock-down. Nevertheless, results obtained, despite so many hurdles, are quite conclusive and definite.

Therefore, the focus was largely on the following three activities:

1. Identification of specimens of dead fauna and their count
2. Sampling to assess the balance of the populations
3. Collect baseline data on populations and species diversity

These activities are listed in increasing order of difficulty and reverse order of urgency. It has also to be noted that sampling conditions also were not constant as the weather conditions varied considerably, and the local scenario kept changing. Incessant rains and floods made the field works quite an uphill task. Many dead samples of fauna were washed away by floods [*and as per local reports, the personnel of OIL were also seen removing carcasses of dead fauna*]

12.4.1 Sampling Methods

Various sampling methods were deployed by different research groups as suited to assess biodiversity of various species. Some of the methods used by various agencies are listed below without describing them in detail.

Table No. 12.2: Sampling Methodologies for Species Assessment

Sl. No.	Species/ Community	Sampling Methodology	Study Area	By
1.	Earthworms	5x5 m^2 grid samples	Baghjan Maguri road side	Sharma N (2020)
2.	Mollusca	Line transects of 500m	Maguri Beel	Sharma N (2020)
3.	Lepidoptera	Point sampling 500m apart with UV light etc.	Baghjan, Maguri, Bherjan	Sharma N (2020)
a.		Point sampling in km grid	Maguri Beel and grassland	WII (2020)
4.	Odonates	Line transect	Maguri Motapung Beel, grasslands	Sharma N (2020)
		Point sampling in km grid	Maguri Beel and grassland	WII (2020)
5.	Herpetofauna	Line transect	Maguri Motapung Beel, DSNP peripheri	Sharma N (2020)
		Area searches in 0-5 km grid	Maguri grassalands & Dibru river	WII (2020)
6.	Fish fauna	Line transects	Maguri Beel	Sharma N (2020)
a.		Point sampling	Maguri Motapung beel/ Dibru river	WII (2020)
b.		Fish catch	Lohit & Dibru rivers	Ahmed I (2020)
7.	Avifauna	Distance sampling (5.2 km)	Radian distance ~ km	Sharma N (2020)
a.		Rapid grid based point sampling (in 25 m radius)	Dibru-Saikhowa NP	BNHS (2020)
b.		Transect walks/ boat transects	Maguri beel/ grassalnd	WII (2020)
c.		Point sampling/ boat survey	Maguri motapung Beels/ grassalnds	Gogoi D (2020)

8.	Benthos	Point sampling with .5mm sieve	Maguri and Chalibari beel (DSNP)	Sharma N (2020)
9.	Hoolock Gibbon	Total population behaviour study	Barekuri group	Sharma N (2020)
10.	Large mammals	Sign survey, Count and Drone survey	Dibru-Saikhowa NP	DFO, Tinsukia, WIldlife

The sampling methodologies and area of study for each of the expert groups are described briefly in the assessment section of this Chapter against each species/ community of the various ecosystems studied. A separate section has been devoted to each of the faunal communities namely: Earthworms, Mollusca, Lepidoptera, Odonates, Herpetofauna, Benthos and Fishes. Birds, Dolphins and Hoolock Gibbons have been covered in Chapter 13 and 14 (without repeating any commonalities with this Chapter)

12.4.2 Habitat Assessment Methodology

Together with identification of various faunal species, collection and identification of dead samples, use of videography and photography for later identification of species, a general assessment of habitat was also carried out by most of the agencies mentioned in the previous paragraph. The following additional information were also gathered;

1. Physical condition of specimen (say drenched in oil/ having oil droplets)
2. Oil spill in the waterbody/grassland
3. Whether the area was burnt in the fire/ explosions
4. Temperature of water, soil and air
5. Noise metering reading at the site
6. In situ pH
7. Collection of water, soil, sediment samples
8. Collection of faunal specimens for testing
9. Satellite based study of the terrain and impact of oil spill/ explosion/ fire
10. Rescue activities

Based on the data collected from the above, a fairly good assessment of the habitat could be arrived at. Quite an extent of the outcome of analysis of the data above is already presented in the previous Chapter. Contextual inputs on habitat shall also be provided in this and the next two Chapters as well.

12.4.3 Permission of The CWLW, Assam

Permission for specimen for entry, specimen collection, testing etc. under the Wildlife (Protection) Act, 1972, was granted by the Chief Wildlife Warden, Assam for all the agencies mentioned in this Report.

12.5 Assessment Of Loss Of Earthworm Community

The earthworm community study was conducted by Sharma N (2020). The Assessment Report (AR) has been freely quoted here wherever required. This also applies to all the reports assembled under the umbrella of the OMEC and EC.

The recorded earthworm species found naturally in the area was identified to be *Eutyphoeus assamensis*. On the 26th June, 2020, when flood waters entered the Maguri grassland and other areas, the collected oil (unburnt areas) resurfaced, and spread to the grassland, killing a large number of faunal species. The most striking feature was death of thousands of earthworms that were swept on the road by the flood waters. The next day morning these were wiped clean by fire brigade waters jets of M/S OIL, but meanwhile several photographic evidences were already collected. Another round of floods came on the 3rd of July, 2020. At that time, WII team was present for the assessment for biodiversity loss, but the work could not continue due to high floods.

12.5.1 Area of Study

The study area was Maguri Beel, Maguri grasslands and parts of Baghjan. The cross section was provided by the Maguri-Baghjan Road after the bridge. The flooded length was about 1.25 km. The field work was conducted from 26th to 28th June, 2020.

12.5.2 Methodology

The sampling was done based on 5x5 m^2 plots at a gap of 200 m. Each plot was sub-divided into 1x1 m^2 sub-plots. In each of the sub plots, earthworm encounter was counted using visual count method. The density (no. of earthworms) per m^2 was calculated from the sample, and multiplied by the area of interest. In this case, an estimate of number of earthworms dead was worked out along the road. Due to quick decay of bodies, several individuals could not be identified. Specimens were collected, and sent to laboratory for tests of toxicity. In situ pH, soil, water and air temperatures were also recorded at each sampling quadrat.

12.5.3 Findings

The sampling showed that about 3.68 earthworms were found dead per m^2. When extrapolated to the entire length of the road, the estimate comes to 18,860 dead

earthworms. The habitat conditions would be discussed in some more detail later in this Chapter, but it suffices to say that the insitu pH of the water was found to be highly acidic. The lowest pH recorded was 3.6, which is against the norms, as already discussed in the previous Chapter. The deaths of small fauna such as earthworms, fishes and snakes were instantaneous.

As per some research studies[226,227], earthworms in soil vary from 0-190 numbers per m^2, with average value of 66.3 in springtime, and between 0 to 45.8 (average being 9.9) per m^2 in summer. Another study by Rajkhowa et al (2014)[228] in the North East India, showed that the earthworm density per m^2 in grasslands is 131, agricultural systems 238 and alluvial soil 62. The earthworms make up 80% of the invertebrate biomass in the soil, and have been aptly called ecosystem engineers.

12.5.4 Control Plots on Earthworm Density

In order to be still close to the site, yet far enough from its ill effects of sound and heat, a control site at about 28-30 km distance from the blowout was chosen in the North East direction, where the oil spill could have had apparently no impact. 8 nos of sample plots were laid and earthworm count was done. The density was calculated for each sample plot, and average worked out. The data table of the earthworm count is reproduced here:-

Table No. 12.3: Earthworm Density in a Control Study

Plot ID	Region	Location	Lat	Long	Plot area	Earthworm Count	Density/sq.m
1	Kakopather	Upor Ubon	27° 38.390'	95° 40.135'	2.25	13	5.8
2	Kakopather	Upor Ubon	27° 38.480'	95° 39.997'	2.25	12	5.3
3	Kakopather	Lazum	27° 38.463'	95° 40.440'	2.25	8	3.6
4	Kakopather	Lazum	27° 38.466'	95° 40.432'	2.25	16	7.1
5	Kakopather	Upor Ubon	27° 38.358'	95° 40.142'	2.25	10	4.4
6	Kakopather	Upor Ubon	27° 38.370'	95° 40.162'	2.25	8	3.6
7	Kakopather	Upor Ubon	27° 38.361	95° 40.134'	2.25	21	9.3
8	Kakopather	Lazum	27° 39.065'	95° 40.581'	2.25	11	4.9

226 Walsh, C.L. and J.L. Johnson-Maynard. 2016. Earthworm distribution and density across a climatic gradient within the Inland Pacific Northwest cereal production region. Applied Soil Ecology 104:104-110.

227 Walsh, C.L, Hewitt H, J.L. Johnson-Maynard. 2014. Earthworm density and activity across three agroecological zones, REACCH Annual Report 3, Page 40-41

228 Rajkhowa, D.J. & Bhattacharyya, Pranab & Sarma, A. & Mahanta Kaberi. 2014, Diversity and Distribution of Earthworms in Different Soil Habitats of Assam, North-East India, an Indo-Burma Biodiversity Hotspot. Proceedings of the National Academy of Sciences, India Section B: Biological Sciences. 85. 10.1007/s40011-014-0380-1

The average earthworm count was found to be 5.5 per m^2. Therefore, the % of earthworms dead per m^2 comes to 3.68/5.5 ~ 66.90%. The control study was guided by Dr. Narayan Sharma and commissioned specially for this Report.

12.5.5 Discussion

Literature is scanty on oil spill and its impact on earthworms in the soil and water. As the results speak, assuming average earthworm number to be 60 earthworms per m^2, we can safely say that 60% of the earthworm population died instantly in the incident. This is only a tip of the iceberg, as almost all dead earthworms might have been washed away, and the sampling found only the remaining dead worms. However, we shall record that **18,860 individuals were found death as per the assessment**. When compared with control within aerial distance of 30 km, it is found that almost 67% of the worms appear to have died in the Baghjan and Maguri areas, atleast within the oil spill zone. This would have the potential to cripple severally the soil health. Another set of assessment needs to be carried out season-wise to assess the damage/ restoration of earthworms in the fields of Baghjan.

12.6 Assessment Of Impact On Mollusca

Mollusca are an important part of the ecosystem, ranking 5th in number of species, and are a very important link in the food chain, themselves being filter feeders (straining suspended matter and food particles from water) and are capable of removing organic pollutants from natural ecosystems. As reported by Sharma N et al (2020), mollusca are less studied in this part of the world. According to Bania R (2020), there were reportedly 26 nos of Mollusca species recorded in Maguri Motapung wetland. According to her, many families of the low income groups consume Molluscs as their food.

12.6.1 Study Area

The field works were carried out from 10th June to 3rd July, 2020 in the Maguri-Motapung Beel, the Maguri grassalnds and Baghjan areas. Affected sites were selected considering oil spillage and burnt areas. Presence of oil was confirmed at all sites which were sampled. It appeared that locations around Baghjan were more affected, as they were closer to the blow out. More empty shells were found nearer to the place of blow out than elsewhere.

12.6.2 Study Methodology

According to Sharma N et al (2020), line transects of 500 m length and 5 in number, total length 2.5 km, were used for the study in each of the location areas. Photographs were taken for record and identification. Each dead individual encountered was recorded. Water pH along with water and air temperatures were also recorded.

12.6.3 Findings of Sharma N et al (2020)

The authors recorded 9 different genera belonging to 6 different families in the transect survey. The authors found 5556 dead individuals in the laid line transects. The 9 species encountered are: *Pila globosa, Macrochlamys glauca, Austenia spp, Brotia costula, Gyraulus convexiusculus, Indoplanorbis exustus, Intha umbilicalis, Mekongia crassa, Angulyagra oxytropis*. The study showed significantly higher mortality record in the grasslands of Maguri and Baghjan areas. Only one individual of *Austenia spp* was found dead, the next best survivor of the disaster was *Mekngia crassa* with only 35 individuals dead. Highest losses were noticed for *Intha umbilicalis* and *Gyraulus convexiusculus*. In the Maguri Beel, towards the blow out, about 800 different dead molluscs were seen floating between 0.7 to 1.5 km radius from the blow out site.

12.6.4 Findings of Bania R (2020)

Bania R (2020) recorded only four species post blowout. These are *Angulyagra oxytropis, Lallelidens marginalis, Pisidium spp, and Sphaerium indicum*.

12.6.5 Discussion

The mollusca mortality is seen to be high due to the oil spill and fire incidents. It is also to be noted that no specimen of soft bodied molluscs were found, which could mean that their bodies would have decomposed faster. In addition to old dead shells, freshly killed shells due to the oil spill were also noticed during the sampling. It is to be noted that *Intha umbilicalis*, *Gyraulus convexiusculus* and *Macrochlamys glauca* had the highest mortality (1675, 1578 & 1477 respectively). The water pH was found to be between 4.9 to 5.5. This is highly acidic. Therefore, it has been a two factor disadvantage for all the species to survive- highly acidic water and large quantities of oil in the water. It also has to be noted that molluscs form a very important part of the stork food, especially the Open Bill Stork.

12.7 Assessment Of Impact On Lepidoptera

Butterflies and moths are indicators ecosystem health, and are an important link in the ecological chain. Their absence can potentially jeopardize the entire ecosystem and cripple agricultural systems by adversely impacting pollination. The whole food chain can get badly affected by their absence. “Butterfly Effect” is remarkable as well in ecological realm. Absence of butterflies and moths can cause catastrophe of unknown proportions.

Two studies were done, one by Sharma et al (2020) and the other by WII (2020). We shall first discuss the findings etc. of Sharma et al (2020) followed by WII (2020).

12.7.1 Study Area

The study area included the grasslands of Maguri and also the Bherjan areas. Bherjan is a part of the Bherjan Borajan Podumoni WLS. The sites are characterized by grassland vegetation dominated by *Sacchurum spontaneum* at Baghjan-Maguri and *Cyperus, Kyllings chloris* etc. dominated near the blast site. *Typha spp* was found at Baghjan. As one moved from the blowout site, it got slowly transitioned into a marshy vegetation dominated by *Sacchurum spp*. Bherjan was taken as a control site.

12.7.2 Methods of Study

Moth Survey: Three locations were chosen for replication evenly spaced within 500 m aerial distance. The sampling was done using UV light (18W) set at 3m above ground and focused on a 3x5m white sheet to attract the moths. The sampling was done from 1700h to 2100 h. Once moths visited the sheets, photographs were captured for species identification and counting. A total of 17 trap hours were spent.

Butterfly Survey: Line transect method was used for butterfly survey. Transects were laid cutting across various habitat types, and incidence of encounter of butterflies was recorded. In addition to recording live butterflies, any dead individual, if found, was also recorded. At every 150m interval, site information and climate information were also collected. All surveys were carried out between 0800 hours to 1600 hours. On foot line transects covered a total distance of 12.3 km.

Bherjan Control: Bherjan control was chosen to eliminate the impacts of high luminosity of the flame, and difficulty in ascertaining the actual impacts of the fire in absence of a control. The area was chosen as it was not only close to the site, but at the same time sufficiently far, as not to have any direct impact on sampling process.

12.7.3 Assessment Of Lepidoptera

Moths Findings: A total of 393 individuals belonging to 148 species were encountered during the survey at two sampling sites. The data table in brief is given below:-

Table No. 12.4: Moth Sampling Details

Parameter	Bherjan	Baghjan-Maguri	Total
N	315	78	393
S	133	42	148
Chao 1	166-264	47-99	
H’	3.96	1.73	

Between the two sites, common species number to 27 indicating the β diversity between the two sites.

Butterflies Findings: A total of 226 butterfly individuals belonging to 63 species at three sampling sites. Between Bherjan, Baghjan and Baghjan-Maguri sites, it was found that the no. of individuals encountered in Bherjan (the control site) was four times higher than Baghjan, and about 9.9 times the Baghjan-Maguri site. The data is given in the Table below:-

Table No. 12.5: Butterfly Sampling Details

Parameter	Bherjan	Baghjan	Baghjan-Maguri	Total
N	169	40	17	226
S	54	26	14	63
Chao 1	57-82	28-67	18-39	
H’	3.23	1.92	1.79	

The number of common species between Bherjan and Baghjan-Maguri was found to be 8, while that between Bherjan and Baghjan was 19. The least number shared was between Baghjan and Baghjan-Maguri, being 6.

Species Preference: The study revealed that in the forested areas of Bherjan, the *Erebidae* moths are more common, as compared to accumulation of *Crambidae* moths in the grassland areas. *Crambidae* moths feed on herbaceous plants which are more abundant in open grasslands.

The Singleton Factor: There is another remarkable finding is that the disturbed areas seem to harbour more singleton populations than the undisturbed control habitat.

Mean population of singleton butterflies was 2±1.4 in Bherjan compared to 12±6.6 in Baghjan-Maguri. In case of moths, the mean singleton population was 15±2.8 in Bherjan as compared to 21±5.6 in Baghjan-Maguri. The authors conclude that this high number of singleton has been caused by a large number of deaths of moths and butterflies by the soaring heat, and possible attraction of the moths dangerously close to the fire. As the luminescence of the flame is very high, it would be able to attract insects from a long distance. The high singleton population of moths in control as well as the blowout site is an indicator of the possibility that moths were attracted to the fire from long distances such as even beyond 3 km.

12.7.4 Assessment by WII (2020)

The WII conducted assessment of butterflies in the Baghjan area. A brief description of the methodology and findings is provided below:

Study Area and Methodology: The sampling was done in a radius of 5 km from the blow out site across across the grassland – short and tall interspersed with water puddles. Observations were made for 20 min between 900 hours to 1400 hours between two spatial sets. The grid at 1 km was short grassland, 2 km was short-tall grassland, 4 km was tall grassland, and at 5 km was short grassland-agriculture.

Findings: A total of 96 individuals belonging to 41 species of butterflies were encountered. The findings show that the sightings appeared to be linear with distance, as distance increased so did the sightings. The Species accumulation curve (wrt time) showed that the grids closer to the blow out site saturated earlier than those far away from the grid. It was found that such a situation prevailed till 5 km radius from the blow out site.

12.7.5 Observations by BNHS

The BNHS team could hardly record any species such as Common Grass Yellow (*Eurema hecabe*), Grey Pansey (*Junonia atlites*), Peacock Pansy (*Junonia almana*) and Slate Fish butterfly (*Rapala manea*) within 1 km radius of the blast site, which are otherwise common throughout the landscape. They observed the dead butterflies namely Circe (*Hestina nama)* and Red Spot Jezebel (*Delias descombesi*) close to the blast site. Altogether only 21 butterfly species were recorded and many common species were found missing. Inside the Dibru-Saikhowa National Park, a total of 64 species of butterflies were recorded, and no visible direct impact on butterfly population was seen. They also reported sighting of Lilac Silverline Butterfly (*Apharitis lilacinus*) near the

riverbank on Park side opposite the blast site. This species is extremely rare, and first photographic record, and second sighting since 1925 (by H. Stevens).



Fig. No. 12.2: Lilac Silverline (*Apharitis lilacinus*)

12.7.6 Discussion

It is clear from the findings that as of now the butterfly and moth population has taken a very bad hit in the 5 km range. If one looks at Bherjan control site, the species diversity in respect of butterflies has reduced to half, and the number of individuals have fallen to one fourth. If one compares the control with Baghjan-Maguri areas, the species diversity has fallen to one fourth and number of individuals to one tenth. This is indeed a very serious situation with long term ramifications on food production and agriculture. The situation could be very serious within a distance of 2 km of the fire, as the local microclimate is adverse for proliferation of species. The soil and air both are polluted.

12.8 Assessment Of Impact On Odonates

The odonates populations were studied by Sharma et al (2020) and WII (2020). We shall be describe the methodologies and findings of Sharma et al (2020) first followed by that of WII (2020). The odonates include the dragonflies and damselflies. These are also a very important indicators of ecosystem health. They are also one of the great friends of human beings that have inspired our art and culture for generations. According to May M. L (2019)[229], the odonates help to keep the environment free of mosquitoes and other harmful insects including agricultural pests. They prey on vectors carrying diseases.

229 May Michael L, 2019, Insects:2019, 10, 62; doi: 10.3390/insects10030062

12.8.1 Study Area and Methodology

The area of study was same as those for the Lepidoptera- Baghjan-Maguri roadside, Maguri Beel and Maguri (Baghjan) grassland. 4 transects were used during the day time from 0800 hours to 1600 hours for on foot sampling. Also random surveys were conducted during day time using two observers to study micro and mega habitats, larval stages in wetlands and adult individuals in grasslands and wetland. Prey availability was also examined during the survey. All individuals were photographed for proper identification and record. Unlike moths and butterflies sampling, there was no control here.

12.8.2 Findings on Odonates

The authors observed a total of 66 individuals belonging to 17 different species. As per the visual count method, only 3 individual members of 3 different damselflies species were encountered, all belonging to *Croenagrionidae* family. The species richness and abundance increased as one moved away from the blow out site. Highest abundance and richness were found beyond 1.9 to 2.7 km away from the flame. Odonate individuals found within 1.5 km range were found to be affected by the blowout. Dragonfly larvae were absent from majority of the water bodies. Furthermore, fresh dead individuals were recorded within 600m of the fire. This implies that due to the intense heat, the insects could not survive within such close range of the fire. The sampling also revealed that the damselflies population was almost extinct in the area, as only one individual of each of the three species could be spotted. Lower humidity in areas close to the fire led to lack of prey base. Even in case of dragonflies, 7 species showed singleton species representation, and another two species of dragonflies showed double individual representation. The authors also observe that odonates survive well in 24^0C to 34^0C. Temperatures were found to be in that range of about 34^0C beyond 1.5 km range. However, within shorter distances, the temperatures varied from 34^0C to 42^0C. Thus, the richness and abundance was negatively affected in these microclimates. Some odonates may get attracted to fire, and die while approaching the flame, while others may even lose their diurnal behaviour by finding- it is always daytime in the surroundings of the flame. The authors observed a pair of odonates and a few laying eggs at the edges of the wetland about 3 km away from the flame, indicating that at such distances the populations are likely to recoup, indicative of a system returning to normalcy.

12.8.3 Odonate Assessment by WII (2020)

Study Area & Methodology: WII (2020) adopted the same methodology and chose the same areas for study of odonates as was done by them for the butterflies.

Findings: A total of 34 individuals of 13 species were sighted during the survey. The authors opine that absence of odonates can adversely impact butterfly populations. Odonates also get impacted with PAH and low DO levels, as the prey population gets affected such as fish fingerlings, tadpoles and other aquatic insects.

12.8.4 Observations by BNHS (2020)

Odonates being semi aquatic insects, direct impact on them was evident as they were less abundant within 1 km of the blast site. Several individuals of dragonflies namely *Crocothemis servilia* and *Pantala flavescens* found dead on the ground. Some individuals of *Urothemis signata* and *Pantala flavescens* were found alive but immobile due to heat from the blast site. The team recorded, however, 15 species of odonates, outside 1 km radius of the blast site. The team also found only one individual female of damselfly *Pseudagrion* spp, found unsettled due to heat, tremor and loss of vegetation. Most importantly, all odonates require good quality water to survive. Therefore, the lack of odonates in the vicinity of the blast site shows that the blowout has impacted the ecosystem adversely. It also shows that the freshwater ecosystem has suffered severe degradation and lost its quality to sustain life. The team observed 22 species of odonates and found abundance of *Crocothemis servilia*. However, these were found dead in Maguri Motapung Beel. The team also found traces of oil spill in the nullahs of Dibru-Saikhowa National Park, and (while no death of odonates was observed) it might have affected the larval stages of the odonates adversely.

12.8.5 Discussion

It is seen that in addition to the 14 species listed by Sharma et al (2020), the WII (2020) also lists additionally six species of odonates including one species of damselfly namely *Ceriagrion coromandelianum*. The five species of dragonflies found are: *Burmagomphus spp*, *Neurothemis tullia, Ictinogomphus spp* (not well identified and not sure if not *I. Rapax*), *Diplacodes nebulosa & Camacinia gigantea*. BNHS reported 22 species.

Therefore, it can now be said that 22 species of odonates, including 4 species of damsel flies, were encountered in the sample surveys.

12.9 Assessment Of Coleoptera By BNHS

The BNHS team observed several dead dung beetles *Lepidiota* sp and aquatic scavenger beetles *Hydrophilus* spp dead within 1 km radius of the blast site. This shows that both grassland and aquatic beetles were adversely impacted. The beetles contribute to ecosystem services in a vital way acting as scavengers of dung, and, thus, aid in nutrient cycling, bioturbation, plant growth enhancement, secondary seed dispersal and parasite control, as well as highlight their more limited role in pollination and trophic regulation, according to Nicols Liz et al (2008)[230]

12.10 Assessment Of Impact On Aquafauna (Benthos)

Benthos are a group of plants and animal communities that live at the bottom of the water body, river beds and sea beds and include a host of commonly known plants and animals. These could be emergent, submergent, or floating. Benthos plants include macrophytic angiosperms like mangrove trees, marshgrasses, Macrophytic algae (green, red, and brown seaweeds etc.), Microphytic algae including Cyanobacteria, and dinoflagellates. Since benthos live under water, light may not reach at the bottom; and they often have to manufacture food from other organic matter. Pressures at the bottom are quite high. Every 10m depth of water adds 1 atm pressure below it. Thus, the living conditions of benthos are quite different from other organisms. It is also to be noted that while fresh water ecosystems world wide account for only 0.01% of the planet's total area, but harbour more than 100,000 species within them.

Sharma et al (2020) carried out the study of the aquafauna, especially the benthos. Further a good checklist of phytoplanktons and zoo planktons was provided by Bania (2020). We shall, however, be discussing the findings of Sharma et al (2020) first.

Study Area and Methodology: Water bodies were chosen for the study, namely the Maguri Beel and Chalibari Beel in Dibru-Saikhowa NP. Sampling was done on two dates in the two beels during the day time for about 5-6 hours. A mesh size of 0.5 mm size was used for sieving the collected samples. Sucrose was added to stain the organisms and then formalin was used for preservation. Analysis was done at AAU, Jorhat.

Findings: The field studies and sample analysis revealed that there were 4 Orders in Maguri Beel (*Diptera, Oligochaeta, Gastropoda & Hirudinea*), and only 2 Orders in Chalibari Beel (*Diptera and Oligochaeta*). However, the number of individuals was very

230 Nichols, Liz & Spector, S. & Louzada, Julio & Larsen, Trond & Amézquita, Sandra & Favila, Mario. (2008). Ecological functions and ecosystem services provided by Scarabaeinae dung beetles. Biological Conservation. 141. 1461-1474. 10.1016/j.biocon.2008.04.011

high in Chalibari (at 83) when compared to Maguri Beel (15). The per m^2 density of benthos in Chalibari beel stands at 2766.67 nos, but in Maguri beel it stands at only 500 nos. Of course, it goes without saying that Maguri Beel is more diverse than Chalibari beel, but the oil spill would have devastated the benthos populations in the beel.

12.10.1 ASSESSMENT BY BANIA R (2020)

Aquatic macrophytes: According to Bania R (2020), there are 57 aquatic macrophytes that were found/ recorded. After the blow out, only 15 species, under 12 families, were recorded. The remaining macrophytes are reported to have been affected very badly. Most of the water hyacinths were covered with copious amount of oil, and actually got burnt during the fire incident. Complete burning was observed in some parts. Oil contamination was observed all around. Certain ornamental plants such as *Vallisneria spp* were found to be highly covered with oil.

Planktons: The beel has record of 30 species of phytoplanktons and 53 species of zoo-planktons. In the rapid assessment, only 11 species of the phytoplanktons and 13 species of zoo-planktons were observed. Since the phyto-planktons are the primary producers at first level, and zoo planktons at secondary level, the entire food chain of the Maguri Beel is likely to be in danger in absence of these important aquatic flora and fauna.

12.10.2 DISCUSSION

There has not been any previous survey of benthos in the area. A detailed study is required to create the baseline. A full assessment of macrophytes and microphytes, as well as planktons are also required. The disastrous impacts of the blow out are more than that can meet the eye. The damages appear to be highly deep rooted, and rapid assessments may not yield the desired result. The remedial measures to be taken must be based on sound scientific studies.

12.11 Assessment Of Impact On Herpetofauna

The wetlands of Maguri Motapung Beel, Dibru river and Lohit river are home to many aquatic fauna, especially amphibians and reptiles, fishes and birds. Between the Dibru river and the Maguri beel is the Maguri (Baghjan) grassland, which provides a healthy ecosystem to various fauna to flourish. The herpetofauna, which comprise of all the amphibians and reptiles are an important class of wild animals that render a great number of ecosystem services. In addition to being important links in the food chain, and being iconic in cultural and religious aspects from time immemorial (and also being

part of myths and folklore), the amphibians and reptiles render other services as well. Noted among these are agricultural pest control, frugivory and seed dispersal, increasing the rate of nutrient cycling to mention a few. Their role in pollination has also come to front[231]. They also control disease carrying vectors. They are efficient converters of food to biomass. They play a great role in energy transformation in the ecosystem. Being the group of animals with lowest metabolic rates, they are about 40-80% efficient in converting prey to biomass. Therefore, herpetofauna are, indeed, a very important part of the ecosystem, and the terrestrial ecosystem cannot be said to be complete without their presence. It has been noticed that there has been large scale loss of herptofauna in the Baghjan blowout.

Herpetofauna impact studies have been conducted by Sharma et al (2020) and WII (2020). We shall be discussing the findings of Sharma et al (2020) followed by WII (2020). It must be mentioned that several individuals and groups came out to rescue wildlife in the immediate aftermath of the Baghjan blow out disaster, as the impact was said to be instantaneous on the Maguri Beel. However, organized studies could only be started about first week of June and the EC could start work only from the 10th June, 2020. Therefore, the numbers of deaths reported here, and elsewhere in this Chapter and the following two Chapters (13 & 14) are only indicative and do not represent 100% of the damage universe.

It also needs to be mentioned that of all the fauna discussed so far, the Herpetofauna group is the largest in the body size and are the vertebrates. These are also highly sound and heat sensitive.

12.11.1 Study Area and Methodology

The study area was the Maguri Beel and the Baghjan grasslands, parts of Dibru river. Bherjan was taken as a control. A total of 10 amphibia species were targeted. Line transects with on foot walking were resorted to in 6 different locations from 1600 hours to 2000 hours observations with two observers were also used for further sampling. This was also to observe any tadpoles etc., in smaller water bodies. All individuals were photographed for proper record and identification.

231 Anyelet Valencia-Aguilar, Angela M. Cortés-Gómez & César Augusto Ruiz-Agudelo, 2013, Ecosystem services provided by amphibians and reptiles in Neotropical ecosystems, International Journal of Biodiversity Science, Ecosystem Services & Management, 9:3, 257-272, DOI: 10.1080/21513732.2013.821168

12.11.2 FINDINGS

A total of 10 species of amphibians belonging to 6 different families, and a total of 6 different species of reptiles belonging to 5 different families were recorded. A total of 73 individuals as per visual count method were recorded. Additionally another 11 sightings were done during the day sampling as live animals. Additionally, 177 carcasses of 4 different species were found between 11th to 22nd June, 2020. 4 dead snakes were also recorded within 450 to 1400 m of the blow out site, of these only 2 could be identified, and the rest two had decomposed beyond recognition. As per the research and field findings, no significant difference in biodiversity richness was found between Bherjan and the Baghjan grasslands. Sightings in the grasslands were very poor. A total of 8 species were found in Bherjan, 7 in Maguri beel and only 4 in Baghjan which was within 1 km range of the blowout site. Of the 177 Anurans (frogs, toads and tree frogs), 94 were beyond recognition. A few snakes were also found dead due to severe air and water pollution.

The question remains as to how such large number of animals could die. The authors theorize that there could only be three reasons. Firstly, by **ingestion** by which the animals feed on sediment associated invertebrates and end up consuming oil metabolites. Secondly, by **inhalation** by which contaminated air (with fine oil droplets) gets into the internal system of the animals; and thirdly through **absorption through the skin** by directly getting in touch with oil contaminated substrate such as soil, water or leaf litter, twigs etc.

Sound also plays a great role in life cycle of amphibians and reptiles. To mention that acoustic breeding displays, mate attraction, territory defense and predator detection are all sound based activities in Anurans and some reptiles. They even are known to adjust/ modify their acoustic signals by adjusting to local noise of agricultural lands, water sources and other anthropogenic activities. When the sound intensity increases beyond a limit, it severely impacts the ability of the individuals to discriminate between biologically correct signals and ambient noise. Currently, the soundscape of the ecosystem has been totally disrupted by the flame acoustics in Baghjan and surrounding areas. Therefore, there is no doubt that the “broadband noise” [*Please refer to Chapter 10 for a detailed treatment of the acoustic behaviour of the Baghjan flame*] spanning from 2 to 20,000 Hz at 60-100 dB at distances 100 to 1500 m or even more, and associated ground shaking would have disrupted continuously non stop 24x7 from 9th June, 2020 till 15th of November, 2020. This is a major disruption caused to the soundscape of the ecosystem. This has adversely impacted the Bherjan ecosystem as

well, which is at least 6 km away from the blow out site. This indicates towards displacement of the various species to other safer locations. The absence of tadpoles in the oil spilled water bodies of Maguri and Baghjan is a matter of concern. This is especially of significance as because the season in question i.e. the rainy season, is the time for breeding of these animals. Winter come, and they would have to hibernate.

To these findings of the authors, the heat regime of the ecosystem also needs to be discussed briefly as an addendum. Reptiles also have heat sensing mechanism over their heads between the eyes (the "Third Eye") with which they can detect prey in the stark darkness. Thus, a change in the heat regime can change the sensing behaviour or sharpness of attack by confusing the animal.

12.11.3 ASSESSMENT OF THE HERPETOFAUNA BY WII (2020)

As per WII (2020), the area has 17 amphibians, 13 turtle, 11 snake and 8 lizard species covering a host of animals commonly known as turtles, tortoises (together known as Chelonians), snakes, geckos, agamid lizards, skinks, frogs, toads and tree frogs. A list of all the species found in the area have been provided in the WII (2020) Report- See Vol II.

Study Area,Methodology & Findings: WII (2020) deployed a time constraint area search in four grids of 1 km, 2 km, 4 km and 5 km) for a pre-determined time of 1 hour. Active search was carried out underneath logs, leaf litters etc. for presence of animals by 1-2 independent observers. This resulted in an cumulative effort of 5.5 km. A total of 4 individuals of house geckos in one of the grids, and no other animal spotted in other grids. However, opportunistic sighting (encounter/ observation) of 9 species of reptiles were found. The authors report that they were not able to locate a commonly found frog (*Euphlyctis cyanophlyctis*- Common skittering frog). A soft shell turtle *Nilssania nigricans*, thought to be extinct in the wild, was rescued in the nearby tea garden areas (as reported in news media).

12.11.4 OBSERVATIONS BY BNHS

The BNHS team recorded several dead Indian Bull frog (*Hoplobatrachus tigerinus*), Indian Skipping frog (*Euphlyctis cyanophlyctis*), and several unidentified snakes within a radius of 1 km of the blast site. The number of these animals was higher on the village side rather than the grassland side. The possible reason could be that all the herpetofauna were totally burnt in the grassland fire. A dead Checkered Keelback (*Fowlea piscator*) was found in the contaminated water body near the blast site. They found an Indian Grey Mongoose (*Herpestes edwardsii*) carrying a dead snake in its mouth. A juvenile Water Monitor Lizard (V*aranus salvator*) was found on the edge of the river.

12.11.5 DISCUSSION

The most important point that has emerged from the field work and the research is that soundscape and heat regime of the ecosystem plays a great role in regulating the life cycle activities of animals. The Baghjan flame has been continuously producing sound and heat and releasing these energies in the nearby ecosystem, and thus has been crippling it day by day. We already have discussed the adverse impact of the luminescence from the flame on the odonates. There are also studies on Anurans, and how they would get impacted with external noise, which the authors, Sharma et al (2020) have quoted in their report. However, pertinent to the current discussion is another study by Roy Debjani & Elepfandt (1993)[232] who studied the sound behaviour of four Anurans namely *Rana tigrina*, *R. cyanophlyctis, R. ehrenbergi, R. limnocharis*, and found that the frequency of their calls are 520 Hz, 940 Hz, 1650 Hz, 2400 Hz, 3190 Hz. If one looks at the various frequencies emitted by the flame at Baghjan, one would find frequencies very near to these. While largely the peak frequency of the fire is at ~200 Hz, there are peaks around 500 Hz, 1000 Hz, 2000 Hz, 3000 Hz as well. These frequencies are almost matching with the call frequencies mentioned in the research on anurans.

Similarly, when one talks of the heat regime impacts, it needs to be kept in mind that most warm blooded animals radiate heat. The animal temperatures vary from 26-39^{0}C (mostly rectum temperature). For birds, this temperature could be higher and may go upto 43^{0}C[233]. When the ambient temperatures are between 25-30^{0}C, the surroundings would dissipate the heat more efficiently [*the Second Law of Thermodynamics*] but when the surrounding air temperature goes almost equal to body temperature say between 35-42^{0}C, the 2nd law of Thermodynamics would make the heat dissipation highly inefficient. For example, if an animal was radiating warm body heat at 39^{0}C, and the surroundings were at 25^{0}C. The organic heat engine (that the animal is) would be 36%, but the moment surrounding temperature shoots to 35^{0}C [and this is a realistic temperature at the surrounding of Baghjan blow out. Please see Chapter 11], the efficiency falls to 10%. This means that the animal, if it does not throw away the extra heat 20% faster, it would burn up. Therefore, the animal starts dehydrating, and subsequently collapses. This paragraph is purely based on simple principles of Thermodynamics, and is being stated here as a matter of fact [unless proved otherwise by a counter argument].

232 Roy, D., Elepfandt, 1993, A. Bioacoustic analysis of frog calls from northeast India. *J. Biosci.* **18,** 381–393 (1993). https://doi.org/10.1007/BF02702996

233 http://www.husbandrypunjab.org/pages/rtemp1.htm

Therefore, the Baghjan fire is a death trap within 1 to 1.5 km radius for small animals; and also disrupts the soundscape very badly and thus, hinders the life cycle of the animals who are dependent upon the acoustic signals for performing key life processes such as mating, prey hunting, communication and navigation etc. Further, the fire is also a threat as it changes the perception of night to "day" for many animals, inducing behavioral orientations counter to the natural habit of the animals [*never ending "jet lags"*]. In conclusion, the Baghjan fire is significant in its power to modify the surrounding ecosystem properties of sound, heat and light to such extents that either would the animals die due to thermal stress, or lose their ability to perform key functions (and eventually die) or get totally disoriented. Death and displacement are the two major outcomes of this relationship of the fire with the ecosystems in the surrounding areas. This is leaving aside the oil spill, PAH and many other ills associated with pollution of the air, water and land, as we normally understand, caused the blow out and subsequent explosion and fire.

12.12 Assessment Of Fish Fauna

Fish communities were one of the most heavily impacted fauna by the Baghjan blow out. Fishes started dying almost instantly after the blowout out as the oily liquid reached Maguri Beel and Dibru river. Fishes continued to die due to large quantities of water contamination. However, next big wave came on the 26th June, 2020 when the collected oil spilled to larger areas when the first floods hit the area.

There were three major assessment of fish fauna: by Sharma et al (2020), WII (2020) and Ahmed I (2020). We shall also examine the views of Bania R (2020).

12.12.1 Assessment of Fish Fauna by Sharma et al (2020)

The region is rich in fish resources and diversity. So far 267 fresh water fish species belonging to 114 genera, under 38 families and 10 Orders have been reported by various authors. This community is almost 33.13% of the total Indian fresh water fishes.

12.12.2 Study Area and Methodology

The survey was done in Maguri Beel, Baghjan grasslands adjoining the beel and the Dibru river and other surrounding areas. The survey was started from the 12th June to 3rd July, 2020. 5 line transects were laid in different locations. Each transect covered a distance of 500m. The GPS locations of each transect were recorded. The fish species were identified in the field with the help of field guide and photographs were also taken for later identification and record. pH and water temperature were also recorded.

12.12.3 FINDINGS

During the survey 9 different species of 9 different genera belonging to 6 different families were recorded in the five different transect lines. 1394 dead individuals were recorded along the transects. Freshly killed/ dead fishes were recorded on the 26th and 27th June, 2020. The species *Puntius chola* sufefred the highest hit with a mortality of 569 dead individuals. This was followed by *Xenentodon cancila* with a mortality of 224, followed by *Channa punctata* with 221 individuals dead. The water pH recorded at certain places was dangerously low with values reaching 4.9 and even 4.3. [It has to be noted that earlier a value of 3.6 has already been reported]. The Dissolved Oxygen levels were reported to be very low as well. Other fish species would have already escaped the site or were possibly very hardy and adaptable. The aquatic waters were conspicuously devoid of fish fingerlings (barring a few), tadpoles (none) and aquatic insects (none). Mortality was higher when the pH values at sites ranged from 4.9 to 5.5. Some species were found dead even when the water pH was between 5.7 to 6.4 hinting clearly at low oxygen levels resulting from the oil spills.

The recorded species are *Chanda nama, Channa punctata, Heterropneustes fossillis, Labeo gonius, Leiodon cutcutia, Puntius chola, Puntius sophore, Trichogaster fasciata* & *Xenentodon cancila*.

12.12.4 FINDINGS ON FISH FAUNA BY WII (2020)

According to the authors WII (2020), 229 fish species have been reported to be found in the Brahmaputra river system due to diverse habitats. 104 species of fishes are reported from the Tinsukia Dibrugarh areas. During the survey, the team recorded 25 species of fishes belonging to 9 families. They found that the sites near the Dibru river (sites 1,2,3) were having higher abundance compared to those near the blow out site (sites 4,5,6,7,8). Toxicity levels were found to be high at sites 4-8. It was found that when DO levels were 5 and higher, the fish abundance was more, but it was very poor when DO levels were between 2-4. The authors also found that of the 25 fishes recorded, about 35-80% [in different species] of the specimens showed toxicity and infection. [According to the locals, never was such large quantities of fish fallen infected]. Toxicity was visible on the body of fishes when compared with normal healthy fish of the same species. According to the authors, fishes show visible specific symptoms on the body due to toxicity. The body color would become pale, body scales are lost and bleeding appears from the body, excess amount of mucus is secreted on the body. Due to toxicity, eggs, fingerlings and juveniles die.

Breeding season of fishes is from April to July. The blow out accident happened during the breeding season and thus the toxicity spread by the oil, high temperatures etc. have impacted the population heavily. Oil toxicity impacts the fish eggs, larvae and fingerlings much more, as these are more vulnerable to even shorter exposures to crude oil such as 50 µg/L. The team found 30 carcasses of dead fish nearer the blast site. According to locals, the number was much higher.

12.12.5 IMPACT OF PAH ON FISH

The fish samples collected from the Maguri Beel and Lohit/Dibru rivers were sent for PAH analysis. The reports reveal elevated levels of ΣPAH & ΣCPAH in the range of 104.3 to 7829.6 µg/Kg and 145.1 to 169.3 µg/kg respectively. The highest concentrations were found in samples from Maguri Motapung Beel. ΣPAH concentrations were found highest in *Mystus vittatus* (11467.9 µg/Kg), *Channa orientalis* (11378.1 µg/Kg), *Rasbora daniconus* (10877.7 µg/Kg) and *Puntius sophore* (10721 µg/Kg). As per the authors, these concentrations are 10-100 fold more than any other reports from India and other parts of the world. Therefore, there is no doubt that the PAHs a whole and the oil spill in general have caused multi fold toxicity such as reduced DO, low (acidic) pH, ingestion of crude oil by animals and fishes leading to direct toxicity in the body. In additions, the other two methods described earlier i.e. inhalation and penetration through skins, and the ingestion in the body directly on intake of prey based food and organic matter which is already contaminated.

PAHs have long term impact on the ecosystem. The authors have reported several harmful long term ill effects of the oil spill. Since the blow out happened during breeding season, embryos would get impacted. It leads to cardio-toxicity, leading to loss of circulatory functions leading to reduced circulatory functions or heart failure, or fluid accumulation. Increased toxicity would lead to, among surviving members, susceptibility to predation, parasite infection and zoonotic diseases. This would also lead to genetic deformities and morphological abnormalities.

12.12.6 ASSESSMENT BY AHMED I (2020)

Imtiaz Ahmed from the College of Fisheries, Raha, Nagaon conducted impact of oil spill on fish fauna under over all guidance of Dean College of Fisheries, Dr. K. K. Tamuli and retired Prof. Apurba Chaktaborty.

River Sites: Three sites were chose to be Dibru river and Lohit river. The sampling was carried out on 22nd June, 2020. Water samples were also collected for analysis. Air and water temperatures were recorded at each of the sampling sites. On the date of

sampling, experimental fishing using cast net and gill net was done, and the species caught were preserved with 8% formaldehyde for further laboratory analysis. In the river catch experiment, it was found that the catches were almost nil. After 3-4 hauls, only 2-3 nos of fish were caught. Fishermen earlier (prior to the blow out) could catch 1.5 to 2 kg of fish in 2-3 hauls. The survey shows that the fish population in the river has become sparse.

Maguri Beel Sites: Three sites in Maguri beel were also selected for the experimental fishing using gill net, drag net, scoop net and stationary gears. The fishes caught were fixed in 8% formaldehyde and brought to laboratory for further testing. Air and water temperatures were also recorded at each sampling site. Sampling was done on 24th June, 2020. It was observed that oil was visible at all the three sites. Fish caught, using dragnet, were about 8-10 kg. 20-25 nos of dead fish were also caught along with live fish. 2-3 numbers of fish were seen dead during the sampling time itself. Carcasses of *Punthius spp*,(Puthi), *Heteropneustes fossilis* (Singhi), *Anabas testudineus* (Kawoi), C*hanna spp* (Goroi), *Tetradon spp* (Puffer fish), *Colisa spp* (Gouramis), prawns, snails etc. were seen floating on the surface of water.

Impact of Sound on Fish: Majority of fish can detect sound from below 50 Hz to 500-1500 Hz. A few species can detect sound upto 3000 Hz, and a few others till upto 100 kHz. Scientific experiments using seismic air guns have proved that in response to sound, the fish catches decline. The decline in catch is noticed upto 52%. It is also seen that fishes abandon the area of sound.

12.12.7 IMPACT ASSESSMENT BY BANIA R (2020)

Dr. Ranjita Bania carried out assessment of ichthyofuna post blow out. The finding of the author was that while 87 species of ichthyofuna have been recorded in Maguri beel, the present survey yielded only 22 species. They found individuals belonging to 35 species of fish, dead.

According to the author, 22 species of the 35 found dead belong to the IUCN “Lower Risk Near Threatened” status. She reported heavy decline in fish catch. The breeding cycle has also been impacted as no fish seedling were recorded from the beel. The number of fishes that died was very high, but actual records are not available. Reported mortality was more in shallow waters than in deep waters. She also reported that no local fisherman collected any dead fish. The second round of wave came on the 26th June and lasted till 28th June, 2020 when again a large number of fishes died. The DO level reportedly came down to 2.1. [On the sidelines, an Oil India Ltd employee was

seen collecting the dead fish in a boat in the Maguri beel. Similar incidents have been reported in media and press as well. It possibly could be an attempt to wipe out evidence of large scale mortality or some other reasons best known to OIL authorities]. Prominent fish found dead were *Labeo rohita*, *Catla catla*, *Wallaga attu* etc, which have high commercial value.

Ornamental Fish: Bania R (2020) reported that the Maguri beel is a habitat of a large number of ornamental fish that are rare and not available easily elsewhere. They also fetch high value in the international market. Some of the listed ornamental fish species are: *Botia rostrata, Channa bleheri, Badis badis, Macrognathus pancalus, Badis assamensis, Devario reria, Ailia coila, Chaca chaca*. The exact status of these species could not be found in the aftermath of the blowout.

12.12.8 DISCUSSION

As is clear from these reports on fishes, April-July was the breeding season, and the blow out has completely disrupted the breeding process by killing a large number of fish, poisoning the water so much that no eggs, larvae and fingerlings were observed in any survey. The fish are an important part of food chain for the humans as well as animals. Therefore, the long term impact of the oil spill may not be visible immediately. The expected outcome is death of various species would continue for some more time, and the young may carry genetic defects and morphological deformations or disabilities that would make them worse survivors. The food chain would get impacted in the long run too. The fate of many species is not yet known. The number of deaths must have been very high for which no reliable estimates are available. A number of assessment needs to be carried out in the times to come not only for fish populations in the beels and rivers, but also the populations of other indicator species already discussed in this Chapter.

12.13 Post Script

As already stated in the beginning, this Chapter and the next two Chapters are in continuation, without any repetitive theme, each focusing on a group of faunal communities in a distinct manner. Discussion would continue in Chapter 13 (for Avifauna) and Chapter 14 for Dolphins and other mammals. To discuss the impact of the blowout on humans and livestock, another brief chapter has been added as Chapter 15.



rds at Maguri Beel before the Blowout



Abandoned Nest of a Bird

CHAPTER 13

13 ASSESSMENT OF IMPACT ON AVIFAUNA

13.1 Introduction

This Chapter and Chapter 14 are in continuation of Chapter 12, and hence shall be in a slightly different format than a regular chapters of this Report. This Chapter has dual purpose: firstly it brings Dibru-Saikhowa National Park into focus (and the next Chapter too); and secondly, the Dibru-Saikhowa and the adjoining landscape are known world over for the rich avifauna that inhabit these parts of the planet, and the Chapter is devoted to avifauna diversity assessment of the Dibru-Saikhowa landscape.

The Dibru-Saikhowa National Park together with the adjoining landscape comprising of Maguri Motapung Beels, Dibru river, Lohit river, on the south of the Park, and Poba RF, Kobo Chapori, Amarpur Chapori and the entire riverine tracts from the downstream of Dhola Sadiya bridge on the east to Bogibeel bridge on the west, river Brahmaputra, being the mainstay that takes its full shape and fervour in this landscape before continuing its long journey westward, is a large biodiversity rich tract in the eastern part of Assam. Besides being a National Park, parts of these tracts have been designated as Biosphere Reserve by the Govt. of India, and an Important Bird Area (IBA) by the Bird Life International.

Several studies have been done on the biodiversity of the Park, noted among them being the pioneering works of Anwaruddin Choudhury on birds of Dibru-Saikhowa[234] and important fauna of the Park[235], PhD work of Ranjan Das on the grassland birds and fauna of the Park[236], floral diversity of the Park[237], to add to that, many checklists of birds, herpetofauna, aquafauna, fishes, molluscs, butterflies and moths to mention a few, prepared by leading researchers such as Ranjana Bania, Deborshee Gogoi, Rajib Rudra Tariang and many others. It would not be out of place to mention here once again the rich biodiversity of the Dibru-Saikhow landscape and just to narrate the

234 Choudhury A, 2006, Indian Birds, Vol 2, No. 4, July-August, 2006, p 95-105

235 Choudhury, A. (1998). Mammals, birds and reptiles of Dibru-Saikhowa Sanctuary, Assam, India. *Oryx, 32*(3), 192-200. doi:10.1046/j.1365-3008.1998.d01-36.x

236 Nongmaithem, R. & Lodhi, Mahendra & Samal, Prasanna & Dhyani, P.P. & Sharma, Subrat. (2016). Faunal diversity and threats of the Dibru-Saikhowa Biosphere Reserve: A study from Assam, India, International Journal of Conservation Science, Vol 7, Issue 2, April-June 2016: 523-532.

237 Joshi, Rajendra Kumar. (2020). Tree species diversity and biomass carbon assessment in undisturbed and disturbed tropical forests of Dibru-Saikhowa biosphere reserve in Assam North-East India. Vegetos. 10.1007/s42535-020-00135-4.

bouquet of faunal biodiversity once again:- ***503 species of birds, 37 mammals, 42 reptiles, 17 amphibians, 104 fishes and 105 species of butterflies*** to sum up broadly, as we know that the list is not complete.

So far in Chapter 12, we have already encountered 1 specie of earthworm, 9 species of mollusc, 63 species of butterflies, 148 species of moths, 17 species of odonates, 4 orders of benthos, 15 species of macrophytes, 30 species of phytoplanktons and 53 species of zoo-planktons – either encountered during the assessment post blow out or from a past check list.

In this Chapter, we shall focus on the assessment of avifauna alone. The assessment of avifauna was first initiated by the EC through BNHS, and the Dibru-Saikhowa NP was assigned to them. WII (2020) carried out assessment of bird life around the blow out site within 5 km range, without any specific area. Deborshee Gogoi was assigned the assessment works of birds of Maguri Motapung beel. The team of Narayan Sharma also carried out an assessment of Maguri Motapung beels and Dibru-Saikhowa NP.

We shall be discussing all the 4 assessments, in the paragraphs to follow. Comments of the OMEC shall be summed in the "Discussion" sub sections, as already done in the previous Chapter, we shall briefly take a look once again at the critical importance of the landscape before we go to individual assessments.

13.2 Criticality Of The Dibru-Saikhowa Landscape

The Dibru-Saikhowa landscape has significant populations of endangered White Winged (Wood) Duck (*Asarcornis scutulata*), the Bengal Florican (*Houbarapsis bengalensis*). And the Western Hoolock Gibbon (*Hoolock hoolock*) However, the current populations are doubtful. The Park is home to 25 threatened, 15 near threatened and two restricted range bird species. It is home to 6 critically endangered, 6 endangered, 12 vulnerable species. There are 218 resident and 173 migrant bird species. The adjoining Maguri Motapung beel has recorded presence of 295 species of bird species that include 4 critically endangered, 2 endangered, 8 vulnerable and 10 near threatened species. The beel has given two new additions to the Indian subcontinent namely Baikal Bush Warbler and White-browed Crake.

13.3 Assessment By BNHS (2020)

BNHS team responded very quickly and took the challenge of the survey despite very hostile conditions and many inconveniences. The team assembled quickly and started the work from the 14th June, 2020.

13.3.1 Methodology and Approach

The survey started from the 14th June and concluded on the 23rd June, 2020. The survey spread over accessible areas of Dibru-Saikhowa and later extended to the Maguri beel. Point sampling was deployed for the rapid assessment. A total of 29 grids were designed, and at each grid point, kept at 300 m distance apart, 10 minutes were spent for observation of birds within a radius of 25 m. Birds outside the fixed circle were also recorded for checklist purposes. Birds in flight were also not included in the count, but were added to the checklist. Point counts were carried out in the morning at 0500 to 1000 hours and in the afternoon 1400 to 1700 hours. The points were well distributed in major habitats namely grasslands, woodlands, wetlands, open areas etc. Two zones were considered. Zone A was within 5 km radius of the blow out dominated by noise of the flame, heat (tremors and high light intensity at night). The Zone B was outside the 5 km zone.

A total of 70 point counts were carried out, 23 in Zone A and 47 in Zone B. The team also visited the ground zero site and surrounding areas to assess the impacts on fauna. For assessment of food availability, the entomofauna (insects) comprising of Butterflies and odonates were also counted at each point. To compare, eBird 2020 data was also used. Historic data from 2015-2019 was pooled for a baseline, mostly for resident birds.

13.3.2 Assessment and Outcome of BNHS Survey

Data from eBird suggested presence of 106 bird species against 47 species recorded within 5 km of the blast site. This indicates significant difference between the species richness before and after the blowout incident.

In total in the 70 counts spread over the study area, as described in the previous paragraph, a total of 123 species were encountered. This included 7 globally threatened and 3 near threatened birds. Of the total species encountered, 87 were only recorded in the point counts, and the rest were opportunistic encounters. The Species Accumulation Curve, as per BNHS (2020), could not get saturated or did not reach asymptote even after 70 point counts. [*However, it took about 28 points to reach species level of 70, whereas it took effort of additional 42 points to reach just another 13 species.*]

While Zone A recorded 47 species with 244 individuals, the Zone B showed up 77 species with 576 individuals. Within 5 km, Zone A, Cattle Egret and Common Mynah were the most abundant birds. Beyond 5 km radius, it was seen that Red-vented Bulbul, Cattle Egret and Straited Babbler were common.

13.3.3 Impact of Oil Spill on Avifauna

The BNHS team reported observations concerning the impact of oil spill and fire on the avifauna. They report that bird watchers observed several birds such as Cattle Egrets, Indian Pond Heron and Indian Spot-billed Ducks fully soaked in oil and unable to fly during the blowout period. A Blue-breated Quail was found fully soaked in oil, and it was rescued and later released after treatment. An oil soaked King Quail was also rescued. Both rescues were reported by Rafikul Islam.

13.3.4 Impact of Fire on Avifauna (<1 Km Radius)

It has to be noted that the period from June to September is typically the breeding time for most of the resident birds. It is during the breeding season that the explosion and fire took place at Baghjan, which is situated at the heart of an Important Bird Area and surrounded by a National Park which is also a paradise for birds. The fire engulfed many birds, their nests and eggs, and their young ones, and animals which we shall never know of, but only the future surveys will predict whether the vacuum left by them would get filled up or not.

The BNHS team found several burnt egg shells, charred bones and burnt nests. But we do not have technology to determine what species these individuals belonged to. Couple of nests were found half burnt. It is noteworthy that the area around the blast was home to many globally threatened grassland birds namely Black-breasted Parrotbill, Marsh Babbler, Jerdon's Babbler and Swamp Francolin. None of these birds were seen in the 5 km radius of the blow out site. One Jerdon's Babler was seen opposite the fire across the Dibru river in Dibru-Saikhowa National Park.

13.3.5 Impact of Flame Noise, Tremors, Light and Heat

The birds are vocal and communicate with each other for mating, distress calls, feeding and many other social and alarm calls. The sound from the flame, as already stated in the previous Chapter, disrupted the soundscape of the ecosystem around and disrupted badly the communication system of the animals [*Do we have a Wildlife TRAI?, and do we have a Universal Service Obligation towards the wildlife?*]. The BNHS team has put a photograph of a juvenile Plain Prinia calling incessantly and trying to communicate with its parents without any success. Its frail voice might have drowned in the raucous of the flame. Several birds such as Red-vented Bulbul, Ashy Pirinia, Plain Pirinia, Striated Babbler were heard calling at high pitch as their normal communication was drowned by the 160 dB monster accidentally created by OIL in their tranquil environs [*converting the entire ecosystem into a war time aerodrome from where turbo jet planes take off*

continuously without ever stopping]. Tremors were felt also by the survey team within 5 km radius. Their estimate is that, given the sound levels and tremors, most of the birds and animals must have fled. Birds with acute hearing capability such as Night Jars and Owls were neither heard or seen in the area. As per eBird data owls were spotted as late as 15th March from the blast area. The team also spotted a Bengal Florican flying to opposite direction of the fire, probably in an attempt to run to safety.



Fig. No. 13.1: Juvenile Plain Pirinia in Distress

13.3.6 Other Observations by BNHS (2020)

There are several other observations from the BNHS team concerning entomofauna such as butterflies, odonates, beetles, herpetofauna, mammals etc. These remarks have been placed in corresponding sections in Chapter 12 and 14 in appropriate sections as special observations by BNHS (2020).

13.3.7 Discussion

The overall Report of BNHS is very touching, as they were one of the very early survey teams to get to work after the explosion. The question remains as to what value do we have for the birds and animals that died, got burnt, their young ones, eggs and nests destroyed, their communication disrupted, their food and prey stood polluted? How do we weigh in the balance of the Oil and Petroleum giants and the proponents of

"modern economic development" that simply got tossed in thin air by a single virus called COVID19? It only shows that our economic foundations are not only weak but built with wrong bricks where nature has no place by design.

In short, giving a snapshot of the most extensive rapid bird assessment by BNHS is here Chart that displays all the 87 species counted in the survey. The mean (μ) and variance (σ) are also given (However, as there were no repeats, therefore, mean stands for actual count and variance is 0). Each color unit represents one species uniquely and means one unit vertically, and 5 units horizontally. This a cumulative frequency cum histogram mixed.



Fig. No. 13.2: Frequency Distribution of the BNHS Bird Survey

The top three birds (most sighted) are Common Egret (72), Striated Babbler (60) and Red-vented Bulbul (50) which can be seen from extreme right of the figure as three singleton bars. It is not difficult to count and find out that 46 species showed up as singleton (52.87%).

13.4 Assessment By WII (2020)

The WII segregated the habitat into grassland and wetland and carried out transects on foot and boat from 0900 to 1400 hours. A cumulative effort of 3.48 km was put in for the bird survey in the grasslands. Transects were so laid that they fell at distances 1, 2, 4 and 5 km from the blow out site. A total of 11 km on boat was surveyed. Data from eBird was also downloaded from 2010-2020 in order to provide a baseline at each of the transects. Incidental sightings were also recorded.

13.4.1 Findings of WII (2020)

The team of WII recorded a total of 447 individuals belonging to 45 species both in grassland and wetland. Of these 213 individuals belonging to 28 species were recorded in grasslands and 213 individuals belonging to 28 species in beel areas. The team also recorded Chestnut-capped Babbler, Grey-throated Martin, Cinnamon Bittern and Asian Palm Swift which were seen incidentally.

[*8 new species not spotted in the point survey of BNHS team were spotted in the WII (2020) survey: These are;- Asian Palm Swift (G+W), Black-winged Kite*[238] *(G+W), Fulvus Whistling Duck (G), Indochinese Roller*[239] *(G), Lesser Adjutant (W), Grey-headed Swamphen (W), and Shikra (W). However, of these, the Asian Palm Swift, Lesser Adjutant & Shikra were part of the opportunistic sightings*]

According to WII (2020), the sampling efforts saturated in 70 min effort. Sites near the blow out saturated faster than those away from it.

13.4.2 Comparison with eBird Baselines

As per the eBird data, a total of 335 species were recorded between 2010-2020. Historically in the grasslands surveyed, 94 species have been sighted in the past, of which 3 not found, 1 summer migrant (Indian Cuckoo), 21 winter migrants and 69 are resident birds. On the other hand, in Maguri Motapung beel, historically all the 335 species spotted, of which 190 are resident, 7 are summer migrants, 125 are winter migrants, 1 autumn/spring (Black Redstart). There was no data from May to July and September. The team reported that some of the threatened resident species namely: Marsh Babbler, Jerdon's Babbler, Swamp Grass Babbler and Black-breasted Parrotbill were not seen. [*The BNHS recorded Marsh Babbler and Jerdon's Babbler in the opportunistic sightings checklist.*]

WII (2020) reported decline in the richness of grasslands to 59% and wetlands to 85% due to the blow out incident, as is evident from the data. The team recorded a few abandoned nests.

13.4.3 WII (2020) on The Blow Out Impact on Avifauna

WII (2020) studied published literature and other research works to assess possible impacts of the blow out and oil spill on the bird species in the surrounding areas. There are two points to be considered: firstly direct disastrous impact and secondly indirect

238 Also considered same as Black-shouldered Kite (Elanus caeruleus)
239 Earlier considered as sub species of Indian Roller (Coracias benghalensis)

effects of chronic exposure to low levels of hydrocarbons in the environment. Most birds survive such disasters by escaping. Several birds get killed too. However, in long term, certain populations may not recover, and many others may not return again, or may take years to return. The population may not recover even in 10 years. Further low doses such as 21.20 to 461.08 ng/g of hydrocarbons were found to be very harmful to embryos and poisoning of even adult birds. These concentrations enter the eggs and cause death.

As regards Maguri Beel, the Baghjan blowout may be its death knell, as there are so many rare and endangered species that either might have got wiped out in the accident or escaped. In either case, chances of return are very thin, if one has to go by the published literature as quoted by WII (2020). [*There are several bird species that have been sighted either for the first time in the Indian subcontinent or second sighting after many years. Noted among them are the Baikal Bush Wabbler (reported by R.K. Das, 2013) for the first time in the Indian subcontinent, White-browed Crake (reported by Dr. D Gogoi, 2016) for the first time in south east Asia, White-bellied Heron (sighted by a tourist in 2015)- very rare and critically endangered tall bird with only 6 sighting records anywhere & on way to extinction, Baer's Pochard (Aythya baeri), an extremely rare and critically endangered duck with a sighting record in Maguri Beel in 2016, and the Indian resident Swamp Prinia (Prinia cinerascens)*[240]*, another extremely rare grassland bird. The list is little longer than presented here. However, the question remains that Maguri Motapung Beel has earned its name world wide for sightings of rare and endangered birds, but can we get the beel back in another 10 years in its prime health? This is the biggest question. Most of all, will OIL and MoPNG see even a barrel of oil's worth in this loss?*][241]

13.5 Assessment Of Avifauna By Sharma Et Al (2020)

The objective of Sharma et al (2020) was to assess the bird population and analyze the impact of fire on the avifauna population. They undertook measurement of water temperature and measured intensity of noise around the blast site within a radius of 5 km.

13.5.1 Assessment Methodology

The assessment methodology was five pronged. (a) Measurement of temperature, (b) Measurement of Noise, (c) Avian diversity, (d) Calculation of land surface temperature &

240 Also called Swamp Grass-babbler (*Laticillia cinerscens*)

241 One need not be misled by the recent sighting of the rare Mandarn Duck (*Aix galericulata*) in the Maguri beel.

(e) Study of vegetation damage. All the assessments were carried out within 5 km radius of the blow out, and in seven directions namely North, North East, East, South, South East and South West. Bird calls were also recorded to identify birds.

The land surface temperature was calculated using Landsat 8 satellite imageries using Band 4 (Red), Band 5 (NIR), Band 10 & Band 11 (Thermal bands). Raster analysis of ArcMap 10.6 was used by the authors. They first calculated Top of Atmospheric (TOA) spectral radiance using the thermal bands, and it was, then, converted to Brightness Temperature (BT). Further, NDVI was calculated and from there proportion of vegetation (P_v) was calculated. From P_v, emissivity was calculated; and thereafter, the Land Surface Temperature (LST). Part of the formula are provided in the Chapter 11. However, reader may refer to the original work for a full study of the subject.

13.5.2 Assessment Outcome

The authors encountered a total of 610 individuals belonging to 56 species of birds. The story appears to be almost similar to the BNHS survey. The most abundant bird was once again Cattle Egret (90), followed by Common Mynah (81), followed by Asian Pied Starling (72), followed by Red-vented Bulbul (64).

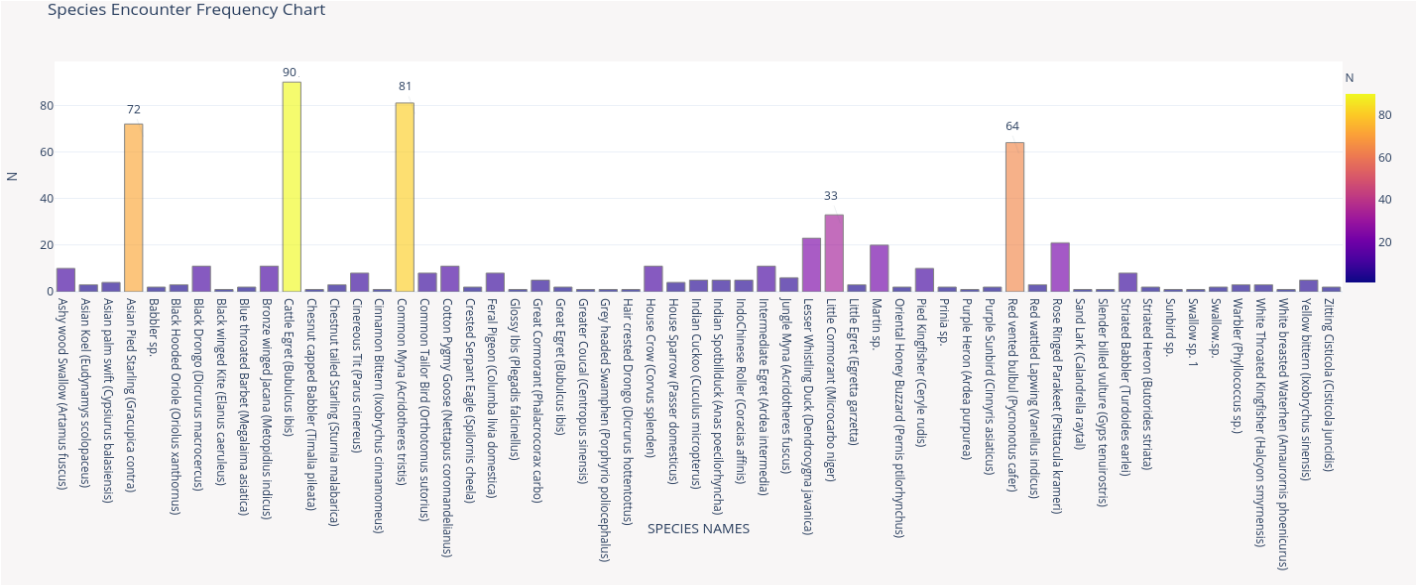


Fig. No. 13.3: Frequency Distribution of Sharma et al (2020) Bird Survey

There is drastic fall in numbers thereafter. The Little Cormorant leads the count with with 33 sightings. The number of singleton species is found to be 13, which is much lower than that found in BNHS survey. The chart above by the [Author] depicts species wise the frequencies of sightings. The survey team reports that a Slender-billed Vulture was encountered near the blast site indicating presence of carcasses around the blast site. The Lesser Whistling Duck (23), which was next to the Little Cormorant (33) in

frequency of sighting, was a cause of worry, as their numbers according to the team were very low. [*If one compares with BNHS survey, the Lesser Whistling Duck sightings reported was 19, and that for the Little Cormorant was 9. While the LWD has gone up marginally by a figure of 4, the LC has gone up substantially up by 24. The fear of the authors may be genuine.*] The authors also note absence of the Asian Openbill (*Anastomus oscitans*) altogether from the Maguri Motapung Beel. As the Openbill feeds on molluscs heavily, and as these have been impacted badly in the blow out, this could indicate to a direct linkage of the bird with its primary food preferences. Mass mortality of fish also could have bearing on the bird population. Furthermore, the breeding season of the birds cannot be ignored, as the timing of the blow out was disastrous for the birds, fishes and other animals that breed during the rainy season.

13.5.3 Other Findings

As regards temperature, the team reported that the temperatures were high near the blow out site. The general observation worth quoting here is that wherever the team found oil spill, the temperature was generally found 4-5 degrees higher than the areas without oil spill. [*Though literature is scarce, it can be proved that water containing oil spill does heat up more than water not containing oil spill*[242].] The authors mention that sound travels more than 4 times faster in water than in air. [*Speed of sound in water could be about 1450 m/s, This is Mach Number 4+; and one can understand the impact of sound in water when the fire at blow out site is radiating at 160W of sound power. No measurements of sound was done under water, except by WII for Dolphins, which has been briefly discussed in Para No. 14.5.2 of the next Chapter.*] The noise could have severe impact on the fish fauna and waterfowls. The team members observed that within 5 km radius wherever water body was examined, it was contaminated with oil spill. The authors calculated damage due to the blow out and fire based on a grid over 10 km range with survey of 86 ground GPS points within 5 km. Visual damages were classified into five classes: 0%, 25%, 50%, 75% & 100%. The damage Table and and the classified image of damages in a radius of 10 km is presented in the table below:-

Table No.13.1: Assessment of Extent of Damages by Sharma et al (2020)

Area/ Zone	Total Area (sq. km)	Area under visible damage (in sq. km)				
		0%	25%	50%	75%	100%
Dibru-Saikhowa NP	341.77	338.91	1.543725	0.628425	0.4383	0.2457
Maguri Beel	16.71	6.866	3.2706	2.10375	1.464525	0.02745

242 https://www.engineering.com/Blogs/tabid/3207/ArticleID/715/Gulf-Oil-Spill-Ocean-Temperatures.aspx

13.5.4 Discussion

From the scattergram of the distance from the fire and sightings (N) and species(S) data, a goodness fit was carried out and correlation equations were worked out. The two figures are presented below:

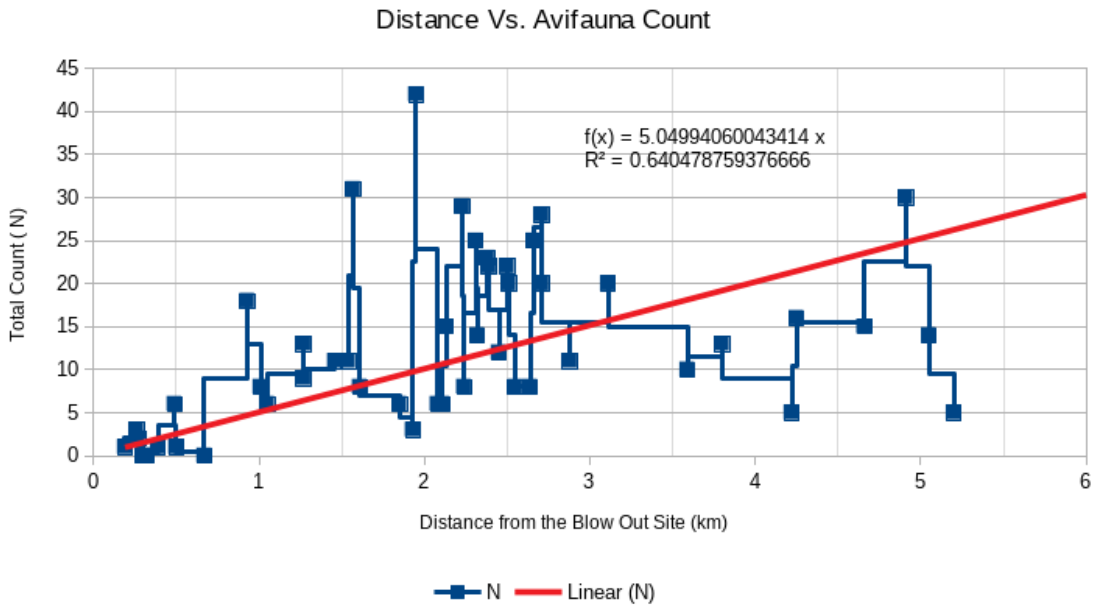


Fig. No. 13.4: Distance vs Avifauna Count

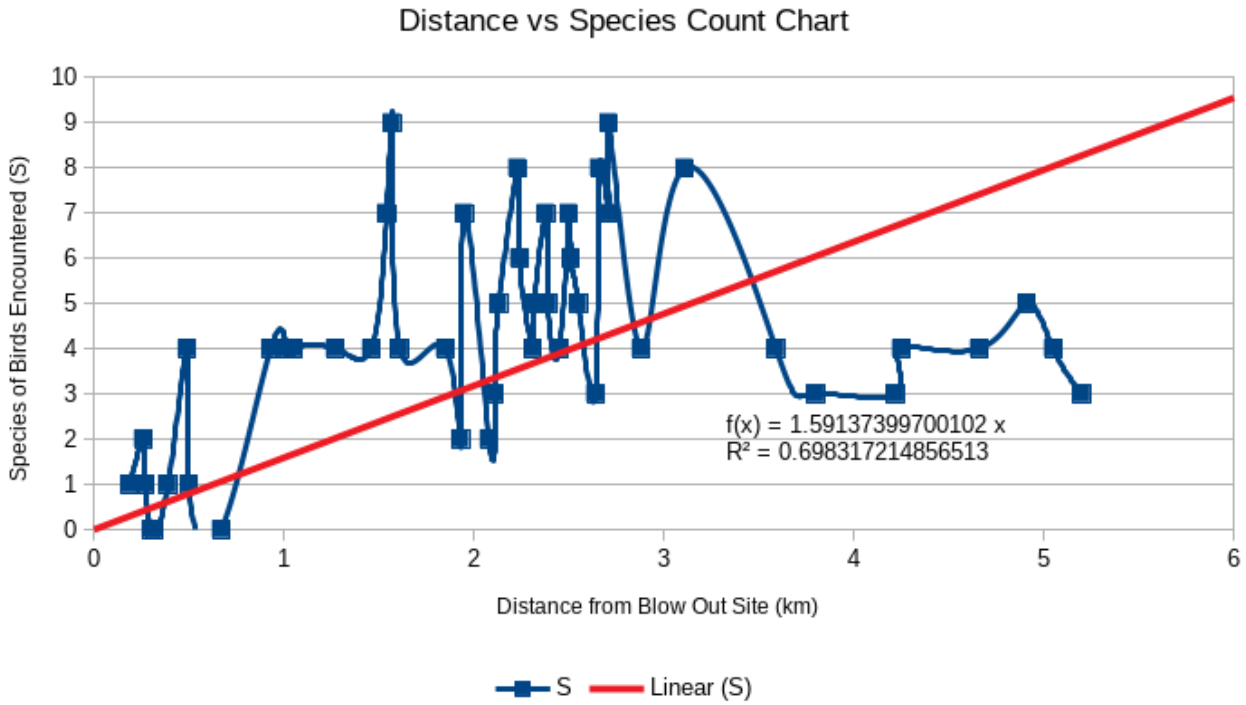


Fig. 13.5: Distance vs Species Count

The goodness fits are best when the line passes through the origin. By thumb rule, we can say that by moving away from the fire, every kilometer we add, as of now, we can add 1.5 nos. of species and 5 no of individuals to the count. At 4 km away from the fire, for example, we can expect sighting of 6 species of birds and 20 individuals. Repeated data needs to be collected at fixed intervals of time in all seasons to build a prediction model, as to how long it will take for the Maguri Beel and the grasslands to reach its original level. Now that the flame has been extinguished, and the sound and tremor have disappeared, we can expect birds to actually start coming back slowly. New arrivals such as the Mandarin Duck may be expected in course of time. Of course, this would not happen fully unless the ecosystem is restored to its near original levels.

13.6 Assessment Of Avifauna By Gogoi D (2020)

Dr. Deborshee Gogoi was entrusted to assess the avifauna in Maguri Motapung beel area. He has worked extensively in the area and is very familiar with its geography. He is credited with sighting of the sighting of the White-browed Crake, which gave a new bird to the whole of South Asia in 2016. He and his other colleagues, especially Dr. Ranjan Kr Das (who is also credited with sighting of Baikal Bush Warbler in 2013 at Maguri) and other colleagues[243] were actively involved in rescuing as many birds and other animals they could do. The rescue of the rarely sighted King Quail (*Excalfactoria chinensis*) fully drenched in oil has been much talked. The photograph of the rescued King Quail is presented below:-



Fig. No. 13.6: The Rescued King Quail

243 Gogoi Deborshee, Islam Rofeequl, Kolong Bitupan, Das Ranjan Kr, Hatibaruah Binanda, Gogoi Gunjan, 2020, Rescue of King Quail from Maguri beel during the Baghjan Oil Spill in May, 2020

13.6.1 Assessment Methodology and Approach

Gogoi D (2020) used sample plot based assessment in the affected areas to identify the bird species present. The team divided the area into three categories:Wetland, Grassland (burnt) and Grassland (intact). The survey was based on observations twice daily morning and evening and calls of birds. The wetland area covered was 3.96 sq km and it was covered by boat. The grassland burnt area was sq km; and the grassland intact area was 13.6 sq km in which survey was carried out.

13.6.2 Findings

The survey in the wetland and grasslands brought sightings of 425 birds belonging to distinct 55 species. In the wetland, a total of 146 individuals covering 35 species were found. In the burnt grassland areas, only 13 individuals belonging to 6 species were sighted. In the intact grasslands, 266 individuals belonging to 49 species were identified.

Other observations included in the wetlands: Oil spills were visible near the blow out site in the water bodies; and the sound from the flame was very loud and disturbing. In the burnt grasslands, oil spill was observed in the water bodies. Bird activities were found to be very low. In the intact grasslands: the team observed a number of nesting sites of Asian Pied Sterling and Black Drongo with chicks. This is a very healthy sign. Oil spillage was found in a few patches of the water bodies. However, sound pollution was very much there.

13.7 Post Post Script

We, hereafter, continue our journey of biodiversity assessment to another important species segment i.e. the Gangetic River Dolphins and other mammals in the next Chapter.



A Dolphin at Dibru [Source: Internet]



Hoolock Gibbons of Barekuri

CHAPTER – 14

14 IMPACT ASSESSMENT OF GANGETIC DOLPHINS & OTHER MAMMALS

14.1 Introduction

The Dibru-Saikhowa National Park and the adjoining landscape are habitat for recorded 37 no. of mammals including the Asian Elephant (*Elephas maximus*), Tiger (*Panthera tigris*), Leopard (*Panthera pardus*), Wild Water Buffalo (*Bubalus arnee*), Sloth Bear (*Melursus ursinus*), Slow Loris (*Nycticebus bengalensis*), Northern Pig Tailed Macaque (*Macaca leonina*), Rhesus Macaque (*Macaca mulatta*), Assamese Macaque (*Macaca assamensis*), Capped Langur (*Trachypithecus pileatus*), Western Hoolock Gibbon (*Hoolock hoolock*), Barking Deer (*Muntiacus muntjak*), Hog Deer (*Axis porcinus*), Wild Boar (*Sus scrofa*), Flying Squirrel (*Petaurista* spp.), Gangetic River Dolphin (*Plantanista gangetica*).

This Chapter focuses on the assessment of Gangetic Dolphins using C-Pods and hydrophones, the matter of the lone Dolphin death in the Baghjan blow out, the status of other mammals in the aftermath of the blow out, and also brings the focus on one of the Hoolock Gibbon troops at Barekuri during the blow out as the last assessment. The Chapter ends with a broad summary and conclusions summing up the three Chapters from 12 to 14, and enlists the various Scheduled species falling under the Wildlife (Protection) Act, 1972, that were found dead during the blowout.

14.2 About The Gangetic River Dolphin

The *Platanista gangetica* is South Asian River Dolphin listed as “Endangered” in the IUCN Red List of Threatened Species; and is found in the waters of river Indus (Pakistan), Ganges and Brahmaputra (India), Meghna and Karnaphuli (Bangladesh) and Karnali (Nepal). Two sub species are recognized 1. the Gangetic River Dolphin (*P. gangetica gangetica*) and 2. the Indus River Dolphin (*P. gangetica minor*). The animals have extremely poor eyesight and rely mainly on echolocation to navigate and locate prey. The Gangetic River Dolphin has been declared as the National Aquatic Animal of India, and the State Aquatic Animal of Assam. Their populations are estimated to be 2500-3000 as a whole, and about 900 in Assam[244].

244 https://indianexpress.com/article/explained/explained-why-india-needs-a-project-dolphin-6167304/

14.2.1 The First Major Gangetic Dolphin Survey in Assam

Most of the matter here is borrowed from Wakid A & Braulick G (2009)[245] Report on the Gangetic dolphin and the pioneering work done during 2009. Incidentally, this Report was generated at the time when M/S OIL was prospecting by way of seismic exploration for crude oil and natural gas in the Brahmaputra bed. Survey was conducted all along the Brahmaputra river covering 1044 km from Arunanchal Pradesh border in the east to Bangladesh border in the west. The whole area was divided into seven sectors. The Sector I of the survey covered Assam-Arunachal Pradesh border to Balijan. It is in this stretch that the Dibru-Saikhowa landscape falls. Together with visual count, attempt was taken for acoustic survey. However, as the Gangetic Dolphins make high frequency sound, the attempt did not succeed.

The survey was a learning point for the Gangetic Dolphin behaviour in the local waters. Some of the observations about Dolphins picked up during this survey shall be described briefly for a better understanding of the behaviour of the animal.

14.2.2 About Behaviour And Habits of the Gangetic River Dolphin

The 2009 survey team observed that the activity pattern of the dolphins could be classified as follows:

(a) Foraging: Dolphins were seen chasing fish, making circles, fish leaping out of the water, and even dolphins with fish in their mouths.

(b) Travelling: directional and persistent movement at speed.

(c) Resting: very slow movements

(d) Foraging-travelling: foraging in a directional movement

The researchers observed the various timings of animal surfacing above the water and their findings are very relevant in the present context. They made altogether 27 hrs of observations on dolphin behaviour during which 828 dives were recorded. An average 107.3 (SD ± 46.8) seconds time under water and 1.26 (SD ± 0.23) seconds above water were recorded. Altogether 81.9% active surfacing and 18.1% calm surfacings were recorded. Exposure of blowhole, rostrum & dorsal fin accounted for 44.2% of all surfacings, showing blowhole and rostrum by 38.4% of individuals and exposure of only the blowhole accounted for 17.4% of surfacings. Leaping clear of the water was recorded only for 0.3% of all surfacings.

245 Wakid A & Braulik G, 2009, Protection of Endangered Gangetic River Dolphin in Brahmaputra river, Assam, India, Final Technical Report to Sir peter Scott Fund, IUCN, Aranyak,2009

14.2.3 Activity Budgeting and Acoustic Studies

The activity budgeting of the animal showed that it foraged almost 50% of the time, forage and traveling 10%, resting 10% and traveling 30%. These budgeting values are approximate and not taken here exactly as reported. The diving time was found to be varying from 94.3 to 310.8 s, with a mean of 133.5 s. Thus, the animals can stay under water well about 150 s. A generic Internet search shows that animals are reported to be capable of being underwater from 5 to 15 min. Further, according to Wakid A, the boat speeds are maintained at about 8-10 km/hr speed to avoid double count. However, in absence of any telemetric studies, it is not possible to ascertain this parameter as to the average time the animal stays in the water without showing up itself. One major study by Sugimatsu H et al (2009)[246] was carried out using multiple acoustic arrays in collaboration with University of Tokyo in 2009 for studying migration behaviour from Karnavas to Narora. Such studies with more advanced equipment need to be undertaken for studying the behaviour of the Gangetic Dolhins in this part of the world.

What is most remarkable research as of now is the attempt to identify individuals successfully based on calls (called clicks) of the Dolphins and study the population pattern such as, based on the pioneering work by Longden E.G et al (2020)[247]. Unless, we push our research to such levels, we shall remain in dark as to what is happening to these rare and endangered species in our ecosystems, and how they are coping with shocks and stresses induced by us in our march to “development”.

14.3 Impact Study On Gangetic Dolphins By WII (2020b)

The WII (2020) team had produced a special Report, and we shall call it WII (2020b), entitled “Impact of oil well blowout at Baghjan oil field on Ganges River Dolphin and their habitat” at the request of the OMEC. This report is presented here in the paragraphs to follow. The salient points observed by the team of experts and associated data have been put forward in the next few paragraphs to highlight the plight of the Gangetic River Dolphins in the Dibru-Saikhowa landscape post blowout at Baghjan.

246 SugimatsuHarumi, Kojima Junichi, Ura Tamaki, Bahl Rajendar, Behera Sandeep, Sagar Vivek Sheel, Khan Bushra, 2009, Underwater behavioral study of the Ganges river dolphins based on the first long-term real-time monitoring using the integrated observation system with multiple acoustic arrays, OCEANS 2009, 26th -29th Oct, 2009, Biloxi, MS, USA, **DOI:** 10.23919/OCEANS.2009.5422429

247 Longden Emma G, Elwen Simon H, McGovern Barry, James Bridget S, Embling Clare B, Gridley Tess, 2020, Mark–recapture of individually distinctive calls—a case study with signature whistles of bottlenose dolphins (*Tursiops truncatus*), *Journal of Mammalogy*, gyaa081, https://doi.org/10.1093/jmammal/gyaa081

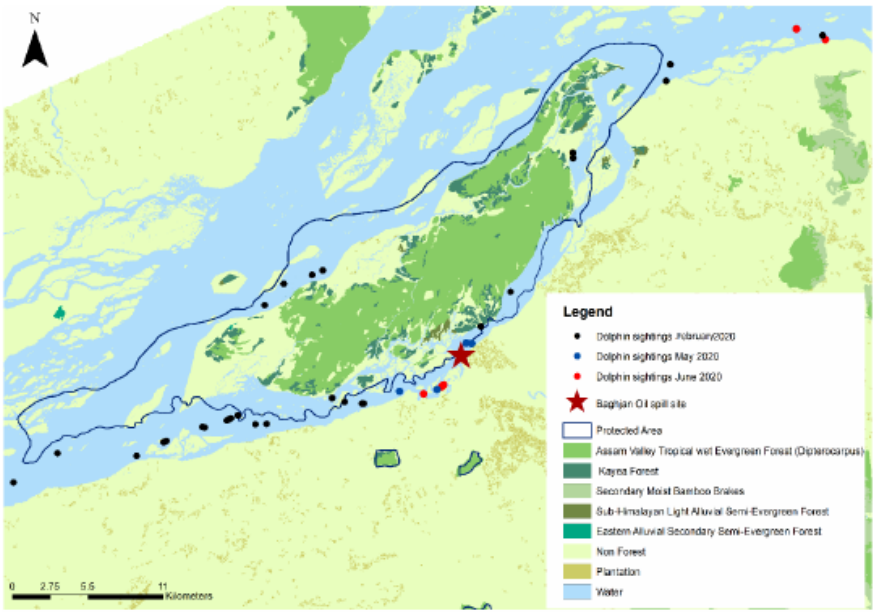
14.3.1 Approach and Methodology

The assessment survey was conducted by the team of WII between 17-18th June, 2020 at Guijan Ghat and then from 23-24th June, 2020 at the confluence point of Dibru river with Lohit river. A total of 54.15 hours of acoustic data was recorded and analysed. On the 6th July, 2020 a C-POD was deployed at Maguri Motapung Beel for 7.15 hours. In addition to these surveys, a complete assessment of the Sector I i.e. from Dhola Sadiya Bridge to Balijan, where Siang river meets Lohit river and becomes the Brahmaputra river towards the west of Dibru-Saikhowa NP, was carried out in the month of June, 2020. A short survey was carried out in May, 2020 after the Oil spill, but before the explosion covering 32 km stretch of the river system. Prior to this, as a part of the normal monitoring, Dolphin survey was done in February, 2020. Therefore, a set of three datasets is available for comparison. In addition to this, hydrophones (not C-POD[248]) were deployed.

[*Encounter rate is a parameter used often to estimate population of dolphins. If no. of encounters by two observers is p and s in a stretch of k km of river, then, the encounter rate per km can be said to be* $E_r = \frac{p+s}{2\times k}$ *. The population (P) in any stretch L km is then P=L.E$_r$.*]

14.3.2 Post Blowout Status of Gangetic River Dolphins

As reported by WII (2020b), and shown in the map below taken from the Report, the team had made in all 28 observations of the dolphins, and it came down to 5 in May, 2020 after the blow out and in June it stood at just 3 sighting.



248 C-POD technology is on phase out and being replaced by F-POD. For more details: https://www.chelonia.co.uk/

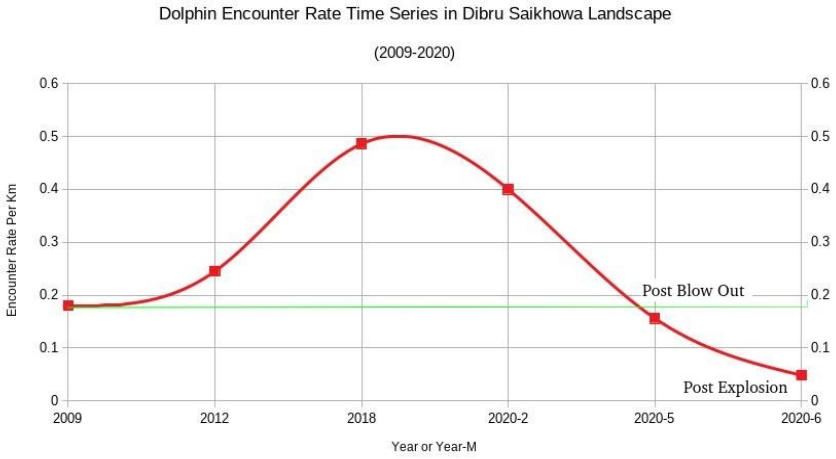
Fig. No. 14.1: Map of Sightings of Gangetic Dolphins in Lohit & Dibru Rivers

The Map above [by WII (2020b)] depicts the locations of the sightings of dolphins around the Dibru-Saikhowa NP. [Therefore, the sighting frequency has got reduced 9 times]. In a 20 km stretch up and downstream of the Baghjan blow out site, the encounter rate per km was ~0.4, and it got reduced to 0.15 in May, 2020 after the blow out. In June, 2020 for a stretch of 62 km, the encounter rate was 0.0484. [*Therefore, it can be said that there scarcely any population in a stretch of 20 km in June, 2020. This is seconded by virtually nil observations of dolphins in the Lohit river*]. The $\hat{N}$ Chapman estimator[249], as per WII (2020b), population of the Dolphins at various times is given below:

Table No. 14.1: Dolphin Encounter Rate Time Series

Sl. No.	Sites of Survey & Month / Year	Length (Km)	$\hat{N}$ Population	Encounter Rate[250] (per Km)
1.	Sector I, 2009[251]	136	25[252]	0.176
2.	Lohit River, Feb, 2012	94	23	0.245
3.	Lohit River, Feb, 2018	70	34	0.486
4.	Lohit River, Feb, 2020	70	28	0.4
5.	Lohit River, May, 2020	32	5	0.156
6.	Lohit River, June, 2020	62	3	0.0484

The above table has been illustrated through a Chart placed below:-



249 $\hat{N}=\left[\frac{(n_p+1)\times(n_s+1)}{n_{ps}+1}\right]-1$ where np is primary observer count, ns, secondary observer count, nps is common count, and $\hat{N}$ is the population estimate.

250 Other than the Sl No. 1, rest worked out from E_r=P/L, where P= $\hat{N}$

251 See Footnote Reference 245

252 Estimated by P=L.E_r [*May differ from WII (2020b) slightly. Under reconciliation*]

Fig. No. 14.2: Depiction of Dipping Encounter Rate of Dolphins post Blowout

It is clearly demonstrated that post blow out the encounter rate had fallen below 2009 level, but after the explosion, the encounter rate has touched an all time low. Species recovery in the ecosystems needs to be monitored rigorously. [*The Chart and the Table above are compiled by the Author based on WII (2020b) Report*].

14.4 Passive Acoustic Monitoring Of Gangetic Dolphins (Diel)

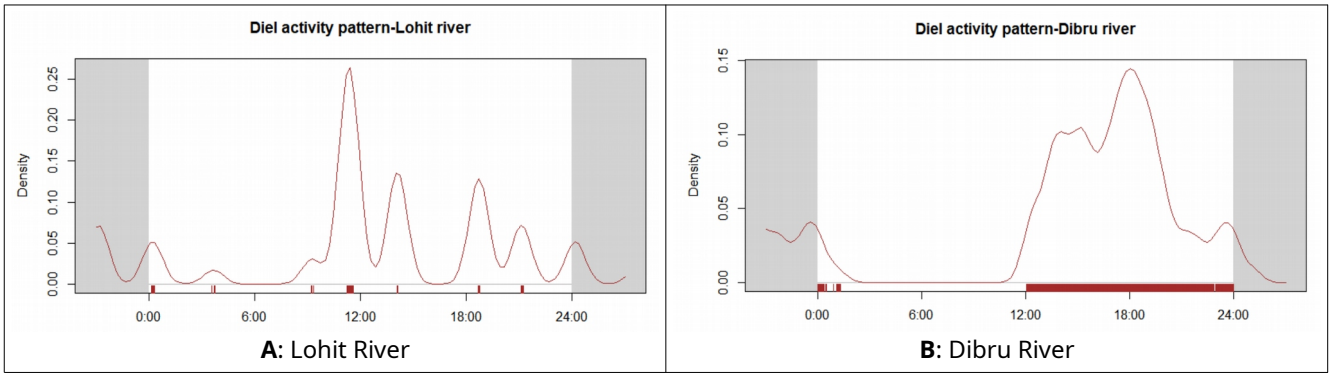
This section is more about throwing some light on behavioral pattern of the Gangetic River Dolphins. Diel monitoring is useful to assess the activity level and its nature. Typically, in terms of diel behaviour, animals are classified in four categories: Diurnal (active during day), Nocturnal (active during night), Crepuscular [active at twilight time, both morning (Matutinal – active only at dawn) or evening (Vespertine- active only at dusk)] and Cathemeral (no particular time of activity and rest, all depends upon situation, or different individuals can be active at different times).

14.4.1 Approach and Methodology

Dolphin calls are high pitch high frequency sound, often termed as clicks. WII (2020b) used C-POD (a hydrophone based equipment fully submersible in water, and especially designed to detect presence and activity of toothed cetaceans by the detection of trains of echo-location clicks that they make), which is proprietary technology, with software having KERNO Classifier which is currently the most advanced train detection and classification algorithm that can be used to detect and identify clicks from the cetaceans. The automated classifier segregates all acoustic recordings into “narrow band High Frequency” sound, ‘Other cetacean (including river dolphins), ‘Sonar’ and ‘Unclassified’. The clicks are also classified as ‘High’, ‘Moderate’ and ‘Low’ or ‘Doubtful’. To eliminate false positives, the settings are kept at ‘High’ or ‘Moderate’ for the click trains of river dolphins. The CPODs were moored in 30-50% of the water column to avoid surface noise. The CPODs were deployed at Dibru river, Lohit river and Maguri Motapung Beel. The results are discussed below.

14.4.2 Outcome of Acoustic Monitoring

Clicks are converted to clicks per minute, and this helps in monitoring the activity pattern. The two charts developed by WII (2020b) for the diel pattern of dolphins in Dibru river and Lohit river are reproduced below.



A: Lohit River **B**: Dibru River

Fig. No. 14.3: Diel Activity Pattern of Dolphins

As can be seen from the figure above, the area under the curve and the activity peak period is clearly more for the Dibru river, and very less for the Lohit river[253]. The dolphins in Dibru river seem to be active in the afternoon and get carried over past midnight. However, in Lohit river, there are smaller bursts of activity round the clock but with least activity morning and evening hours. As the authors rightly point out, the Lohit river is much bigger, and needs more sampling efforts. As the Dibru river is narrow and acts as gateway between Maguri beel and Lohit river, the prey density may be higher in Dibru. Nevertheless, dolphins appear to be cathemeral in nature. The other reason as pointed out by the authors could be that due to high volume of water in Lohit river, the dolphins might have moved to Dibru river. As the Maguri CPOD did not show any activity, it is certain that there are no dolphins there at all. The locals have stated that dolphins were always found in Maguri Beel because of a good and diverse prey base. This seems to be not holding good any more post blow out/ oil spill and explosion.

14.4.3 Acoustic Characteristics of the Gangetic River Dolphins

As per the WII (2020b), the dolphins were seen to using a higher frequency click (whistle) hovering about 57.31±16.01 kHz in Dibru river, and a lower frequency 56.77±11.67kHz in Lohit river. When the sound pressure is compared, it is seen that the SPL (a measure of loudness of sound) of the emitted sound by dolphins was about, on average, 54.93±47.94 Pa in Lohit river, while it was 77.10±53.31 Pa in Dibru river. [*It could be that the dolphins in Dibru river, being closer to the blowout site, are behaviorally trying to cope with the ambient noise generated by the flame. There could be a possibility that the dolphins in Dibru have developed a tendency to "shout" to overcome the background noise.. Also the flame may be emitting sound in 20-40 kHz. Several of the frequency plots of*

253 Pixel count shows that Dibru chart has 68705 pixesls under it, and the Lohit chart has 38829 pixels. The quantum of activity at Dibru river is almost double (1.8 times more) than that at Lohit river

the flame acoustic measurements show 2 to 3 small peaks between 10-20 kHZ. These are, however, matters of investigation. Nevertheless, there is a clear scientific proof, as per WII (2020b), of difference in acoustic behaviour of the dolphins nearer to the blow out site than those farther away.]

14.4.4 How Many Gangetic River Dolphins are There Now?

From the WII (2020b), one cannot get a direct answer to the question, as to how many dolphins are there around in the Dibru-Saikhowa landscape. The February, 2020 direct sightings show 28 individuals. Statistically, the population prior to the blow out can be said to be between 28-34, as per the population estimates shown in this Chapter in the sections above. With the current measured encounter rate of 0.0484 per km (assuming that from east of Saikhowa Ghat to Balijan on the west, its about 65-70 km aerial distance). This would mean that, possibly, there are only 3 dolphins left. Of late, a calf was also spotted in Dibru river, so we could say, now, 4. At least one of them could be coming back to Lohit on and off (as can be seen from the diel chart), say, in a 3 hour interval (as can be roughly guessed from the peaks in the Lohit diel chart), and returning back.

14.4.5 Where are the Rest of the Gangetic River Dolphins?

Assuming 3 resident dolphins at Dibru river (now additionally a new calf), 1 dolphin (a juvenile calf) already dead – and we shall get to this case a little later in this Chapter, roughly we need to account for 28-34 dolphins. Since the local situation did not permit (there were in all 9 waves of flood in Dibru-Saikhowa region this year, starting from June 26th, 2020. To add to that, one large house boat sank in the floods this time. Therefore, it was not possible to initiate any large scale systematic survey. The quick assessments done by WII at a short notice have come handy and revealed very useful pieces of information, and collection of new empirical data on the dolphins in this part of the country. All speculations talk of the dolphins either moving upstream, or getting into some tributaries. May be, we need to look further north and east, assuming all are safe and no unnoticed mortality. Therefore, a survey needs to be initiated at the earliest after the fire is extinguished.

14.5 Measuring Under Water Sound Pollution

WII (2020b) carried out under water measurement of sound pollution using hydrophones to assess possible stress levels to the Gangetic River Dolphins and other aquatic animals. A brief of methodology, assessment and possible impacts is proposed to be discussed in this section based on the WII (2020b).

14.5.1 Approach and Methodology

Passive Acoustic Monitoring (PAM) device Cetacean Research C57 hydrophones and a digital recorder (Tascan DR-100) Sound recording was carried out at every 500 m interval to get the sound profile. The sampling rate was 192 kHz with a gain of 5dB. 12 such samples were taken, and each sample was for 1 min. Thus, a total of 12 min recording was obtained and analyzed.

14.5.2 Assessment of the Underwater Noise Pollution

The 12 sampling sites are plotted in the Google Earth map and reproduced below:-

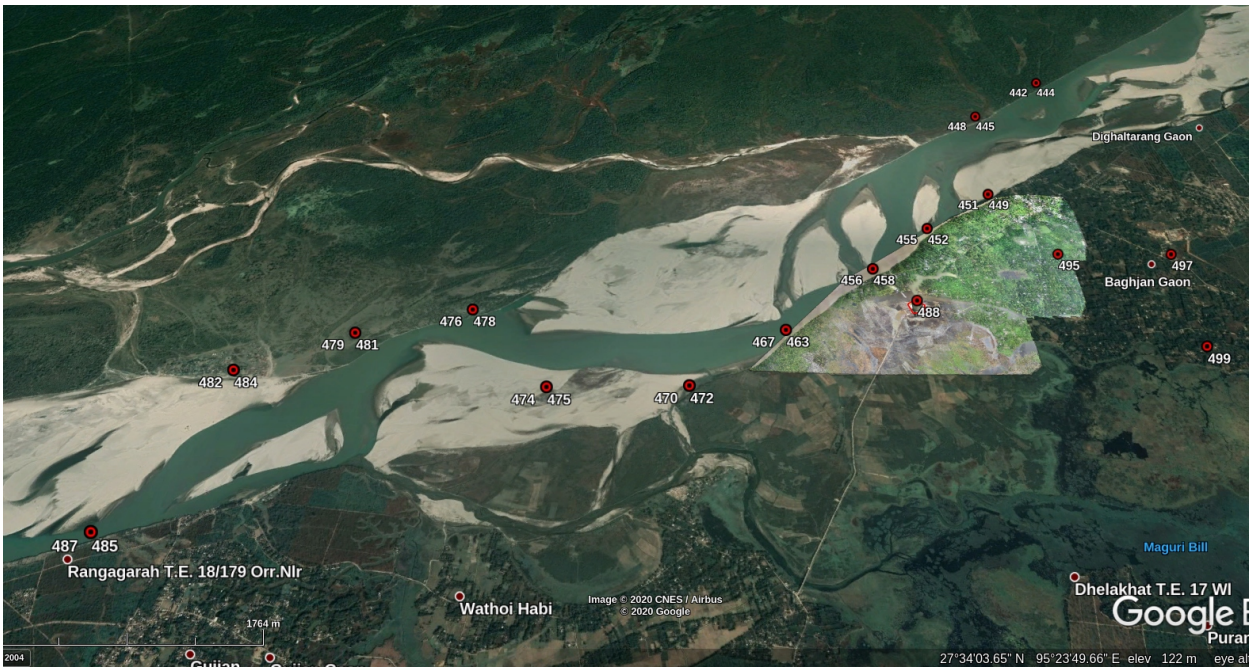


Fig. No. 14.4: Underwater Noise Sampling Sites by WII (2020)

[*In the figure above, the reader can see the use of high resolution drone based photography having been superimposed in the Google image around the blast site*. Courtesy - *GIS@AMTRON*]

Since, at some of these points, sound levels were also measured, one can easily compare the SPL values in water as well as in air. It is seen that the SPL values for water are much higher than those for air. The measured water noise levels vary from 113.2 – 135 dB (while variation in distance is 0.48 – 6.51 km in inverse relationship). On the other hand, sound levels in air vary from 81.68 to 96.48 dB; and distances vary from 0.48 to 4.6 km in inverse relationship. These have been depicted in the figure given below:-

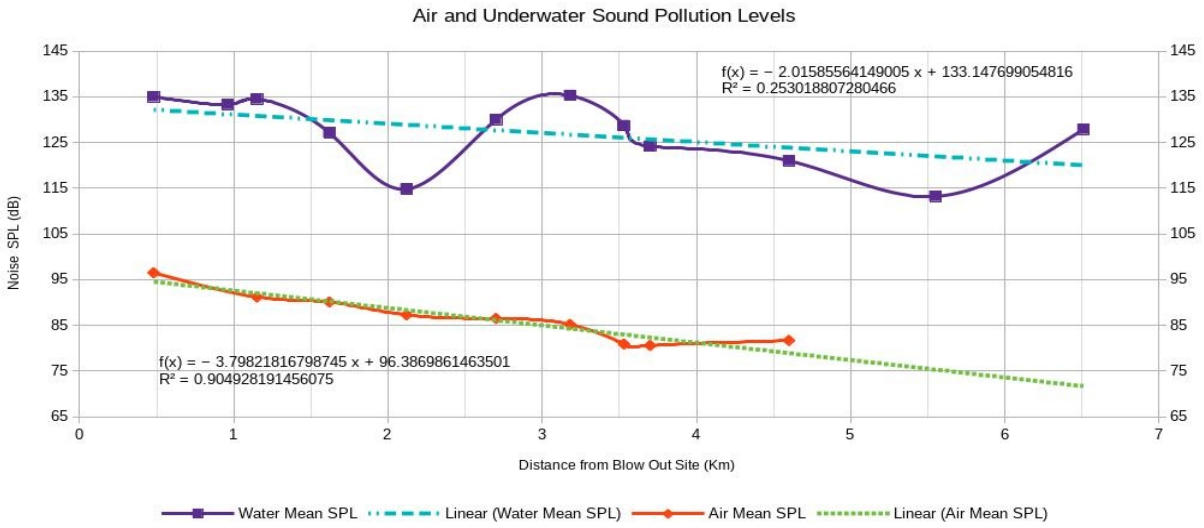


Fig. No. 14.5: Depiction of Noise Levels in Water and Air wrt Distance from Blowout Site

As can be seen above, the correlation equation for the variation of sound level in air has got a very high correlation coefficient. The underwater sound level correlation equation has a poor fit though. Nevertheless, the thumb rule appears to be that in air, the sound level is decreasing @ ~4 dB per km, while in water just by 2 dB per km. Therefore, from the data sampled by WII (2020b) in the surroundings of the Baghjan blowout is crystal clear in telling that the impact in water is actually several magnitudes higher than that in air. To press the point home, lets take the highest SPL value in air, and the highest and lowest SPL values in water[254], all the three, as reported by WII (2020b), and convert them into sound pressure in Pa and sound intensity in Wm^{-2}.

Table No. 14.2: Comparison of Sound Pressure Levels & Intensity in Air & Water

Medium	SPL (dB)[$]	Sound Pressure (Pa)	Intensity (Wm^{-2})[255]
Air	96.48 (*157.98*)	1.3336	0.004446
Water	115 (*53.5*)	11.2468	0.316
Water	135 (*73.5*)	112.468	31.62

$ Values in brackets are for the other medium. For air, its equivalent value in water shown in brackets, and for water vice-versa. [Rest of the values are in "air". Further, the table is meant to be demonstrative only]

254 Sound levels in water are measured @ 1 μP of pressure against 20 μP in air. This accounts for a difference of 26 dB. Further due to different in speeds and density medium, another 35.4 dB needs to be accounted for. Thus, from air to water dB would be more by ~61.5 dB and vice versa. A 60-dB difference in relative intensity represents a million-fold difference in power. (*Ref: https://dosits.org/science/sounds-in-the-sea/how-does-sound-in-air-differ-from-sound-in-water/*)

255 Intensity of sound in water (I_w) from a source in air (intensity I_a) at a distance h from water surface, and at depth d, refracted at angle φ, then, $I_w=4.n^2\cos^2 \varphi.I_a/d^2$, where $n=C_a/C_w$, or 0.22. It implies that source of sound from inside water would appear closer by nh, and I_w would be $4n^2$ times I_a. For Baghjan, $\varphi = 5^0$-7^0, depending where one is; and I_w can be approximated as $I_w=⅛.I_a/d^2$. [*Ref: Urick R.J, 1972, J. Accoust. Soc. Am, Vol. 53, Num 3(2), p993-999, 1972*]

In the Chart above, the two parallel lines have a difference of roughly 40 dB. This means that at the same point, the difference in power in absolute terms is 10,000. The rest of the underwater acoustics, we shall examine in the next section. However, the relationship of acoustics between air and water is complex. In the words of Urick R. J (1972), "*The problem is surprisingly difficult, and the resulting expressions for the sound field, as found from either wave theory or its special case, ray theory, are remarkably complicated, even in the most simple condition of two uniform fluids separated by a plane boundary*".

14.5.3 The Peak Frequency of the Underwater Noise

From the recorded spectrogram (see figure below), as per one sample from WII (2020b), and also as reported by the authors, the peak sound lies between 5 to 100 Hz, [*with possible peak around 10 Hz*]. This piece of information tells many things about what has been happening underwater at Baghjan blowout site.

Firstly, basic physics tells us that water acts as a very good reflecting surface (*and hence also a good trap by not allowing sound waves to escape from within the water surface*) for sound waves. Further, attenuation of sound waves is proportional to the square of its frequency[256]. Therefore, on either count, all the high frequencies either would get reflected or attenuated and, thus, converted to heat energy. That leaves us with lower end frequencies to deal with. Latest research[257] indicates that there is an anomalous transparency at the "infrasound" frequencies <20 Hz. The ratio of acoustic impedance (air to water), given by $\rho_a C_a / \rho_w C_w$, comes to about ~ 1/3500 (depending upon the values deployed in the calculation [ρ_a=1.3 kg m^{-3}, C_a= 330 ms^{-1}, ρ_w=1000 kg m^{-3}, C_w=1500 m s^{-1}.]. Therefore, only a small fraction of the sound energy is transmitted from air to water. However, low frequency sound waves seem to bypass this. Contribution to sound generation in a media such as water from a source in air above it, happens from multiple paths. Urick R. J (1972) identified at least 4 paths. Shallow water adds a lot more reflectance than deep water. Additionally, there adds up a "lateral" component in the underwater soundscape that can be many times of the geometric sound intensity I_w, if the radial distance of the underwater point under consideration, R, far exceeds h or d (R>>h & R>>d). May please see Footnote 255 for more details. [In case of a point in Lohit river, the source i.e. the flame being of height 108 m average, can be said to be radiating from middle point at h=54 m, depth of placing the hydrophone could be @ d=1-5 m maximum. R for all the points, other than nearest 4 points as shown in the

256 For water, $\alpha=0.0253xf^2$, where f is in MHz. Therefore, attenuation for 100 Hz is of order of 10^{-6}.
257 Goding Oleg A, 2008, Contemporary Physics, Vol 49, No. 2, March-April 2008, p105-123

figure above, are >> 2000 m. Further at 10 Hz of peak frequency, λ=150 m under water. Therefore, d/λ = 0.03, & R/d=200. This takes the the lateral wave attenuation to more than 100 times].

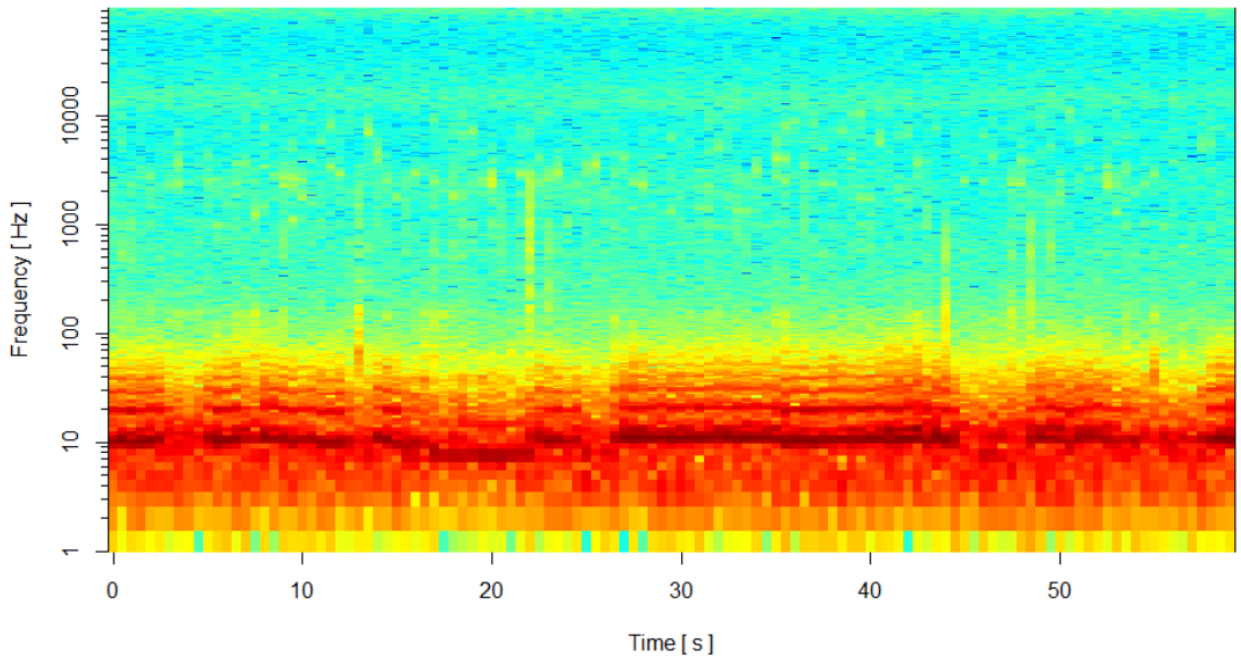


Fig. No. 14.6.: An Underwater Power Spectral Density (PSD) Spectrogram from WII (2020b)

Waye K. P (2011)[258], in Encyclopedia of Environmental Health, defined low frequency sound as between 20-200Hz. Though he distinguishes between infrasound (< 20 Hz) and low frequency (LF) sound, he admits that these are mere conventions, and sounds may merge due to high SPL. According to him, "*In nature, sound frequencies below 200 Hz are signals of thunder, volcano eruptions, earthquakes, or storms – events that are likely to induce arousal or fear*". Further LF sound can travel long distance without attenuation, and, under water, it can travel much longer distances with very little attenuation. Loudness also gets a different meaning at LF levels: To be perceived as twice as loud, it is enough for the level to increase with 5–7 dB, or stated in another way, a 10-dB increase at 50–63 Hz may be perceived as up to four times as loud, but only doubly loud at 1 kHz. Most importantly, the author says "***low frequency noise may occur in combination with vibrations***".

Therefore, the underwater spectrogram provided by WII (2020b) is very significant on two counts, firstly, it establishes the nature of noise propagating underground, and secondly, testifying to such high SPL values in underground water, despite direct

258 Waye K. P, 2011, Encyclopedia of Environmental Health, 2nd edition, Volume 2 https://doi.org/10.1016/B978-0-444-63951-6.00245-X

underwater geometric values being one fifth of the air intensities. Thus, the soundscape underwater appears to be a continuous "boom boom", 24x7. It would not only scare away wildlife, but also would be "*killing*" many of them. Field teams have been reporting dead fish regularly from the Maguri beel.

14.6 The Dead Dolphin

This Report cannot be treated complete without a discussion on the young Dolphin that was found dead on the morning of 29th May, 2020 in the wake of the Baghjan Well No. 5 blow out that occurred at 10.30 AM on the 27th May, 2020. The incident was reported at 9.45 AM, but the animal would have died earlier. The GPS location, as informed by the DFO, Tinsukia Wildlife Division was 27^0 34' 22.15" N & 95^0 22' 8.34" E. Post mortem was done at 4.00 PM the same day. Due to lock down, it took quite some time to organize sample collection and dispatch. The photo and videos of the dead dolphin became quite viral in the social media, and the Baghjan blow out no more remained just a oil blowout, but assumed proportions of an ecological disaster. We, as Forest Department, spinned into action, which finally led to constitution of the Expert Committee (EC) under the Chairmanship of the undersigned, and so many steps in so many directions that followed thereafter. The photograph of the dead Dolphin is placed below. The fact that a Gangetic River Dolphin traversed 9 km of riverine channel and waterbody and be there where it was, about 600 m from the blow out site, speaks volumes about the Dolphins being there all the time, and testifies to the fact of the oil spill would be so very harmful to the wildlife. Before we proceed further, we must pay our tribute this Dolphin that is no more with us together with so many other animals [and men too] that we know not of and may never be able to know, and pray to the powers that be on the mother earth and the heavens that such ecological disasters may never happen.



Fig. No. 14.7: The Dead Dolphin at Baghjan

The photograph of the Dolphin taken from the Maguri bridge just before lifting in the boat, which is seen at the top edge of the photo. The milky opaqueness in water due to mixing of oils is very much visible in the photograph which is taken from the top. The loss of skin epidermal layer of the Dolphin is also visible.

14.6.1 A Brief Profile of the Dead Dolphin

Officially, the dead dolphin was reported by Mohandeep Gogoi FrI, and an offence was registered by the Tinsukia Wildlife Division. On post mortem, the following data were recorded about the dead animal;-

Date and hour of detection:- 29/05/2020 9.45 am
Offence report No:- GWL/06 Dt. 29/05/2020
Weight:- 6.51 kg
Length: 96 cm
Neck girth: 42 cm

As per Post-mortem report, the tentative reason of death was - *inhalation or ingestion of substance of toxic origin leading to hypoxia and death*. Changes were observed in lungs, liver, heart, brain and gastrointestinal tract in PM report. 4 samples containing stomach content, Liver CS, lung CS, Kidney CS were sent to Directorate of Forensic Science Kahilipara, Assam and College of Veterinary Science, Khanapara, Guwahati on 30.05.2020 for Forensic and anatomical changes' analysis. Two samples were sent to Sriram Institute for Industrial Research, Delhi for 16 PAHs analysis.

14.6.2 Did The Dolphin Die before or After the Blow Out

There are claims and rumors that the Dolphin was already dead when the blow out occurred, and later as an after thought, the dead Dolphin was dragged into the blow out just to portray M/S OIL into a bad light. Such an argument is quite justified, plausible and sounds believable too. However, what are the facts? There is no doubt that the death of the Dolphin was reported only on the 29th May, 2020 at 9.45 AM; and there is every possibility that the animal was dead prior to that. In wildlife, there is always a time lag before staff reaches the Place of Occurrence (PoC), and start his investigation. There is every possibility that the animal might have died the previous night.

The Report from the College of Veterinary Science, Khanapara Dt. 22nd October, 2020 states that the death was more than 24 hours before performing of post mortem; and that autolysis was complete. We can assume that post mortem happened exactly at

4.00 PM on 29th May. Therefore, the dolphin could not have died after 4.00 Pm on 28th May. Therefore, conclusion that the dolphin died before 4 PM of 28th May, 2020 appears to be sure, but then could it have died before 10.30 AM of the 27th May, 2020? This is what needs to be examined. Assuming that the dolphin died just minutes before, say at 10.25 AM on the 27th May, 2020, it would be exactly 53.35 hours between death and postmortem. The post mortem report clearly mentions two things, firstly that time of death could be 24-48 hours, and that carcass was "fresh". It was found below the Maguri bridge, which means that it was in full public eye, and the local wildlife conscious people would not have allowed to let a dolphin sample rot for two days in the waters, i.e. beyond 48 hours. Therefore, the death could not have happened before evening of 28th of May, 2020. The forest staff were informed at 6.35 AM on 29th May, 2020 by the villagers of Maguri Motapung beel area. The animal would have died the previous day during evening time, and the body might have surfaced early morning. Going by the research study by Brooks J. W (2016)[259], the carcass should not be older than 36 hours. Therefore, the death could not have been earlier than 36 hours.

Therefore, all evidence is against the animal being dead prior to 53 hours. The death is undoubtedly post blow out and in all probability on the afternoon of the 28th May, 2020.

14.6.3 What Could be the Cause of Death?

The dolphin was a juvenile estimated to be 2 month old. It was reportedly found dead and floating on water on the wee hours of 29th May, 2020. After post mortem, samples were sent to several laboratories for testing to ascertain the cause of death. The site where the body was recovered was just 600 m away from the blow out site in the south direction. The post mortem report mentions of four major findings:-

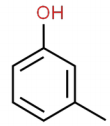
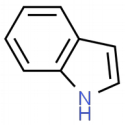
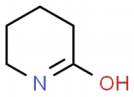
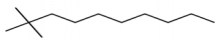
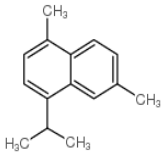
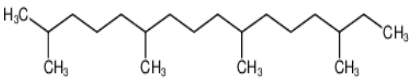
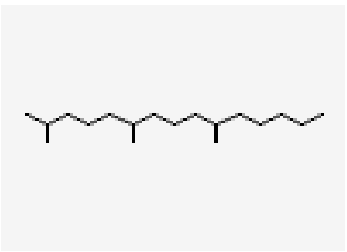
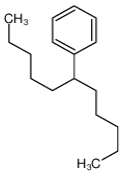
1. Heart examination showed haemorrhages and ventricular damage
2. Lungs showed haemorrhages and edema
3. Stomach, intestinal lumen showed haemorrahge
4. Brain shows congestion

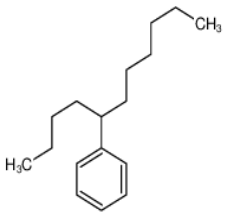
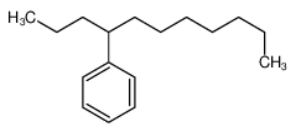
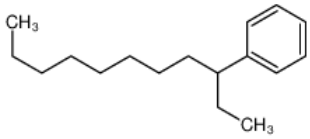
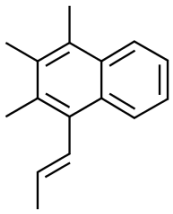
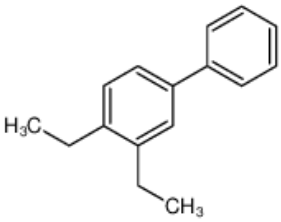
Such multiple possibilities could happen if the animal ingested oil and petroleum products in dangerous quantities. This is well supported by the Forensic report. They examined presence of hydrocarbons and other organic chemicals using Gas Chromatography and Mass spectrometry techniques, and the ascertained the presence of several organic long chain and polycyclic hydrocarbons and their derivative chemicals

259 Brooks J. W, 2016, Veterinary Pathology, 2016, Vol. 53(5) 929-940

having long chain carbon C_5-C_{22} in the Dolphin vicera. The chemicals reported are listed here -these are highly toxic and carcinogens or derivatives of known carcinogens.

Table No. 14.3: Chemicals Found in the Dead Dolphin Viscera

Sl. No.	Chemical	Symbol
1.	3-Methyl Phenol (C_7H_8O)	
2.	Indole (C_8H_7N)	
3.	2-Piperidone (C_5H_9NO)	
4.	2,2-Dimethyl-Decane ($C_{12}H_{26}$)	
5.	N-Hexadecane ($C_{16}H_{34}$)	
6.	Decahydro-1,6-dimethyl-4-(1-methylethyl)-Napthalene ($C_{15}H_{26}$)	
7.	2,6,10,14- Tertramethyl Pentadecane (Phytane) ($C_{22}H_{46}$)	
8.	2,6,10- Triimethyl Pentadecane ($C_{17}H_{28}$)	
9.	6-Phenyl-Undecane ($c_{17}H_{28}$)	

10.	5-Phenyl-Undecane ($c_{17}H_{28}$)	
11.	4-Pheny-Undecane ($c_{17}H_{28}$)	
12.	3-Phenyl-Undecane ($c_{17}H_{28}$)	
13.	1,2,3-Trimethyl-4-[(IE)-1-propenyl] Naphthalene ($C_{16}H_{18}$)	
14.	3,4-Diethyl-1,1' Biphenyl ($C_{16}H_{18}$)	

Therefore, in all likelihood, the dolphin was a victim of the oil spill, and its death was post blow out. According to Prof. Apurba Chakraborty, former Director of Research (Veterinary), AAU, Khanapara and also member of the Expert Committee (EC), on the cause of death of the Dolphin, "*The histopathological study could not reveal any changes since the tissue samples were autolysed as reported by both the Departments of College of Veterinary Science. The Forensic Science laboratory detected hydrocarbons with carbon numbers ranging from C7 to C25 in the organs like liver, lung and kidney and in the stomach content. Therefore, based on changes at post-mortem examination coupled with toxicological study of the Forensic Science Laboratory it can be concluded that the said dolphin has died due to hydrocarbon poisoning*."

14.6.4 The Observations of WII On the Death of the Dolphin

According to WII (2020), the post mortem report of the dolphin is in conformity with reported effects of PAHs. WII (2020) has relies on the study be De Guise et al (2017)[260] who reported similar abnormalities such as adrenal and lung abnormalities that died within the oil spill footprint. Oil spill seem to contribute to dolphin mortality in the now famous Deepwater Horizon (DWH) Oil Spill. As per the findings, the DWH oil spill resulted in the contamination of prime marine mammal habitat in the estuarine, nearshore, and offshore waters of the northern Gulf of Mexico (GoM), and tens of thousands of marine mammals were exposed to the DWH surface slick, where they likely inhaled, aspirated, ingested, physically contacted, and absorbed oil components.

14.7 Impact Of Blow On Hoolock Gibbons

A population of 20-25 Hoolock gibbons are surviving in Barekuri GP towards the south-east of Baghjan about 6 km away. This group is unique as they have been now living with humans for a long time [scientifically, not a very desirable situation]. It is said to be a break away group from Dihing Patkai. The three villages of Barekuri namely Matapung, Dighalhaku and Borgaon were studies by observation during the blow out period and are under monitoring till date. These three troops were studied by Sharma et al (2020). The feeding, locomotion, resting, social, grooming and other behaviour and activities, and calls were observed.

It has been reported by the nearby villages that the oil spill had reached the troops as well, and they had stopped feeding completely for two days. They did not make any calls and grooming, a social behaviour, had stopped. As reported by the villagers, the trees were dripping oil, and leaves were soaked in oil. Breathing had become heavy and difficult. The animals resumed feeding once the fire occurred, and the shower of oil spill had stopped. [*Rains must have washed away most of it*].

Two unfortunate incidents happened thereafter. One of the pregnant females gave birth to a still born baby on the 2nd October, 2020, but the mother did not leave the baby and clung to it for almost 4 days, and then dropped it one night. Since it happened in the night, the fallen dead baby must have been eaten away by dogs etc. The villagers could not find a trace of it. The mother later on died on the 27th October, 2020. The

260 De Guise, Sylvain & Levin, Milton & Cote, Erika & Jasperse, Lindsay & Hart, BL & Smith, Cynthia & Venn-Watson, Stephanie & Townsend, Forrest & Wells, R & Balmer, Brian & Zolman, Eric & Rowles, T & Schwacke, Lori. (2017). Changes in immune functions in bottlenose dolphins in the northern Gulf of Mexico associated with the Deepwater Horizon oil spill. Endangered Species Research. 33. 10.3354/esr00814.

primary post mortem report revealed badly punctured liver and damaged lungs. [*Still births have been reported among domestic animals. See Chapter 15*]. See the figure below. From the top, clock-wise, the photographs are:- 1. Mother Hoolock Gibbon with her still born baby, 2. The dead mother Hoolock Gibbon, 3. The punctured liver of the Hoolock Gibbon mother & 4. The punctured lungs of the Hoolock Gibbon mother.



Fig. No. 14.8: The Story of the Hoolock Gibbon Mother at Barekuri

There is no denying that the Barekuri gibbons were directly exposed to oil spill. Still birth could be attributed to organic chemicals such as long chain hydrocarbons and polycyclic aromatic hydrocarbons. However, as postmortem opportunity was lost, it remains a guess only. This calls for a long term dedicated research on health of the wild animals.

14.8 Impact On Other Wildlife

Among other wildlife impacted were wild buffaloes and barking deer that normally roamed in the grasslands of Maguri-Baghjan, Dibru river, and parts of Maguri beel. While no direct death of any such wildlife was reported, there was a fake news of a charred deer. It turned out to be an image from the recent fires in Australia. A search through drones was made even on the 10-12th June, 2020, but no carcass could be located. [*Carcass and burnt bones of several small animals such as birds and snakes were found in the grassland subsequently, but!, and reported by many members of the study teams in their report.*]. There was no other report of any mammals' death, other than the juvenile dolphin, and now a Hoolock Gibbon mother and child. Therefore, it is assumed that no other mammals died due to the blow out incident. However, exposure to oil spill on barking deer and wild buffaloes cannot be denied. Immediate impact of the exposure is not known.

A drone survey of the Dibru-Saikhowa NP was also carried out. No trace of wildlife was found anywhere in all areas directly facing the blow out site. However, on the northern side of the Park, elephant herds and the wild horses were located. Most of large animals seemed to have migrated from the affected areas of the Park to safer areas northwards.

A periodic reassessment needs to be done once the fire is extinguished to assess restocking of the areas. It may also need habitat improvement interventions.

14.9 Feedback From Laika Dadhia Villages

The two forest villages of Laika and Dadhia staying from prior to formation of the sanctuary and National Park are situated in the heart of the Park. The student representatives and village elders met the OMEC on the days of the public hearing, and reported of oil spill, and their travails from the incessant high pitch noise. They also requested for immediate relocation from the site and compensation for their suffering and losses from the blow out.

The sampling from PCBA has confirmed presence of oil and grease in water samples in parts of Dibru-Saikhowa National Park, especially Kolomani nullah where 4.5-5.1 mg/l oil and grease were found in the water samples. However, due to rains, a lot of the oil must have got washed away. However, in stagnant waters and especially on the days when it did not rain (i.e. 7-10th June, 2020), a lot of animals and villagers must have been exposed due to inhalation, ingestion and touch of the oil spill. The ill effects may not be visible immediately.

14.10 Impact Of Blow Out On Scheduled Animals

So far we have examined the impact of the Baghjan blowout on the habitat (air, water, soil and land), impact on biodiversity in terms of impact on many indicator species such as earthwroms, mullsucs, butterflies, moths, odonates, anurans, fishes, reptiles, and also on birds and mammals. It is seen, therefore, that there has been a high degree of damage to the ecosystem and biodiversity as can be gauged from many dead animals and organisms described above. There has also been pollution in varying degrees in the air, water and land. Therefore, as a matrix of organisms and ecosystems, it is found that the overall impact has been profound, and damages may take a long time to recover/ restore, while some may not recover at all. We also need to keep in mind that this study or the studies conducted under the umbrella of the OMEC are not sufficient on their own to tell us the manner in which future of this area would unfold in view of these damages. Here, we tarry, to look at all these damages, especially of the wildlife in terms of the Wildlife (Protection) Act, 1972. The Act lists a number of Scheduled animals that have been exclusively protected with various provisions of the law. There are six Schedules (I to VI) and ten Parts among these Schedules (Part I, II, IIA, III, IV, IVA, IVB, IVC of Schedule I, Part I 7 II of Schedule II). There are no parts to Schedule III to VI. As explained already at the beginning of the Chapter 12, if the animal is Scheduled, then any tampering with either the animal or its habitat is tantamount to hunting. Just to reiterate, in case of a Scheduled animal, “killing”, “poisoning”, “driving”, “injuring”, “destroying”, “damaging of eggs”, “disturbing of eggs or nests” all are prohibited under Section 9 of the Act, and have the same meaning as “hunting”. In this section, we shall examine if any of the provisions of the Wildlife (Protection) Act, 1972 have been breached in respect of any of the Scheduled animals.

14.10.1 BAGHJAN BLOW OUT AN ACCIDENT OR A NATURAL “ACT OF GOD”

All reports supplied by M/S OIL and other reference materials gathered, say only one thing- **BLOW OUT** happens always due to human error. Whether the error was by a third party, or miscreant or a person (s) with delinquent mind (s) or just an accident in course of an honest performance of duties due to wrong estimations or assessments or faulty equipment deployed - are all under the purview of human error. It would not have been “Act of God” even if the whole area would have been deep in deluge and BOP under water and no access to it, as because, the designers of the project were supposed to foresee such unforeseen circumstances and design their equipment (say for 100 years of storm and run-off or earthquake 8.0 on Richter scale) Until these normal engineering considerations fail to apply in a force majeure, i.e. earthquake of intensity

>8.0 strikes or the deluge was a storm in >100 years, one cannot take recourse to such excuses as “Acts of God”. Therefore, there is nothing that comes to mind in case of Baghjan that can be said to be in the nature of “Act of God”. It is a pure human error. We shall refer to the cause of the Baghjan blow out as “human error”, irrespective of the fact as to who is responsible. Thus, the people who are responsible for the human error that caused the blow out, explosion and fire, and their owners, employers and agents and assigns all together can be clubbed together as “persons responsible”.

14.10.2 UNDERSTANDING THE LEXICON OF “HUNTING”

While most of the prohibited acts such as “killing”, “poisoning”, “driving”, “injuring”, “destroying”, “damaging of eggs”, “disturbing of eggs or nests” have at least one example in almost all the reports during the assessments. The word “Weapon” has also been explained in the Chapter 12. Firstly it is the blowout consequent upon which oil and gas leaked in huge quantities (and OIL is not aware as to what is the actual quantum of the substances leaking/ leaked) and spread over areas more than 6 km is extent and radius covering the surrounding ecosystems and animals living therein. The natural gas and oil, in form of condensate, carried heavy straight chain, cyclic and aromatic hydrocarbons that are not only toxic but also carcinogenic which when inhaled, ingested or contacted through skin are capable of inflicting severe injuring killing of embryos, eggs, larvae, young ones and even the animals themselves, and also adversely affecting the food chain and future generations of these animals genetically and morphologically. The oil spill spread over bigger areas during the floods from 26th to 18th and killed many more wildlife and animals. All persons responsible may be charged of “hunting on this count under the Section 9 of the Wildlife (Protection) Act, 1972.

Similarly, the explosion and fire damaged the habitat, killed many animals that could not be even identified (or we would never know about), damaged eggs and nests of birds and snakes, it destroyed the habitat, especially the grassland by burning. All persons responsible for this “commission” of offences as mentioned above may be charged of “hunting on this count under the Section 9 of the Wildlife (Protection) Act, 1972.

Further, the high dB noise which was not less than 70 dB within the National Park boundaries, day and night alike, as against mandated 50 dB during day and 40 db during night as per the EPA, 1986, and in the process disturbed and drove all the wildlife big and small away from their habitat to other territories, so much so that there was marked difference in count of birds and other wildlife when an assessment of the same

was made. All persons responsible for this "commission" of offences as mentioned above may be charged of "hunting on this count under the Section 9 of the Wildlife (Protection) Act, 1972.

Further, the piercing sound created secondary wave propagation processes and vibrations were induced in the ground and water leading to shaking of the ground, and creation of sonic boom and echos in the water bodies and rivers, that were measured, and were found to be harmful to wildlife, by way of damaging their organs, raising their blood pressures, disrupting their communication systems, disrupting their hearing faculties and damaging the same and other bodily discomforts and panic creation and even leading to death of animals, especially fish in the water bodies, and thus causing injuries to wildlife were caused. All persons responsible for this "commission" of offence as mentioned above may be charged of "hunting on this count under the Section 9 of the Wildlife (Protection) Act, 1972.

Further, the immense heat that has been released by the burning flame at a distance of just 900 m to 1500 m of the National Park boundary and even closer to other grasslands and wet land habitats of animals, has changed the temperature of the water, air and soil, and in intense heat many valuable butterflies, reptiles and snakes died and animals continued to suffer, feel discomfort to the point of dehydration, and have been disturbed in their tranquil environment and the areas are no more fit to inhabit. All persons responsible for this "commission" of offence as mentioned above may be charged of "hunting on this count under the Section 9 of the Wildlife (Protection) Act, 1972.

Further, the amount of light that the flame has been radiating has changed the lightscape of the ecosystems and habitats to such an extent that the animals get disoriented and are not able to distinguish between day and night and have been exhibiting abnormal behaviour all along, and many butterflies and moths and other insects have been "trapped" and killed in the flame. All persons responsible for this "commission" of offences as mentioned above may be charged of "hunting on this count under the Section 9 of the Wildlife (Protection) Act, 1972.

Further, due to consequences of the blow out, oil spill, explosion and fire, a lot of ecosystem support systems and plant and animal life got killed, and to mention a few- earthworms, molluscs, odonates, moths and butterflies, fishes, which in turn have now affected the food chain of the wildlife adversely and rendered the habitat unsuitable for the animals, and thus caused serious injury, disturbance and damage to the animals, their young ones and eggs etc. All persons responsible for this "commission" of offences

as mentioned above may be charged of "hunting on this count under the Section 9 of the Wildlife (Protection) Act, 1972.

[*Of course, One cannot be sure if one can charge anybody for future damages!, so any such charge may be omitted*]

Further, due to negligence of the persons responsible, a juvenile dolphin, a rare and endangered animal lost its life. Further, the young one of a Hoolock Gibbon was still born and this is tantamount to killing of the young one; and the mother also expired within a month; and all these animals were heavily exposed to oil spill during the blow out. All persons responsible for this "commission" of this offence may be charged of "hunting on this count under the Section 9 of the Wildlife (Protection) Act, 1972.

Further, a whole lot of other animals were killed, their young ones and eggs destroyed and damaged and the nests of birds and other animals damaged and destroyed. A list of all such animals is provided hereunder. All persons responsible for this "commission" of the offence may be charged of "hunting on this count under the Section 9 of the Wildlife (Protection) Act, 1972. Therefore, the offences are many fold, and these make the charges serious. Multiple injuries at multiple levels and at multiple times have been inflicted upon the voiceless animals. Their life is not at our mercy. We must understand that it is our life, the life of human beings, is at their mercy. They die, we die, they live we live.

14.10.3 THE LIST OF SCHEDULED ANIMALS IMPACTED BY THE BLOW OUT

As per the Wildlife (Protection) Act, 1972, the following animals that have died (or rather have been killed, poisoned, trapped, driven, injured, or destroyed and their young ones, eggs and nests also damaged and destroyed.

Table No. 14.4: List of Scheduled Species Impacted in the Blowout

Sl No.	Class/order	Common Name	Scientific Name	Schedule of WPA, 1972	Remarks
1	Lepidoptera (*Cucujidae*)		*Apharitis lilacinus*	Sch- 2, Part-II	
2	Reptilia (Lizards)		*Varanus species*	Sch- 1, Part II	
3	Lepidoptera (*Papilionidae*)		*Appias lyncida latifasciata*	Sch-2, Part-II	
4	Lepidoptera (*Hespiriidae*))		*Pelopidas assasmensis*	Sch-4, Part-II	

Sl No.	Class/order	Common Name	Scientific Name	Schedule of WPA, 1972	Remarks
5	Lepidoptera (*Lycaenidae*)		*Hypolimnas*	Sch-2, Part-II	
6			*Jamieds*	Sch-1, Part-IV	
7			*Xenochorphis*	Sch-2, Part-II	
8	Aves (*Timaliinae*)	Bablller	*Timaliinae*	Sch-4	
9	Aves (Asseriformes)	Black Drongo	*Dicrurus macrocercus*	Sch-4	
10	Aves (*Capitodinae*))	Blue throated barbet	*Capitodinae*	Sch-4	
11	Aves (*Cuculidae*)	Cuckoos	*Cuculidae*	SCh-4	
12	Aves (*Asseriformes*)	Drongos	*Dicruridae*	Sch-4	
13	Reptilia (*Testudines*)	Eastern hill terrapin	*Melanochelys triearinata*	Sch-1, Part-II	
14	Aves (*Ardeidae*)	Egrets	*Ardeidae*	Sch-4	
15	Aves (*Phalacrocoracidae*)	Great Cormorant	*Phalacrocorax carbo*	Sch-4	
17	Reptilia (*Testudines*)	Indian soft-shelled turtle	*Lissemys pun*	Sch-1,Part-II	
18	Reptilia (*Elapidae*)	King cobra	*Ophiophagus hannah*	Sch-2, Part-II	
19	Aves (*Coraciiformes*)	Kingfishers	*Aclednidae*	Sch-4	
20	Reptilia (*Squamata*)	Large Bengal Monitor Lizard	*Varanus bengalensis*	Sch-1, Part-II	
21	Aves (*Anatidae*)	Large Whistling Teal	*Dendrocygna bicolor*	Sch- 1, Part - III	
22	Aves (*Sturnidae*)	Mynas	*Sturnidae*	Sch-4	
23	Aves	Slender-billed	*Gyps tenuirostris*	Sch-I, Part-III	

Sl No.	Class/order	Common Name	Scientific Name	Schedule of WPA, 1972	Remarks
	(*Accipitridae*)	Vulture			
25	Reptilia (*Testudines*)	Spotted black terrapin	*Geoclemys hamiltoni*	Sch-1, Part-II	
26	Reptiles (Lizard)	Water Lizard	*Varanus salvator*	Sch-1, Part- II	
27	Mammalia	Gages River Dolphin	*Plntanista gangetica*	Sch-I, Part I	1 dead
28	Mammalia	Hoolock gibbon	*Hoolock hoolock*	Sch-I, Part I	1+1 dead
29	Mammalia	Barking Deer	*Munticacus muntjack*	Sch-III	
30	Mammalia	Wild Buffalo	*Bubalis arnee*	Sch-I, Part I	
31	Mammalia	Hog Deer	*Axis porcinus*	Sch-III	

14.10.4 LIST OF SPECIES IDENTIFIED AS DEAD

The various field teams came across carcasses of various individual members of different species during the field work. This is based on actual count of animals during the field visit. It does not reflect the actual number of individuals that might have died or got burnt in the fire, or their carcasses could not be located, or bodies decomposed beyond recognition.

Table No. 14.5: List of Dead Species in the Blowout

Group	Species Name	Common Name	No. of Dead individuals	Schedule (WPA)
Lepidoptera	*Eurema hecabe*	Common Grass Yellow	2	Unassessed
Lepidoptera	*Athyma selenophora*	Staff Sergeant	2	Unassessed
Lepidoptera	*Hestina nama*	Circe	2	Unassessed
Lepidoptera	*Delias pasithoe*	Red-base Jezebel	1	Unassessed
Lepidoptera	*Junonia atlites*	Grey pansy	1	Unassessed
Lepidoptera	*Cyclidia sp.*	Hook Tip Moth	1	Unassessed
Lepidoptera	*Symbrenthia hippoclus*	Common Jester	1	Unassessed
Lepidoptera	*Nyctemera sp.*	NA	1	Unassessed
Lepidoptera	*Appias lyncida*	Chocolate Albatross	1	Sch II (PartII)
Lepidoptera	*Asota sp.*	NA	1	Unassessed
Lepidoptera	*Nola sp.*	NA	1	Unassessed
Total	***11***		**14**	
Odonata	*Crocothemis servilia*	Scarlet skimmer	1	Unassessed
Total	***1***		**1**	

Earthworm	*Eutyphoes assamensis*	Earthworm	18860	Unassessed
Total	***1***		**18860**	
Mollusca	*Angulyagra oxytropis*	NA	281	Unassessed
Mollusca	*Austenia sp. Snail*	NA	1	Unassessed
Mollusca	*Brotia costula*	NA	124	Unassessed
Mollusca	*Gyraulus convexiusculus*	NA	1578	Unassessed
Mollusca	*Indoplanorbis exustus*	NA	230	Unassessed
Mollusca	*Intha umbilicalis*	NA	1675	Unassessed
Mollusca	*Macrochlamys glauca*	NA	1477	Unassessed
Mollusca	*Mekongia crassa*	NA	35	Unassessed
Mollusca	*Pila globosa*	NA	155	Unassessed
Total	***9***		**5556**	
Amphibian	*Hoplobatrachus tigerinus*	Indian Bull Frog	18	Sch IV
Amphibian	*Fejervarya pierrei*	Pierre's Cricket Frog	22	Sch IV
Amphibian	*Duttaphrynus melanostictus*	Common Asian Toads	25	Sch IV
Amphibian	*Euphlyctis cyanopthyctis*	Indian Skipping Frog	18	Sch IV
Total	***4***		**83**	
Reptile	*Lissemys punctata punctata*	Indian Soft-shell Turtle	1	Sch I (Part II)
Reptile	*Xenochrophis piscator*	Checkered Keelback	1	Sch II (PartII)
Reptile	*Amphiesma stolatum*	Stripped Keelback	1	Sch IV
Total	***2***		**2**	
Fishes	*Xenentodon cancila*	Cancila	224	Unassessed
Fishes	*Chanda nama*	Elongate Glassy Perchlet	27	Unassessed
Fishes	*Channa punctata*	Spotted Snake Head	221	Unassessed
Fishes	*Labeo gonius*	Kuria Labeo	102	Unassessed
Fishes	*Puntius sophor*	Spot- fin swarm barb	151	Unassessed
Fishes	*Puntius chola*	Swarm Barbs	569	Unassessed
Fishes	*Heteropneustes fossillis*	Stinging Catfish	1	Unassessed
Fishes	*Trichogaster fasciata*	Banded Colisa	98	Unassessed

Fishes	*Leiodon cutcutia*	Ocellated Puffer	1	Unassessed
Fishes	*Monopterus albus*	Eel	1	Unassessed
Total	***10***		**1395**	
Aves	*Gracupica contra*	Asian-Pied Starling	1	Sch IV
Total	***1***		**1**	
Mammal	*Platanista gangetica*	Gangetic River Dolphin	1	Sch I (Part I)
Mammal	*Hoolock hoolock*	Hoolock Gibbon	2	Sch I (Part I)
Total	**2**		**3**	

14.10.5 BASELINE OF SPECIES ENCOUNTERED

It was also decided to compile a list of species encountered during the assessment by all the groups whose reports have been summarized under the banner of this Report, in order to create a baseline in the 1st round of capture & mark. A summary of the number of species encountered is given in the Table below, while the detailed list is appended towards the end of this Volume.

Table No. 14.5: Number of Species Encountered

Groups	No. of species Encountered Live	Past Checklist Records	% Biodiversity Loss
Phytoplanktons	11	30	63.33
Zooplanktons	13	53	75.47
Butterfly[261]	130	268	51.49
Moths[262]	148	273	45.79
Odonates[263]	17	23	26.09
Mollusca	12	26	53.85
Fish	49	104	52.88
Amphibians	10	17	41.18
Reptiles	12	42	71.43
Birds[264]	151	502	69.92
Mammals	16	37	56.76
Total	**569**	**1375**	**55.29**

14.11 Conclusion

1. The Baghjan blow out is an accident of grave nature caused by an accident (a

261 Das G. N, Tamuly T, Hussain, A., Boruah, A. & Das, S. 2017, An update list of butterflies (Lepidoptera) of Dibru-Saikhuwa National Park, North-East India. Munis Entomology & Zoology, 12 (2): 408-418

262 Arandhara S, Barman S, Tanti R, Boruah A, Journal of Entomology and Zoology Studies 2017; 5(6): 1612-1621

263 Gogoi Arundhati and Barman Alakesh, Distribution Of Aquatic Insects At Maguri Beel Of Tinsukia District, Assam, North East India, Ecology, Environment and Conservation Paper, Vol 25, Issue 1 2019; Page No.(360-364)

264 Joshi Rajendra, Chaudhry Shivaji, Painin Lok Man Singh Palni, and Mathur Vaibhav Chandra, Avifaunal diversity, distribution and threats in Dibru-Saikhowa Biosphere Reserve North-East India Assam (India): A review, Archives of Applied Science Research, 2014, 6 (5):113-124 [Also see 236]

human error), but has proved to be of such diabolic proportions that it may be difficult to recover from it altogether. This is against the backdrop that the Dibru-Saikhowa and Maguri-Motapung landscape houses some of the most endangered animals not only in the State, but also in the country and the world. Some of the species have only few members, and we may find them finally locally "extinct", and many others may not return to site for decades, and still many others may have genetic and morphological disabilities in the present or future generation and in unpredictable ways (as we now seem to have just stated to witness still births and deaths with multiple complications).

2. The punishment, penalty and fine together with compensation must have demonstrative and deterrent effect, so that such costly human errors do not get repeated, and the companies and their owners that are indulging in "polluting" activities, must be extra cautious and avoid such environmental catastrophe at all costs. However, since the matter is of accident, the Government of Assam and the Government of India and the Hon'ble Courts have set up multiple Committees to examine and fix responsibility. Once the responsibilities are fixed, the following are suggested for actions:-

(a) All the responsible persons must be proceeded against under the Wildlife (Protection) Act, 1972.

(b) If such persons happen to be individuals, then their employers, including the principal employers and owners must ALSO be proceeded against.

(c) If within six months of submission of this Report, still no one is found guilty for whatsoever reasons, then the Chief Wildlife Warden, Assam, shall appoint an Inquiry Officer and thereafter, move a proceeding in the appropriate Court of Law at Tinsukia, through the DFO, Tinsukia Wildlife Division, and the DFO, Dibrugarh Division having jurisdiction in their respective territories to move issue of process against the management of M/S Oil India Ltd, and their owners i.e. the Ministry of Petroleum & Natural Gas.

(d) Adequate compensation, in addition to any other compensation and award that this Committee recommendation may make, as indicated in a subsequent Chapter shall be charged from the erring entities/owners as well as the persons responsible.

(e) It has been seen and observed with a lot of pain and that this ugly incident has demonstrated lack of good wildlife institutions in the region, good testing

facilities, computational power to simulate on the fly, have electronics set up to measure and assay, all parameters on the fly and store and use big data analytics to analyze and retrieve patterns and take corrective action before hand. Therefore, it is recommended to open an institute of wildlife health and research here and another computational R&D, Electronics test and simulation hub as a Centre of Excellence.

(f) The Laika and Dadhia villages must be relocated in order to make the habitat better. It is also recommended to acquire the Erasuti village (and relocate them elsewhere) and redraw the boundary of the Dibru-Saikhowa National Park to its original value of 650 sq km or higher, and link it with the proposed Poba Sanctuary on the north.

(g) There are encroachments (but now very old) on the north-eastern portion of the proposed sanctuary where the Pillar No. 1 starts and then along to Pillar No. 2 and 3. These areas must be acquired after paying adequate compensation and the entire Dibru-Saikhowa National Park should be consolidated for making it a better habitat.

(h) The Park is devoid of infrastructure and staff. All this must be upgraded to at least 5-6 times of the current size, or atleast 400 staff whichever is higher. Also there is a need to raise a company of river patrolling forest force from Dhola Sadiya bridge to Bogibeel and beyond.

(i) The Maguri Motapung beel must be restored to its original. The fishing communities should be provided alternative green livelihood options. The educated youth should be given adequate training, and all the emerging job opportunities in that area, especially in the wildlife must be provided to them, provided they decided to compete with the rest on equal terms.

(j) The tourist glory of the Maguri Motapung beel should be brought back. A Green Development package must be designed for implementation by the local youth.

(k) A total 511 number of uniquely identified species in various classes/ orders/ genera of animals were encountered during the assessment by all the groups that worked on the ecological assessment, against a recorded checklist of 1235 species, ***showing a loss of 55% of biodiversity after the blowout***.

CHAPTER-15

15 LOOKING AT MAN & BIOSPHERE

15.1 Introduction

We have seen so far the Chapters 6-7 about the flame and the fire, Chapter 8-11 about air pollution, noise pollution, thermal pollution and soil and water pollution, Chapter 12-14 about damages to ecosystems and biodiversity losses. This Chapter is about damages caused to the people in the surroundings of the blowout, and their effects and properties, and also impacts that they may have to bear in the long run due to the polluted environment that was created around them in Baghjan from 27th May to 15th November, 2020.

Though a detailed assessment is not possible; and already several departments have been doing their own assessments, the aim of this Chapter is two fold: firstly to assess briefly the degree and extent of human sufferings, and secondly, to suggest ways for long term monitoring. In the matter of compensation, already the Committee under Justice B. K. Katakey, Retired Judge of the Gauhati High Court has given recommendations and the Hon'ble National Green Tribunal (NGT) is pleased to pass certain orders. Before proceeding further, we shall briefly go through the various orders of the Hon'ble NGT and the Hon'ble Gauhati High Court.

15.2 The OA NO. 43/2020 & 44/2020 Before The Hon'ble NGT (EZ)

Two applications were filed by Siddhartha Mitra and Ranu Purohit in the Hon'ble National Green Tribunal (EZ) vide OA No. 43/22020 and OA No. 44/2020 respectively. The Hon'ble Tribunal was pleased to intervene in the matter of the Baghjan blowout and fire incident and vide order dt. 24th June, 2020, the Hon'ble Tribunal had constituted a Committee under the Chairmanship of Justice B. P. Katakey, Retired Judge of the Hon'ble Gauhati High Court. The Justice B.P. Katakey Committee submitted its interim report together with recommendations on the 24th July, 2020 and the Hon'ble Tribunal was pleased to pass certain orders on the 6th August, 2020.

Orders Dt. 6.8.2020: The Hon'ble NGT (EZ) was pleased to pass the following orders on the 6th August, 2020, "…. **18.** We have given due consideration to the objections. We are unable to accept the same at this stage for prima facie view and interim compensation.

The recommendations of the Committee on the subject of compensation for three categories of victims are accepted with the clarification that the compensation already paid will be taken into account and excluded from the interim compensation recommended by the Committee. Compensation to victims of categories (ii) and (iii) will be subject to identification by the District Administration which may be completed preferably within one month. We request the Assam State Legal Services Authority to oversee the process. **19**. We also accept the recommendation for interim compensation to the families who have moved out of the relief camps after the blowout of 27.05.2020 and to the families who have shifted to the relief camps after explosion on 09.06.2020. **20**. The disbursement may be made through the District Administration by deposit to the bank accounts of the affected families which may also be overseen by the State Legal Services Authority. **21**. The amount calculated and quantified by the District Magistrate may be made available by the OIL within two weeks of letter of the District Magistrate. **22**. Other interim recommendations may be complied to the extent there is no dispute, subject to call being taken by concerned statutory authorities and finally by this Tribunal on the next date. The Committee may give its final report before the next date by e-mail at judicial-ngt@gov.in preferably in the form of searchable PDF/OCR Support PDF and not in the form of Image PDF. A copy of this order be sent to Justice B.P. Katakey, former Judge of the Gauhati High Court, the Chief Secretary, Assam, MoEF&CC, Member Secretary, Assam State Legal Services Authority and District Magistrate, Tinsukia by e-mail. List again on 03.11.2020."

Proceedings on 03.11.2020: Justice B. P. Katakey, retired Judge of the Hon'ble Gauhati High Court and Chairman of the 8 member Committee appointed by the Hon'ble NGT, submitted another interim Report to the Hon'ble Tribunal. However, the matter had been listed for hearing on the 15th December, 2020, so did not come for hearing on the 3rd November, 2020.

15.2.1 DIRECTIONS OF THE HON'BLE SUPREME COURT OF INDIA

In the IA No. 3934 of 2016 in IA No. 3788 of 2014 in the matter of WPC 202/1995 in the Hon'ble Supreme Court of India filed by M/s Oil India Ltd. seeking directions of the Standing Committee of the NBWL to consider the proposal of extraction of oil and gas from deep wells beneath the Dibru-Saikhowa National Park in Assam, The CEC had submitted a Report to the Hon'ble Supreme Court on the 9th May, 2016.

The Hon'ble Supreme Court, vide its Order dated 07.09.2017 in T.N. Godavarman Vs. Union of India was pleased to relax the aforesaid prohibition in favour of OIL and

granted conditional approval to OIL to undertake the present extraction of hydrocarbons from the proposed wells including the Well Baghjan-5. As evident from the Order dated 07.09.2017, the relaxation granted by the Hon'ble Supreme Court necessitated compliance by OIL of the following conditions which included : (i) OIL will carry out a Bio-diversity Impact Assessment study through Assam State Biodiversity Board, for which budgetary offer have already been obtained on 12.05.2017. (ii) OIL will carry out subsidence study followed with taking mitigation measures, in order to ensure that there is no impact in the forest surface above the reservoir at height 3,900 to 4,000 m, due to extraction of hydrocarbon from the reservoirs. (iii) All mitigation measures will be in place in case of any eventuality causing oil spillage inside the Park such as – install Blow Out Preventer at well head and provide necessary valves in the production installations located outside the Park area. Standard Operating procedure (SOP), approved by the competent authority, pertaining to Oil Spillage, will be strictly adhered to. 56 (iv) Undertake schedule test and inspection of the area periodically in order to assess any abnormality in the surface area above the reservoir inside the Park. (v) OIL will also ensure strict compliance of the conditions stipulated in EIA Notification 2006 for both inside the Park areas as well as the ESZ area of it.

15.2.2 APPEAL NO. 8/2020/EZ WITH IA NO. 64/2020 IN THE HONBLE NGT (EZ)

The appeal is filed in the Hon'ble National Green Tribunal by Mridu Paban Phukan & Anr. –Vs- Union of India & Others. The appeal is filed challenging the Environmental Clearance accorded to M/S Oil India Limited for **Onshore Oil & Gas Development Drilling and Production from 16 wells and setting up 4 production installations and laying of gas pipeline in an area of 82 Ha in Mechaki Area covering Mechaki, Mechaki Extension, Baghjan and Tinsukia Extension PMLs in District Tinsukia, Assam,** under the provisions of the EIA Notification, 2006, and the amendments therein, subject to compliance of the terms and conditions as laid, vide MoEF & CC, Govt. of India's F. No. 1-11011/1260/2007-IA-II (I), dated 9th April, 2020. The petitioner has raised that the project in question is proposed to come up in a highly ecologically sensitive and fragile landscape. The Mechaki block is situated in close proximity to the Dibru-Saikhowa National Park, Maguri Motapung Wetland complex and is a part of Dihing Patkai Elephant Reserve which altogether harbor wide variety of species of Birds, Mammals, Herpetofauna etc. and flora. Many of these species belong to endangered category of animals/plant and a few of them are endemic to Assam. It is alleged that the EIA report submitted by M/S Oil India Limited is highly lacking and faulty. The EIA report specifically states that the risk due to "blowout" is negligible while attention is drawn by

the petitioner to the incident of blowout which took place in OIL Well No-5 on 27th May, 2020 and subsequent explosion on 09.06.2020 at Baghjan, Tinsukia and Well is still burning. The EIA reflects shoddy & erroneous risk assessment, improper noise impact assessment and no cumulative impact assessment etc. Attention is also drawn to the fact that more than 25 wells are planned and almost same number exist in this conservation complex (Dibru-Saikhowa National Park, Bherjan Borajan Padumani Wildlife Sanctuary, Important Bird Areas (IBA) Poba Reserve Forest, Kobo Chapori, Amarpur Chapori and Maguri-Motapung Wetland and Dihing Patkai Wildlife Sanctuary.

The Prayer:

1. Quash the impugned Environment Clearance letter dated 09.04.2020 granted to M/S Oil India Limited for onshore oil and gas development drilling and production in Mechaki area covering Mechaki, Mechaki Extension, Baghjan and Tinsukia Extension PMLs in Tinsukia district of Assam.

2. Direct that a Biodiversity Impact Assessment by the Assam State Biodiversity Board be conducted and the Report be placed before the public under the provisions of the Section 36 (4) of the Biological Diversity Act, 2002.

3. Direct that a comprehensive assessment be carried out of the present project along with all existing and planned drilling in the region as recommended by the Wildlife Institute of India with specific focus on Risk Assessment.

15.2.3 PIL No. 35/2020 in the Hon'ble Gauhati High Court

PIL No. 35/2020 was filed by Mrinmoy Khataniar & Anr vs Union of India & Ors in the Hon'ble Gauhati High Court pleading that the Dibru-Saikhowa is a National Park as well as a Biosphere Reserve, situated on the south bank of river Brahmaputra in the extreme east of Assam State of the country, and as per notification dated 14.09.2006 of the MoEF&CC, Government of India, prior environmental clearance and public consultation were mandatorily required for all offshore and onshore oil and gas exploration, development and production projects. However, by way of Environment Appraisal Committee recommendation dated 28.02.2017 under hearing/serial No.20.03.1 for onshore oil and gas development, drilling and production in Tinsukia and Dibrugarh districts under Hugrijan, Naharkatiya, Sapekhati & other parts of Upper Assam and under hearing/serial no. 20.6.17 for extension drilling & testing of Hydrocarbons at 7 locations under Dibru-Saikhowa, public hearing for the proposed projects by Oil India Ltd. was dispensed on extraneous grounds. Furthermore, vide impugned notification dated 16.01.2020 of the MoEF&CC, the Ministry has made an amendment to the EIA

notification dated 14.09.2006 by which all onshore and offshore oil and gas exploration have now been categorized as "B2 Project" from "A Project", thereby exempting public hearing and consultation for all offshore and onshore oil and gas exploration, development and production projects. By virtue of this petition legality and validity of the environmental clearance/approval dated 11.05.2020 granted by MoEFCC to M/s Oil India Limited for extension drilling and testing of hydrocarbons at 7 (seven) locations under Dibru-Saikhowa National Park (DSNP) area has been challenged.

Order Dt. 17.8.2020: The Hon'ble Gauhati High Court heard the matter on the 17th August, 2020 and passed orders as quoted herein, "…. **5**. Be that as it may, in view of the nature of issue raised, we hereby direct respondent Nos. 9 and 10 who are represented in Court to file parawise reply to the petition. **6**. Mr. P. N. Goswami, learned Standing Counsel, Forest Department who has put in appearance for respondent Nos. 4, 6 and 8 and Mr. S. C. Keyal, learned Assistant Solicitor General of India who would appear for respondent Nos.1 and 2 would also file replies on behalf of the said respondents. **7**. Let the affidavits be filed in the Registry by 21.09.2020. **8**. List on 30.09.2020, high up on the list".

Order Dt. 30.9.2020: On the 30th September, the Hon'ble Gauhati High Court was pleased to pass the following orders, quoted herein, "It is also made clear that at the time of filing of the affidavit the concerned respondents will also refer to the direction of the Hon'ble Supreme Court passed in Interlocutory Application No.3934 in Writ Petition (Civil) No.202/1995 on 07.09.2017 in which the following directions were issued by the Hon'ble Supreme Court:

"*In view of the above, the application is allowed. However, we make it clear that the Oil India Limited will also be bound by the undertaking dated 25.07.2017 as mentioned in the letter of Dr. R. Dasgupta, Executive Director (Corporate Affairs) for Chairman and Managing Director: (i) OIL will carry out Bio-diversity Impact Assessment study through Assam State Bio-diversity Board, for which budgetary offer have already been obtained on 12th May, 2017. (ii) OIL will carry out subsidence study followed with taking mitigation measures, in order to ensure that there is no impact in the forest surface above the reservoir at height 3,900 to 4,000 mtr, due to extraction of hydrocarbon from the reservoirs. (iii) All mitigation measures will be in place in case of any eventuality causing Oil Spillage inside the Park area such as-Install Blow Out Preventer at well head and provide necessary valves in the production installations located outside the Part area, Standard Operating Procedure (SOP), approved by the competent authority, pertaining to Oil Spillage, will be strictly adhered to. (iv) Undertake schedule test and inspection of the area periodically in order to asses any abnormality in the surface area*

above the reservoir inside the Park. (v) Oil will also ensure strict compliance of the conditions stipulated in EIA Notification, 2006 for both inside the Park areas as will as ESZ area of it."

As the respondent nos. 9 & 10 have already filed their affidavit, they will file additional affidavit with reference to the direction of the Hon'ble Supreme Court passed on 07.09.2017 referred to above. List the matter on 20.10.2020."

Order Dt. 20.10.2020: On the 20th October, 2020, the Hon'ble Gauhati High court was pleased to pass the following order in the matter, "*Mr. Goswami prays for 2(two) weeks' time to file affidavit. Since this Court had given sufficient time to the State respondent to file their affidavit, the above prayer is allowed on payment of 10,000/-. Prayer for passing interim order in terms of reliefs claimed under prayers (c) and (i) of this petition will be considered on the next date*"

Order Dt. 07.12.2020: On the 7th December, 2020, the Hon'ble Gauhati High Court was pleased to pass the following order in the matter:-"*However, the learned counsel for the petitioners has prayed that an interim order may be passed for suspending the operation of the environmental clearance issued by the Ministry of Environment, Forest and Climate Change (IA-II Section) issued on 11.05.2020 primarily on the ground that the said environmental clearance was issued in violation of the Hon'ble Supreme Court's order dated 07.09.2017 passed in Interlocutory Application no. 3934 in Writ Petition (Civil) no. 202/1995 (T.N. Godavarman Thirumulpad Vs. Union of India and Others).*

In the said order, the Hon'ble Supreme Court had made it specifically clear that Oil India Limited (OIL) will be bound by the undertaking given on 25.07.2017 under which the OIL will carry out Biodiversity Impact Assessment Study through Assam State Biodiversity Board for which budgetary offer had already obtained on 12.05.2017 for starting any drilling activity. It has been submitted that the aforesaid direction of the Hon'ble Supreme Court has not been carried out inasmuch as the OIL has not yet carried out the Biodiversity Impact Assessment Study through Assam State Biodiversity Board and as such, since the said environmental clearance was given by the Ministry of Environment contrary to direction of the Hon'ble Supreme Court it would create serious prejudice to the cause of environment.

It has been submitted at the Bar by the learned counsel for the respondent, Mr. Pathak, Standing counsel for the Forest Department that at the instance of the OIL, the Assam State Biodiversity Board is proceeding to make the impact assessment. If that is so, let them proceed with the aforesaid exercise. However, till such exercise is completed by the Assam State Biodiversity Board clearing any such activity, the Environmental Clearance issued on 11.05.2020 may not be given effect for Extension Drilling and Testing of Hydrocarbons at 7

(seven) locations by OIL under Dibru-Saikhowa National Park area, Tinsukia.

It has been submitted by the learned Senior standing counsel for the OIL that this is subject matter which the Hon'ble Supreme Court as well as NGT are also considering, which however, has been denied by the learned counsel for the petitioners. Accordingly, it is made clear that this interim order passed by us in this proceeding today will be subject to any order that may have been passed or may be passed by the Hon'ble Supreme Court or NGT as the case may be.

It is also made clear that our direction above regarding the environmental clearance dated 11.05.2020 that it will not be acted upon for the purpose of executing as mentioned above, however, will not come in the way of other purposes, viz., making assessment etc. in terms of law.

In view of the order passed in I.A.(Civil)/1905/2020, the Assam State Biodiversity Board, Aranya Bhawan, 2nd Floor, Panjabari, represented by its Member Secretary, is made party respondent no. 15 in this PIL.

Issue notice to respondent no. 15 returnable by 25.01.2021.

Petitioners are to take steps for service of notice upon the newly impleaded respondent no. 15 by registered post with A/D. Dasti is also permitted."

15.3 Committees On Baghjan Blowout Matter

The Hon'ble Chief Minister, Assam announced inquiry into the oil well blowout and subsequent fire incident in Baghjan, Tinsukia and entrusted Addl. Chief Secretary Manindra Singh IAS with the responsibility to conduct the enquiry and submit report within 15 days. The Chief Minister also directed Additional PCCF (Wildlife) & CWLW, Assam, M. K. Yadava IFS, to conduct a study on the effects of the explosion incident on the environment and ecology of the surrounding areas. He was directed to cover effect of the incident on flora and fauna along with different species living in the water bodies of the area in his study. Accordingly, two One Man Enquiry Committees were instituted vide Govt. of Assam Notification No. HMP-19/50/2020-POI(A)/4 dated 12-6-2020 and FRW.6/2020/1 dated 12-6-2020 respectively. In addition, the Principal Chief Conservator of Forests & Head of Forest Force (PCCF&HoFF) notified an Expert Committee under the Chairmanship of Sri M. K. Yadava IFS, Addl PCCF (Wildlife) & CWLW, Assam on the 2nd June, 2020. Further, the Ministry of Petroleum and Natural Gas, Got. Of India, New Delhi, has constituted a three-member committee comprising SCL Das, Directorate General of Hydrocarbons, BC Bora, former Chairman ONGC and TK

Sengupta, former Director, ONGC who have been asked to identify the lapses in following protocols and procedures which led to the accident. The committee will also recommend short and long-term measures to prevent the recurrence of such incidents including identification of any gaps in the existing standard operating procedures (SOPs). The Expert Committee notified by the PCCF & HoFF and headed by M. K. Yadava IFS, APCCF (Wildlife) & CWLW, Assam has compiled groupwise various reports on diverse matters of wildlife, biodiversity and forest assessment, and all these have been amalgamated into this Report of the One Man Enquiry Committee.

The Committee headed by Justice B. K. Katakey, Retired Judge of the Hon'ble Gauhati High Court was appointed by the Hon'ble National Green Tribunal on the 24th June, 2020. The Committee has already submitted two Interim Reports. The matter is sub-judice in the Hon'ble Tribunal.

15.4 Damages To Human Life And Property

As already outlined in the previous sections, the Hon'ble Gauhati High Court and the Hon'ble National Green Tribunal have been seized of the matter already, and several orders have been passed since the first order of the Hon'ble NGT (EZ) on the 24th June, 2020. The matter of compensation has also been covered extensively in the Reports of the Committee headed by Justice B. K. Katakey, retired Judge of the Hon'ble Gauhati High Court.

Therefore, this OMEC Report shall not focus on family wise compensations per se, and categories of people to be considered. Here, only a brief assessment would be provided from ecological point of view, as more details can only be obtained by house to house survey/ enumeration within 3-5 km radius of the blowout site. However, some assessment of damages to houses, trees etc. from an aerial view is possible in the areas where the drones were flown. It would still require some ground truthing and verification. This exercise has not been undertaken here.

15.5 Methodology

The human element and misery of the people was all over the place to see. Humans, being organic in nature by default, have been subjected to same travails and tribulations as the birds, snakes, reptiles, butterflies, odonates, molluscs and many other animals including the lesser mammals. The only difference was that man had the mechanism to escape somewhat in a better way, and secondly, body weight would surely matter in terms of harmful dosages of the oil spill. Nevertheless, three human lives were lost and another three suffered burn injuries. Therefore, there is an

ecological lookout to all this.

Some of the methodologies adopted to make a quick assessment of the nature and extent of damages are described here briefly.

15.5.1 Public Hearing

Public hearings were organized at the Circuit House, Tinsukia, and notices were published in the print media and electronic media. The news also spread through social media. Hearings were held on the 26th June, 2020, (Friday), thereafter, on the 27th, 28th, and 29th of June, 2020, for 4 days. Several groups came forward such as Society for Wildlife Conservation, Researchers from Tezpur University and Rajib Gandhi University, Tinsukia College, All Assam Gurkha Students Union, AJYCP, All Moran Students' Union, All Assam Matak Yuba Chatra Parishad, ATTSA, All Assam Students' Union, Baghjan Gaon Milajyoti Yuba Sangha, TMPK, Reporters, social workers etc.

In addition to the public hearing, at least two meetings were organized through the Deputy Commissioner, Tinsukia involving local organizations, especially the Baghjan Gaon Milanjyoti Yuba Sangha and All Moran Students' Union etc. Further, several NGOs and Research scholars working independently in the area, especially for conservation of the Maguri Motapung Beel, noted among them being Dr. Ranjan Kr. Das, Dr. Deborshee Gogoi, Niranta Gohain, Jainal Abedin, Jeevan Dutta, Binanda Hatikakati among others came forward with their stories of travail and suffering.

Appeal in the newspapers were also inserted asking people, researchers, and all concerned to submit their views by email to the OMEC. Several responses were received thereof.

15.5.2 Drone Based Assessment

The Drone based assessment and extensive photography of the 3 km radius area from the blow out was also carried out. The ortho-photography of the 3 km area has already carried been out and is ready for use for ground assessment, if required by the District Administration or any other authority.

15.5.3 Assessment from the Expert Committee Teams

The Expert Committee teams in groups visited the site, mingled with the people, and collected a lot of useful information, and feedback continues to come from the field.

15.5.4 Interaction with the Line Departments

Two to three rounds of meetings were held with the line departments in presence of the DC and SP Tinsukia. Several issues were thrashed out, and a common methodology was evolved for damage assessment in the field. However, most of these reports are still with the DC, Tinsukia, and not much could be made of these. The departments of major concern were Agriculture, Veterinary, Health & FW, Soil Conservation and Fisheries.

15.6 Assessment Of Man & Biosphere Damages

Here, a brief and possible impacts on man, agriculture and cattle would be discussed in a few paragraphs that follow.

15.6.1 Impact on Local Populace

Condensate Ingestion: The blowout's first and continuous subsequent impact, from 27th may, 2020 at 10.30 AM to 9th June, 2020 1.30 PM, was drenching people in nearby areas in a rain of condensate oil. The Drone assessment shows that the effective area was almost 3 km. However, due to winds blowing from north east to south west, the impact was more towards the south, and areas to the north towards the Dibru-Saikhowa NP were relatively safe from direct impact of the condensate. There are several stories of people drenched in the oil, and many people said that it was like an oil rain. People could wring their clothes and black oil would come out of their clothings that they were wearing. It was equally true of the journalists, researchers and others who rushed to the site to help and participate in the rescue operations.

Therefore, people within 3 km radius, and beyond, to the south of the well No. 5 were heavily exposed to the condensate oil, and might have ingested quantities ranging from large and small through skin.

Exposure to Heat: Furthermore, the heat exposure would have occurred since 9th June, 2020, from 1.30 PM onwards, in the nearby areas by way of change of temperature of air, water and soil. This would more be in the lines of discomfort for human beings than anything else. Of course, excessive heat could lead to dehydration and other ailments, as reported in literature.

Exposure to High Decibels Noise: The noise part has already been discussed in detail in the Chapter 9. So, here it would suffice to mention that there have been serious breach of the prescribed noise levels in the surrounding of the blowout, and many people would have suffered serious hearing disability.

Exposure to Ground Vibrations: The aspect of ground vibrations became very much

visible from the 9th itself, but most prominently from the 11th June, 2020, and was the surprise element of the whole fire episode. First reactions were that of earthquake, and then a series of them, and then everyday all the time. There has been visible signs of cracks in walls, ceiling and floors of houses. People could not stand still at times. There is no direct danger to human life, but it makes people giddy and other symptoms may follow. [*Investigation by several agencies proved that the fire had no link with the vibrations!!!*]

15.6.2 Impact on Livestock

The impact of cattle at the time of the blast and fire was that of utter confusion, loss of cattle etc. However, exact figures are yet to come in the hands of the undersigned. As explained in some details, though scattered over Chapters 13 & 14, the condensate and the PAH that came out of the well (as well as from the burning fire) were very harmful to livestock. The issues as we see are:-

Issue of No Postmortems: As a matter of caution, all livestock death must be subjected to post mortem to ascertain the presence of hydrocarbons and heavy metals. However, no postmortems are being done, as the village communities find it to be a lengthy process. Firstly, the people will have to inform the local police station in writing. Secondly, the Police will investigate the case. Thirdly, The police will send a report to the local veterinary doctor for postmortem. Fourthly, the local vet. doctor will then come to the spot. By the time they reach the spot, most of the organs would have got damaged. When the people directly inform the doctors for post mortem, veterinary doctors don't respond. They will only move to spot when they get an official report from Police. This is the condition and no cattle carcasses were subjected to any post mortem. This only implies that a lot of valuable data was already lost.

Visuals of Still Births: The biggest threat of the oil spill is still births, as anticipated by the members of the Expert Committee. The visuals[265] below speak for themselves. As one can see from these photographs, a large number of still births in domestic livestock was observed. Whatever has happened to the wildlife, it is most likely to be repeated with livestock too. The situation could become alarming in times to come, unless adequate steps are taken to monitor every single death and investigate scientifically with open mind. The actual percentage of all such cases needs to ascertained to understand the extent of the damage that may hit in future. Control sampling must also be carried out scientifically. However, unlike the wildlife, where post mortems are the

265 Photo credits: Diplab Chutia, collection and compilation: Teriang Rajib Rudra, 2020

norm, in case of livestock, there does not seem to be any such provision. The Deputy Commissioner need to enforce it by an executive order for at least three years that every death of livestock would have to be brought for post mortem and every still birth or abnormal birth would have to be reported. Unless such steps are taken forthwith, no remedial measures could be taken. This is a matter of serious concern. Some photographs have been shown in the next few pages here to highlight the issues.



Fig No. 15.1-1: Still Birth in Cattle



Fig No. 15.1-2: Still Birth in Cattle



Fig. No. 15.2-1: Dead Ducklings



Fig. No. 15.2-2: Dead Ducklings



Fig. No. 15.2-3: Dead Silk Worms



Fig. No. 15.2-4: Still Born Puppies



Fig. 15.3-1: Still Born Calf



Fig. No. 15.3-2: Another Dead Calf



Fig. No. 15.3-3: Another Dead Calf



Fig. No. 15.3-4: A Still Born Calf

15.6.3 Impact On Agriculture and Land Use

The oil spill and the explosion had ravaging effect on the nearby agricultural lands, wetlands, village ponds, and grasslands. These damages have already been described in the previous Chapters in some detail. The worrisome fact is that the blowout has started to impact flowering and fruiting of plants. If careful and transparent monitoring of such seemingly unnatural phenomena are not done, we may not be able to guess the damages that the disaster would cause in the long run. Honesty of purpose and transparency are very important here. It is about understanding the underlying causes and their effects, so that the future of the area and the affected populations (human and livestock) and agricultural crops can be treated well and steps could be taken to restore the damaged systems in scientific manner.

Here is a photograph that speaks for itself about the ecological impact of the oil spill on agricultural/ horticultural land use and cropping, and how it can continue to affect us in times to come in the blowout areas. The photograph shows shedding of flowers and fruits from trees before time.



Fig. No. 15.4: Premature Fruiting in Trees

Damage to Tea Gardens and Other Crops: There have been damages to tea gardens, home gardens, orchards, fruit and vegetable gardens and climbers. Some of these damages can be assessed using Drone pictures, while for others door to door visits are necessary. The leaves were found soaked in condensate oil. Several tea plants were seen with dead leaves. The soil must have been contaminated with oil and grease, heavy metals and PAH. Further, the soil needs to be treated, tea bushes need uprooting. Therefore, first an extensive testing is required of all such areas. The output crop must be very well tested against harmful chemicals. Consumption of contaminated food could cause cancer in the long run.

Common sense would say that if the crop is growing and a good harvest occurs, all is normal. However, in reality, unless the yield is very well tested in standard laboratories for contamination of chemicals and harmful substances, and proved fully that no such chemicals are found, the crop should not be considered fit for consumption.

15.6.4 Damages to Houses and Other Properties

The property damages can be categorized into three clear cut classes: 1. Fully burnt houses together with all possessions, 2. Partially burnt houses and possessions and 3. damages that were caused by the vibrations and ground motion. Fully burnt houses are well recorded by the drone and a comparison with corresponding high resolution Google images is able to establish the loss without any field visits. The case of partially burnt and houses damaged by ground vibrations needs field verification. An issue may come in case of fully and partially burnt houses as to the value of possessions that one might have had prior to the fire. These would have to be established indirectly.

15.7 Conclusions

1. The matter is sub-judice, so only limited suggestions can be given here.
2. The need of the hour is to assess scientifically the health status of the populations (in a research mode with a host of health aspects) to ascertain the risks that the exposed population faces, including high risk groups such as pregnant women, children and medically high risk persons.
3. High value health care policy must be provided to all living within 3-5 km of the blowout site. A Risk Zonation Map could be prepared once the fire is extinguished.
4. All livestock deaths must be subject to post mortem, and screened by way of laboratory tests of viscera and organs to ascertain if the animal was affected by the oil spill. All deaths must be reported. Post mortem should be made compulsory for all dead livestock in the area for next three years.
5. All affected soils must be tested prior to treatment. All water sources including ground water must also be tested for presence of Oil and Grease, PAH and Heavy Metals.
6. Research scholars must be engaged in association with the Agriculture/ Horticulture/ Soil conservation/ Fishery/ Veterinary Departments to carry out continuous monitoring and research and establish the extent of damages that might be on the cards, or would be visible in the future.
7. Compensations of the actual damages and loss of property must be paid as per the best possible norms [as people have suffered multiple agonies directly and indirectly, and not all sufferings can be converted to money values]

CHAPTER 16

16 BAGHJAN BLOWOUT BALANCE SHEET

16.1 Introduction

This is an extremely short Chapter dedicated to an accounting of the losses that could be counted (but not the losses that could not be counted or ascertained) on one hand, and on the other the capacity of the owners of the company M/s Oil India Ltd to pay. It is also to be noted that since issues of statutory clearances, procedures followed or not, those responsible for the lapses have now become matters sub-judice, it may not be appropriate to revisit the same and take a view separately in this Report. (*However, it is proposed to raise a few pertinent matters in the next Chapter*).

It must also be stated that not everything that was seen or one came across in the field could be counted or converted to economic value, so the assessment of the damages to the environment, loss of biodiversity, wildlife, forests and ecology has been qualitative and quantitative in nature. Some of the quantitative damages were also converted to money terms either by way of remediation or by way of directs costs. This Chapter is only in the spirit of adding up all that has already been estimated quantitatively and that which cannot be estimated quantitatively. Hence, named Baghjan Blowout Balance Sheet. The property of a balance sheet is that Dr and Cr side (left and right) are always equal. We shall see if, at all, both the sides can be balanced. How much can be the estimated value of the damages that can be counted, and how much can be paid by the owners of the company responsible for the ecological disaster has also been looked into this Chapter.

16.2 The Uncountable Damages

This section contains damages that were either estimated and no cost values were assigned to them, or those damages that were mentioned qualitatively and also no costs were assigned to them. We shall enumerate briefly the damages without going into so much of details.

16.2.1 Air Pollution

CO, NOx Emissions: As per estimations arrived at in this Report, CO emission was found to be 1.649 Millions Tonnes, NO to be 0.539 Million Tonnes and NO_2 to be 0.793 million tonnes.

SOOT: It was estimated that about ~78000 Kg of soot was produced. Most of the PAH would get to the soil from the soot that falls on the ground, and it may travel longer distances.

Breaches in Air Pollution Standards: There were breaches in the levels of NO_2, CO, PM_{10}, $PM_{2.5}$ as measured in the field.

16.2.2 Noise Pollution

Breaches in Noise Pollution: Breaches of the prescribed limits of noise pollution within 20-40 km of the blowout site with various breaches from crossing 75 dB within 700 meters, 55 dB within 5 km and 40 dB up to 40 Km radius (Silence zones).

Ground Vibrations & Tremors: The explosion on the 9th June, 2020 at 1.30 AM has been estimated at 3.9 magnitude of seismic tremor. The flame has been found capable of causing 0.013g to 0.13g vibrations in the ground causing damage to houses in the area. One needs to multiply these values 5 times to get the feel of the vibrations.

16.2.3 Heat Radiation and Thermal Pollution

Changes in Ambient Temperature: The assessment found that nights were warmer in summer with diurnal temperature gap reduced to less than 8^{0}C. Temperature of structures was found to be higher by 5-10^{0}C. Hot winds from the flame could raise the exposed body temperature of a person by 5.7^{0}C above the normal at distance 2-3 km away from the flame. In short, the microclimate has been heavily impacted by the continuously burning fire. Heat Island Effect was very much visible in water, soil and air in the vicinity of the blowout site. It is a case of heat pollution (but the same is not yet recognized legally). It's impact on ecosystem are damaging. One of the findings was that the continuous pumping of heat would have reduced the levels of photosynthesis in the plants, retarded plant growth, and created thermal stress in the trunks of the trees. Some of the more susceptible trees/ plants may die consequently. A continuous watch is needed.

16.2.4 Soil and Water Pollution

Water Pollution: Water temperature at places was found to be higher than 5^{0}C above the ambient temperature. This is a breach of the prescribed standards. Dissolved Oxygen (DO) levels dipped to below the prescribed limits. Insitu pH dropped to dangerously low levels beyond the prescribed limits. Pb and Cu were found in the water in amounts in qualities/concentrations that exceeded the prescribed limits. BOD and COD were found in violation of the prescribed limits. Oil and Grease were found in

concentrations which are not acceptable as per the prescribed standards for water. These are all breaches in concentrations above the statutory limits prescribed for various water quality parameters.

Impact on Soil Quality: The soil in the vicinity of the 3 km of the blowout site was polluted by an amount of estimated ~64000 kg of condensate. The ~78000 Kg of soot that got produced in the burning of the natural gas and condensate, would eventually settle down in a larger radius (more than 3 km) with falling rain, and enhance the concentrations of PAH in the entire area. PAH is a group of dangerous carcinogenic chemicals that can trigger still births, kill embryos, larvae and young ones of smaller animals. These could also get ingested directly by contact of skin or through contaminated food/ prey. Once in the food chain, it would be difficult to remove it, and may impact water body and land based ecosystems, agricultural fields etc adversely.

16.2.5 Damages and Loss of Biodiversity

Direct Count Loss: As per direct count by the various assessment groups, only 511 species were encountered against recorded (as per various checklist and previously published research) number of 1253 species of different organisms and animals, indicating a ***direct loss of 55% loss of biodiversity due to the Baghjan blowout***.

Impact on Scheduled Species: As counted/ evaluated on ground by various methods, in all, it was found that the blowout, explosion and fire impacted directly 40 listed scheduled animals in the Wildlife (Protection) Act, 1972 belonging to different classes/ orders, genera, families and species. Habitat of these animals was disturbed, destroyed, the young ones, larvae, eggs and nests damaged. This is a clear cut case of "hunting" under the Act.

Counted Dead Animals/Wildlife: The actual visual count of dead animals listed in the Schedules of the Wildlife (Protection) Act, 1972 was found to be 91, including 1 Gangetic River Dolphin and 2 Hoolock Gibbons (mother and baby). These are all cases of "***hunting***" under the Wildlife (Protection) Act, 1972. In addition to these deaths, there were counted deaths of 25,825 wildlife belonging to 41 genera/ families.

Devastated Ecosystems: Condensate oil spread to a large area of 13.85 sq km, of which 7.97 sq km got burnt almost fully, 1.02 sq km in the surroundings got burnt partially, Secondary affected areas spread to 13.75 sq km. Dibru-Saikhowa National Park got impacted to the extent of 12.07 sq km. Total wetland area of 16.32 sq km got affected, grassland area of 5.23 sq km, rivers/ streams 19.76 sq km and forest areas 2.13 sq km got impacted adversely. These figures do not include uncountable damages

caused by the overall sound and light pollution and impacts of heat radiation. Sound impacted the whole of the National Park and the BBP WLS. The Maguri Motapung Beel was directly the most impacted and devastated.

Alarm Signals: Some of the alarm signals found in the biodiversity assessment survey are listed (in the order they appear in Chapter 12 to 15):

1. A total 511 number of uniquely identified species in various classes/ orders/ genera of animals were encountered during the assessment by all the groups that worked on the ecological assessment, against a recorded checklist of 1235 species, ***showing a loss of 55% of biodiversity after the blowout***.
2. Almost 70% of the earthworms in the Maguri grasslands and condensate affected areas were estimated to be dead due to the blowout and fire.
3. Open Bill Stork population may be at risk due to high molluscs death in the areas.
4. Moths and butterflies have suffered heavily in the area due to constant deaths because of the flame. Moths and butterflies have been seen largely as singletons which is a cause of worry. Damage continued during the life of the flame.
5. Of odonates, damsel flies have suffered a beating. Lack of odonates can adversely impact butterfly populations. PAH concentrations and low DO affect adversely populations of fish fingerlings, tadpoles and other aquatic insects which are prey/ food of odonates. The damage continued during the life of the flame.
6. The Hepetofauna have been adversely impacted by the disaster, and continued to get impacted due to heat and sound levels during the life of the flame.
7. The Baghjan fire has been a death trap within 1 to 1.5 km of its radius for many animals.
8. Fish populations have been impacted by PAH, oil spill, low DO and low pH. There has been noticed a sizeable decline in the fish catch. Further, several of the rare and ornamental fish populations of Maguri are at risk. A detailed assessment of the ecological status of the Beel is required
9. Most bird species, in the assessment, have been seen in single counts only, other than 15-20 most common bird species. 53% of the bird species showed up only as singleton. Maguri Motapung beel and the Dibru-Saikhowa NP are unique bird habitats. Bird richness of the grasslands declined by 59%, and that of the

wetlands by 85%. Since there are many threatened, endangered, critically endangered and rare birds inhabiting these parts, a systematic study is immediately required to evaluate and work on a long term basis. Birds give miss to oil spill sites for more than 10 years even. A study is also needed, now that the fire has been extinguished, to create the first baseline post fire in order to evaluate the impact in the long run. This is the wintering time [November to March], and a baseline can be created now.

10. Post blowout, the Gangetic River Dolphin population has taken a hit. From an estimated population of 28-34 dolphins earlier, the current estimates point to not more than 4 dolphins. The underwater sound pollution has possibly impacted the dolphins adversely. Once again it is emphasized that, now that the fire has been extinguished, a hydrophonic survey of the dolphins in Sector I is very much needed.

11. It is confirmed from the reports that the lone dead Dolphin died because of ingesting organic chemicals and PAH.

12. The Hoolock Gibbons at Barekuri were adversely impacted by the oil spill. They refused to eat for atleast two days. One mother gave birth to a still born baby, and herself died after a gap of 25 days.

13. Most of the large mammals have clearly moved out the area, and a few trapped within a vicinity of 2-3 km could have ingested organic chemicals while grazing and drinking water. The animals include, possibly, Wild Buffalo, Barking Deer and Sambar.

14. The human population, in the vicinity of the blowout, was exposed very severely to the oil spill and the exposed persons are also at risk. There could be other health hazards due to excessive heat exposure and high decibel noise pollution as well.

15. The livestock also appears to be showing impact of PAH contamination, which is evident from large number of still births in all domestic animals as reported by the field survey teams.

16. The Oil spill seems to have affected the plant community, especially agricultural and horticultural crops, adversely. It has been reported that flowering and fruiting in several species have been impacted, as the new flowers appear to be falling off from the plants prematurely. Crop production may, eventually, decline.

17. The crop grown on contaminated soil may appear to be normal and healthy in appearance, but might be, internally, accumulating harmful chemicals. Such crop on consumption would pose a serious risk of cancer amongst the consuming population.

16.3 The Countable Damages

This section lists the damages which have been estimated and for which money value has been worked out by some mechanism of arriving at a cost price. These methods are subject to challenge by polluters and others who see more value in drop of oil than in the bounty of nature. Nevertheless, the previous section shows that the services rendered by nature are not market driven and cannot be procured at will or be substituted by another service. Market driven economy does not enough power to put a value tag on these services from nature. While certain principles of valuation of ecosystem services such as hedonic pricing and willingness to pay methods could have been used, somewhat obliquely though, Baghjan is a case of an ecological disaster and there are chances that, in an attempt to arrive at monetary valuations for all the losses, one may get stuck into nested assumptions and calculations, many of which would sound unrealistic. [*One may question, then why so many chapters were written on making all kinds of calculations on the fire? The answer is simple. Oil and gas are materials quite well characterized by their physical and chemical properties. Therefore, established principles and laws of physics, chemistry, mechanics etc. can be used to arrive at reasonable estimates of physio-chemical phenomena occurring out of burning of oil and gas. However, the case of ecological losses, on the contrary, is more complex, and may require a lot more relationships, laws and principles, experimental data and assumptions*] For example, cost of damages from PAH can be estimated in simple cases of humans and cattle:- one would have to assume that the probability of cancer is, say, 'x' per thousand due to exposure to PAH, and most likely, in a population 'P' exposed to PAH, 'Px' would get affected, and 'y' is the cost of treatment during lifetime of a cancer patient, then the estimation of damages on account of PAH contamination would be 'Pxy'. This is for humans, and for for the livestock- probably, cost of a new animal 'z', and 'n' number of animals likely to suffer from PAH related cancer to be replaced, and hence, the cost would be 'nz'. Therefore, total damages:- Pxy+nz. So far it works fine, but what about potential cancer threat to so many wild animals? What valuation we shall put as cost of cancer for a 'wild snake' or a 'wild migratory goose'? Therefore, as an afterthought, such methodologies of assessment were not pursued. Instead, the route of 'shadow pricing' was adopted, wherein, in the cost of one item, cost of other items for which price is not known, can be

subsumed. Therefore, it was decided to list a very limited number of "countable" damages which can be directly and rationally arrived at, and assume that the cost of the rest of damages have been paid for. Even these may sound absurd and imaginary for the hard core 'oil loyalists'. It is tragedy of our market economy that damages which are either not seen or of no direct and immediate consequence to us, are largely considered as purely "incidental" and hence, of little consequence. [*The 'Homo economicus' economic cycle is very ridiculous indeed:- First grow more food by artificial means by pumping more money into chemicals, more people get sick, and so more hospitals, more medical colleges, and more medicine factories, more GDP. This would make a lot more sense than a drive for growing clean uncontaminated food by more labour, more hard work, more people healthy, less people sick, less hospitals, less medicines, less GDP, less development.*]

An attempt has been made here to create a Balance Sheet from a few of the "countable" damages alone. To the critics of environment and 'oil loyalists', this may sound unrealistic. Nevertheless, it is time that we start thinking of evolving from *Homo economicus to* a true '***Homo ecologicus***', that's what our forefathers were in the long long past. The Balance Sheet is proposed here as a new instrument of arriving at ecological damages and costs that the pollutor may pay in an ecologically correct sense. If he is fully capable of paying, so be it, else it ought to be accounted for by other means.

The records here are shown in a tabular format with a Dr side total at the end. Let's call it Er (Environment Right) side.

Table No. 16.1: Balance Sheet- Right Side (Environment)

Baghjan Blowout Balance Sheet - Er – Environment (is) Right Side		
Dates (From To)	**Environmental services (Lost/ Cost)**	**Value (Er) in Crore INR**
27/5/20 - 9/8/20	Cost of fixing {CO_2 and CO_2 eqv CH_4 emissions- 14.92 MMT} @ US$ 66.60 per tonne (=Rs. 70 INR per US$)	8672.01
- Do -	Cost of energy {137 PJ that was wasted by way of burning, sufficient to light whole of Delhi for 1 year} @ Re. 1.00 per kWH value.	3800.00
- Do -	Cost of heat sink services availed from the tree canopy ecosystem {if one were able to erect a cooling system of such a magnitude) L.S. 350,000 Cr. [*Complementary*]	0.00

Baghjan Blowout Balance Sheet - Er – Environment (is) Right Side		
Dates (From To)	**Environmental services (Lost/ Cost)**	**Value (Er) in Crore INR**
- Do -	Environmental Services Cess {on the heat sink services availed} @ 1%	3500.00
10 Years	Loss of ecosystem services {due to fully damaged 1632 Ha of Tropical floodplain wetland} @ Rs. 40,47,039 per Ha per year for 10 years	6606.07
10 Years	Loss of ecosystem services {due to fully damaged 523 Ha of Tropical grassland } @ Rs. 6,56,645 per Ha per year for 10 years	343.43
5 Years	Loss of ecosystem services {due to partial damage to 1976 Ha of Tropical river/ stream systems} @ Rs. 19,72.141 per Ha per year for 5 years	1948.48
10 Years	Loss of ecosystem services {due to partially damaged 213 Ha of Tropical Forest ecosystem} @ Rs. 8,47,996 per Ha per year for 10 years	180.62
	TOTAL	**25050.61**

Now lets make the Polluter (is) Liable Side of the Balance Sheet. If all costs on the Er side cannot be met by the Polluter who is liable, we can treat it as environmental debt on the company and/or its owners, as the case may be[266].

Table No. 16.2: Balance Sheet-Liable Side (Polluter)

Baghjan Blowout Balance Sheet - Pl – Polluter (is) Liable Side		
Dates (From To)	**Environmental services (Lost/ Cost)**	**Value (Er) in Crore INR**
10 Years	Being Polluter's Liability towards the {Environmental damages at Baghjan} of Ministry of Petroleum & Natural Gas, Govt. of India, limited to 10% of 86.44% per annum of their annual central budget (being Rs. 272,116 cr for 2018-19) for a maximum period of 10 years	23526.00
10 Years	Being Polluter's Liability towards the {Environmental damages at Baghjan} of M/s Oil India Ltd, limited to 13.56% per	3512.00

266 It shall be proportional to the ownership patterns (x%) and be equal to x% of the Annual Profits After Tax for 10 Years (which is the maximum time assumed for recouping of the ecosystem services)

Baghjan Blowout Balance Sheet - Pl – Polluter (is) Liable Side		
Dates (From To)	**Environmental services (Lost/ Cost)**	**Value (Er) in Crore INR**
	annum of their profits after tax (being Rs. 2,590 cr for 2018-19) for a maximum period of 10 years	
	TOTAL	27038.00
	Less Er Side Charges **(**To be proportionally deducted from all, being surplus**)**	1987.39
10 Years	**Liability to be realized**	**25050.61**

16.3.1 The Carbon Balance Sheet

The formation of the balance sheet shows that the polluters are fully capable to meet all environmental costs out of their pockets in the proposed 10 years' restoration time that the ecosystems would need. However, there are possibility of trading the carbon. The current prices of carbon are US$ 250 per tonne in the developed world and US$175 in emerging economies. Therefore, a Carbon Balance Sheet is presented to see how much of the total damages can be offset by carbon trading. The total carbon being at stake is 14.94 Million Tonnes.

Table No. 16.3: Carbon Balance Sheet

Carbon Earnings		**Polluters' Liabilities**		**Profit/Loss**
Description	**Amount**	**Description**	**Amount**	
Carbon prices @ US$ 140[267] per tonne for 17.6 MMT [1 US$=74 INR]	18234.00	10 Yr Liabilities	25050.61	**-6816.61**

16.3.2 Net Annual Share of Liability

Therefore, the amount to be realized from the Polluters should not be less than Rs. 6800.00 cr. Or **Rs. 680 cr** per annum for 10 years from M/S OIL and their owner MoPNG (as indicated below). It has to be noted here that MoPNG and the other Government owned Oil PSUs own together a share of 86.44 % in OIL. As, the Government of India is the owner, it can be deduced that the MoPNG may be made liable upto 86.44% and for the rest, OIL may foot the bill from its own resources, which comes to 13.56%:-

267 After 20% discounting of the carbon prices suggested by BP (2020). Actual carbon prices in the market are much lower today. Please the section on carbon Prices at the end of this Chapter.

Table No. 16.4: Share of Liability among Owners of M/S OIL

Sl. No.	Name of Owner/ Company	% Shareholding in M/s OIL	Amount (Rs. Crore)
1.	MoPNG, Govt. of India	66.13	449.68
6.	MoPNG, Govt. of India, for other CPSUs	20.31	138.11
7.	M/s OIL (for the balance shares)	13.56	92.21
	TOTAL	**100**	**680**

Therefore, the share of the Government of India, comes to Rs. 587.79, say Rs. 588.00 cr per annum, and that for M/s OIL it comes to Rs. 92 cr per annum. However, it doe not mean that OIL has to pay all. The onus is squarely on the owner to pay all ecological dues, as he is fully capable of paying. It is only the 'capacity to pay' alone is judged in the paragraphs outlined above.

16.4 Royalties And Taxes Of The Govt. Of Assam

The blowout started on 27th May at 10.30 hours in the morning, and, technically, it has been assumed to continue, in this Report, till 13th September, 12 Noon time. This amounts to continuous uncontrollable blowout for 109 days and 1 hour 30 min, totalling to 9,423,000 s. Assuming a flow rate of 343.50 kg s^{-1}, and a density of 0.7710, the volume of gas that escaped unaccounted comes to 4198 MMSCUM. The royalty on the lost NG (4198 MMSCM) comes to Rs. 489 cr @ Rs. 42.50 cr. Per 365 MMSCM, and an additional cess and 14.5% VAT on the top of it. This must be paid by M/s Oil India Ltd. to the Govt. of Assam over maximum of 10 years.

16.5 Current Carbon Pricing Scenario In India And Elsewhere

The BP (2020) Report estimates the carbon prices at US$ 175.00 per tonne (and we have used these prices with ~20% discount to assess the actual amount that may be realized from the polluters). Nevertheless, an independent review of carbon prices through the Internet search was carried out. It reveals that currently the carbon prices hover around US$ 20.00 per tonne in USA, as can be seen from the figure below produced from the website of the Carbon Credit Capital[268]. This is almost less than 10% of what BP (2020) says regarding carbon prices in the developed countries (~US$ 250 per tonne) at 2018 prices.

268 Reed Shapiro, 2020, https://carboncreditcapital.com/value-of-carbon-market-update-2020/

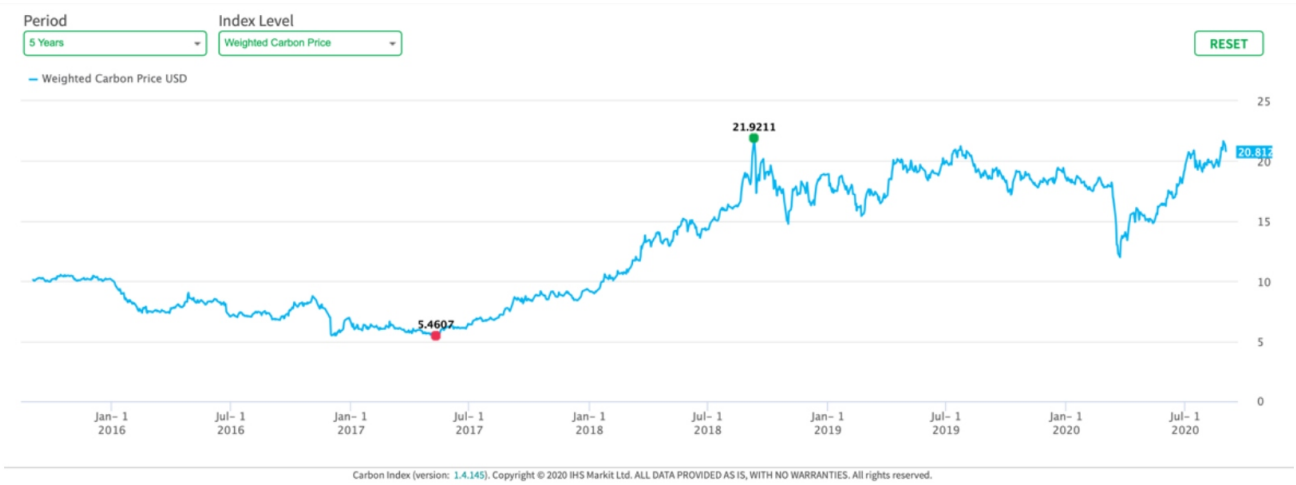


Fig. No. 16.1: 5 Year Weighted Carbon Price Index (in US$)

On the other hand, the Voluntary Carbon Market Report 2020[269], in short, FTA (2020), reveals that the average carbon prices per tonne were about 4.3 US$ for forestry and land use projects. While these prices are much higher than those for other types of carbon routes such as renewable energy and transport, the overall transactions are higher in case of renewable energy. The figure produced below from FTA (2020) shows the current carbon prices for various sectors in per tonne basis, as well as the carbon volumes associated with the sectors:-

	VOLUME $MtCO_2e$	AVERAGE PRICE	VALUE
RENEWABLE ENERGY	42.4	$1.4	$60.1 M
FORESTRY AND LAND USE	36.7	$4.3	$159.1 M
WASTE DISPOSAL	7.3	$2.5	$18.0 M
HOUSEHOLD DEVICES	6.4	$3.8	$24.8 M
CHEMICAL PROCESSES / INDUSTRIAL MANUFACTURING	4.1	$1.9	$7.7 M
ENERGY EFFICIENCY / FUEL SWITCHING	3.1	$3.9	$11.9 M
TRANSPORTATION	0.4	$1.7	$0.7 M

Fig. No. 16.2: Carbon Prices and Volumes in various Sectors of the Economy

However, there are two important takes from the FTA (2020). Firstly, it says that "*Carbon markets that have historically been used to finance renewable energy development because*

269 FTA, 2020, Forest Trends' Ecosystem Marketplace, Voluntary Carbon and the Post-Pandemic Recovery. State of Voluntary Carbon Markets Report, Special Climate Week NYC 2020 Installment. Washington DC: Forest Trends Association, 21 September 2020.

the technology was more expensive than traditional energy sources and couldn't be implemented without carbon finance. This, however, is changing as renewable energy becomes more affordable, which means carbon finance is only needed to implement certain types of projects in some countries. As a result, carbon standards are phasing out their recognition of offsets generated through the provision of renewable energy." Secondly, the Report hopes that demand for voluntary carbon offsets must grow to prevent disaster of climate change and states further that "*The United Nations Environment Programme's 2019 Emissions Gap Report showed that even if all countries meet their current climate action plans (NDCs, for "nationally-determined contributions"), greenhouse gas emissions will remain a staggering 32 billion metric tons (GtCO2e) higher in 2030 than they need to be in order to meet the Paris Agreement's 1.5°C target. To meet that goal, companies must not only slash their greenhouse-gas emissions but offset any emissions they cannot eliminate and actively support activities that remove carbon from the atmosphere. Several scientific bodies and environmental NGOs are now calling for companies to follow the lead of groups like Google, which used offsets to become carbon negative, or Danone and Nestlé, which aim to become carbon negative through better land-management practices blended with offsetting*".

16.6 Is The Ecological Damage Estimation Unrealistic?

As already stated in this Chapter itself, damages have been categorized in two categories- Uncountable and Countable. The countable damages arising out of only two parameters- **firstly**, cost of carbon capture and **secondly**, loss of ecosystem services, alone stand at Rs. 25,000 crore, which also acts as shadow price[270] for the unaccountable damages. The concept of carbon credits have been brought with a three fold objective, **firstly**, if the prices realistically climb to 140 US$, in future, then, huge amount of resources would flow in and to that extent, the pressure on the public exchequer [MoPNG and OIL, being Government and Government entity] gets reduced; **secondly**, the Baghjan blowout disaster was a major contributor of CO_2 atmospheric pool by adding > 17.6 Mt of CO_2. Therefore, its mitigation must largely be looked from carbon angle. Thirdly, we do not want M/S OIL to die. Thus, this would definitely not be the first major compensation package for environment in the country. Karnataka tops with Rs. 25,000 crore for mine reclamation[271].

270 Shadow Price is an "artificial" price assigned to a non-priced item

271 https://timesofindia.indiatimes.com/city/bengaluru/rs-25k-cr-lying-idle-under-mining-rehab-project/articleshow/72698168.cms

16.7 Conclusion

1. Barring all the complementary services that the ecosystems offer (for example the cost of service to absorb all the heat radiated from the flame comes to Rs. 350,000 cr), the loss and damages to the ecosystem, to the extent that it was scientifically possible to account for, it is estimated that the damages to the environment come to ~Rs. 25,000 cr. The maximum restoration period was taken as 10 years.
2. The polluters/ owners' capacity to pay was also measured, and based on the assumed principles adopted for the payments of the environmental liability, it is seen that the polluters can pay upto 27,000.00 cr.
3. It was estimated that possible carbon earnings could be 18234 cr.
4. After offsetting the carbon earnings, net deficit that remains is Rs. 6800 cr. to be paid by the Polluters over a period of 10 years. The per annum amount comes to Rs. 680 cr.
5. When apportioned with % shareholdings of the owners, it is seen that the share of annual environmental liability comes to Rs. 588 cr. on MoPNG and Rs. 92 cr. On M/s OIL
6. The Govt. of Assam's due on royalty on lost production of 4198 MMSCM of NG comes to Rs. 489 cr with additional cess and 14.5% VAT on the royalty.



A Snake Trapped in the Oil Spill [Photo: Merin Jacob]



A Moth Trapped in the Oil Spill

CHAPTER 17

17 ITI VARTAH

17.1 The End Word

This is the last Chapter of the Report and has been christened as "Iti Vartah" which in Sanskrit means "It is the Message or the End of the Message". The English "*it is*" sounds very close to Sanskrit "*iti*".

This Chapter consists of 3 sections, namely **1**. What are the faults and learning, **2**. Conclusions and Recommendations, and **3**. Budget of proposed activities for a period of 10 years. Even at the cost of repeating, it must be emphasized here once again that Baghjan Blowout is a grim tragedy, and probably there is no second disaster that comes to mind, other than the Bhopal Phosgene Gas Leak Tragedy. While Bhopal gas tragedy was a grim human tragedy unfolding in the aftermath of the gas leak at Bhopal in December, 1984, Baghjan is an ecological disaster unfolding in the aftermath of the Baghjan blowout on 27th May, 2020. The assessment point out that there is a loss of about 55% of the biodiversity in the Dibru-Saikhowa landscape. It is time that, as a country, when we relook at our development priorities, institutions and instruments that have been created to safeguard the environment. These seriously need a revisit. While every attempt has been made to present almost all aspects of the Blowout and the disaster that followed, it may still appear to be wanting in several details due to constraint of time and resources. The "*Vartah*" or the messages are scattered all over right from Chapter 1 to Chapter 16. Little attempt has been made to gather all of them here to keep the readability of the Report optimum. It is assumed that these would be read on "as is where is basis", and appropriate attention by the authorities and decision making bodies may be taken if deemed fit and proper.

This One Man Enquiry Committee (OMEC) has no power of awarding any compensation, but only power of assessment and recommendations thereof. Whatever has been presented in the Chapter 16 is only by way of scientific inferences and logical deduction. It is strongly felt that it is time to come out of "*Compensation*" manner of looking at ecological disasters, as it is not in our powers to create "nature", we can only try to conserve and preserve it by keeping our human greed on the back burner and strive to give a future which should not be worse than what we have lived in our past. The Law of Entropy is supreme, and it is in nature of things to disintegrate and recombine in some new form ["*…. sambhawami mi yuge yuge*"- *Bhagwat Gita Chapter 4,*

Verse 8]. The manner of looking at disasters such as Baghjan from the eyes of compensation not only demeans human dignity, it very much demeans the dignity of nature, the very Mother Earth, the Supreme Mother of all beings. Therefore, this Report has made an attempt from the very beginning to understand the inner processes rather than a superfluous stock taking. The work has just begun. This Report is just a beginning and at the very start point. More assessments, with attempts at precise measurements, would be needed, hereafter. In India, largely, it is seen that biodiversity assessment, is mostly confined to checklists of flora and fauna [*and invariably, most of it are lifted from the existing Working Plans or Wildlife Management Plans*]. Realistic assessment of ecosystems, the services offered by the ecological entities and the floral and faunal communities, their interrelationships and interdependence in locality of the study area remains an aspiration. It may be inferred that precious little has been achieved by superficial assessments of biodiversity. A complete change of methodology in this respect is called for.

17.2 Faults And Learnings

This Report is not so much about fault finding. Nevertheless, several faults have been pointed out in the environmental clearance issued the drilling project at the blast site in Baghjan. A few of the apparent "omissions" and "commissions" has been dwelt upon in the paragraphs to follow. No judgment is passed- it is the domain of the Hon'ble Courts and Tribunal who may be pleased to pass orders and levy penalties on those found guilty, as deemed fit, for these faults.

17.2.1 The Issue of the Faulty EC

The Environmental Clearance issued by the MoEF&CC to M/s Oil India Ltd vide Letter F. No. J-11011/1255/2007- IA II (I) Dt. 01.11. 2011 in the matter of "Drilling of Development Well (26 Nos.) and Exploratory Well (15 Nos.) at N. Hapjan-Tinsukia-Dhola Area in District Tinsukia Assam by M/s Oil India Limited – Environmental Clearance" in response to the letter of M/s OIL No. DRLG/DS/A.19-192/10 dated 28th December, 2010, mysteriously states that "*Borajan reserve forest (RF), Bherjan RF, Padumani RF, Dibru RF, Upper Dihing (west) RF complex including Lakhipathar RF are located within 10 Km. No national park/wildlife sanctuary/eco-sensitive area are located within 10 km.*".

It appears that the Ministry (MoEF&CC), somehow, seems to have overlooked the existence of the Bherjan Borajan Podumoni Wildlife Sanctuary (BBPWLS) declared in 1999 by the Govt. of Assam vide Notification No. FRW-47/99/66 Dt. 13th October, 1999. The Ministry has, by some providence, has missed the knowledge of existence of the

Dibru-Saikhowa National Park declared in 1999 by the Govt. of Assam vide Notification No. FRW.21/90/171 Dt. 5th March, 1999. The Ministry also seems to have forgotten its own MoEF&CC Notification No. J-22016/17/94-BR Dt. 28th July, 1997 addressed to the Chief Secretary, Assam, declaring the Dibru-Saikhowa area as a Biosphere Reserve.

While the EIA Report [EIA-GU (2009)] clearly mentions on Page 104 and 116 that there exists a National Park and a Wildlife Sanctuary in the immediate vicinity of the Project, neither M/s OIL nor the MoEF&CC have the knowledge of it. It is also not known whether any amendments were subsequently issued to the EC Dt. 1/11/2011. ***If not, then, the MoEF&CC may be burdened with a heavy penalty, and the fund added to the Balance Sheet proposed in the last Chapter, without upsetting the balance already arrived at.***

Communication from the Wildlife Wing, Assam: In response to the Govt of India in MoEFCC communication vide their Letter No. J-11011/682/2008-IA II(I) Dt. 17th November, 2008 and M/S OIL Letter No. PDNG:27/14(Env Cl)-307/10 Dt. 11th May, 2010, the then PCCF (Wildlife), Assam replied vide his Letter No. WL/FG.35/Nodal Proposal/OIL Dt. 18th June, 2010, mentioning clearly which National Parks and Wildlife Sanctuaries fell within 10 km of which of the proposed sites of OIL, wherein the word "Baghjan" appears 3 (three) times. Therefore, to find that EC issued by the MoEF&CC clearly mentions that there is no National Park and Sanctuary within 10 km of the proposed project site is beyond comprehension.

It is clear that since the proposed OIL site did not fall on any forest land, and was not obviously within "10 km" of any National Park and Wildlife Sanctuary, M/S OIL got a wide berth vide the faulty EC issued by the MoEF&CC on 1st November, 2011.

17.2.2 THE ISSUE OF FAULTY EIAS

The Environmental Impact Assessment documents produced by M/s OIL were studied from various aspects during compilation of this Report. The surprise elements were that in some respects, the EIA reports' messages were loud and clear that certain emission levels were approaching limits of breach, as per the prescribed statutory levels, and no attempt was made to simulate the case and find out if additional emissions would aid to the existing emission levels; and how to mitigate the emerging scenario. If this was done, probably, M/s OIL would have been allowed a lesser number of wells. It appears that the Expert Appraisal Committee has totally overlooked the subject. The EIA-ERM (2019) clearly showed already breached noise levels, but no one took note of it- neither the EIA authors/experts, nor the OIL authorities and, nor the EAC members. These

examples, and many more quoted in the Report in the previous chapters, clearly show that the EIA documents are ***mere formalities*** to be met by the user agencies to which is not meant for any indepth study, and neither the user agency nor the Regulator are in anyway appear to decipher the possible impacts of the proposed project on the environment in light of the findings of the EIA. It would be not an exaggeration to say that in the instant case, the EIA reports did not serve any purpose fit for grant of Environmental Clearance by the MoEF&CC. The irony is that just like the Biodiversity assessment reports (which are mere checklists and copy paste affairs of the local area Working Plans or Wildlife Management Plans), the EIA reports are also very heavily relied upon by all authorities, the Courts of Law and the Tribunals, without often suspecting, in the least, that such documents would have been produced so unprofessionally that they would hardly serve any purpose of environmental safeguards.

The EIAs were found very much "***mundane***" and "***run of the mill***" for a project of such a grave import for the Environment. With such a low quality content with nearly nil research inputs or little simulations of possible threats, the project evaluation can be at best considered next to nothing. The MoEF&CC and the Expert Appraisal Committee may rethink and abandon the present "***BAU***" principles of EIA and project evaluation of such sensitive projects; and may proactive by incorporate new ideas. By continuing on the mundane principles, we are only keeping the innocent people vulnerable and exposing the environment, biodiversity and ecosystems of the country to a great risk.

17.2.3 A Case of Discharge of Untreated Effluents

It may be noted that at the time of blowout and subsequent fire, 4 to 8 numbers of fire tenders and HVLRs were placed to throw water jets onto the emerging fluid during the blowout period from the well, and later at the flame. This continued from 27th May, 2020 to 15th November, 2020 for almost 172 days with occasional breaks in between. During the blowout period, the water mingled well with the blowout fluid including condensate. The waters were used to cool the blowout on 24x7 basis from 27th May, 2020 to 9th June, 2020 prior to the point of explosion. The water mixed well with condensate and was allowed to flow untreated and get discharged into the river Dibru. There was no provision made to treat the waters. Thus, the washed water would have contained high amount of condensate. Similarly, during the fire, the water was often used to keep the temperatures cool and not allow the fire to spread. Whenever water jets were sprayed on to the fire, it led to cut in the supply of oxygen to the fire, and the combustion would happen under insufficient oxygen, leading to formation of excessive

soot. As already discussed in the Chapter 7, high load of soot would imply higher amounts of PAH. All the soot together with PAH would have fallen to the ground and washed away with water into the nearest exposed soil, water bodies and river Dibru. As a part of the long term disaster and industrial accident preparedness in dealing with hazardous substances like crude oil and natural gas, there was little sign of any mechanism of treating such "effluent" water and its safe discharge. It has to be noted that all tests indicated high degree of petroleum products. Tests by ERM for two sets of water from the surrounding of the blowout indicated Oil/Grease to the extent of >43,000 mg/l, >48,000 mg/l, and TPH to the extent of 160,000 mg/l. The O/G in the drain at 200m away from the blowout site was found to be 38,610 mg/l. In the 2nd set of tests PAH was found to be varying from 0.12 to 0.67 mg/l. The PAH values at Dangori river and at the confluence of Dangori and Dibru were 0.16 and 0.12 mg/l respectively. At Guijan Ghat it was found to be 0.21 and 0.34 mg/l. The Dibru and Dangori rivers are Class A water bodies, and hence such high levels of PAH discharge are unwarranted. In one test, DO reported was 3.6. These tests were done from 1st to 9th June, 2020 on various dates. Therefore, it is a clear indication that no due diligence was done from disaster management point of view to handle such waste water in a blowout/ fire emergency situation. This points to a high degree of failure in emergency planning on part of the OIL authorities and their owners. On top of this, the oil authorities, as per the order Dt. 6th August, 2020 of the Hon'ble NGT, pleaded innocence by stating that "*Contribution of Polycyclic Aromatic Hydrocarbons (PAH) is from tea gardens, forest land and insecticides/pesticides*" and with regard to environmental impact, they stated that *"damage is on account of agricultural activities or other reasons in the area*". [Para 15, line 12 of the Order]

17.2.4 A Case of Mining Outside the EC Areas

As already depicted in Fig. NO. 4.3A (in Chapter 4 under Para 4.4), it is seen that the wells BGN#25, BNG#26 & BGN#27 which are all development wells and producing, fall outside the bounding rectangle defined by the EC of MoEF&CC Dt. 1st November, 2011, and hence, legally cannot be said to have any prior environmental clearance of the Govt. of India in MoEF&CC. Drilling and production from these three wells (of the only 29 wells for which coordinates were provided by OIL). The matter, however, was further not examined if more wells out of the 26+15 wells fell inside or outside of the EC specified geographic limits. One is good enough an evidence, and here there are three cases of direct violation of the EC granted to OIL. The reply to this by OIL was in respect of the three wells falling outside the EC was, "*Altough BGN#25 plinth is marginally outside*

the boundary of EC, however, it is within the Baghjan PML boundary. OIL has already applied for new EC for additional well. The BGN#25, BGN#26 & BGN#27 will be within the boundary limit proposed EC. The TOR for new EC was applied on dated 12.11.2016. As per TOR conditions the EIA study has been carried out and public consultation has also been done on dated 12.03.2020." Therefore, it is clear that the Wells BGN#25, 26 & 27 have been operating without any "**prior**" Environmental Clearance in stark violation of the Notification No. S.O. 1533(E) Dt. 14th September, 2006.

17.2.5 Whether Public Hearing Clause was Rightfully Exempted?

The EC Dt. 1st November, 2011 granted by the MoEF&CC, New Delhi to OIL, in Para 6.0, exempted public hearing, despite the fact that all drilling and explorations are **Category A** projects, and public hearing is not exempt except under the provisions of Clause No. 7(i) III (I) a to f of the Notification No. S.O. 1533(E) Dt. 14th September, 2006. Drilling and oil exploration do not fall within any of the exempted categories a to f. Therefore, there does seem to be any apparent ground for granting such an exemption.

17.2.6 Violation of Forest (Conservation) Act, 1980

As already stated in Para 4.4 and 5.8.4, and also observation made by CAG (See Sl. 17 of Para 4.8.3), there does not seem to be any clearance under the Forest (Conservation) Act, 1980, despite the fact that the lease areas, including all PML of OIL in these parts, fall substantially within the reserved forests and protected area networks of the Upper Assam. The case in point is directly the EC Dt. 1st November, 2011 which falls partly in the Dibru-Saikhowa National Park as well as the BBP WLS, wherein no FCA clearance has been obtained mainly on the ground that the site on which the wells are located fall on revenue land, irrespective of the areas whether located in forests or not. MoEF&CC and MoPNG need to examine this issue more closely, as apparently, both the lease as well as the EC are in violation of the Forest (Conservation) Act, 1980 and the Orders Dt. 12.12.1996 of the Hon'ble Supreme Court of India in WPC 202/1995.

17.2.7 Lack of Monitoring by MoPNG, DGH and DG Mines Safety

While the MoPNG is the owner of OIL and the administrative Ministry for the PSU, there are also other bodies such as the DG, Hydrocarbons (DGH), who among many roles that he has, advises the MoPNG on Exploration Strategies & Production Policies, to provide technical advise to the Ministry on issues relevant to the exploration and optimal exploitation of hydrocarbons in the country. The role of DG, Mines Safety appears primarily to be safety of "workmen" at the mines. Therefore, it is not clear as to who has

the mandate in MoPNG to handle accidents related to oil wells (as we have already seen in the case of USA in Chapter 4 and 5). This appears to be a gray area.

The question, therefore, becomes pertinent whether can M/s OIL, MoPNG, DGH, and DG Mines Safety possibly explain why the nature of accident that the Baghjan blowout was, does not find any mention in any of the EIA or Risk Assessment documents? Why we still do not know that a fire like Baghjan can not only damage ecosystems within 0-3 km totally, but also can produce 160 dB of deafening sound, can create tremors and vibrations that can shake houses several kilometers away? Why none of these reports mention possibility of a 100+m flame, and that more than 300 kg fluid flow per second in a blowout well? Can these authorities claim that atleast some of these and more parameters, as mentioned in this Report, were predicted by the oil experts, or explicitly mentioned in the EIA and Risk Assessment documents?

Hence, this assessment of damages worth Rs. 6800 cr on OIL and MoPNG is inconsequential and little compared to the ecological disaster that was unfolded by carelessness of these agencies, more so, they could, probably, never had any clue of any such event of this scale unfolding ever. This is the saddest part of all- working with hazardous substances in complete ignorance of possible accidents and scale of their impact [*my apologies to these institutions of the Govt. of India. No offence meant]*. These institutions need to understand that ecology is very fragile and sensitive as compared to oil drilling, and the lesson to be learnt from Baghjan is, not that the Oil authorities could not bring the blowout/fire under control before 109 days, but rather why the Oil engineers and experts failed to foresee such an ecological disaster could unfold wiping out almost 55% of the biodiversity. BoP mishandling and malfunctioning are just issues of engineering details, but failing to understand the phenomenon once the blowout occurred, speaks volumes about our lack of understanding of all the related phenomena on part of the MoPNG and their various agencies and bodies. I see this as a complete failure of the MoPNG, DGH, DG Mines Safety and Oil authorities- they do not appear to be going the extra mile on oil accidents, maintaining accident details in public domain, undertaking research on accidents and their prevention, scenario predictions, safety and ecological concerns.

17.2.8 Lack of Monitoring and Assays by PCBA

The PCBA should have been the pioneering Regulator to have acted proactively in the field of environmental monitoring. The institution appears to lack currently the capacity to handle such an ecological disaster. They did not have the means to carry out a

detailed systematic sampling around the blowout site. The PCBA should have gone through the EIA Reports, and provided their critical comments, and even cross-checked the data provided therein. This assessment Report would have been much better had PCBA had the capacity to conduct detailed surveys/ assessment. The PCBA needs to be strengthened 100 times than what it is today. One cannot leave the fate of our Environment on such poorly equipped and poorly financed institutions.

The root cause is also, probably, in my humble opinion, poor financial standing of the MoEF&CC. Compare the MoEF&CC budget of Rs. 3,000 crore with that of Rs. 27,000 crore of MoPNG (without counting the Rs. 100,000 cr of IEBR). The financial standing of the Regulator (MoEF&CC) is so low compared to the pollutor (MoPNG), that the Regulator is in no position to have updated and sophisticated systems to keep sharp eyes on the Pollutor. Therefore, how does one expect that MoEF&CC could actually monitor the vast ecological resources of the country. One can imagine that MoeF&CC is vested with responsibility to keep safe and secure so vast an ecological resource, that a damage of only a few sq km would surpass the whole budget of MoPNG for a year. There is a very strong case for financial empowering of MoEF&CC. ***Why not the MoEF&CC be empowered with thrice as big an annual budget as MoPNG***? Unless the protectors of the ecosystems, ecology, biodiversity, forests and wildlife have complete financial independence and financial muscle to protect the "voiceless", those that cannot "vote", and those who do not count in the "economy", their protection against such polluters as MoPNG and other agencies cannot be ensured. The Government of India, as such, needs to rethink its budgetary priorities for ecosystems and ecology. From ecological perspective, the Government can be divided into three color categories:- 'Red': those that pollute, 'Green': those that mitigate pollution and 'White': those that are neutral. MoPNG is clearly a 'red' Ministry, and MoEF&CC a 'green' ministry. Actually, the 'red' ministries must pay an annual green tax to the MoEF&CC in order that the MoEF&CC can ensure sustained supply of the ecosystem services for the nation and the world.

17.2.9 Lack of Monitoring by Mines and Mineral Department, Assam

It has to be noted that officially all oil leases are signed between the oil companies and the Government of Assam through the Department of Mines and Minerals. However, the Department does not seem to be fully aware about its roles and responsibilities. In the light of the CAG Report, 2017, already discussed in the Chapter 4, the following suggestions are made:-

1. It is quite relevant that Mines & Minerals Department, Govt. of Assam has failed in monitoring, auditing and ground inspection of all the petroleum license holders' oil Baghjan field.
2. Mines & Minerals department, Government of Assam should prepare a road map in order to stop the illegal mining activities Section 23 of the Mines and Minerals Development and Regulation Act, 1957 empowered the State Govt. to frame rules for preventing all illegal mining transportation and storage of minerals.
3. The Department did not have a vigilance enforcement and inspection mechanism for conducting search, seizure and detecting fraud, evasion and preventing illegal mining.

17.2.10 RETHINKING NEEDED ON PLI ACT, 1991

There is a multiplicity of agencies and Regulators in the matters of industrial accidents, disasters. However, the focus is always amiss on ecological part of disasters. Industries having dealing with hazardous materials in large quantities, especially crude oil and natural gas with possibilities of large pool fires, jet fires, blow outs and oil spills. The PLI Act somehow does not seem to be able to cover such scale of disasters of which the Baghjan blowout is an instance. May be that it would be better to have a more comprehensive legislation that can provide the much needed and timely umbrella coverage to affected people and ecosystems.

17.2.11 ENVIRONMENT RELIEF FUND

As per the independent report of Sinha D (2020), the ERF is in a real mess. Furthermore, it (including the mother Act, PLIA,1991) does not meet the aspirations of a large scale industrial disaster which has not only human angle, but also wide ecological ramifications. Firstly, it is a "tied" fund in the sense that if there was a general ecological disaster not connected with any industry not subscribing to the PLIA, 1991, or otherwise, no relief can be sought under the Fund. The entitlement amounts are also so meagre that one is bound to look outside for financial support to reach out to the affected populations and the ecosystems. Meanwhile, the MoEF&CC, may streamline the ERF itself in the first place, else it raises doubts on the sincerity of the regulators' willingness to make things easy for the affected people.

17.2.12 FAULTY RESPONSE TO AN ECOLOGICAL DISASTER

The efforts in the Baghjan disaster were only targeted to "***Fire Fighting***", a great opportunity was missed to understand the underlying causes, their possible impacts and ramifications on various aspects of ecosystems, impacts on people and their properties. It appeared as if all evidences of damages must be erased as quickly as possible, else "***Compensation***" amounts would go higher. Including M/s Oil India Ltd and so many others associated with the Baghjan disaster, the scientific temper was thrown miles away. Is it not surprising that with best of talents available at IIT Guwahati and NEIST, Jorhat, we still could not figure out why the grounds were not shaking prior to 9th June, 2020, and why suddenly seismic activities started to manifest out of the blue after the fire broke? In terms of ecological research and understanding of such great fires, Baghjan was only a badly missed opportunity. The question is who would pay for the cost of the "Lost Opportunity"?

17.2.13 OF THE ENVIRONMENT (PROTECTION) ACT, 1986 AND THE RULES THEREOF

The point of discussion here are the various Schedules I, III, IV and VI under the Rule 3, and Schedule V under the Rule 12 of the Environment (Protection) Rules, 1986 which have been promulgated under the Sections 6 and 25 of the Environment (Protection) Act, 1986. These schedules describe the various prescribed limits of emissions, against a host of "pollutants" specific to a variety of industries, into the surrounding environment. As already explained in this Report, air, water, land and soil are simply "sinks", and they have a very limited capacity to absorb pollutants. The industry specific emission/ effluents, as mentioned in the schedules, is, practically a maze of figures and defies reason as to why such divergent standards were formulated. Just to point a simple but specific case of pH, which we have discussed extensively in Chapter 11 of this Report, let us see how the pH is placed across the industries:-

1.	Man-made fibers (synthetic)	5.5 to 9.0
2.	Oil-refinery industry	6.0 to 8.5
3.	Dye & Dye	6.0 to 9.0
4.	Fertilizer Industry	6.5 to 8.0
5.	Straight Phosphatic Fertilizers	7.0 to 9.0
6.	Natural Rubber Industry (inland surface waters)	6.0 to 9.0
7.	Natural Rubber Industry (into land for irrigation)	6.0 to 8.0

8. Jute processing Industry 5.5 to 9.0
9. Large Pulp/ rayon etc. 7.0 to 8.5

The list above is indicative, which clearly demonstrates that effluents into the land and water can have pH values ranging from 5.5 (highly acidic) to 9 (alkaline) against neutral pH which is considered to be 7 to 8. How does one monitor and on whom to fix responsibility upon, supposing a number of industries were to release their effluent water into a single water body, and the fish start dying? Irrespective of the industry, any effluent being discharged into any water body, land/ soil or air must adhere to a single set of standards which sum up all required parameters. As one can see in the Chapter 11 of this Report, pH below 6.5 is very harmful for the aquatic wildlife, fish and other organisms. Therefore, it is not understood how can pH as low as 5.5 to 6.5 be actually allowed in any water to be discharged into a water body or land/soil?

Therefore, it is strongly suggested that the CPCB must come up with robust single roaster of "effluent" standards, irrespective of industry for discharge into the "sinks"- air, water, land/soil. Unless common standards are evolved shortly, EIA Reports would continue to be faulty, and fixing responsibility on polluters would continue to be a challenge. Also it has to be noted that chemicals such as PAH and CPAH do not find mention in these standards.

Time to Make Other Entries: In the time of climate change, certain new forms of pollution so far unrecognized such as CO_2 emissions, waste heat discharge into the surroundings, Heat Island Effects, vibrations along with ground motion caused by mechanical or artificial devices/ equipment/ large jet fires must also be seriously researched and considered. Similarly, PAH/PAH are not reflected well in the Schedules, whereas these are one of the most dangerous carcinogens. It ought to be incorporated in the Schedule with very stringent limits.

Emission norms for ESZ and Wildlife Areas: While all Eco-Sensitive Zone notifications by the MoEF&CC talk of "*Discharge of treated effluent in Eco-sensitive Zone shall be in accordance with the provisions of the General Standards for Discharge of Environmental Pollutants covered under the Environment Act and the rules made thereunder or standards stipulated by State Government whichever is more stringent.*", under the Para "**Discharge of Effluents**" in the ESZ notifications, it is not known if any State Government has actually come with "more stringent" standards of effluent discharge in an ESZ. It is felt that an area of 10 km surrounding all National Parks and Sanctuaries must be separately having specific discharge levels which are lower than the limits that would

not jeopardize survival of organisms, floral and faunal communities, ecosystems and biodiversity of the protected areas. The specifications must also include soundscape and lightscape conservation standards including underwater disturbances, ground vibrations and motions caused artificially.

17.3 Conclusions And Recommendations

It is reiterated here that each of the Chapters 3, 4, 5, 6, 7, 8, 9, 10, 11, 14, 15 and 16 have certain conclusions at the end. A snap-shot of these would be provided to make this Chapter readable and conclusive. It is to be noted, however, that there are several conflicting opinions and values, especially pertaining to the physical and chemical properties of the blowout, explosion and the "**Baghjan Flame**" especially starting from Chapter 6, 7, 9 & 10 which primarily deal with the basic phenomena associated with the Baghjan flame. While only the final figures have been used in estimations, there have been several rounds of iterations to estimate parameters such as flame height, mass flow rate, power of the flame, acoustic power etc. and there are visible traces of abandoned tracts (due to shortage of time or lack sufficient materials at hand) of these pursuits well scattered in the Report. These have been left as it is, mainly because, they aid considerably in understanding the phenomenon first hand, and secondly, exhibit the proof of the complexities involved in the estimations and the speak of the efforts taken to circumvent them. This should not, however, be seen by the critics to be inconsistencies. The critics may contest this Report, if they so wish, by bringing in scientific principles, alternate valid theories and authentic data. The author of this Report shall be more than happy to be proved wrong, and get an opportunity to learn beyond what is already contained in the Report.

17.3.1 Conclusions

This section of the Chapter has been designed to act as a single point snap-shot of the Report so that the reader may have the benefit of grabbing the essence of the Report at once. Care has been taken to keep the labyrinth of formulae and calculations as short and as clean as possible. Chapter wise conclusions are presented here for the benefit of the readers:-

Table No. 17.1: Chapter wise Conclusions

Chapter No.	Conclusions
3	**1.** The Dibru-Saikhowa National Park and adjoining ecosystems of Maguri Motapung beel, Dibru river etc. which comprise of grasslands, wetlands, river systems and wet evergreen forest formations are very rich in biodiversity. **2.** Many Scheduled I species listed under the Wildlife (Protection) Act, 1972 and as per IUCN criteria such as endangered, threatened, nearly threatened, vulnerable etc. are found in these habitats including mammals, avifauna, fishes, herpetofauna, butterflies etc. **3.** These ecosystems are home to some very rare and endangered fauna such as White winged duck, Northern capped langur, feral horses, rare fish, birds and reptiles. **4.** The Laika and Dadhia villages should be relocated. The Dibru-Saikhowa National Park should be re-consolidated with additional areas. **5.** The EIA reports prepared for M/S OIL India Ltd for the two projects was found highly deficient in Emergency Response Management and Environmental Management Plans. These deficiencies render the EIA document of little consequence in wake of a major accident or ecological disaster. The overall quality of the EIA Reports was found to be very poor. There is an urgent need to change all these “run of the mill” processes which do not serve any real purpose.
4	**1.** M/S Oil India Ltd. which is a Central PSU in the MoPNG has annual profits to the tune of Rs. 2500 cr (after taxes), while all its owner companies, who hold stake together of 21.46%, have together profit after tax amounting to more than Rs. 33,000 cr. On the other hand, MoPNG has a budget of Rs. 27,000 cr and the IEBR of the MoPNG CPSUs stands at about Rs. 89,000 cr and actual spending about Rs. 100,000 cr. All these figures are approximations for 2018-19. M/S OIL hold more than 22,600 sq km of PML/PEL leases in India and owns more than 44,600 sq km of assets abroad. **2.** In Assam, M/S OIL has drilled more than 1000 wells. It took 49 49 wells afresh in 2009 North Hapjan PML, and has now proposed another 7 ERD wells in Baghjan area. **3.** The Climate Change energy use pathways for 2050 and 2100 foretell that if we have to overcome the 1.5^0 and eventually 2^0 rise in surface

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	temperature, the use of natural gas and oil must either remain constant at 2018 levels or dip to lower than (more than half of) present consumption levels. **4.** India's import of crude oil and LNG has been increasing steadily, and is about 200 MMT of crude oil and 30 BCM of LNG. Further, the inhouse production of crude oil and natural gas are falling gradually- standing at 17% of crude oil and 48% of LNG. M/S OIL share of crude oil production is roughly 10% of crude oil and 8% in natural gas. The total oil imports amounts to US$ 83 billion. **5.** In addition to taxes etc, the Govt. of Assam would get Rs. 287 cr per MMT of crude oil production, and Rs. 42.5 cr per 365 MMSCM (~0.4 BCM) of natural gas production. These are at USD 1=63 INR exchange rates and crude oil price at $ 50 / bbl and LNG being at $4.66/MMBTU. **6.** The CAG Audit Report of 2017 brings out several shortcomings and regulatory issues including under-reporting of production by the oil and natural gas producing companies of MoPNG. **7.** Oil spills and blow outs are due to human errors. The effective blow out probability in the Tinsukia district comes to $7.5x10^{-3}$, and internationally $1.26x10^{-3}$, taking off-shore blow out probabilities. The EIA reports do not seem to focus on worst case scenarios possible. There also does not seem to be any oil related accidents' database in the country maintained in public domain. A study showed that for every 100 wells drilled, one can expect 52 kicks, of which 21% can be very serious. There is, therefore, chances of 1 blowout every 110 kicks. Given the well concentration in Tinsukia district, there is every chance of one more blow out happening in next 5 to 10 years. Tinsukia district should be very well studied in terms of oil and gas industry and its impacts on local populations, ecosystems and environments. **8.** There does not seem to be any public record keeping of oil exploration and drilling related accidents including kicks in India. **9.** Baghjan could be the largest onshore blowout that would last for more than 4 months at the same intensity of fire without the well drying up.
5	**1.** The State may claim damages on account of loss of taxes and revenues. Therefore, the State shall have a claim of the total revenue loss and

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	taxes thereof. **2.** The injury caused to natural systems such as ecology and ecosystems, and loss of biodiversity form another component of the damages **3.** The losses to individuals by way of actual damages and those by way of damages in public nature need to be looked into as the third component of the damage universe **4.** The amount of compensation or cost of damages should be commensurate to the pocket size of the owners of the Company that inflicted the damages, even if its a Government company. **5.** The compensation claim can be challenged in the Court of Law/ Tribunals having jurisdiction on the subject matter. **6.** The PLI Act, 1991 has a very limited or insignificant role in large ecological disasters such as Baghjan blowout. The Act needs complete overhauling.
6	**1.** The blowout at Baghjan BGN-5 OIL Well was not only a "catastrophic" but also a large and worst case blow out (As per definitions provided under OIL ERM EIA, December, 2019) **2.** The condensate was "oil" with heavier hydrocarbons **3.** The explosion on the 9th June, 2020 at 1.30 PM gave rise to a mushroom cloud that rose 2500m into the sky, and its yield was 0.1 million m^3 of natural gas (≡0.9 kiloTon of TNT) **4.** The flame temperature was estimated to be 1200^{0}C. **5.** The flame height was estimated at 90m . **6.** The discharge from the well head was estimated at about 10.7 lakh cubic meter per day (≡ 9.54 or 10 kg s^{-1} discharge)
7	**1.** The flame is supersonic and its lift-off height was found to be 11m, flame height was estimated at 108m. **2.** The Heat Release Rate (HRR) of the flame was estimated to be 16450 MW, and the mass flow rate to be 343.50 Kg m^{-1}. **3.** The well-head pressure during the blow out/burning was estimated to be 13.8 MPa, (with 20.32 outer dia of 203.2 mm) & 35.5 MPa (with inner dia 127 mm) and the fluid exit velocity (single phase) to be 1082 m s^{-1} at

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	the hypothetical converging-diversing nozzle just below the flame. Therefore, the blowout pressure could have been more than 5100 psi. **4.** The Mach number estimated for the flame could vary from 3.1 to 8.5. It depended on the combustion conditions at any given point of time. Similarly, the Reynold's Number was estimated to be ~251170, but it would vary too. **5.** The flame is expected to generate shock waves traveling in a narrow cone of 19^0 to 90^0 in the wind direction axis. **6.** The radiative flux estimated at 5m from the edge of the flame was 2742 kW, while that measured by M/S ERM was 260 kW. **7.** The air temperature above the flame at 1000m height was estimated to be 34^0C, where at that elevation, normal temperature is supposed to be 8.7^0C. This is a case of thermal pollution. It has been this way now for almost 4 months. The damages to the upper levels of atmosphere have not been studied. **8.** The Thermo-Acoustic Efficiency of the flame was estimated at $4x10^{-4}$, and the acoustic power to be 158 dB. The noise level at 500 m from the flame could be from 61 to 68 dB estimated. **9.** The Baghjan natural gas chemical composition was seen to be $C_{1.1144}H_{4.2026}$. **10.** The emission from 1 m^3 burning of the gas estimated to be: CO_2: 1.54 Kg, CO: 0.34 Kg, NO: 0.92 Kg, NO_2: 1.42 Kg.
8	**1.** The National Ambient Air Quality Standards (NAAQS) were prescribed by CPCB in 2009 for the country as a whole; and these are binding under the various legal provisions of the EPA, 1986, EP Rules, 1986 and the Air (P&CP) Act, 1981 for all industrial units. **2.** The emissions into the air were estimated using conjectural as well as empirical methods; and in addition to the field measurements of various emission levels, baseline data from the EIA reports provided by M/S OIL was taken into account. **3.** From conjectural estimates, methane (in equivalent CO_2 terms) and CO_2 emissions from the blow out, prior to the explosion and fire, were estimated at 10.145 Million Tons till 15th August, 2020.

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	4. Based on similar methodology, emissions of CO_2, CO, NO, NO_2 from combustion of the well fluid during and post explosion and fire were estimated to be 7.451, 1.649, 0.539 and 0.793 Million Tonnes respectively. **5.** The study reveals that no breach in terms of ambient levels of SO_2 were observed at any point of time. **6.** The NO_2 levels were found to be as high as 97 µg/m^3 during the blow out, and projected estimates till May, 2021 come to 31.8 µg/m^3. The base levels were already running 20.38 µg/m^3 in 2019. Thus, there is found to be breach in ambient NO_2 levels in 24 hourly as well as annual prescribed levels. **7.** Due to direct CO emissions from the fire, the CO levels reached a high average of 9.05 mg/m^3, and the annual levels are projected to cross 2.2 mg/m^3. Thus, there is found to be breach in ambient CO levels in 1 hourly as well as annual prescribed levels at 8 hourly. **8.** The baseline levels of PM_{10} were at 80.22 µg/m^3 levels in 2017 already. The values touched 78 µg/m3 during the blow out, and levels are expected to be not below 78 µg/m^3 during the year. Thus, there is found to be breach in ambient PM_{10} levels in 24 hourly as well as annual prescribed levels. **9.** The baseline values for $PM_{2.5}$ were already 42.58 µg/m3 for 2017. During blow out the emission levels touched 67.8 µg/m3, and the projected annual value for the year is expected to be 48.2 µg/m3. Thus, there is found to be breach in ambient $PM_{2.5}$ levels in 24 hourly as well as annual prescribed levels. **10.** There was lack of systematic sampling design by PCBA. Due to lack of a proper design, the outcome appeared to be random. The capacities of PCBA need to be upgraded. It needs to be modernized with a new lease of life. It simply does not have the capacity, in the present shape, to handle such a disaster. **11.** The estimated environmental damages, in terms of costs to be incurred for remediation of the emitted green houses gases, comes to Rs. 8672 cr INR. **12.** The damages have been ascertained only upto 13th September, 2020, being 95 days, against the fire actually raging upto 15th November,

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	2020, being 172 days altogether. Monetary valuation of CO_2 alone was done, as a majority representative pollutant among all the pollutants.
9	**1.** There is a breach in respect of permissible limits of noise in residential, industrial and silence zone during day and night. There is a violation of the various prescribed levels of noise pollution under the Environment (Protection) Act, 1986 and Environment (Protection) Rules, 1986. **2.** The people affected from the noise are spread in a radius of 20-40 km of the blast site, but persons residing within 5 km radius have been acutely affected as the noise levels were more than 55 dBA on 24x7 basis. **3.** Similarly, all those who worked or lived within 700m of the blowout site, were exposed to extreme noise of more than 75 dBA. These are all breaches of the permissible limits under the EPA, 1986. **4.** The acoustic spectra of the noise emanating from the flame was examined. It was found that noise can be characterized as "Broadband Noise" radiating at almost all frequencies from 1 Hz to 20000 Hz. **5.** The peak acoustic frequency was found centered around 100-200 Hz in the undisturbed flame at the original BGN#5 oil well site. **6.** The characteristics of the sound and pressure levels of the emitted frequencies changed considerably after the new arrangement towards the end of September, 2020 till date. The acoustic radiation is almost equal in all frequencies from 50-7000 Hz. **7.** It was estimated that the explosion on the 9th June, 2020 at 1.30 PM was 3.9 on Richter Scale. It caused vibrations in the ground that would have been felt upto 25 km from the blast site. **8.** There are possibilities of some small explosions happening in the flame itself due to severe turbulence, and these could be of the order of 1.3 magnitude, and vibrations could be perceived even beyond 3-5 km distance from the blowout site. **9.** All ground structures having natural frequencies from 1 to 10 Hz would resonate, as the low frequency waves would be travelling without much attenuation in the ground (and water). **10.** The acoustic impact of the flame, assuming 160 dB power in the flame, on triggering ground vibrations was also examined. It was found that

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	the acoustic power of the flame was capable of causing, independently of other factors, a velocity of 2 cm/s. This ground wave, while interacting with objects having natural frequencies 1-10 Hz could cause accelerations from 0.013g to 0.13g which are almost 10-100 more than the minimum of acceleration that a human being can detect, i.e. 0.001g. **11.** As regard the various vibrations caused by the flame because of the large amount of fuel that it engulfs every second on 24X7 basis, and because of the inherent turbulence and noise that it creates thereon, the flame by its very nature generates ground waves in infrasound range (1-20 Hz). These frequencies match with the objects on the ground having natural frequencies in the similar range. This causes resonance resulting in vibrations in houses and dwelling units and other infrastructure, causing rattling sound to even cracking of walls, ceilings and floors. Since the vibrations could vary from 0.013g to 0.13g, these are strong enough to cause even difficulty in standing. **12.** There are currently no prescribed limits of maximum permissible ground motion or vibration due to human induced factors such as pile driving, running of trains, heavy vehicle movement on the road, large mechanical rotating devices or even fire such as at Baghjan. Therefore, no breach. However, people affected may be awarded compensation for the damages caused to their properties. There is a need, as some other countries have done, to bring prescribed limits to ground vibrations in the environmental laws of the country. **13.** The findings of IIT Guwahati in respect of vibration and noise have not been considered in this Report.
10	**1.** It is high time that we redefine Thermal Pollution as also pollution of the air if air temperature outside of an industrial installation or any usage of power or energy gets impacted and creates a heat island. **2.** The tree ecosystem components respond differently to rise in air temperature. The leaves would try to absorb as much heat as possible without impacting their temperatures, and the trunk, on the other hand, may get impacted by high levels of heat radiation and the bark and cambium temperatures may rise to levels where the tree may even die. **3.** The response of photosynthesis rate to temperature shows that at

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	temperatures higher than the optimum growth temperature (25-30^{0}C), the photosynthesis rates would drop to more than half. This adversely impacts the food production in the plant, and also cuts the sequestration rates by more than half. **4.** The total heat generated by the Baghjan flame is estimated at 137PJ. It is also estimated that the diurnal temperature gap has been reduced to 7.9^{0}C from the observed usual average of 10.6^{0}C. **5.** The various measurements show that temperatures have risen by 5-10^{0}C depending upon the distance at which the structures (houses) are located. **6.** Hot wind gusts that are capable of raising human face temperature by almost 12^{0}C from the normal body temperature have been observed. **7.** The valuation of the waste energy of 137PJ in terms of a 100% inefficient heat engine (that the flame is), in terms of energy price, is equivalent to the total energy consumption of Delhi in 2011, and can be priced at Rs. 3800 cr @ Rs. 1.00 per kWH value. Further, in terms of the heat sink services that the tree ecosystem around Baghjan flame has offered, comes to a staggering Rs. 3,50,000 cr. Just about 1% cess on these services which could actually be charged to M/S OIL would come to Rs. 3500 cr. **8.** Therefore, the heat that the Baghjan flame has been spewed appears to have marked footprint on the local microlimate. Though, there are no legal bars on creating and propagating such a big naked flame, ecological considerations discussed and circumstantial evidence presented warrant levy of penalties on the owners of the flame; and furthermore, heat radiation beyond certain radiative power should be strictly prohibited, and it should be made a part of the environmental regulation of the country.
11	**1.** There are no soil quality standards defined in the country. The water quality standards are there, but they differ considerably from context to context. In all these standards are very clumsy for application in the field. **2.** Baseline for water temperature and water quality was difficult to obtain for the main water bodies, and even for the river Brahmaputra. A very

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	few research studies were found on the subject. **3.** Water temperature was found to be, at places, higher than 5^0 C, which falls in the category of thermal pollution. This is a contravention of the provisions of the Environment (Protection) Rules, 1986. A breach was found in this regard by M/s OIL. **4.** The DO level were found dipped to dangerous levels of below 4 mg/L, which is dangerous for aquatic fauna. At places DO levels were found to be as low as 0.94 mg/L. This is a breach of water quality on the part of M/s OIL. **5.** Breach was also found in respect of amount of Oil and Grease in the water as well as soil. **6.** There was neither any baselines studies done by M/s OIL in the EIA, among so many other shortcomings, nor any study by regulators. However, assessments showed very high amounts of PAH in water, soil and organic samples of fauna. As regards breach, PAH limits were clearly breached for water, as per the existing standards. There being no standards for PAH in soil and organs of fauna. However, one needs to consider these as breach too. **7.** There was breach in respect of Pb and Cu in water samples tested by PCBA. **8.** The BOD and COD were found to be in violation of the standards within 500m of the blast site. This constitutes a breach in the water quality. **9.** In the assessment, 250 points were found showing pH below 6.5. Low pH in combination with low DO became a fatal combination for the wildlife in the wetlands and the grasslands. All lab tested pH values were rejected, as the standards followed could not be determined, and pH values of stored water in contact with air would tend to move to 7 or 7.5 over a period of time. There was a breach in respect of pH in the water. **10.** It was also found that a "Heat Island Effect" was created by the flame in the surrounding areas. However, since, there is no such regulatory prohibition, we cannot call it breach technically. It is a kind of heat pollution (as dealt with in the previous Chapter), and accordingly, should be brought under environmental regulatory regime.

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	11. Drone-based assessment of damages on land and water was evaluated in a 3 km radius along with other adjoining areas. The total affected area came to 58.8 sq km. **12.** The total quantity of natural gas and condensate that would have flown out of the well during the blowout prior to the explosion was estimated. It was found that the amount of fuel needed to explode (equal approximately to 0.833 kT) could effectively have been emitted in just about 2 to 4 minutes time alone. **13.** It was assumed that about 50% of the condensate would have fallen within 300 m radius (as is seen from the drone assessment, which shows an average of 277 m radius). The total condensate has been estimated at 64000 Kg during the blowout period prior to the explosion. **14.** The amount of condensate that would have fallen in the surrounding areas, and was left unburnt by the fire was estimated for the affected site. The generic estimate yielded values from 5.4 to 16 mg/m^2 of land surface assuming a uniform penetration depth of 10 cm. However, this is a very generic supposition. Therefore, it was seen that the field values observed (1.11 to 17.15 gm/Kg) could be justified easily from the above generic values. **15.** The valuation of loss of ecosystem services for 4 ecosystems namely 1. Flood plain wetlands, 2. Grassland, 3. River and streams and 4. Tropical forest was evaluated based on the work by Costanza et al (2014). The valuation was recast to 2020 prices and in INR. The time period was considered 10 years for land based systems, and 5 years for river/streams. The total loss, accordingly, came to Rs. 9078.60 cr. **16.** Bioremediation was suggested as a method of recovering the land and water. A detailed writeup on bioremediation has been produced. However, certain precautions have been suggested while carrying out the bioremediation. **17.** Sink is a sink, and is to be treated equally everywhere. All emissions to air, water, soil and land must follow a single set of standards. The current provisions under the Environment (Protection) Rules, 1986 are quite difficult to work with on the ground. Sink standards should be uniquely and universally defined.
14	**1.** The Baghjan blow out is an accident of grave nature caused by accident

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	by human error, but has proved to be of such proportions that it may be difficult to recover from it altogether. This is against the backdrop that the Dibru-Saikhowa and Maguri Motapung landscape houses some of the most endangered animals not only in the State, but also in the country and the world. Some of the species have only few members, and we may find them finally locally "extinct", and many others may not return to site for decades, and still many others may have genetic and morphological disabilities in the present or future generation and in unpredictable ways (as we now seem to have just stated to witness still births and deaths with multiple complications). **2.** The punishment, penalty and fine together with compensation must have demonstrative and deterrent effect, so that such costly human errors do not get repeated, and the companies and their owners that are indulging in "polluting" activities, must be extra cautious and avoid such environmental catastrophe at all costs. However, since the matter is of accident, the Government of Assam and the Government of India and the Hon'ble Courts have set up multiple committees to examine and fix responsibility. Once the responsibilities are fixed, the following are suggested for actions:- **(a)** All the responsible must be proceeded against under the Wildlife (Protection) Act, 1972. **(b)** If such persons happen to be individuals, then their employers and owners including the principal employers and owners must ALSO be proceeded against. **(c)** If within six months of submission of this Report, still no one is found guilty for whatsoever reasons, then the Chief Wildlife Warden, Assam, shall appoint an Inquiry Officer and thereafter, shall move a proceeding in the appropriate Court of Law at Tinsukia, through the DFO, Tinsukia Wildlife Division, and the DFO, Dibrugarh Division having jurisdiction in their respective territories to move issue of process against the management of M/S Oil India Ltd, and their owners i.e. the Ministry of Petroleum & Natural Gas. Action should also be initiated against the DGHC for abatement of these offences. **(d)** Adequate compensation, in addition to any other compensation and award that this Committee recommendation may make, as indicated in a subsequent Chapter shall be charged from the erring entities as

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	well as the persons responsible. **(e)** It has been seen and observed with a lot of pain and that this ugly incident has demonstrated lack of good wildlife institutions in the region, good testing facilities, computational power to simulate on the fly, have electronics set up to measure and assay, all parameters on the fly and store and use big data analytics to analyse and retrieve patterns and take corrective action before hand. Therefore, it is recommended to open an institute of wildlife health and research here and another computational R&D, Electronics test and simulation hub as a Centre of Excellence. **(f)** The Laika and Dadhia villages must be relocated in order to make the habitat better. It is also recommended to acquire the Erasuti village (and relocate them elsewhere) and redraw the boundary of the Dibru-Saikhowa National Park to its original value of 650 sq km or higher, and link it with the proposed Poba Sanctuary on the north. **(g)** There are encroachments (but now very old) on the north-eastern portion of the proposed sanctuary where the Pillar No. 1 starts and then along to Pillar No. 2 and 3. These areas msut be acquired after paying adequate compensation and the entire Dibru-Saikhowa National Park should be reconsolidated for making it a better habitat. **(h)** The park is devoid of infrastructure and staff. All this must e upgraded to atleast 5-6 times of the current size, or atleast 400 staff whichever is higher. Also there is a need to raise a company of river patrolling forest force from Dhola Sadiya bridge to Bogibeel and beyond. **(i)** The Maguri Motapung beel must be restored to its original. The fishing communities should be provided alternative green livelihood options. The educated youth should be given adequate training, and all the emerging job opportunities in that area, especially in the wildlife must be provided to them, provided they decided to compete with the rest on equal terms. **(j)** The tourist glory of the Maguri Motapung beel should be brought back. A Green Development package must be designed for

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	implementation by the local youth. **(k)** A total 511 number of uniquely identified species in various classes/ orders/ genera of animals were encountered during the assessment by all the groups that worked on the ecological assessment, against a recorded checklist of 1235 species, ***showing a loss of 55% of biodiversity after the blowout***.
15	**1.** The matter is sub-judice, so only limited suggestions can be given here. **2.** The need of the hour is to assess scientifically the health status of the populations (in a research mode with a host of health aspects) to ascertain the risks that the exposed population faces, including high risk groups such as pregnant women, children and medically high risk persons. **3.** High value health care policy must be provided to all living within 3-5 km of the blowout site. A Risk Zonation Map could be prepared once the fire is extinguished. **4.** All livestock deaths must be subject to post mortem, and screened by way of laboratory tests of viscera and organs to ascertain if the animal was affected by the oil spill. All deaths must be reported. Post mortem should be made compulsory for all dead livestock in the area for next three years. **5.** All affected soils must be tested prior to treatment. All water sources including ground water must also be tested for presence of Oil and Grease, PAH and Heavy Metals. **6.** Research scholars must be engaged in association with the Agriculture/ Horticulture/ Soil conservation/ Fishery/ Veterinary Departments to carry out continuous monitoring and research and establish the extent of damages that might be on the cards, or would be visible in the future. **7.** Compensations of the actual damages and loss of property must be paid as per the best possible norms [as people have suffered multiple agonies directly and indirectly, and not all sufferings can be converted to money values]
16	**1.** Barring all the complementary services that the ecosystems offer (for example the cost of service to absorb all the heat radiated

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	from the flame comes to Rs. 350,000 cr), the loss and damages to the ecosystem, to the extent that it was scientifically possible to account for, it is estimated that the damages to the environment come to ~Rs. 25,000 cr. The maximum restoration period was taken as 10 years. **2.** The polluters/ owners' capacity to pay was also measured, and based on the assumed principles adopted for the payments of the environmental liability, it is seen that the polluters can pay upto 27,000.00 cr. **3.** It was estimated that possible carbon earnings could be 18234 cr. **4.** After offsetting the carbon earnings, net deficit that remains is Rs. 6800 cr. to be paid by the Polluters over a period of 10 years. The per annum amount comes to Rs. 680 cr. **5.** When apportioned with % shareholdings of the owners, it is seen that the share of annual environmental liability comes to Rs. 588 cr. on MoPNG and Rs. 92 cr. On M/s OIL **6.** The Govt. of Assam's due on royalty on lost production of 4198 MMSCM of NG comes to Rs. 489 cr with additional cess and 14.5% VAT on the royalty.

17.3.2 Recommendations

The recommendations of this Report are not binding, as already stated once elsewhere, and it is on the Government of Assam and the Hon'ble Gauhati High Court, the Hon'ble Supreme Court of India and the Hon'ble National Green Tribunal to accept, reject, modify, annul or prescribe, in part or full, any of the recommendations and/ or conclusions of the Report, or any matter thereof.

17.3.3 Conclusions in the Nature of Recommendations

There are several recommendations contained within the text and some of them have been also brought out at the end of the chapters in the 'Conclusions' section. Since all the conclusions have already been listed in the previous sub section, we shall mention just the Chapter No. and Conclusion serial number for those conclusions which are in

the nature of Recommendations. The reader, is however, advised to read the Report, if possible, and reflect upon some of the recommendations made throughout the Report. It was not possible to capture all of them. These are taken to be read, and the ones in the "Conclusions" section of the Chapters are listed below:-

Table No. 17.2: Chapter wise Conclusions (in the nature of Recommendation)

Chapter No.	Conclusions in the Nature of Recommendations
3	5
4	7
5	1, 2, 3, 4, 6
7	7
8	10
9	12
10	1, 8
11	1, 10, 16, 17
14, 15, 16	All

17.4 Specific Recommendations

17.4.1 The Premise

The Baghjan blowout that lasted from 27th May, 2020 to 15th November, 2020, more than five months, claimed three human lives, three Scheduled I wild animals and more than 29,000 scheduled and unscheduled wild animals and organisms, and caused widespread burning, fire, sound, air and water pollution, vibrations and ground motion causing tremors in houses, drenching thousands of people, livestock and wildlife in black colored "oil rain", still birth of uncounted numbers of livestock, and above all devastation of the Maguri Motapung Beel ecosystem and damages to the Dibru-Saikhowa National Park ecosystem, burning of grasslands, unbearable radiation of heat and strong blazing light, was no mean and ordinary ecological disaster. It brought innumerable misery to the populations around, and adversely affected wildlife and biodiversity. The true extent of the ill effects of the disaster are not even fully known, as only scanty studies could be done so far, as people continued to protest violently, and the site and surrounding areas remained out of bound. All this misery was further compounded by COVID19, lock-down, and a series of flood waves, atleast 9 during the year, compounding the misery of the common man. Normalcy in the law and order

appears to have returned after the fire was extinguished at the end of 109 days of the blowout on the 15th November, 2020.

The Baghjan ecological disaster revealed so many gaps in the system:- relief was not forthcoming as desired, samples of viscera of dead wild animals could not be tested for organic chemicals, PAH and other pollutants, only a handful of air pollution, noise, water and soil samples could alone be collected by various agencies, there was no way to measure flame temperatures, mass flow rates, radiative flux, thermo-acoustic coefficients, soil-air and water temperatures, unavailability of baseline data, highly deficient baseline data, deficient and faulty EIA reports, total lack of instrumentation to assess ecological parameters, lack of airborne spectroscopy and other sensor based measurements, complete lack of resources, software, compute power and expertise to run Computational Fluid Dynamics models/ simulations, Finite Element Methods, lack of testing equipment to characterize soil, water and air samples, lack of night vision devices to study flora and fauna at night, utter lack of thermal sensing devices and IR based equipment for thermal, adequate number of hydrophones and CPODs for underwater studies, to mention some of the glaring gaps in the assessment of the damages.

When one looks at the nearest ecological units of the Dibru-Saikhowa National Park, the Bherjan Borajan Podumoni Wildlife Sanctuary and the Maguri-Motapung Beel from the view point that more than 100 drilling sites are located in the surroundings of these ecologically fragile and sensitive areas, but this appears to be of little concern to OIL. This situation has come to be because the Environmental Clearance provided by the MoEF&CC to these projects clearly stated that there were no National Parks and Wildlife Sanctuaries within 10 km of the project sites. As a result, no mandatory wildlife clearance was required, and hence, there was no any “Regional Wildlife Management Plan” or any “Biodiversity Management Plan” were prepared at the cost of the OIL; and hence, no expenditure was incurred towards any systematic and planned wildlife management from industrial perspective.

While the EIA reports show environmental degradation to a certain extent, no efforts at systematic plantations to mitigate the pollution caused by the industrial installations were taken up, or even no “green barriers” were created to mitigate any accident in the area. Similarly, without any concern for the mandatory 500 m Hazard Zone declaration, all these installations in and around Baghjan are in the middle of thick populations, and apparently no safety and precautions such as insurance of the life and properties of the inhabitants, or adequate and appropriate compensation for people who could be

willing to relocate themselves to other areas.

Further, despite the Baghjan area being strewn with drilling sites, as one can count several drill sites all along the bank, if one were to survey the landmass from the riverside, the people centric infrastructure is in pathetic condition. There are no good schools, hospitals and veterinary centres, as already narrated in Chapter 2. It was surprising to find that the Baghjan Well site BGN#5 did not have access/ escape routes right from the drill site because of which two firemen lost their lives. It also has to be noted that while 4 (four) or more engines were throwing water jets on the blowout fluid, to keep it cool, and often water-jets were continuously being bombarded at the flame, no attempt was made to treat this "effluent" water. The water was continuously mixing with natural gas and condensate, and would have brought down copious amounts of hydrocarbon to the nearby water bodies and the river Dibru. The burning flame was often strewn with water jets, leading to reduction in the oxygen supply to the flame, and higher degree of production of soot (may please see Chapter 7) which would largely contain PAH and CPAH. All these carcinogenic and dangerous chemicals would have been flowing freely with the water. In all, it can only be said that while the whole focus was on extinguishing the fire, environmental concerns were totally ignored by the Central Oil PSU.

17.4.2 Brief of Some Specific Recommendations

There are some specific recommendations proposed here, and described briefly:-

Creation of A Special Fund: There is a strong requirement to create an "untied" fund in the State for ecological disasters and industrial accidents of large proportions. The State is rich in oil and natural gas. There is a crude pipeline all across the State. Most of the oil installations are either located in or run through the highest ecologically sensitive and biodiversity rich areas of Assam such as Dibru-Saikhowa National Park, Dihing Patkai WLS (now upgraded to a National Park), Panidihing Bird Sanctuary, Hollongapar Gibbon Sanctuary, Garampani Wildlife Sanctuary and Kaziranga National Park. It may be noted that the OIL pipeline passes through the Kaziranga National Park. If any unforeseen accident were to happen in Kaziranga National Park, everyone would be caught unawares and totally unprepared. The Sekoni Pumping Station at Rangalugarh is at stone's throw distance from the KNP. The Dihing Patkai is very much at risk, as the oil installations housed there pose threat to the local ecology due to poor maintenance (as reported by the Conservator of Forests, Eastern Assam Circle, Jorhat who was specifically asked by the undersigned to visit the installations of OIL in Digboi, after the

Baghjan blowout and fire). Therefore, it is proposed to create a State level fund for ecological disaster caused by industrial accidents and similar such emergencies. At the time when such a disaster strikes, there are no readily available resources to depend upon without being at the mercy of agencies such as OIL, who find it dear to part with funds.

Institute of Wildlife Health & Research: The Baghjan Blowout clearly showed that Assam lacks the infrastructure and paraphernalia to cope with large scale ecological disasters. The research and testing facilities were found wanting and not up to the mark. There is no doubt that Assam has been a leader in wildlife management, but the support infrastructure and research activities have been lagging behind. During the baghjan disaster many samples of viscera, water and soil remained untested due to lack of facilities, and lack of a single point expertise. Rescue and treatment of wild animals put extreme stress on the existing system. It is, therefore, proposed to establish a State of the Art Institute of Wildlife Health and Research in the vicinity of the Dibru-Saikhoa National Park and Dihing Patkai WLS (which is now upgraded to a National Park). The Institute would have satellite centres spread across the State to cater to the wildlife emergencies. It shall have all testing facilities including DNA, SEM, Atomic Absorption Spectroscopy, NMR etc. The institute would be housed at Dinjan in Dibrugarh district.

Consolidation of Dibru-Saikhowa National Park and BBP WLS: The ecological richness of the Dibru-Saikhowa landscape has been described in some detail in Chapter 3 and 14. The various ecological units constituting the unique landscape have also been described in detail in Chapter 3. However, the irony is that such a biodiversity rich landscape is facing acute crisis due to non relocation of the two Forest Villages of Laika and Dadhia who are occupying more than 1000 Ha of the core of the Park area in widely scattered fashion, leading to rampant poaching, increasing encroachment, degradation of the habitat, plight of large mammals from the core of the Park and many other issues of management. Fortunately, due to active interference of the Hon'ble Chief Minister of Assam, now the issue of Laika Dadhia villages is on the verge of reaching a solution. Similarly, the eastern part of the park appear to be encroached. The National Park as declared is just 340 sq km, and has a buffer of 422 sq km. Most of the area is riverine and inaccessible most of the year. More areas need to be brought to the park, as erosion has been constantly eating away prime habitat year after year. The White Winged Duck, once the pride of the Park, is now a rare sight and not reported for past several years. It is only an indication that all is not well with DSNP. Similarly, the Bherjan Borajan Podumoni WLS, comprising of 7.21 sq km of three fragments of forest patches

were once known for the habitat of primate species and the only ape of India, the Hoolock Gibbon. These species are getting extinct locally due to heavy biotic pressure and further destruction of the habitat. These patches are all surrounded by oil drill sites and prospective gas and oil wells of future. All these areas need immediate attention, and consolidation to begin with. Enrichment of habitat is an immediate requirement for BBPWLS.

River Patrol and Other Infrastructure for DSNP & Adjoining Areas: The protection and anti poaching infrastructure of Dibru-Saikhowa NP and that of the BBP WLS are in shambles. While the National Park is just 340 sq km, the Biosphere area is 765 sq km. The old DSWLS sanctuary was declared over 650 sq km of area, most of which also falls in the buffer. Thus, the effective area for management, during rains, comes to about 800 sq km. It is difficult to manage the large rivers with a handful of staff and little country boats to navigate the swelling rivers. Therefore, two companies of river patrol may be raised, and the infrastructure of the Park may be revamped. Similarly, the anti poaching infrastructure of the BBP WLS also needs to be upgraded along with supplement of increased staff and equipment.

Maguri Motapung Rejuvination Plan: The Maguri Motapung beel has been devastated in the Baghjan blowout disaster. It is one of the most charming and world famous birding site. The beel is a rich habitat for many endangered and rare birds, fish fauna and other wildlife. The local people are dependent upon the waterbody for their livelihoods and protein source as well. Therefore, it is proposed to draw up a comprehensive conservation and rejuvination plan involving the local communities, with a 10 year perspective. The entire plan must be implemented with a SPV based time bound mission mode approach.

Centre of Excellence for Resource Studies and Simulations: Right from the beginning, while working on the Baghjan flame, one major bottleneck faced was lack of high performance computing infrastructure with capabilities to simulate large events using Finite Element Method (FEM), Computational Fluid Dynamics (CFD), large eddy simulations and other computer based numerical problem solving, Augmented Reality / Virtual Reality (AR/VR) etc. In absence of professional approach in simulating the flame and its various properties, actual assessment of damages was made difficult. A complete computational Centre of Excellence well equipped with not only simulation capabilities, but also all electronic equipment, sensors and assessment tools required to carry out field assessment of risks. Using such a state of the art facility, all the wells in the State (and later in the country) can be fully mapped for all possible risks, and risks

around pipelines could also be mapped, especially in the ecologically sensitive areas. All accidents, big and small can be simulated and characterized. Thus, events can be simulated well in time and risks can be reduced by understanding the underlying phenomena in a better way. Such a Centre of Excellence can ideally come up at the upcoming Tech City near Guwahati Airport where there would be an excellent environment for such a facility.

Implementation of 500 m Hazard Zone: Outside the well boundary, a radius of 500 m should be clearly demarcated as hazard zone, and every attempt should be made to ensure that there are no permanent habitations within the zone. If required, compensation should be paid, and people should be encouraged to relocate. As can be seen from the Baghjan experience, almost everything was burnt within a 300 m range. Properties within 500 m range also would be at a great risk, and depending upon wind direction, may get affected by fire. As per the Oil Mines Regulation, 1984, an area of 500 m around the well should be declared hazardous. In thickly populated areas, the populations in close proximity of the oil well would be exposed to a great risk. Therefore, in larger safety interests, every attempt should be made to ensure that, as much as possible, the 500 m area should be free of human habitation.

Insurance of Life, Health & Property: All persons at risk, especially all populations within 3 km radius, with first preference for people within 500m range, followed by 1 km range, and likewise, should be insured for life, health disorders and property. The value of the sum assured may vary depending upon the distance from the well sites. Zonation would be, however, best way to segregate and identify populations and properties at risk.

People Centric Infrastructure: Within 30-40 km of Baghjan, there are more than 100 oil drilling wells. Most wells are located in thickly populated areas. Close proximity of hazardous substances with human population is not desirable, but it may not be an option in Tinsukia. Nevertheless, the populations around the wells needs to be well taken care of in terms of best of schools, health centres, hobby centres, coaching and skilling centres, veterinary care units, seed farms, cold storage, sports infrastructure etc. Regular health check ups, counseling, provision of scholarships etc. are some of the regular activities that must be carried out throughout the year.

Carbon Sink Plantations: The best way to mitigate ill effects of CO_2 emissions is carbon sequestration with the help of large scale tree plantations. Plantations can be of two types, namely carbon sink plantations that would not be harvested before 60 to 100 years of age, and production forestry wherein short rotation timber crops can be grown

to meet the requirement of timber. Assuming that every tree sequesters about 5 tons of CO_2, in its lifetime of 100 years, (and we plan a mix of production and carbon sink forestry) and we need to sequester 30+ MMT CO_2, then, there is a requirement to plant roughly 50-80 year rotation carbon sink plantations, and short rotation 20-30 years timber production plantations. The total area to be covered may vary from 500-750 sq km depending upon species coverage. It is estimated that about 12-20 cr seedlings may be required at the beginning of the plantations, and after thinning, about ¼ to ⅕ trees may remain standing, depending upon the silvicultural requirements of the species. This would ensure that at least 1.20-3 crore trees are standing. This would ensure adequate carbon sequestering large enough to absorb the excess CO_2 emitted in the Baghjan blowout from 27th May, 2020 to 15th November, 2020. In order to achieve this arduous task, a SPV or a Forest Corporation would be required. The carbon may be traded in the voluntary market. However, selection of the carbon registry would depend upon many factors existing at the time of start of the project implementation. The project would require stringent monitoring and would be based verifiable carbon units (VCU) quality assurance principles.

Modernization of the Makum Timber Treatment Plan: When we talk of carbon capture and storage (CCS), timber treatment and preservation come to the centre stage. No CCS scheme can succeed without a modern timber treatment and seasoning infrastructure. Such a timber seasoning and treatment facility would ensure quality parameters in wood, and ensure longevity of the timber, ensuring that carbon remains locked firmly for a longer period of time. There is already an existing facility very near to Dibru-Saikhowa NP at Makum. However, it is in a dilapidated condition, and all the machinery has become very old and outdated. The facility needs to be modernized for a full scale production where timber from the departmental sources as well as from the members of the public can be treated. This facility would be essential for any major carbon capture initiative in the State.

17.5 Budgetary Proposals

A budgetary schema is provided hereunder, with a maximum of 10 year time frame and agenda plan to take up various schemes of ecosystem restoration, protection, livelihoods, wildlife etc. in a manner that, if implemented successfully, would not only create requisite infrastructure in the region, but also bring positive changes in the lives of people around these wells. The Government, if accepts some of these recommendations, would have to put in place an administrative mechanism for smooth running and sustenance of the programmes. It is expected that some of the schemes

could be run through the Deputy Commissioner, Tinsukia, or through a SPV, or a Forest Corporation, or an ecological society (ideally for the ecosystem restoration). Some works could be directly carried out through the line departments (say Forest Department for protected areas consolidation works to protection related infrastructure creation in the nearby protected areas).

Table No. 17.3: Brief of Proposed Projects & Schemes

Sl. No.	Project/ Scheme/ Program	Amount (Rs. Crore)
1.	State Level Fund for Ecological Disasters	1000.00
2.	Consolidation of Dibru-Saikhowa NP etc.	100.00
3.	Institute of Wildlife Health & Research	350.00
4.	Centre of Excellence	300.00
5.	Support to Wildlife logistics, manpower & research (Through Corpus)	350.00
6.	Maguri Motapung Beel Rejuvination Plan	200.00
7.	Carbon Capture & Storage	2000.00
8.	Peoples' infrastructure support projects in affected areas (Tinsukia district only)	1000.00
9.	Affected peoples' welfare	250.00
10.	Restoration of agriculture, homesteads, fisheries, livestock, livelihoods etc. of affected persons	300.00
11.	Special Package for Baghjan and surrounding areas	850.00
12.	Cost of Design, Planning, Execution and Management, ecosystem rejuvination monitoring	100.00
	TOTAL	**6800**

17.5.1 Cost of Report To be Defrayed

M/S Oil India Ltd. is required to defray all cost and expenditure involved in preparation of this Report including cost of equipment, consumables, logistics, Honoraria to all researchers & staff, professional fees, drone survey, sample testing etc. While, the recommendation of compensation fund of Rs. 6800 cr is subject to acceptance by the authorities concerned, it is strongly felt that at least for 3 (three) years, the ecosystem monitoring must continue under the aegis of the Expert Committee (notified by the

PCCF & HoFF). Therefore, the expenditure for at least 3 years' monitoring should be directly paid by OIL based on the recommendation of the Chief Wildlife Warden, Assam. It is estimated that about Rs. 3.00 cr would be required for monitoring, and another Rs. 2.50 cr for procurement of equipment. While monitoring expenditure can be made through the DFO, Tinsukia Wildlife Division for Dibru-Saikhowa National Park, Dibru River and BBPWLS, the DFO, Dibrugarh Forest Division for the Maguri Motapung Beel. The electronics sensors/ equipment drones, thermal cameras, spectral sensors etc. may be at the custody and disposal of the Assam Electronics Development Corporation Ltd.

The Expert Committee would continue its assessment on at least 6 monthly basis, and from time to time, and submit 6 monthly reports to the Government of Assam in the Forest Department, highlighting any major observations and may put forth suggestions. The assessment reports also would be put in public domain.

17.6 Publication Of The Report

On submission of this Report (in three volumes) to the Government of Assam, the Report would be put in public domain. The author reserves the right to use the contents of the Report for any scientific publication in peer reviewed journals and / or in a book form.

17.7 The Last Words

This Report is dedicated to the Fire of Baghjan, as it brought home so many new lessons to learn, dedicated to the people who lost their lives in the fire, dedicated to the people of Baghjan who suffered immensely and braved it all, lastly dedicated to the cause of ecology, environment, ecosystems, biodiversity, forestry and wildlife.

The recommendations of this Report are in no way binding on the Government of Assam or any authority for that matter. The Report may be summarily rejected or accepted or be acted upon fully or partially. No offence is meant towards any organization, entity, institution or individual or group(s) of individuals, or school(s) of thought.

While every attempt was made to make the Report error free, thanks to a few dedicated researchers and family members, such a voluminous report may still have a few errors left. Hope the reader would understand and pardon the author. However, for any factual errors, the reader is requested to get in touch with the undersigned at mkyadava@gmail.com.



Oil Spill in the Waterbodies at Baghjan



Oil Spill in the Dibru River at Dibru-Saikhowa National Park

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PHOTO GALLERY

BLOWOUT AND EXPLOSION AT OIL WELL NO. BGN-5








REDMI NOTE 6 PRO
MI DUAL CAMERA









Retrieval of human dead bodies on the second day of explosion (10th June 2020)



View of the flame from the closest possible site











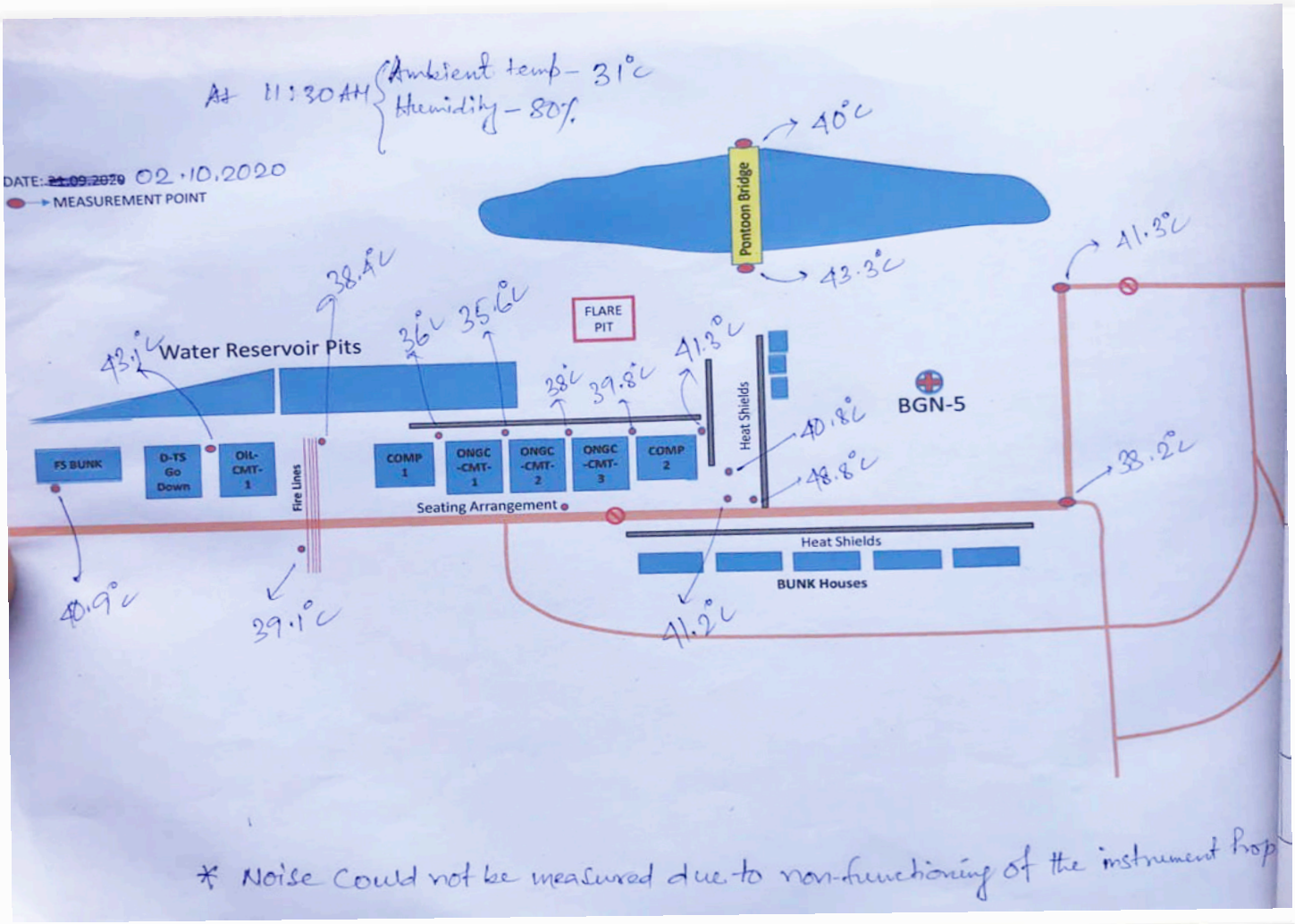

CAUTION
PRESSURING LINE



Diverting the original well to a new place






At 11:30 AM
Ambient temp – 31°C
Humidity – 80%
DATE: ~~21.09.2020~~ 02.10.2020
MEASUREMENT POINT
40°C
Pontoon Bridge
43.3°C
41.3°C
38.4°C
43.1°C
Water Reservoir Pits
36°C
35.6°C
FLARE PIT
38°C
39.8°C
41.3°C
Heat Shields
BGN-5
40.8°C
48.8°C
38.2°C
FS BUNK
D-TS Go Down
OIL-CMT-1
Fire Lines
COMP 1
ONGC -CMT-1
ONGC -CMT-2
ONGC -CMT-3
COMP 2
Seating Arrangement
Heat Shields
BUNK Houses
40.9°C
39.1°C
41.2°C
* Noise could not be measured due to non-functioning of the instrument prop





FAULTY EIA FAILED TO FORESEE SUCH A DISASTER
STEPS TAKEN BY OIL INDIA LIMITED AFTER THE BLOWOUT TO CONSTRUCT ESCAPE ROUTE, ROADS FOR MOBILIZING EMERGENCY SUPPORT, CONSTRUCTION OF PIPELINE FOR EMERGENCY DIVERSION OF GAS/OIL FLOW








KOEL
KOEL

















ACTIVITIES CARRIED OUT BY THE OMEC AND EC TO ASSESS THE ECOLOGICAL & ENVIRONMENTAL DAMAGES

IN DIBRU-SAIKHOWA NATIONAL PARK, BHERJAN-BORAJAN-PODUMONI WILDLIFE SANCTUARY AND OTHER ADJOINING WILDLIFE HABITATS


































08













DAMAGES CAUSED TO VARIOUS ECOSYSTEMS
&
HABITATS












©Merin.J







DAMAGES CAUSED TO VARIOUS ECOSYSTEMS

SOME AERIAL VIEWS







DAMAGES TO VARIOUS ECOSYSTEMS

AFFECTED WILD ANIMALS AND OTHER WILDLIFE



Gangetic River Dolphin (*Platanista gangetica*)



Dead Fish



Dead Softshell Turtle



Dead mollusc sighted 530 m from the blowout site



Dead Asian Pied Starling



Burnt eggs of a grassland bird

REPEATED WAVES OF FLOOD AFTER THE BLOWOUT THAT CAUSED LOSS OF EVIDENCES













LEPIDOPTERA



Atlas Moth (*Attacus atlas*)



Bush Brown Butterfly (*Mycalesis perseus*)



Lesser Zebra (*Graphium macareus*)



Striped Tiger (*Danaus genutia*)



Peacock Pansy (*Junonia almana*)



Paris Peacock (*Papilio paris*)

Some of the moths encountered in the survey (Photos: SA)



Heterocnephes lymphatalis Swinhoe 1889



Choreutis ophiosema (Lower, 1896)



Rhagoba octomaculalis (Moore, 1867)



Belippa horrida Walker, 1865



Hydrillodes sp.



Idonauton apicalis Walker 1855

ODONATA



Scarlet Skimmer- Female (*Crocothemis servilia*)



Scarlet Skimmer- Male (*Crocothemis servilia*)



Indian Common Clubtail (*Ictinogomphus rapax*)

HERPETOFAUNA



Banded Krait (*Bungarus fasciatus*)



Red-necked Keelback *(Rhabdophis subminiatus*)



Assam roofed turtle (*Pangshura sylhetensis*)



Yellow-spotted wolf snake *(Lycodon flavomaculatus*)



Indian Bull frog *(Hoplobatrachus tigerinus*)



Himalayan tree frog (*Polypedates himalayensis*)



Indian Bull frog *(Hoplobatrachus tigerinus*)



Indian Skipping Frog (*Euphlyctis cyanophlyctis*)



Pierre's Cricket Frog (*Fejervarya pierrei*)



Indian Skipping Frog
Euphlyctis cyanophlyctis



Pierre's Cric et Frog
Minervarya pierrei



Assam Forest Frog
Hydrophylax leptoglossa

AVIFAUNA



White-winged Duck (*Asarcornis scutulata*)



Black-breasted Parrotbill (*Paradoxornis flavirostris*)



Oriental Pied Hornbill (*Anthracoceros albirostris*)



Collared Scops Owl (*Otus lettia*)



Slender-billed Vulture (*Gyps tenuirostris*)



Steppe Eagle (*Aquila nipalensis*)



Flock of Gadwall (*Mareca strepera*)



Mixed flock of vultures



Red-wattled Lapwing (*Vanellus indicus*)

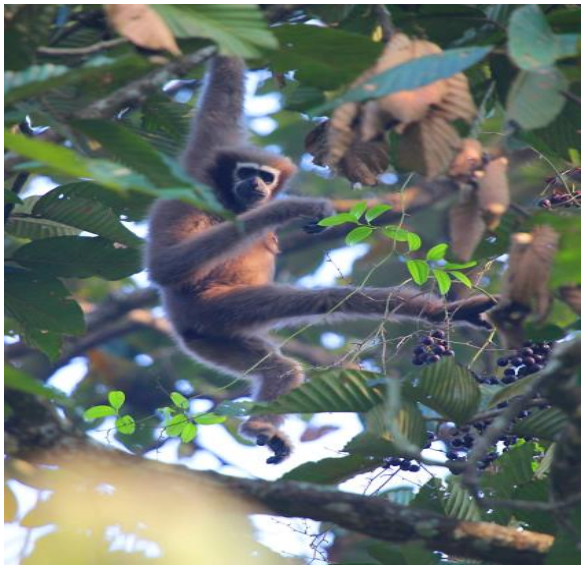


Brown Hawk Owl (*Ninox scutulata*)



Little Cormorant (*Microcarbo niger*)

MAMMALS



Hoolock Gibbon-Female (*Hoolock hoolock*)



Hoolock Gibbon-Female with infant (*Hoolock hoolock*)



Capped Langur-Female with infant (*Trachypithecus pileatus*)



Feral Horse (*Equus ferus*)



Capped Langur (*Trachypithecus pileatus*)



Particolored Flying Squirrel (*Hylopetes alboniger*)



Red Giant Flying Squirrel (*Petaurista petaurista*)



Malayan Giant Squirrel (*Ratufa bicolour*)

ANNEXURES

सत्यमेव जयते

GOVERNMENT OF ASSAM

OFFICE OF THE ONE MAN ENQUIRY COMMITTEE

(ORDER NO- FRW.6/2020/1 DATED.12/06/2020)

ROOM NO.08, CIRCUIT HOUSE,
TINSUKIA, ASSAM,
PIN-786126.

Email ID:
onemancommitteemky@gmail.com

No. OMEC/MKY/BGN-5/2020/L01/48 **Dt. 12th November, 2020**

From: M.K. Yadava, IFS,
Addl. PCCF (WL) & CWLW and
One Man Enquiry Committee

To
The Principal Secretary to the Govt. of Assam,
Department of Environment & Forests, Dispur,
Guwahati-781 006, Assam

Sub:- Submission of Enquiry Report of the One Man Enquiry Committee
Ref:- Govt. Of Assam Letter No. RW.6/2020/1 Dt.12th June, 2020 &
Letter No. FRW.6/2020/83 Dt. 4th July, 2020

Sir,

With reference to the subject cited above, I am submitting herewith the Report of the One Man Enquiry Committee to assess damages that occured due to the blowout, explosion and subsequent fire at the Baghjan Oil Well in Tinsukia District.

The Report is in three Volumes, First Volume being the Report per se, the Second Volume being compilation of all subsidiary reports received from the members of the Expert Committee, constituted by the PCCF & HoFF under the Chairmanship of the undersigned, and other organizations notably the Wildlife Institute of India, Bombay Natural History Society, Dr. Narayan Sharma of Cotton University and his team, College of Fisheries, Raha, Assam Agricultural University, Jorhat, and other noted research scholars and experts such as Dr. Deborshee Gogoi, Dr. Ranjita Bania. Heat and noise and other sensor based measurements, drone based orthophotography were done by AMTRON. Environmental tests were carried out by PCBA, and also EIA by agencies employed by M/S OIL. The Third Volume is compilation of

secondary documentary records, petitions and material received from the members of public and the correspondences of the Committee. However, currently only Volume I is being submitted. The compilation work for the other two volumes is in progress.

Furthermore, since, the Baghjan flame is yet to be extinguished, this Report may not be considered as final. It is proposed to compile an updated version together with the other two volumes, once the flame is extinguished and a ground reconnaisance is done once again.

I must admit that the Baghjan blowout has been quite a tragedy and an ecological disaster. It was very challenging to approach at the beginning. The scene near Ground Zero in the first few days after the fire, was almost like a holocaust. Things were made so much easier after the visit of the Hon'ble Chief Minister, Assam, Sri Sarbananda Sonowal together with the Hon'ble Union Minister, MoPNG, New Delhi, Sri Dharmendra Pradhan on the 14th June, 2020. The actual assessment works started only thereafter.

As the work progresed steadily, inflow of new inputs and observations continued demanding additional strategies and experiments. The Committee under Justice B. P. Katakey, Retired Judge of the Hon'ble Gauhati High Court, which has been entrusted by the Hon'ble NGT to enquire into the matter, also referred the Report on heat and noise by the IIT Guwahati to this Committee. M/s Oil India was also asked to forward the vibration study reports (for two months) carried out by NEIST, Jorhat. OIL also provided noise measurements done by agencies appointed by them, and submitted reports on daily basis to the Chief Secretary, Assam after the Baghjan disaster. The DFO, Tinsukia Wildlife Division and DFO Dibrugarh also carried out assessment of the dead wildlife, and applicability of the Wildlife (Protection) Act, 1972. Therefore, the Report increased manifold in complexity, resulting in a detailed analtics of the incident and consequences thereof. Some results came as recent as first week of November, 2020, especially the Report on the death of the Ganges River Dolphin from the College of Veterinary Science, Khanapara.

I wish to take this opportunity to thank the Government of Assam for appointing me to head the Committee as one man, and thus, to serve the cause of environmental protection. Hope the Report finds some utility and is able to serve the cause for which it was commissioned.

Thanking you,

Yours faithfully,

(Mahendra Kumar Yadava IFS)

List of species encountered during the survey by all the groups:

Phytoplanktons

Sl. No.	Scientific Name
1	*Navicula sp.*
2	*Cholerella sp.*
3	*Clamydomonas sp.*
4	*Cladophera sp*
5	*Closterium sp.*
6	*Cosmarium sp.*
7	*Desmidium sp.*
8	*Netrium sp.*
9	*Volvox sp.*
10	*Anabaena sp.*
11	*Oscillatoria sp.*

Zooplanktons

Sl. No.	Scientific Name
1	*Anuraeopsis fissa*
2	*Collurella sulcata*
3	*Depheuchlanis propatus*
4	*Fillinia longiseta*
5	*Keratella cochlearis*
6	*Lecane aceleate*
7	*Lecane ovalis*
8	*Monostyla bulla*
9	*Alona sp.*
10	*Alonella dentifera*
11	*Bosmina longirostris*
12	*Daphnia sp.*
13	*Diaptomus sp.*

Earthworm

Sl. No.	Scientific Name
1	*Eutyphoeus assamensis*

Butterfly

Sl. No.	Common Name	Scientific Name
1	Staff Sergeant	*Athyma selenophora*
2	Plum Judy	*Abisara echerius*
3	Uraniid moth	*Acropteris sp*
4	Common Hedge Blue	*Acytolepis puspa*
5	Pygmy Scrub Hopper	*Aeromachus pygmaeus*
6	Bush Hopper	*Ampittia dioscorides*
7	Common Ciliate Blue	*Anthene emolus*
8	Pointed Ciliate Blue	*Anthene lycaenina*
9	wild tasar silk	*Antheraea frithi*
10	Lilac Silverline	*Apharitis lilacinus*
11	Chocolate Albatross	*Appias lyncida*
12	Indian Fritillary	*Argynnis hyperbius*
13	Centaur Oakblue	*Arhopala centaurus*
14	Angled Castor	*Ariadne ariadne*
15	Common Castor	*Ariadne merione*
16	Common Sergeant	*Athyma perius*
17	Blackvein Sergeant	*Athyma ranga*

18	Common Batwing	*Atrophaneura varuna astorion*
19	Small Greeen Awlet	*Bibasis amara*
20	Orange Awlet	*Bibasis jaina*
21	Orangetail Awl	*Bibasis sena*
22	Elbowed pierrot	*Caleta elna*
23	Colon Swift	*Caltoris cahira*
24	Common Pierrot	*Castalius rosimon*
25	Common Emigrant	*Catopsilia pomona*
26	Leopard Lacewing	*Cethosia cyane*
27	Mandarin Blue	*Charana mandarina*
28	Common Imperial	*Cheritra freja*
29	Lime Blue	*Chilades lajus*
30	Orchid Tit	*Chliaria othana*
31	Indian awlking	*Choaspes benjaminii*
32	Metalmark Moth	*Chreotuis ophiosena*
33	Common Yeoman	*Cirrochroa tyche*
34	Angled Sunbeam	*Curetis acuta*
35	Assam Sunbeam	*Curetis saronis*
36	Common map	*Cyrestis thyodamas*
37	Plain Tiger	*Danaus chrysippus*
38	Common Tiger	*Danaus genutia*
39	Redbase Jezebel	*Delias acalis*
40	Redspot Jezebel	*Delias descombesi*
41	Painted Jezebel	*Delias hyparete*
42	Red-Base Jezebel	*Delias pasithoe*
43	Common Palmfly	*Elymnias hypermnestra*
44	Tiger plamfly	*Elymnias nesaea*
45	Common Crow	*Euploea core*
46	Striped Blue Crow	*Euploea mulciber*
47	Magpie Crow	*Euploea radamanthus*
48	Three Spot grass yellow	*Eurema blanda*
49	Small Grass Yellow	*Eurema brigitta*
50	Common Grass Yellow	*Eurema hecabe*
51	Baron	*Euthalia aconthea*
52	Powdered baron	*Euthalia monina*
53	White-edged Blue Baron	*Euthalia phemius*
54	Tailed Jay	*Graphium agamemnon*
55	Fivebar Swordtail	*Graphium antiphates pompilius*
56	Common Bluebottle	*Graphium sarpedon*
57	Common Awl	*Hasora badra*
58	Common Banded Awl	*Hasora chromus*
59	Great Orange-tip	*Hebomoia glaucippe*
60	Purple Sapphire	*Heliophorus epicles*
61	Circe	*Hestina nama*
62	Great Eggfly	*Hypolimnas bolina*
63	Danaid Eggfly	*Hypolimnas misippus*

64	Common Tit	*Hypolycaena erylus*
65	Glassy Tiger	*Ideopsis juventa*
66	Dark Cerulean	*Jamides bochus*
67	Common Cerulean	*Jamides celeno*
68	cerulean	*Jamides sp*
69	Peacock Pansy	*Junonia almana*
70	Grey Pansy	*Junonia atlites*
71	Chocolate Pansy	*Junonia iphita*
72	Lemon Pansy	*Junonia lemonias*
73	Pea blue	*Lampides boeticus*
74	knight	*Lebadea martha*
75	Psyche	*Leptosia nina*
76	Dark Archduke	*lexias dirtea*
77	yamfly	*Loxura sp*
78	Common red eye	*Matapa aria*
79	Common Evening Brown	*Melanitis leda*
80	Dark Evening Brown	*Melanitis phedima*
81	Great Evening Brown	*Melanitis zitenius*
82	Uraniid moth	*Micronia aculeata*
83	Dark-brand Bushbrown	*Mycalesis mineus*
84	Common Bushbrown	*Mycalesis perseus*
85	Long-brand Bushbrown	*Mycalesis visala*
86	Sullied Sailer	*Neptis clinia*
87	Common Sailer	*Neptis hylas*
88	Clear Sailer	*Neptis nata*
89	Pallas Sailer	*Neptis sappho*
90	Sailer	*Neptis sp*
91	Redbreast	*Papilio alcmenor alcmenor*
92	Common Raven	*Papilio castor*
93	Lime Butterfly	*Papilio demoleus*
94	Red helen	*Papilio helenus*
95	Great Mormon	*Papilio memnon*
96	Yellow Helen	*Papilio nephelus*
97	Paris Peacock	*Papilio paris*
98	Common Mormon	*Papilio polytes*
99	Spangle	*Papilio protenor euprotenor*
100	Glassy Tiger	*Parantica aglea*
101	Chocolate Tiger	*Parantica melaneus*
102	Chestnut Tiger	*Parantica sita*
103	Straight Swift	*Parnara bada*
104	Great swift	*Pelopidas assamensis*
105	Common Leopard	*Phalanta phalantha*
106	Indian Cabbage White	*Pieris canidia*
107	Contiguous Swift	*Polytremis lubricans*
108	Common Lineblue	*Prosotas nora*
109	Bagworm catterpillar	*Psychidae sp*

110	Slate Flash	*Rapala manea*
111	Scarce Slate Flash	*Rapala scintilla*
112	Stathmopod moth	*Stathmopodidae sp.*
113	Popinjay	*Stibochiona nicea*
114	Common Acacia Blue	*Surendra quercetorum*
115	Common Jester	*Symbrenthia lilaea*
116	Plain Earl	*Tanaecia jahnu*
117	Grey Count	*Tanaecia lepidea*
118	Common Palmdart	*Telicota colon*
119	Butterfly Moth	*Tetragonus catamitus*
120	Blue Tiger	*Tirumala limniace*
121	Dark Blue Tiger	*Tirumala septentrionis*
122	Golden Birdwing	*Troides aeacus*
123	Common Birdwing	*Troides helena*
124	Vagrant	*Vagrans egista*
125	Common Fivering	*Ypthima baldus*
126	Fluffy tit	*Zeltus amasa*
127	Punchinello	*Zemeros flegyas*
128	Dark Grass Blue	*Zizeeria karsandra*
129	Pale Grass Blue	*Zizeeria maha*
130	Common grass blue	*Zizina labradus*

Moths

Sl. No.	**Scientific Name**
1	*Psychidae sp.*
2	*Lecithoceridae sp.*
3	*Opogona sp.*
4	*Stathmopodidae sp.*
5	*Pterophoridae sp.*
6	*Choretuis ophiosena*
7	*Clepsis sp.*
8	*Loboschiza sp.*
9	*Pandemis sp.*
10	*Xyleutes sp.*
11	*Narosa sp.*
12	*Parasa pastoralis*
13	*Bellipa sp.*
14	*Demonarosa sp.*
15	*Limacodidae sp.*
16	*Melinaria pseudorepanda*
17	*Phocoderma sp.*
18	*Prapata sp.*
19	*Setora sp.*
20	*Setothosea sp.*
21	*Spatulifimbria sp.*
22	*Nephelimorpha sp.*
23	*Cyclosia papilionaris*
24	*Eterusia aedea*
25	*Cyclidia substigmaria*
26	*kunugia sp.*
27	*Antheraea frithi*
28	*Dysaethria sp.*
29	*Micronia aculeata*
30	*Acropteris sp.*
31	*Acropteris sp.*
32	*Micronia aculeata*
33	*Phazaca sp.*
34	*Urapteroides sp.*
35	*Cleora sp.*
36	*Cleora sp.*
37	*Epipristis sp.*
38	*Episothalma robustaria*
39	*Eumelea sp.*

40	*Fascellina sp.*
41	*Abraxas sp.*
42	*Acolutha pictaria*
43	*Amblychia sp.*
44	*Astygisa sp.*
45	*Hyposidra sp.*
46	*Lacera sp.*
47	*Ourapteryx sp.*
48	*Parasynergia sp.*
49	*Pelagodes sp.*
50	*Pingasa sp.*
51	*Scopula sp.*
52	*Tanaorhinus sp*
53	*Thinopteryx crocoptera*
54	*Thinopteryx sp.*
55	*Traminda aventiaria*
56	*Traminda sp.*
57	*Xandrames sp.*
58	*Protuliocnemis sp.*
59	*Biston sp.*
60	*Biston suppressaria*
61	*Argina argus*
62	*Cispia sp.*
63	*Creatonotos gangis*
64	*Creatonotos transiens*
65	*Cyana sp.*
66	*Hemonia sp.*
67	*Hydrillodes sp.*
68	*Hypena sp*
69	*Laspeyria sp.*
70	*Miltochrista sp.*
71	*Mocis frugalis*
72	*Oeonistis altica*
73	*Ovipennis sp.*
74	*Oxaenanus sp.*
75	*Progonia sp.*
76	*Amerila sp.*
77	*Anomis flava*
78	*Arctornis sp.*
79	*Asota caricae*
80	*Asota egens*
81	*Asota heliconia*
82	*Baradesa sp.*
83	*Barsilene sp.*
84	*Barsine sp.*
85	*Lyclene sp.*

86	*Numenes sp.*
87	*Numens sp.*
88	*Nyctemera sp.*
89	*Nygmia sp.*
90	*Oreta sp.*
91	*Orgiya sp.*
92	*Perina nuda*
93	*Bastilla arcuata*
94	*Somena sp.*
95	*Bastilla simillima*
96	*Bastilla sp.*
97	*Garella variegata*
98	*Callyna jugaria*
99	*Episparis liturata*
100	*Naranga diffusa*
101	*Spodoptera litura*
102	*Spodoptera sp.*
103	*Arcte modesta*
104	*Athetis sp.*
105	*Callopistria sp.*
106	*Calamotropha sp.*
107	*Chabula sp.*
108	*Cnaphalocrocis sp.*
109	*Cotachena sp.*
110	*Diaphania indica*
111	*Eoophyla sp.*
112	*Glycythyma sp.*
113	*Glyphodes sp.*
114	*Haritalodes derogata*
115	*Herpetogramma luctuosalis*
116	*Heterostegane sp.*
117	*Hyalobathra sp.*
118	*Nacoleia sp.*
119	*Nosophora semitritalis*
120	*Orthospila sp.*
121	*Pagyda sp.*
122	*Paraponyx sp.*
123	*Paraponyx stagnalis*
124	*Parapta sp.*
125	*Prooedema incisalis*
126	*Prophantis adusta*
127	*Prophantis sp.*
128	*Pycnarmon sp.*
129	*Ramila sp.*
130	*Rhagoba octomaculalis*
131	*Rhimphalea sp.*

132	*Sameodes cancellalis*
133	*Schoenobiinae sp.*
134	*Scirpophaga incertulas*
135	*Scirpophaga sp.*
136	*Tysponodes sp.*
137	*Dichorosis sp.*
138	*Analthes semitritalis*
139	*Antigastra sp.*
140	*Arthroschista hilaralis*

141	*Arthroschista sp.*
142	*Cnaphalocrosis medinalis*
143	*Heterocnephes lymphatalis*
144	*Limbobotys sp.*
145	*Tetragonus catamitus*
146	*Trilocha sp.*
147	*Eupterote sp.*
148	*Bostra indicator*

Odonates

Sl. No.	Common Name	Scientific Name
1	Trumpet Tail	*Acisoma panorpoides*
2	Scarlet Marsh Hawk	*Aethriamanta brevipennis*
3	Rufous-Backed Marsh Hawk	*Brachydiplax chalybea*
4	Ditch Jewel	*Brachythemis contaminata*
5	Orange-tailed marsh dart	*Ceriagrion cerinorubellum*
6	Scarlet skimmer	*Crocothemis servilia*
7	Blue Ground Skimmer	*Diplacodes trivialis*
8	Common Blue damselfly	*Enallagma cyathigerum*
9	Indian Common Clubtail	*Ictinogomphus rapax*
10	Fulvous Forest Skimmer	*Neurothemis fulvia*
11	Slinder skimmer	*Orthetrum sabina*
12	Wandering Glider	*Pantala flavescens*
13	Blue Riverdamselfly	*Pseudagrion microcephalum*
14	Common Picture Wing	*Rhyothemis variegata*
15	Crimson Marsh Glider	*Trithemis aurora*
16	Greater crimson glider	*Urothemis signata*
17	Slinder skimmer	*Orthetrum sabina*

Mollusca

Sl. No.	Scientific Name
1	*Austenia sp.*
2	*Gyraulus convexiusculus*
3	*Indoplanorbis exustus*
4	*Pila globosa*
5	*Brotia costula*
6	*Angulyagra oxytropis*

7	*Mekongia crassa*
8	*Intha umblicalis*
9	*Macrochlamys glauca*
10	*Lamellidens marginalis*
11	*Pisidium sp.*
12	*Sphaerium indicum*

Fish

Sl. No.	Common Name	Scientific Name
1	Kalabans	*Bangara dero*
2	Barna baril	*Baralius barna*
3	Sand Loach	*Acanthocobititis botia*
4	Badis	*Badis badis*
5	Tiger loach	*Botia dario*
6	Catla	*Catla catla*
7	Chaguni	*Chagunius chagunio*
8	Elongate Glassy Perchiet	*Chanda nama*
9	Orange-spotted Snakehead	*Channa aurantimaculata*
10	Gaint snake head	*Channa marulius*
11	Spotted Snake Head	*Channa punctata*
12	Indian glass fish	*Chela laubuca*
13	Mrigal carp	*Cirrhinus mrigala*
14	Reba carp	*Cirrhinus reba*
15	Walking catfish	*Clarius batrachus*
16	Indian flying barb	*Esomus danricus*
17	Batchwa vacha	*Eutropiichthys vacha*
18	Tank gobi	*Glossogobius giuris*
19	Stinging Catfish	*Heteropneustes fossillis*
20	Bata labeo	*Labeo bata*
21	Calbasu	*Labeo calbasu*
22	Kuria Labeo	*Labeo gonius*
23	Roho labeo	*Labeo rohita*
24	Ocellated Puffer	*Leiodon cutcutia*
25	Spiny eel	*Mastacembelus armatus*
26	Striped spiny eel	*Mastacembelus pancalus*
27	Rice swamp eel	*Monopterus albus*
28	Gangetic mystus	*Mystus cavasius*
29	Tengara mystus	*Mystus tengara*
30	Striped dwarf catfish	*Mystus vittatus*
31	Kanduli	*Notopterus notopterus*
32	Hafua	*Osteobrama cotio*
33	Indian glassy fish	*Parambassis ranga*
34	Blackline rasbora	*Parluciosoma daniconius*
35	Golden dwarf barb	*Pethia gelius*
36	Swarm Barbs	*Puntius chola*
37	Red barb	*Puntius conchonius*
38	Olive barb	*Puntius sarana sarana*
39	Spot fin swamp barb	*Puntius sophore*
40	Ticto Barb	*Puntius ticto ticto*
41	Gangetic scissortail rasbora	*Rasbora rasbora*
42	Large razorbelly minnow	*Salmophasia bacaila*
43	Long-whiskered catfish	*Sperata aor*
44	Gaint river catfish	*Sperata seenghala*

45	Gangetic latia	*Tariqilabeo latius*
46	Banded Colisa	*Trichogaster fasciata*
47	Dwarf gourami	*Trichogaster lalia*
48	Boal	*Wallago attu*
49	Freshwater garfish	*Xenetodon cancila*

Amphibians

Sl. No.	Common Name	Scientific Name
1	Asian Common Toad	*Duttaphrynus melanostictus*
2	Common skittering frog	*Euphlyctis cyanopthyctis*
3	Pierre's Cricket Frog	*Fegervarya pierrei*
4	Bangladeshi Cricket Frog	*Minervarya asmati*
5	Indian Bull Frog	*Haplobatrachus tigerinus*
6	Brahmo Frog	*Humerana humeralis*
7	Assam Forest Frog	*Hydrophylax leptoglossa*
8	Ornamented Pigmy Frog	*Microhyla ornata*
9	Tree Frog	*Polypedates sp.*
10	Terai tree frog	*Polypedates teraiensis*

Reptiles

Sl. No.	Common Name	Scientific Name
1	Stripped Keelback	*Amphiesma stolatum*
2	Diard's Blind Snake	*Argyrophis diardii*
3	Eyed Cat Snake	*Boiga siamensis*
4	Common Garden Lizard	*Calotes versicolor*
5	Checkered Keelback	*Fowlea piscator*
6	Brook's house gecko	*Hemidactylus brookii*
7	Common House Gecko	*Hemidactylus frenatus*
8	Brahminy blind snake	*Indotyphlops braminus*
9	Peacock Softshell Turtle	*Nilssonia hurum*
10	Oriental Ratsnake	*Ptyas mucosa*
11	Red-necked keelback	*Rhabdophis subminiatus*
12	Common Water Monitor	*Varanus salvator*

Birds

Sl. No.	Common Name	Scientific Name
1	Jungle Myna	*Acridotheres fuscus*
2	Intermediate Egret	*Ardea intermedia*
3	Indochinese Roller	*Coracias affinis*
4	Asian Palm Swift	*Cypsiurus balasiensis*
5	Lesser Whistling-Duck	*Dendrocygna javanica*
6	Black Drongo	*Dicrurus macrocercus*
7	Black-winged Kite	*Elanus caeruleus*

8	Barn Swallow	*Hirundo rustica*
9	Yellow Bittern	*Ixobrychus sinensis*
10	Bronze-winged Jacana	*Metopidius indicus*
11	Red-vented Bulbul	*Pycnonotus cafer*
12	Shikra	*Accipiter badius*
13	Jungle Myna	*Acridotheres fuscus*
14	Great Myna	*Acridotheres grandis*
15	Common Myna	*Acridotheres tristis*
16	Common Iora	*Aegithina tiphia*
17	Crimson Sunbird	*Aethopyga siparaja*
18	Oriental Skylark	*Alauda gulgula*
19	Common Kingfisher	*Alcedo atthis*
20	White-breasted Waterhen	*Amaurornis phoenicurus*
21	Indian Spot-billed Duck	*Anas poecilorhyncha*
22	Asian Openbill	*Anastomus oscitans*
23	Oriental Darter	*Anhinga melanogaster*
24	Oriental Pied Hornbill	*Anthracoceros albirostris*
25	Paddyfield Pipit	*Anthus rufulus*
26	Little Swift	*Apus affinis*
27	Great Egret	*Ardea alba*
28	Intermediate Egret	*Ardea intermedia*
29	Purple Heron	*Ardea purpurea*
30	Indian Pond Heron	*Ardeola grayii*
31	Striated Babbler	*Argya earlei*
32	Ashy woodswallow	*Artamus fuscus*
33	Spotted Owlet	*Athene brama*
34	Cattle Egret	*Bubulcus ibis*
35	Indian Thick-knee	*Burhinus indicus*
36	Green-backed Heron	*Butorides striata*
37	Sand Lark	*Calandrella raytal*
38	Large-tailed Nightjhar	*Caprimulgus macrurus*
39	Lesser Coucal	*Centropus bengalensis*
40	Greater Coucal	*Centropus sinensis*
41	Pied Kingfisher	*Ceryle rudis*
42	Greater Flameback	*Chrysocolaptes guttacristatus*
43	Jerdon's Babbler	*Chrysomma altirostre*
44	Purple sun bird	*Cinnyris asiaticus*
45	Common Green Magpie	*Cissa chinensis*
46	Golden-headed Cisticola	*Cisticola exilis*
47	Zitting Cisticola	*Cisticola juncidis*
48	Feral Pigeon	*Columba livia domestica*
49	Pale-capped Pigeon	*Columba punicea*
50	Oriental Magpie Robin	*Copsychus saularis*
51	Indochinese Roller	*Coracias affinis*
52	Indian Cuckooshrike	*Coracina macei*
53	Large-billed Crow	*Corvus macrorhynchos*

54	House Crow	*Corvus splendens*
55	Indian Cuckoo	*Cuculus micropterus*
56	Rufous-capped Babbler	*Cyanoderma ruficeps*
57	Rufous Treepie	*Dendrocitta vagabunda*
58	Fulvus Whistling Duck	*Dendrocygna bicolor*
59	Lesser Whistling Duck	*Dendrocygna javanica*
60	Scarlet-backed Flowerpecker	*Dicaeum cruentatum*
61	Hair crested Drongo	*Dicrurus hottentottus*
62	Black Drongo	*Dicrurus macrocercus*
63	Green Imperial-pigeon	*Ducula aenea*
64	Little Egret	*Egretta garzetta*
65	Black-winged Kite	*Elanus caeruleus*
66	Asian Koel	*Eudynamys scolopaceus*
67	Verditer Flycatcher	*Eumyias thalassinus*
68	Little Pied Flycatcher	*Ficedula westermanni*
69	Swamp Francolin	*Francolinus gularis*
70	Watercock	*Gallicrex cinerea*
71	Red Junglefowl	*Gallus gallus*
72	Lesser Necklaced Laughingthrush	*Garrulax monileger*
73	Rufous-necked Laughingthrush	*Garrulax ruficollis*
74	Asian Barred Owlet	*Glaucidium cuculoides*
75	Common Hill Myna	*Gracula religiosa*
76	Asian Pied Starling	*Gracupica contra*
77	White-rumped Vulture	*Gyps bengalensis*
78	Slender billed vulture	*Gyps tenuirostris*
79	White-throated Kingfisher	*Halcyon smyrnensis*
80	Common Hawk-cuckoo	*Hierococcyx varius*
81	Barn Swallow	*Hirundo rustica*
82	Bengal Florican	*Houbaropsis bengalensis*
83	Pheasant-tailed Jacana	*Hydrophasianus chirurgus*
84	Black-naped Monarch	*Hypothymis azurea*
85	Cinnamon Bittern	*Ixobrychus cinnamomeus*
86	Black Bittern	*Ixobrychus flavicollis*
87	Yellow Bittern	*Ixobrychus sinensis*
88	Lesser Adjutant	*Leptoptilos javanicus*
89	Chestnut Munia	*Lonchura atricapilla*
90	Black-headed Munia	*Lonchura malacca*
91	Martin	*Martin Sp*
92	Blue throated barbet	*Megalaima asiatica*
93	Striated Grassbird	*Megalurus palustris*
94	Asian Green Bee-eater	*Merops orientalis*
95	Blue Tailed Bee Eater	*Merops philippinus*
96	Bronze-winged Jacana	*Metopidius indicus*
97	Little Cormorant	*Microcarbo niger*
98	Black Kite	*Milvus migrans*
99	Bengal Bushlark	*Mirafra assamica*

100	Pin-striped Tit-babbler	*Mixornis gularis*
101	Cotton Pygmy Goose	*Nettapus coromandelianus*
102	Black-crowned Night-heron	*Nycticorax nycticorax*
103	Black-hooded Oriole	*Oriolus xanthornus*
104	Dark-necked Tailorbird	*Orthotomus atrogularis*
105	Common Tailorbird	*Orthotomus sutorius*
106	Osprey	*Pandion haliaetus*
107	Cinereous tit	*Parus cinereus*
108	House Sparrow	*Passer domesticus*
109	Eurasian Tree Sparrow	*Passer montanus*
110	Stork-billed Kingfisher	*Pelargopsis capensis*
111	Spot-billed Pelican	*Pelecanus philippensis*
112	Marsh Babbler	*Pellorneum palustre*
113	Puff-throated Babbler	*Pellorneum ruficeps*
114	Oriental Honey Buzzard	*Pernis ptilorhynchus*
115	Green-billed Malkoha	*Phaenicophaeus tristis*
116	Great Cormorant	*Phalacrocorax carbo*
117	Grey-cheeked Warbler	*Phylloscopus poliogenys*
118	Lesser Yellownape	*Picus chlorolophus*
119	Glossy ibis	*Plegadis falcinellus*
120	Gray-headed Swamphen	*Porphyrio poliocephalus*
121	Purple Swamphen	*Porphyrio porphyrio*
122	Yellow-bellied Prinia	*Prinia flaviventris*
123	Graceful Prinia	*Prinia gracilis*
124	Grey-breasted Prinia	*Prinia hodgsonii*
125	Plain Prinia	*Prinia inornata*
126	Coppersmith Barbet	*Psilopogon haemacephalus*
127	Lineated Barbet	*Psilopogon lineatus*
128	Alexandrine Parakeet	*Psittacula eupatria*
129	Rose-ringed Parakeet	*Psittacula krameri*
130	Red-vented Bulbul	*Pycnonotus cafer*
131	Red-whiskered Bulbul	*Pycnonotus jocosus*
132	White-throated Fantail	*Rhipidura albicollis*
133	Asian Plain Martin	*Riparia chinensis*
134	Greater Painted-snipe	*Rostratula benghalensis*
135	White-tailed Stonechat	*Saxicola leucurus*
136	Eastern Spotted Dove	*Spilopelia chinensis*
137	Crested Serpent Eagle	*Spilornis cheela*
138	River Tern	*Sterna aurantia*
139	Red Turtle-dove	*Streptopelia tranquebarica*
140	Chestnut-tailed Starling	*Sturnia malabarica*
141	Chestnut-capped Babbler	*Timalia pileata*
142	Orange-breasted Green-pigeon	*Treron bicinctus*
143	Thick-billed Green-pigeon	*Treron curvirostra*
144	Ashy-headed Green-pigeon	*Treron phayrei*
145	Yellow-legged Green Pigeon	*Treron phoenicopterus*

146	Striated Babbler	*Turdoides earlei*
147	Eastern Grass-owl	*Tyto longimembris*
148	River Lapwing	*Vanellus duvaucelii*
149	Red-wattled Lapwing	*Vanellus indicus*
150	Warbler	*Warbler sp.*
151	Indian White-eye	*Zosterops palpebrosus*

Mammals

Sl. No.	**Common Name**	**Scientific Name**
1	Asian Elephant	*Elephas maximus*
2	Indian Hog deer	*Axis porcinus*
3	Barking deer	*Muntiacus muntjak*
4	Feral horse	*Equus ferus*
5	Gangetic dolphin	*Platanista gangetica*
6	Wild water buffalo	*Bubalus arnee*
7	Hispid hare	*Caprolagus hispidus*
8	Common Leopard	*Panthera pardus*
9	Sambar	*Rusa unicolor*
10	Rhesus Macaque	*Macaca mulatta*
11	Assamese Macaque	*Macaca assamensis*
12	Wild Boar	*Sus scrofa*
13	Hoolock Gibbon	*Hoolock hoolock*
14	Capped Langur	*Trachypithecus pileatus*
15	Bengal Slow Loris	*Nycticebus bengalensis*
16	Small Indian Civet	*Viverricula indica*

GOVERNMENT OF ASSAM
OFFICE OF THE PRINCIPAL CHIEF CONSERVATOR OF FORESTS AND HEAD OF FOREST FORCE, ASSAM :: PANJABARI :: GUWAHATI-37

OFFICE ORDER NO: 100 Dated: 02.06.2020

In view of a blow out at one of the OIL Rigs at OIL Well No. 5 Baghjan in the Motapung Maguri Beel area adjacent to the Dibru Saikhowa National Park which has taken place at 10.30 AM of 27th May, 2020, that has been beyond control since then and it is not known for how long this condition is going to continue. Since a lot water jets are being thrown at the well at the gushing natural gas to prevent possibility of fire, formation of aerosol with water molecules and natural gas particules is taking place and a thin oily layer is being formed on the water surfaces in the surrounding area. Its other impacts on environment, forests, wildlife and ecology need to be assessed immediately in order to protect habitat and entire Biodiversity of the National Park including humans and their livestock within (forest village) and in the fringe area of the National Park. Therefore, an Expert Committee comprising the following Govt. Officials and Scientists is hereby constituted to assess the impact of the blow out of the OIL Rigs at OIL Well No. 5 Baghjan and suggest measures for immediate necessary action.

1	Shri M.K.Yadava, IFS, Addl. Principal Chief Conservator of Forests, Wildlife	-	Chairman
2	Dr. Samarendra Hazarika, Soil Scientist, ICAR, Barapani	-	Member
3	Dr. Kishore Sharma, Plant Scientist, AAU, Jorhat	-	Member
4	Dr. Narayan Sharma, Professor, Zoology and Environmental Science Department, Cotton University, Guwahati	-	Member
5	Dr. Apurba Chakroborty, Profesor (Retd.), Department of Pathology, College of Veterinary Science, AAU, Khanapara	-	Member
6	Dr Aswini Kumar Borua, Director (Retd), Science, Technology & Environment Council	-	Member
7	A Domain Expert from Pollution Control Board, Assam	-	Member
8	Deputy Commissioner or his representative , Tinsukia District	-	Member
9	Conservator of Forests, Wildlife O/o the PCCF, WL & CWLW, Assam	-	Member
10	Divisional Forest Officer, Tinsukia Wildlife Division, Tinsukia	-	Member Secretary

Terms of Reference (ToR):

a) The Expert Committee shall proced to the place of occurance (PO) immediately.
b) The Expert Committee shall assess the impact of blow out at one of the OIL Rigs at OIL Well No. 5 Baghjan, on the habitat and Biodiversity of Dibru-Saikhowa National Park including humans & their livestocks within (forest village) and in the fringe areas of the National Park.
c) The Expert Committee shall undertake similar impact assessment in the notified Eco-Sensitive Zone of Dibru-Saikhowa National Park too.
d) The Expert Committee shall suggest both short term and long term mesures for protection of habitat, Biodiversity of the National Park including humans and their livestock within(forest village) andin the fringe area of the National Park.

e) The Expert Committee shall assess the damage already caused/likely to cause to the habitat, Biodiversity, environment etc. in terms of quantity and value

f) The Expert Committee shall submit their report within 10th of June, 2020.

g) The exercise of the Expert Committee shall be restricted to the Dibru Saikhowa NP including its Buffer Area, the fringe areas falling in the zone of influence of the NP, down stream up to Kaziranga National Park and ESZ of Dibru-Saikhowa NP.

h) The Expert Committee shall adhere to the advisories issued by Govt. of India and Govt. of Assam in view of COVID/19. The Experts may undertake their field visit in smaller sub groups of 2-3 members as a precautionary step during COVID/19 observing all social distancing norms.

i) The TA/DA etc. (including means of conveyance) of the members of the Expert Committee (other than the Forest Officials) shall be borne by the department as per relevant rules and procedure.

(A.M. Singh, IFS)
Principal Chief Conservator of Forests
& Head of Forest Force, Assam
Dated:02.06.2020

Memo No. WL/FG.35/Dibru-Saikhowa National Park/Pt,

Copy for information & necessary action to:

1. Shri M.K.Yadava, IFS, Addl. Principal Chief Conservator of Forests, Wildlife.
2. Dr. Samarendra Hazarika, Soil Scientist, ICAR, Barapani
3. Dr. Kishore Sharma, Plant Scientist, AAU, Jorhat,
4. Dr. Narayan Sharma, Professor, Zoology and Environmental Science Department, Cotton University, Guwahati
5. Dr. Apurba Chakroborty, Profesor (Retd.), Department of Pathology, College of Veterinary Science, AAU, Khanapara
6. Dr Aswini Kumar Borua, Director (Retd), Assam Science, Technology & Environment Council
7. A Domain Expert from Pollution Control Board, Assam
8. The Deputy Commissioner, Tinsukia District , Tinsukia.
9. Conservator of Forests, Wildlife O/o the PCCF, WL & CWLW, Assam
10. Divisional Forest Officer, Tinsukia Wildlife Division, Tinsukia
11. Office Order Book.

Addl. Principal Chief Conservator of Forests
Wildlife.

Copy for kind information to:

1. The Chief Secretary, Assam, Dispur, Guwahati-06
2. The Principal Secretary to the Govt. of Assam, Environment & Forest Department, Dispur, Guwahati-06.
3. The Principal Secretary to the Govt. of Assam, Assam Science & Technology Department, Dispur, Guwahati-06.
4. The PS to the Hon'ble Minister Environment & Forest Department, Dispur, Guwahati-06.
5. The Chairman, Pollution Control Board, Assam, Bamunimaidam, Guwahati-21. He is requested to nominate a domain Expert from his Organization to join the above Expert Committee as a Member.
6. The Dean, Assam Agriculture University, Jorhat. He is requested to kindly extend necessary co-operation and direct Dr. Kishore Sharma, Professor, Plant Scientist to join the above Expert Committee as a Member.
7. The Dean, Cotton University, Guwahati. He is requested to kindly extend necessary co-operation and direct Dr. Narayan Sharma, Zoologist and Envy scientist to join the above Expert Committee as a Member.

Addl. Principal Chief Conservator of Forests
Wildlife.

GOVERNMENT OF ASSAM
ENVIRONMENT AND FOREST DEPARTMENT
DISPUR, GUWAHATI-6

The Principal Chief Conservator of Forests
4441
18-6-2020

ORDERS BY THE GOVERNOR OF ASSAM
NOTIFICATION

Dated Dispur, the 12th June, 2020

No. FRW. 6/2020/1: The Governor of Assam is pleased to constitute an One Man Enquiry Committee to be headed by Shri M. K. Yadav, IFS, Addl. PCCF (WL & CWLW) Assam to assess the damage to the following due to the incidents occurred in Baghjan Oil Well in Tinsukia District.

1. To ascertain damage of wild life.
2. To ascertain damage of Bio-Diversity.
3. To ascertain damage to water and air quality.
4. To ascertain any other damage to Forest & Environment.

The enquiry report is to be submitted within 15 days from the date of the issue of this order.

Sd/-[Smti. M. Baruah (Sen), IAS]
Secretary to the Government of Assam
Environment & Forests Department

Memo No. FRW. 6/2020/1-A Dated Dispur, the 12th June, 2020

Copy to-

1. The Principal Chief Conservator of Forests and HoFF, Assam, Panjabari, Guwahati-37.
2. Shri M. K. Yadav, IFS, Addl. PCCF (WL & CWLW), Assam, Panjabari, Guwahati-37 for information and necessary action.
3. The Chairman, Pollution Control Board Assam, Bamunimaidam, Guwahati-21.
4. The Deputy Commissioner, Tinsukia.
5. P.P.S. to the Hon'ble Chief Minister, Assam for kind appraisal.
6. S. O. to the Chief Secretary, Assam for kind appraisal.
7. P.S. to the Hon'ble Minister, Environment and Forest Department, Assam for kind appraisal.
8. P.S. to Principal Secretary to the Govt. of Assam, Environment & Forest Department, Dispur, Guwahati-6 for kind appraisal of the Principal Secretary.

By order etc.,

12/6/2020

Secretary to the Government of Assam
Environment & Forests Department

MINUTES OF THE 1ST MEETING OF THE EXPERT COMMITTEE ON THE BLOW OUT OF WELL NO. BGN-5 NEAR DIBRU SAIKHOWA NATIONAL PARK HELD ON THE 6TH JUNE, 2020 AT 12 NOON AT THE ASSAM STATE ZOO CONFERENCE HALL.

Members present- See Annexure

The 1st meeting of the Expert Committee on Dibru Saikowa National Park Blow out in Baghjan area was held at Assam State Zoo under the Chairmanship of M.K Yadava IFS, Addl PCCF Wildlife on 6th June 2020 at 12 Noon. The meeting was attended through VC by the Chairman, PCBA, DFO Tinsukia WL, and Dr. Aswini Baruwah, and the rest of the attendees were physically present. The Chairman welcome the members present, explained the burning issues in short. The CWLW highlighted that the blow-out of gas has had serious implications on grassland ecosystem and stated that the loss of grassland may lead to ecological crisis in the DSNP. He, then, asked DFO Tinsukia Wildlife to show photographs/videos for the benefit of the members present. The following deliberation and decisions were taken in the meeting:

1. The DFO, TSK WL, showed photographs/ videos to the Expert Committee which indicated the effects/impacts on the biodiversity due to gas blowout in the Bhagjan area. The DFO indicated that over 100 samples of water, soil, biomass and specimens has been collected and is being sent to Delhi for laboratory testing. IIT Guwahati being not fully operational is not accepting samples for the time being. The DFO, TSK WL, shared with the expert committee that the footages of gas leak being shown in media is from civil area and the leakages near the NP is much worse but currently mitigated by incessant rains which is washing out any spillages in the area. However, he raised concerns that if the rain stops, the oil spills may settle down and may cause greater damage to the ecosystem. He appraised the Committee that the DC Tinsukia has constituted an expert committee comprising of expert from all line departments and their report can be used to learn about the impact of the leakage on cattle. He also added that the locals are right now very vocal and volatile.

2. The Chairman PCB indicated that Gas leak is heavy and as per the assessment report of PCB the gas is leaking at a rate of 1.52 lakh m^3 per day at very high pressure. The leaked gas is pushed eastwardly by the natural winds. However, there is no fire incident report currently. The report of the PCBA dt. 1st June, 2020 was also showed online to all members, and its content deliberated upon. However, members asked certain clarifications on the report.

3. The CWLW raised concerns that the gas leaked at high pressure (4000 psi, as reported by OIL officials) and in high volume (1 lakh cubic meter per day) may dissolve with the surrounding water and in turn may result in serious irreversible damage. He directed DFO, Tinsukia to clarify the composition of the gas being leaked from Oil India so that the impact assessment can be made.

4. Dr. Apurba Chakraborty, Professor (Retd.), Department of Pathology, CVSc., AAU, Khanapara seconded the opinion of DFO DSNP and asked to find out the thickness of the oil spillage films. He also suggested that the final impact assessment should be carried out after the leakage completely stops and current assessment will only be pre-mature. He also opined that due to the oil spillage the soil pH may turn acidic. He also asked the DFO, DSNP to indicate the effect on mammals to which DFO said that in the area of the leakage mammals (wildlife) do not frequent. Dr. Apurba Chakraborty, then, said that the effect on domestic cattle can be indicative of the effect that will be on wild mammals.

5. Dr. Narayan Sharma, Professor, Zoology & Environmental Science Department, Cotton University, Guwahati suggested studying of the impact of leakages on the micro flora fauna especially butterflies, spider etc as the area is very rich in biodiversity of micro flora and fauna. It was also suggested to Geo-tag the sample collection point and to collect samples from non-affected areas which can serve as reference point. Repeated collection of samples from same place will also be helpful to assess the change in behavior and long term impact of the spills.

6. Dr. Aswini Bauwah also shared his concerns on the matter and asked for the full details of the composition of ejected materials, their chemical composition and quantity so that a holistic and scientific view can be taken about the damages caused to the ecology and possible remediation measures/ mitigation pathways. He requested the Chairman PCBA to look into certain possible mismatch of figures in the PCBA report dt. 1st June, 2020.

7. The DFO TSK WL said that due to spillages in the Park, staff from three camps from the National Park have been evacuated for safety to the Range HQ.

8. The CWLW opined that the concerned divisions to study the impact downstream of Brahmaputra especially Dihingmukh RF, Pani Dihing WL and Kaziranga NP.

9. All opined that a small team must visit the site at the earliest possible.

The following decisions were arrived at Decisions:

1. The team comprising of following expert members will visit the Baghjan area and assess the impact of gas leakage.

i. Dr. Apurba Chakraborty, Professor (Retd.), Department of Pathology, CVSc., AAU, Khanapara.
ii. Dr. Narayan Sharma, Professor, Zoology & Environmental Science Department, Cotton University, Guwahati.
iii. Dr. Kulen Das, Professor, Soil Science Department, AAU, Jorhat.
iv. Dr. Kishore Sarma, Plant Scientist, AAU, Jorhat.
v. The APCCF/CF Wildlife to accompany the team.

2. The DFO, TSK WL, will ascertain from OIL India, the exact quantity ar d composition of gas leakage, and other materials being ejected from the well.
3. The DFO, TSK WL, will procure all required test kits and equipment for collection of samples from the affected area. However, as many chemicals and equipment may not be available at Tinsukia, it was decided to carry all necessary things from Guwahati itself.
4. The Committee decided to co-opt Dr. Kulen Das, Professor, Soil Science Department, AAU, Jorhat as member of the Expert Committee.
5. The Committee asked the Forest Department also to study the impact downstream of Brahmaputra especially Dihingmukh, Pani Dihing and Kaziranga NP.
6. It was also decided that all work would be done observing social distancing ard following other norms to fight COVID19 as per guidelines of the Health Department.

The meeting ended with vote of thanks from the Chair.

6/6/2020

(M.K.Yadava, IFS)
Addl. Principal Chief Conservator of Forests
Wildlife. Assam
&
Chairman, Expert Committee

MINUTES OF THE 1ST VISIT OF THE EXPERT COMMITTEE ON BLOW OUT OF BGN-5 NEAR DIBRU SAIKHOWA NATIONAL PARK

HELD AT GUIJAN IB, TINSUKIA ON AFTERNOON OF 10TH JUNE 2020

List of the expert member present in meeting is attached herewith.

Expert Committee notified by the PCCF & HoFF, Assam, visited the Dibru Saikhowa National Park on 10th June, 2020. The Chairman of the Committee reached the Dibru Saikhowa National Park in afternoon of 9th June, 2020. The Chairman visited the BGN-5 blast site from Dibru River as the law and order situation due to blast, on the other side, was very bad and the site could not be approached by road. So it was decided to approach the blast site from the Dibru River.

All the expert members of Committee gathered at Guijan IB and chalked out a strategy for next day. Accordingly expert members of Committee, Research Associates and field staff of the Tinsukia Wildlife Division assembled at 7 AM on 10th June, 2020 at Guijan IB and proceeded towards field in order to assess the damages. The team decided to take most contaminated samples for reference and subsequent gradient analysis centered around ground zero. However, soon after reaching the area with 200-300m of the ground zero the Chairman of committee was approached by team of OIL fire service personnel to inform that they were looking for two missing fire personnel from last evening and suspected to find them in this area. On their request APCCF (WL) decided to provide all assistance like drone, DSLR camera and binocular immediately and moved along with them for the search operation. Shri D D Gogoi IFS (Retd), Shri RS Bharti IFS, DFO Tinsukia WL, Shri Jagannath Aggarwala Range Officer Guijan WL, Mohandeep Fr-1 and equipment handling team along with OIL team started the search operation, while other members continued field work. While searching around the area could not give any result so it was decided to move to ground zero through water pump area at the bank of Dibru River. The team approached ground zero site from around 75 m distance. With no result from DSLR and binocular, it was decided to fly drone, despite great risks and the fact that the drone could catch fire. After 15 minutes of flying one body was located very close to the rig in the water body. OIL fire personnel were shown the direction and location of the dead body and thereafter the team returned back to original group. Thereafter team was split it into smaller groups and different type of studies were conducted during the day and all reassembled at Guijan Range office at 4 PM and meeting was held in which the debriefing of events of the day was done and plan was chalked out for further course of action.

Following decisions were taken in the meeting-

1. It was seen that due to heavy rain several part of Park inundated and lot of oil, gas and condensate deposit appears to be washed out. However, it was observed that in the last 24 hours water also receded by almost 3 feet which lead to isolation of certain water bodies and nearer to blast site oil was observed on the water surface. Also a layer of oil was seen floating on water as well as in the Dibru River and its sub-streams. Thereafter it was

decided to carry out further drone based study of the Park, as the area of the Park together with buffer was 762 sq km and surrounding areas to have a better assessment.

2. It was also observed that since there was considerable heat even from 1.5 km from the blast site into Park area and hot air current was felt. So it was decided to do profile assessment test on following parameters-
   - soil temperature
   - air temperature
   - wind direction assessment at different time to collect Point wise weather data using AWS
   - Sound level- as almost equal intensity of sound in around 2 km inside DSNP.
3. Team observed almost complete absence of wildlife in Park and surrounding areas including mammals, avian fauna, aquatic wildlife like dolphin and large fishes therefore it was decided to carry out following studies-
   - observe dolphin sighting at regular interval at known places of database
   - study distribution of bird in Park
   - assessment of herpetofauna like turtle, snakes, amphibians etc
4. It was also decided to see any change in micro flora and fauna and accordingly to take samples for study of zooplankton and phytoplankton etc.
5. All members of expert committee opined that though Maghori-Motapung beel is not part of the Park but it is a continuous habitat and connect directly with Dibru river and is also recognized as Important Bird Area by Birdlife International and BNHS so sample from areas should also be considered for arriving at actual assessment of damage of ecology of the Dibru Saikhowa National Park .
6. Member secretary would coordinate with experts and onboard other exports for surveys needed as indicated above.
7. The PCB team from Dibrugarh would collect data on noise and air pollution of area under study.
8. It was also decided to include Dr Ujjawal Deka Barua Assistant Professor Gauhati University, Dr Kuleshar Singh Assistant Professor, Abhayapuri College, Bongaingaon, Dr Manjit Borthakur Assistant Professor OKD Institute of Social Science, Guwahati, Dr Pritam Assistant Professor Punjab University would also be included in the Expert Committee for on spot water sampling.

Meeting ended with formal vote of thanks from the Chairperson.

(M. K. Yadava IFS)
Addl PCCF (Wildlife) &
Chairman, Expert Committee

Visit of Expert Committee on 10/06/2020 formed by PCCF & HOFF to assess the damage caused by Baghjan Oil Leakage.

Sl. No.	Name & Designation	Signature
1.	MK Yadava	Myadava
2.	R.S. Bhatt, IFS DFO TNWL	Rajiva
3.	Dr Kishore Kumar Sharma Prof, Dept. of PBG, AAU.	drkks1@yahoo.co.in
4.	Bikash Jyoti, Asst Engineer, PCBA, RO Dibrugarh	10/06/2020 bikashdrayogi@gmail.com
5.	Narayan Sharma, Cotton University Assistant Prof, Dept of EBWS	10/06/2020
6.	Hemanta Kr. Sarma AEE, PCBA, RO, DIB	10/6
7.	Rajib Rudra Tajang, Asst, Dept of Zoology, Kharupetia College, Darrang.	10/06/2020
8.		
9.	Dr. SHAMIM RAHMAN Asstt. Professor. Dept. of Zoology DCB Girls' College, Jorhat	10/06/2020 shamim.pikues@gmail.com
10.	Dr. Samiran Dutta, Professor, Dept of Soil Sc, AAU, Jorhat	10/6/20. duttasamiran@rediffmail.com
11.		
12.	Dr. Chijal Deka Baruah. Asst. Professor Geography Deptt, Gauhati University	10/6/20. udb@gauhati.ac.in
13.		
14.	Dr. Kuleswar Singha Asst. Professor. Geography Dept. Mahapurush College.	10.6.20. kuleswarsj@gmail.com
15.		

SYNOPSIS of The EXPERT COMMITTEE on the Blow out at Baghjan Well No-5 of OIL in terms of its impact on Wildlife, Biodiversity, Ecology, Water, Air, Soil, Forests & Environment:

The Background :

The Blow out incident at Baghjan Well No-5 of OIL occurred on 27-05-2020 in the forenoon at 10.30 AM. The well started flowing gas uncontrollably since 27-05-2020. Although there was no incidence of fire and casualties as reported by the OIL in its report dated 28-05-2020, but hundreds of families residing within a radius of about two KM had to be evacuated for their safety to relief camps. Staff from three Forest Camp of Dibru Saikhowa NP had also to be evacuated to the Range Head Quarters for safety. The gas was leaking at a rate of 1.5 lakh cubic meter per day at a very high pressure of reportedly at 4000 psi (Pounds per Sq. Inch). About 4-8 OIL Fire Service vehicles were pressed into service 24×7 at site since 27-05-2020 for continuous water jacketing the Well to avert any eventualities, as reported by OIL. This has been an industrial disaster. It also needs to be mentioned that it had been raining incessantly since 25th May, 2020 due to Storm Amphan effects in the region. As a result of water jacketing and incessant/frequent rain fall the oil spilled into the nearby water bodies (beels), water channels connected to Dibru river passing through Dibru Saikhowa National Park. Besides, the condensates spread over trees and grassland within a radius of about 1.5 KM to 2KM or more depending upon the wind direction. The above situation continued till the forenoon of 09-06-2020, but the Well exploded at about 1.30 PM causing a significantly higher degree of **DISASTER**. The houses, trees and grasslands were burnt completely in the nearby areas. The water bodies with oil spill caught fire. Heavy smoke with carbon and other particles were emitted and spread over large areas up to the Dibru Saikhowa NP. The emission of heavy smoke continued for about 22 hours continuously until the trees, grass and other particles covered with oil spill and condensate got burnt completely. Nearly 90-100 decibel of noise with very high heat was generated in the surrounding areas. Now the flame of more than 50M height is burning at the Well with equal intensity of noise and heat. The heat could be felt from right inside the Park even from 1.5 KM from the source. As learnt from OIL, it may take another three to four weeks to be brought under control. Actual assessment of damages to forests, wildlife and environment would require extensive scientific measurements.

The Cause of Concern:

The perpendicular/aerial distance from the Place of Occurrence to the boundary of Dibru Saikhowa NP is about 800 M to 1 KM only. The uncontrollable flow of gas and condensate at very high pressure and condensate has detrimentally impacted the nearby water bodies like Maguri and Motapung beel with the channels connecting the beels with Dibru river including grassland & trees within a radius of 2-3 KM from the

PO (Place of Occurrence). The said area forms an ideal habitat to important avifauna including species like White Winged Wood Duck (critically endangered), aquatic animals including River Dolphin (critically endangered) and varieties of fishes. The area is notified as Important Bird Area (IBA) by the Bird International. The area is connected to Dibru Saikhowa NP through Dibru river forming a contiguous habitat of the NP. From day one of the incident till the explosion of the Well, the wildlife, biodiversity, water, air, soil, ecology and environment of the area was significantly impacted which was indicated by the recovery of carcass of River Dolphin (one), snake (one), Flying Squirrel (one), Rhesus Macaque(one). Large number of fish populations were also found dead in the waterbodies and the Dibru river.

The explosion of the Well that occurred on 09-06-2020 has manifold aggravated the original industrial **DISASTER.** It has detrimentally impacted the above narrated sites and caused irreversible damage to the Wildlife, Biodiversity, Habitat and Ecology including water, air and soil. These conditions have instantly pushed the management of Dibru Saikhowa NP to a significant degree in **DISASTER MODE,** and to have preparedness of any eventuality at any point of time.

Response to the Situation by the Department:

The situation was devastating to warrant immediate response of the Forest Department. The incidents have been first of its kind from out of the blue, without established knowledge to handle the situation. However, the Divisional Forest Officer, Tinsukia WL Division, was asked to evacuate the staff from the vulnerable camps for safety from day one of the blow out. The DFO has evacuated staff from 3 Camps for safety to the Range Headquarters.

The DFO was asked to collect samples of water, soil, dead animals and fishes. He was also asked to send the collected samples to the designated Laboratories for analysis. The DFO has collected about 100+ samples of water, soil and parts of dead animals & fishes from the NP and nearby potential habitats. Samples were sent to the Sriram Test Centre, New Delhi under the aegis of WII team.

The Blow out was beyond control and the flowing gas, condensate and oil spill were impacting the environment, habitat, wildlife and ecology detrimentally, leading to a serious crisis in the NP as well as other potential habitats within the Zone of Influence of the NP. Situation demanded immediate study & assessment of the impact of the blow out and preparation of advisories/preventive measures along with damages caused, through Scientists and Experts.

An Expert Committee was constituted by the PCCF & HoFF, Assam, vide No.WL/FG.35/Dibru Saikhowa NP/Pt. dated 02-06-2020, comprising 9 Nos of Govt. Officials and Scientists for assessment of Impact. The EC comprises of the following Members:-

1. Shri M.K.Yadava, IFS, APCCF(WL) & CWLW, Assam, Chairman
2. Dr A,K,Baruwa, Director (Retd.), ASTEC
3. Dr A,Chakravarty, Director (retd.), Research, AAU, (Vety), Khanapara
4. Dr Kishore Kumar Sharma, Professor, Plant Science, AAU, Jorhat
5. Dr Samiron Dutta, Professpr, Soil Science, AAU, Jorhat
6. Dr Narayan Sharma, Environmental Biology & Wildlife Science, Cotton University
7. Domain Expert, PCBA
8. Shri Bankim Sharma, IFS, CF Wildlife
9. Shri Rajendra Bharti, IFS, Divisional Forest Officer, Tinsukia WL Division, Member Secretary.

The first meeting of the Expert Committee was held on 06-06-2020 in the Conference Hall of Assam State Zoo cum Botanical Garden, Guwahati and through Video Conferencing. The DFO presented photographs shot in the habitats affected by the Blow out, that showed significant damage caused to the grassland, water bodies by the oil spill and condensate, death of River Dolphin (one), snake (one) and lot of Fishes. That altogether indicated a significant ecological crisis both in the NP and in other potential habitats in the Zone of Influence of the NP.

The EC decided to visit the site in a smaller group in view of COVID-19 protocol from 09-06-2020 onwards with full preparation of test kits/ equipment and sample collection systems, though it was opined that actual damage could be assessed after Blow out is completely stopped and brought under control.

The EC co-opted the following members to assist the members of the EC during the study and assessment of impact in the field:-

1. Dr Shamim Rahman, Assistant Professor, Zoology Department, Devi Charan Girl`s College, Jorhat.
2. Shri Rajib Rudra Tariang, Assistant Professor, Zoology Department, Digboi College.
3. Md. Imtiaz Ahmed, Assistant Professor, Fishery Resource Management, AAU, Raha.

The members of the EC that had made first visit to the site from 09-0602020 to 11-06-2020 comprised of the following Members:

1. Shri M.K.Yadava, IFS, APCCF (WL & CWLW), Assam & Chairman of the EC
2. Dr KK Sharma, Professor, Plant Science, AAU, Jorhat.

3. Dr S. Dutta, Professor, Soil Science, AAU, Jorhat
4. Dr N. Sharma, Professor, Environmental Biology & Wildlife Science, Cotton University.
5. Shri Hemanta Kr Sharma, Asstt Engineer, PCBA.
6. Shri Bikash Gogoi, Asstt. Engineer, PCBA
7. Dr Shamim Rahman, Assistant Professor, Zoology Department, Devi Charan Girl's College, Jorhat.
8. Shri Rajib Rudra Tariang, Assistant Professor, Zoology Department, Digboi College.
9. Md. Imtiaz Ahmed, Assistant Professor, Fishery Resource Management, AAU, Raha.
10. x. The team was also accompanied by Shri D.D.Gogoi, IFS &CCF WL(Retd.), WL Consultant, O/O PCCF WL & CWLW, Assam
11. Shri Rajendra Bharti, IFS, DFO, Tinsukia WL Division.

The Well exploded in the afternoon of 09-06-2020 at 1.30 PM. The Chairman of the EC reached the site at about 5pm and approached the site by boat as he could not follow the road due to **agitation** demonstrated by the affected local people. The rest of the Team Members reached Guijan about 6 PM. The Team upon a brief discussion, after the Chairman returned from the site, decided to proceed to the NP and other potential habitats adjacent to the PO at 7 AM on 10-06-2020.

The Team collected samples of water and soil and micro-fauna from the affected sites both from within the NP and from the potential habitats adjacent to the PO and the NP. During a debriefing held in the night of 10-06-2020 at Guijan Range Head Quarters, it was decided to take the additional parameters like soil temperature, air temperature, wind direction, sample collection for bottom line micro fauna/flora including zoo plankton and Phyto plankton, study of Herpetofauna, installation of AWS and use of DRONE to cover large area.

All the team members have submitted Work Plan for the next 15 days for continuing the Impact Assessment in their respective field of study as the situation is going to continue for at least for four more weeks as informed by the OIL. This will be followed by a subsequent Work Plan to be prepared by the EC based on its experience, observations and Laboratory reports. The members from PCBA would also collect data on air temperature, noise pollution in addition to soil and water sample collection continuously.

The First Impressions:

The grasslands nearest to the ground zero, the blow out site at BGN-5, were badly charred, and the water had traces of oil still. The side streams to the main channel of Dibru river also had quite a good layer of oil on the top (but flowing downstream). The heat was felt upto 1.5 km from the ground zero at all the sites where there was direct line of sight clearance. The first impression at all almost all sites that the EC members visited, was that wildlife was scarce to spot, and the following observations are pertinent:-

1. No dolphins were sighted in the water bodies, and at the known colony sites. It is a matter of great concern.
2. No major fish fauna was observed. However, nothing can be said without proper and systematic sampling. However, the observation is pertinent.
3. In all about 20 spp of avifauna were spotted at different point, but not more than one or two individuals, and all species were common birds of the area.
4. The sound level which was about 100 DB at the ground zero (60-70 M away), was almost 60 DB at various distances in the DSNP.
5. Plumes of gas were seen hanging at different parts in the air at low heights inside the Park area. The situation could have been much worse earlier.
6. The grasses and vegetation on the landmass inside the Park was seen not much affected, but the actual results/stress levels could be ascertained only after conducting a series of tests.

Man Power:

The Division is running short of staff at present in all the categories like ACF, Frontline Staff and Office Assistant. The existing strength needs to be kept up forthwith. Additional deployment of AFPF and Frontline staff ought to be made immediately as the fringe communities have gone hostile due to the blow out and subsequent explosion of the Well, that has caused unbearable damages to the fringe population. As a result, it has become difficult for the Division to protect and manage the NP and its areas in the Zone of Influence with desired efficiency and effectiveness.

Emergency Budget:

The emergency activities which needed to be undertaken by the DFO at war footing, in order to respond to the above narrated **DISASTER** situation instantly, involves the following:

1. Cost of sample collection Kit and chemicals.
2. Cost of Lab Charges for sample analysis.

GOVERNMENT OF ASSAM
OFFICE OF THE ONE MAN ENQUIRY COMMITTEE
(ORDER NO- FRW.6/2020/1 DATED.12/06/2020)
ROOM NO.08, CIRCUIT HOUSE,
TINSUKIA, ASSAM
PIN-786126
Email ID: onemancommitteemky@gmail.com

No. OMEC/MKY/BGN-5/2020/L01/48(A) **Dated: 17/08/2020**

From: M. K. Yadava, IFS
Addl. PCCF (WL) & CWLW and
One Man Enquiry Committee

To

The Principal Secretary to the Govt. of Assam
Environment and Forest Department
Dispur, Guwahati – 781006

Sub: Delay in submission of report.

Ref: Your letter no:

(i) FRW.6/2020/1, dated 12/06/2020
(ii) FRW.6/2020/83,dated 04/07/2020.

Sir,

With reference to the subject cited above, let me thank you at the outset for extending time to the One Man Enquiry Committee. The work of the Committee has progressed much. However, due to lack of availability of certain vital parameters about the fire, the entire fire dynamics had to be "worked" de novo and it took quite some time as these involve a series of complicated calculations.

Further, reports from WII, BNHS and the Expert Committee Members have been received and these are being reviewed by the undersigned. I should be in a position to submit the report within August, 2020.

This is for your kind information and needful action with a special request kindly to extend time for submission of the report till 31-08-2020.

Thanking you,

Yours faithfully,

(M. K. Yadava, IFS)
Addl. PCCF (WL) & CWLW

C.C.

The PCCF & HoFF, Assam

Office of the D.F.O. Tinsukia W/L Division
Receipt No. 1076 Date 29/9/2020
File No. G-38

FORM No. – I

GOVERNMENT OF ASSAM

DIRECTORATE OF FORENSIC SCIENCE :: ASSAM

KAHILIPARA :: GUWAHATI – 781 019

FORENSIC Gram:

By special messenger
By registered A.D.

GUWAHATI, Tel. No. 2381385, 2381696, 2381305
Fax: 0361-2381305, Email: directorfslassam@yahoo.co.in

No. DFS. 1192/20/67 Dated Guwahati the 18/9/2020

From : The Director-cum-Chemical Examiner to the Government of Assam
Directorate of Forensic Science, Assam, Kahilipara, Guwahati – 781 019

To :

The Divisional Forest Officer,
Tinsukia Wildlife Division, Tinsukia.

Sir,

Please find herewith the enclosed Report No. DFS. 1192/942/Tox-245/20 dated 31/08/2020 received vide your Memo No. B-TWL/G-38/2020/684 dated 30/05/2020 by special Messenger. Please acknowledge receipt.

For all future correspondences/summons the *Report/Opinion number may please be quoted* and Dr. Abhijit Gogoi, Scientific Officer, Toxicology Division, Directorate of Forensic Science, Assam, Kahilipara, Guwahati – 781 019 may be summoned for evidence if necessary.

Yours faithfully,

Director-cum-Chemical Examiner to the Government of Assam,
Directorate of Forensic Science, Assam, Kahilipara, Guwahati – 781 019

Memo No. DFS. (A) Dated Guwahati the 2020

Copy Forwarded ;-

Director-cum-Chemical Examiner to the Government of Assam,
Directorate of Forensic Science, Assam, Kahilipara, Guwahati –781019.

Form-3

CONFIDENTIAL

GOVERNMENT OF ASSAM

DIRECTORATE OF FORENSIC SCIENCE :: ASSAM

KAHILIPARA : GUWAHATI – 781 019

ORENSIC Gram :
Guwahati, Tel. No. 2381385, 2381696, 2381305 Fax: 0361-2381305, Email: directorfslassam@yahoo.co.in

Report No. DFS. 1192/942/Tox-245/20

Dated. 31/08/2020

To,

The Divisional Forest Officer,
Tinsukia Wildlife Division, Tinsukia.

Your Memo No. B-TWL/G-38/2020/684 dated 30/05/2020 advising the examination of 1 (one) parcel per messenger which was received in this office on 01/06/2020.

Mode in which parcel (s) found to be packed on receipt and description of Seal.

The parcel consisted of 4 (four) exhibits in four small plastic containers enclosed in a carbon box and wrapped with cloth cover which was sealed with the seal impression of Divisional Forest Officer, Tinsukia Wildlife Division, Tinsukia.

DESCRIPTION OF ARTICLES:-

1. One small plastic container containing stomach content in saturated salt solution is marked by me as exhibit no. Tox-245/20(a).
2. One small plastic container containing liver CS in saturated slat solution is marked by me as exhibit no. Tox-245/20(b).
3. One small plastic container containing lung CS in saturated salt solution is marked by me as exhibit no. Tox-245/20(c).
4. One small plastic container containing kidney CS in situated salt solution is marked by me as exhibit no. Tox-245/20(d).

RESULT OF EXAMINATION:-

Using GC (Gas Chromatography) and GC-MS (Gas Chromatography-Mass spectrometry) techniques, the following hydrocarbons with carbon nos ranging from C_7 to C_{23} were detected in the exhibit nos Tox-245/20(a), Tox-245/20(b), Tox-245/20(c) and Tox-245/20(d) -

(i) 3 methylphenol
(ii) Indole
(iii) 2-Piperidone
(iv) 2, 2 – Dimethyldecane
(v) n – Hexadecane
(vi) 1, 6 – Dimethyl -4-(1-methylethyl) decahydro naphthalene
(vii) 2, 6, 10, 14 –Tetramethylpentacecane (Phytane)
(viii) 2, 6, 10 – Trimethylpentadecane
(ix) 6 –Phenylundecane
(x) 5 –Phenylundecane
(xi) 4 –Phenylundecane
(xii) 3 –Phenylundecane
(xiii) 1, 2, 3 –Trimethyl - 4 - [(IE) - 1- propenyl] naphthalene
(xiv) 3, 4 – Diethyl -1, 1′ -Biphenyl

31/08/2020

(Dr. Abhijit Gogoi)
Scientific Officer
Toxicology Division
Directorate of Forensic Science
Assam, Kahilipara, Guwahati-19.

Office of the D.F.O. Tinsukia Wildlife Division
Receipt No. 1075 Dated 29/9/2020
File No. G-38

FORM NO. – I
GOVERNMENT OF ASSAM
DIRECTORATE OF FORENSIC SCIENCE :: ASSAM
KAHILIPARA :: GUWAHATI – 781 019

FORENSIC Gram:

GUWAHATI, Tel. No. 2381385, 2381696, 2381305
Fax: 0361-2381305, Email: directorfslassam@yahoo.co.in

By special messenger
By registered A.D.

No. DFS. 1192/20/169 Dated Guwahati the 18/9/2020

From : The Director-cum-Chemical Examiner to the Government of Assam
Directorate of Forensic Science, Assam, Kahilipara, Guwahati – 781 019

To :
The Divisional Forest Officer,
Tinsukia Wildlife Division, Tinsukia, Assam.

Sir,

Please find herewith the enclosed Report No. DFS. 1192/1124/Tox-301/20 dated 31/08/2020 in connection with Nil P.S. Case No. Nil U/S Nil received vide your Memo No. B-TWL/G-38/2020/794 dated 22/06/2020 by special Messenger. Please acknowledge receipt.

For all future correspondences/summons the *Report/Opinion number may please be quoted* and Shri Rupam Lachit, Scientific Officer, Toxicology Division, Directorate of Forensic Science, Assam, Kahilipara, Guwahati – 781 019 may be summoned for evidence if necessary.

Yours faithfully,

Director-cum-Chemical Examiner to the Government of Assam,
Directorate of Forensic Science, Assam, Kahilipara, Guwahati – 781 019

18/9/20

Memo No. DFS. (A) Dated Guwahati the 2020

Copy Forwarded ;-

Director-cum-Chemical Examiner to the Government of Assam,
Directorate of Forensic Science, Assam, Kahilipara, Guwahati –781019.

Form-3

GOVERNMENT OF ASSAM

DIRECTORATE OF FORENSIC SCIENCE :: ASSAM

KAHILIPARA : GUWAHATI – 781 019

CONFIDENTIAL

FORENSIC Gram :
Guwahati, Tel. No. 2381385, 2381696, 2381305 Fax: 0361-2381305, Email: directorfslassam@yahoo.co.in

Report No. DFS. 1192/1124/Tox-301/20

Dated. 31/08/2020

To,

The Divisional Forest Officer,
Tinsukia Wildlife Division, Tinsukia, Assam.

Your Memo No. B-TWL/G-38/2020/794 dated 22/06/2020 advising the examination of 1 (one) parcel per messenger which was received in this office on 24/06/2020 in connection with Nil P.S. Case No. Nil dated Nil Under Section Nil.

Mode in which parcel (s) found to be packed on receipt and description of Seal.

The parcel consisted of 3 (three) exhibits in three small plastic containers enclosed in a carton box with cloth cover which was sealed with the seal impression of RFO, TSK Range.

DESCRIPTION OF ARTICLE:-

(1) One plastic container containing stomach contents of Flying Squirrel -marked by me as exhibit no. Tox-301/20(a)
(2) One plastic container containing lung of Flying Squirrel – marked by me as exhibit no. Tox-301/20(b).
(3) One plastic container containing liver of Flying Squirrel – marked by me as exhibit no. Tox-301/20(c).

The above mentioned Articles were preserved in saturated solution of common salt.

RESULT OF EXAMINATION:-

No toxic gaseous components, hydrocarbons and heavy metals were detected in the exhibit nos Tox-301/20(a), Tox-301/20(b) and Tox-301/20(c).

Rlachit
31/08/2020

(Rupam Lachit)
Scientific Officer
Toxicology Division
Directorate of Forensic Science
Assam, Kahilipara, Guwahati-19.

Office of the D.F.O. Tinsukia W/L Division
Receipt No. 1131 Date 15/10/2020
File No. G-38

DEPARTMERNT OF ANATOMY & HISTOLOGY
COLLEGEOF VETERINARY SCIENCE
KHANAPARA, GUWAHATI, ASSAM
INDIA– 781022

Prof. (Dr)MunmunSarma, Ph.D. FIAVA
Professor of Veterinary Anatomy & Histology &
Academic Cell Incharge, CVSc, AAU

Phone: (Mobile) 09435047065/ 07002814140
E-mail:munmunsarma4@gmail.com

Recipient of *Lifetime Achievement Award on Wildlife Health* conferred jointly by Orissa University of Agriculture & Technology and Indian Association of Zoo and Wildlife Vets in 2013

No. 99/ DRV/ FV/ 2020-21/ 19 **Dated 1st October, 2020**

To.

The Divisional Forest Officer,
Tinsukia Wildlife Division,
Tinsukia, Assam

Sub: Request for detection of Anatomical changes & study caused by toxic gaseous hydrocarbon agent

Ref.: Your letter issued vide Memo No. B-TWL/G-38/2020/682 Dtd. 30-05-20

Sir,

With reference to the subject cited above and letter from the DFO, Dibru Saikhuwa N. P. under reference, the detailed examination of three tissue samples (viz. Liver, lung and piece of intestine, as mentioned in the letter no lymph node was received) of river dolphin received from the DFO, Dibru Saikhuwa National park, Tinsukia revealed that there was complete autolysis of the parenchyma of all the samples. It may be mentioned here that as per reference 'mild to moderate autolytic changes occur if the death occurred within 24 hours, and complete autolysis occur it death occurred beyond 24 hours.'

As per the information received -

1 First sight of this dead river dolphin in Maguri beel = 6.00 AM on 29.05.2020

2 Recovery time of this carcass from the beel = 12.30 PM (which was then kept in ice) on 29.05.2020

3 Post mortem examination performed = 4.00 PM on 29.05.2020 and biological samples were collected

4 Sample sent to the department on 30-05-2020

5 Samples received in the department on 01-05-2020

It may be interpretated that the death of the river dolphin occurred more than 24 hours before performing the Post-mortem examination.

This is for your kind information and necessary action.

Yours faithfully,

01-10-2020

(Munmun Sarma)
Professor,
Deptt of Anatomy & Histology
College of Veterinary Science,
AAU, Khanapara
Guwahati 781 022, ASSAM

Memo No. No. 99/ DRV/ FV/ 2020-21/ _____ **Dated 1st October, 2020**

Copy for information and necessary action to:-

1. The Chief Wildlife Warden, Department of Environment & Forests, Govt. of Assam, Aranya Bhawan, Panjabari, Guwahati 781037
2. Office file for record

(Munmun Sarma)
Professor,
Deptt of Anatomy & Histology,
College of Veterinary Science,
AAU, Khanapara
Guwahati 781 022, ASSAM

To,

The Chief Wildlife Warden, Assam,
Panjabari, Guwahati-37.

Reference: E-mail dated 30th October, 2020 with attachments containing report of the Toxicology Division, Directorate of Forensic Science, Guwahati on death of Dolphin and report of Department of Anatomy & Histology, College of Veterinary Science, AAU, Khanapara on death of Dolphin, received from Shri D.D. Gogoi, Wildlife Consultant, O/o the PCCF, WL & CWLW, Assam.

Sir,

With reference to the above, comments are furnished below:

Comments

It was reported that at post mortem examination of the river dolphin haemorrhages were seen in most of the vital organs along with edema in lung and congestion of brain and materials were send to the following laboratories for confirmation of cause of death.

i) State Forensic Science Laboratory, Govt. of Assam, Kahilipara for toxicological examination.

ii) Department of Anatomy and Department of Pathology, College of Veterinary Science, Assam Agricultural University for histopathological examination.

Result:

The histopathological study could not reveal any changes since the tissue samples were autolysed as reported by both the departments of College of Veterinary Science.

The Forensic Science laboratory detected hydrocarbons with carbon numbers ranging from c7 to c25 in the organs like liver, lung and kidney and in the stomach content.

Therefore, based on changes at post-mortem examination coupled with toxicological study of the Forensic Science Laboratory it can be concluded that the said dolphin has died due to hydrocarbon poisoning.

Yours faithfully,

Place: Panjabari
Date: 7/11/2020

(Dr. Apurba Chakraborty)
Former Director of Research (Vety.),
Assam Agricultural University, Khanapara

F. No. J-11011/1255/2007- IA II (I)
Government of India
Ministry of Environment and Forests
(I.A. Division)

Paryavaran Bhawan
CGO Complex, Lodhi Road
New Delhi – 110 003
E-mail : plahujarai@yahoo.com
Telefax: 011 – 2436 3973
Dated: February 28 , 2008

To,

The Group General Manager(SB)
M/s Oil India Limited.
Duliajan District Dibrugarh,
Assam – 786 602

Ph. 0374-2803 296 / 2804 254 Fax : 0374-2803 296
Email: drilling@oilindia.in

Sub: Exploratory Drilling at N. Hapjan-Tinsukia-Dhola Area in District Tinsukia Assam M/s Oil India Limited. (TOR)

Sir,

Kindly refer to your letter No. GM(OD&RS):2/10-200- dated 19.11. 2007 alongwith Form-I and proposed TORs as per the EIA Notification, 2006.

Draft Terms of Reference (TOR) have been discussed during 77th meeting of the Expert Appraisal Committee (Industry) held on 21st – 24th January 2008 and finalized the following 'TORs' for preparation of EIA/EMP:

1. Executive summery of the project.
2. Project Description and Project Benefits
3. Site details including satellite imagery for 10 km area. Conformation that there is no National Park/ Wild life Sanctuary/ Eco sensitive area.
4. Land use along with maps & cropping pattern, vegetation Ecology, Flora & Fauna
5. Demography & Socio-economics of the area.
6. Process details for survey and drilling.
7. Baseline data collection for air, water and soil for 5 weeks leaving the monsoon season in an area of 10 Km radius with centre of Oil Field as its centre covering the area of proposed drilling well.
   - Ambient Air Quality monitoring at 8 locations for SPM, RPM, SO2, NOx
   - Background levels of hydrocarbons (HC) and VOCs (5 samples)
   - Soil sample analysis at 10 locations
   - Base line underground and surface water quality in the vicinity of 10 km area.
   - Climatology & Meteorology including wind speed, wind direction, temperature, rainfall etc.
   - Measurement of Noise levels at 10 locations in the block
8. Detailed water balance, waste water generation and discharge.
9. Treatment and utilization of produced water.
10. Detailed solid waste generation, collection, segregations, its recycling and reuse, treatment and disposal
11. Estimation and computation of air emissions resulting out of drilling operations
12. Assessment of impact on air , water, soil, solid/hazardous waste and noise levels
13. Evaluation of the adequacy of the proposed pollution control measures to meet the air quality emission standards, water discharge norms, solid/hazardous waste generation and disposal
14. Estimation of Noise level due to operation of drilling , its associated equipments and vehicular movement & prediction and evaluation of impacts due to increase in noise levels arising out of the proposed activities on the surrounding environment. Proposed mitigation measures for noise pollution.
15. Permission for diversion of forest land under the Forest (Conservation) Act, 1980.

16. Impact of transportation and traffic density.
17. Details of compensation for acquisition of agriculture land.
18. Storage of chemicals at the site, proposed preventive measures for spillage and accident.
19. Environmental Management Plan
20. Risk Assessment & Disaster Management Plan

    a. Identification of hazards
    b. Consequence Analysis
    c. Risk Presentation & proposed measures for Risk Reduction
    d. Disaster Management Plan (DMP)
    e. Oil Spill Contingency Plan and Emergency Response Plan

21. Measures for decommissioning of the rigs and projects
22. Post project closure and monitoring programme for minimum 10 years
23. Documentary proofs for Memberships of common disposal facilities, if any.
24. Details of proposed occupational Health Surveillance program for the employees and other labour.
25. Environmental Monitoring program while survey and drilling is undertaken
26. Action plan to the issues raised during the public hearing meeting in tabular form.
27. Information as per the Questionnaire on the Industrial projects as earlier devised by the Ministry.

The 'TORs' prescribed by the Expert Appraisal Committee (I) should be considered for the preparation of EIA / EMP report for the above mentioned project in addition to all the relevant information as per the 'Generic Structure of EIA' given in Appendix III and IIIA in the EIA Notification, 2006. As soon as the draft EIA/EMP report is prepared, the same may be submitted to the Assam and Arunachal Pradesh Pollution Control Boards for conducting public hearing/public consultation as per EIA Notification, 2006. On finalization of EIA/EMP prepared as per TORs and addressing and incorporating all concerns raised during public hearing / public consultation, the same should be submitted to the MOEF for obtaining prior environmental clearance.

Yours faithfully,

(Dr. P. L. Ahujarai)
Director

Copy to:

1. **The Chairman, Assam Pollution Control Board, Bamunimaidan, Guwahati- 781 021.**

(Dr. P. L. Ahujarai)
Director

GOVERNMENT OF ASSAM
OFFICE OF THE PRINCIPAL CHIEF CONSERVATOR OF FOREST, WILD LIFE, ASSAM
BASISTHA, GUWAHATI-29

No.WL/FG.35/Nodal Proposal/OIL, Dt.18.6.2010.

To,

The Dy.CEPG (GFD & NGF),
OIL India Limited,
Production (Gas) Department),
Duliajan-786602 , Assam.

Sub: Expansion of Gas field Development in Tengakhat-Nahorkatia Jorajan, Dumduma – Pengri, Moran-Sapekhati, Khowang-Shalmari Assam and Arunachal area in Arunachal Pradesh by M/s Oil India Ltd. – TOR reg.

Ref: **1.** GOI MOEF's letter F No J-11011/682/2008–IA–II(I), dated 17.11.2008
2. Your letter no. PDNG: 27/14 (Env Cl) – 307/10, Dated: 19.5.2010

Sir,

With reference to the above I am to inform you that out of the 5 areas, the following three proposed project areas are not falling within 10 kms from the boundary of Wildlife Sanctuary (WLS) / National Parks (NP).

i) Moran-Sapekhati Area
ii) Khowang-Shalmari and
iii) Dumduma-Pengri.

However, the following two project areas namely (i)Tengakhat-Naharkatia-Jorajan and (ii)Tinsukia Dhola are falling within 10 kms from the boundary of Wildlife Sanctuary (WLS) / National Parks (NP), details of which are given below:

Sl. No.	Proposed Project Areas	Proposed Project sites	Falling within 10 kms from the boundary of Wildlife Sanctuary (WLS) / National Parks (NP).
i.	Tengakhat-Naharkatia-Jorajan	i)Field Gathering Station (FGS) Ushapur	Dehing-Patkai WLS
	- Do -	ii) FGS Jorajan	-Do -
		iii)Gas Pipelines near existing OCS – 3 & Kathalguri	Bherjan-Borjan-Padumoni (BBP) WLS
		iv)) FGS –OCS – 4	BBP, WLS
		v) Central Gas Gathering Station (CGGS) & Offtake Point (OTP) Madhuban	BBP, WLS

ISSUED ON 18/6/10

ii.	Tinsukia Dhola	vi)GCS in Baghjan & Barekuri	Dibru-Saikhowa (DS) NPK
		vii)FGS in Bagjan	-Do-
		viii) FGS South Chandmari	BBP, WLS
		ix)GCS Makum	BBP, WLS
		x)FGS Hapjan	BBP, WLS
	Tengakhat-Naharkatia-Jorajan & Tinskia - Dhola	xi) Pipelines from Baghjan & Barekuri	Dibru-Saikhowa (DS) NPK & Bherjan-Borjan-Padumoni (BBP) WLS
		xii)Pipeline from Chabua	BBP, WLS

Since these project activities are falling in the eco sensitive areas located within 10 km from the boundaries of the nearest National Park/Wildlife Sanctuaries, they are likely to have adverse environmental impact on the said protected areas. As such, the required EIA/EMP under the provisions of the EIA Notification, 2006 is necessary. Such EIA/EMP must be submitted to MOEF, Govt. of India to ascertain its appropriateness and adequacy prior to considering your proposal for environmental clearance by the Govt. of India.

This is for favour of your information and necessary action.

Your's Faithfully

Principal Chief Conservator of Forests,
Wildlife, Assam.

Copy to Sri H.S.Malviya, Joint Director, Ministry of Environment & Forests, Govt. of India (IA Division), CGO Complex, Lodi Road, New Delhi-110003 for his information and necessary action.

Principal Chief Conservator of Forests,
Wildlife, Assam.

Drilling of Development Well (26 Nos.) and Exploratory Well (15 Nos.) at N. Hapjan-Tinsukia-Dhola Area in District Tinsukia Assam by M/s Oil India Limited – Environmental Clearance reg.

****

This message has been scanned by the InterScan for CSC SSM and found to be free of known security risks.

****

F. No. J-11011/1255/2007 - IA II (I)

Government of India
Ministry of Environment and Forests
(I.A. Division)

Paryavaran Bhawan
CGO Complex, Lodhi Road
New Delhi – 110 003

E-mail : pb.rastogi@nic.in
Telefax : 011: 2436 7668

Dated 1st November, 2011

To,

The Group General Manager (SB)
M/s Oil India Limited.
Duliajan District Dibrugarh- 768 602, Assam

E-mail: drilling@oilindia.in ;
Fax No.: 0374-2803 296

Subject: Drilling of Development Well (26 Nos.) and Exploratory Well (15 Nos.) at N. Hapjan-Tinsukia-Dhola Area in District Tinsukia Assam by M/s Oil India Limited – Environmental Clearance reg.

Ref. : Your letter no. DRLG/DS/A.19-192/10 dated 28th December, 2010.

Sir,

Kindly refer your letter dated 28th December, 2010 alongwith project documents including Form I, Terms of References, Pre-feasibility Report, EIA/EMP Report and subsequent communications vide your letter dated 25th June, 2011 on the above mentioned subject.

2.0 The Ministry of Environment & Forests has examined your application. It is noted that proposal is for drilling of development well (26 Nos.) and exploratory well (15 Nos.) at N. Hapjan-Tinsukia-Dhola Area in District Tinsukia Assam by M/s Oil India Limited. Block Coordinate is between Longitude 95^0 20' -- 95^0 32' and Latitude 27^0 27' -- 27^0 37'. Block area is 650 sq KM. Project cost is Rs. 15.00 Crores for each well. Borajan reserve forest (RF), Bherjan RF, Padumani RF, Dibru RF, Upper Dihing (west) RF complex including Lakhipathar RF are

located within 10 Km. No national park/wildlife sanctuary/eco-sensitive area are located within 10 km.

3.0 Stack of adequate height will be provided to DG set. Flaring will be done in a controlled manner through scientifically designed flaring system. Water requirement will be 40 m^3 per well/day for drilling purpose and 2 m^3 per well/day for domestic use. Effluent generation will be 20 m^3 (approx) per well/day during drilling phase. Effluent will be stored in HDPE lined pit and treated as per CPCB/SPCB norms and recycled. Water based mud will be used in drilling. Drill cuttings generation will be 200 m^3/well. Drill cuttings will be stored in HDPE lined pit for safe disposal.

4.0 The proposal was considered by the Expert Appraisal Committee (Industry-2) in its 77th, 21st and 26th meetings held during 21st-24th January, 2008, 23rd–24th March, 2011 and 17th–18th August, 2011 respectively.

5.0 All the projects related to offshore and onshore Oil and Gas exploration, development and production are listed in para 1(b) of schedule of EIA Notification, 2006 covered under category 'A' and appraised at centre level.

6.0 Public hearing was exempted as per Para 7 (II) of EIA Notification 2006.

7.0 The Ministry of Environment and Forests hereby accords environmental clearance to the above project under the provisions of EIA Notification dated 14th September, 2006 subject to strict compliance of the following specific and general conditions:

A. SPECIFIC CONDITIONS :

i. As proposed, only development well (26 Nos.) and exploratory well (15 Nos.) shall be drilled. No additional wells shall be drilled without prior permission from this Ministry.

ii. As proposed, no drilling of well and any construction work shall be carried out in forest land.

iii. Permission shall be obtained from the State Forest Department regarding the impact of the proposed drilling on the surrounding reserve forest viz. Borajan RF, Bherjan RF, Padumani RF, Dibru RF, Upper Dihing (west) RF complex including Lakhipathar RF.

iv. Drilling site shall not be close to villages, schools etc.

v. Ambient air quality shall be monitored near the closest human settlements as per the National Ambient Air Quality Emission Standards issued by the Ministry vide G.S.R. No. 826(E) dated 16th November, 2009 for PM_{10}, $PM_{2.5}$, SO_2, NO_X, CO, CH_4, HC, Non-methane HC etc.

vi. The flare system shall be designed as per good oil field practices and Oil Industry Safety Directorate (OISD) guidelines. The stack height shall be provided as per the regulatory requirements and emissions from stacks will meet the MOEF/CPCB guidelines.

vii. The company shall make the arrangement for control of noise from the drilling activity. Acoustic enclosure shall be provided to DG sets and proper stack height shall be provided as per CPCB guidelines.

viii. Mercury shall also be analyzed in air, water and drill cuttings twice during drilling period.

ix. Approach road shall be made pucca to minimize generation of suspended dust.

x. Total fresh water requirement shall not exceed 42 m^3/day/well and prior permission shall be obtained from the concerned agency.

xi. The company shall construct the garland drain all around the drilling site to prevent runoff of any oil containing waste into the nearby water bodies. Separate drainage system shall be created for oil contaminated and non-oil contaminated. Effluent shall be properly treated and treated wastewater shall conform to CPCB standards.

xii. Drilling wastewater including drill cuttings wash water shall be collected in disposal pit lined with HDPE lining evaporated or treated and shall comply with the notified standards for on-shore disposal. The membership of common TSDF should be obtained for the disposal of drill cuttings and hazardous waste. Otherwise, secured land fill shall be created at the site as per the design approved by the CPCB and obtain authorization from the SPCB. Copy of authorization or membership of TSDF shall be submitted to Ministry's Regional Office at Shillong.

xiii. Good sanitation facility shall be provided at the drilling site. Domestic sewage shall be disposed off through septic tank/ soak pit.

xiv. Oil spillage prevention and mitigation scheme shall be prepared. In case of oil spillage/contamination, action plan shall be prepared to clean the site by adopting proven technology. The recyclable waste (oily sludge) and spent oil shall be disposed of to the authorized recyclers.

xv. The company shall comply with the guidelines for disposal of solid waste, drill cutting and drilling fluids for onshore drilling operation notified vide GSR.546(E) dated 30th August, 2005.

xvi. The Company shall take necessary measures to prevent fire hazards, containing oil spill and soil remediation as needed. Possibility of using ground flare shall be explored. At the place of ground flaring, the overhead flaring stack with knockout drums shall be installed to minimize gaseous emissions during operation.

xvii. The company shall develop a contingency plan for H_2S release including all necessary aspects from evacuation to resumption of normal operations. The workers shall be provided with personal H_2S detectors in locations of high risk of exposure along with self containing breathing apparatus.

xviii. The Company should carry out long term subsidence study by collecting base line data before initiating drilling operation till the project lasts. The data so collected should be submitted six monthly to the Ministry and its Regional Office at Shillong.

xix. Blow Out Preventor (BOP) system shall be installed to prevent well blowouts during drilling operations. BOP measures during drilling shall focus on maintaining well bore hydrostatic pressure by proper pre-well planning and drilling fluid logging etc.

xx. Emergency Response Plan (ERP) shall be based on the guidelines prepared by OISD, DGMS and Govt. of India.

xxi. The company shall take measures after completion of drilling process by well plugging and secured enclosures, decommissioning of rig upon abandonment of the well and drilling site shall be restored the area in original condition. In the event that no economic quantity of hydrocarbon is found a full abandonment plan shall be implemented for the drilling site in accordance with the applicable Indian Petroleum Regulations.

xxii. Occupational health surveillance of the workers shall be carried out as per the prevailing Acts and Rules.

xxiii. In case the commercial viability of the project is established, the Company shall prepare a detailed plan for development of oil and gas fields and obtain fresh environmental clearance from the Ministry.

xxiv. Restoration of the project site shall be carried out satisfactorily and report shall be sent to the Ministry's Regional Office at Shillong.

xxv. Oil content in the drill cuttings shall be monitored by some Authorized agency and report shall be sent to the Ministry's Regional Office at Shilong.

xxvi. Company shall prepare and circulate the environmental policy.

xxvii. Company shall prepare operating manual in respect of all activities. It shall cover all safety & environment related issues and system. Measures to be taken for protection. One set of environmental manual shall be made available at the drilling site/ project site. Awareness shall be created at each level of the management. All the schedules and results of environmental monitoring shall be available at the project site office.

xxviii. Base and side of Drill cutting storage pits and supernatant storage pit shall be provided with HDPE lining. Overflow channel and oil grease trap facility shall be provided.

xxix. Chemical characteristics and toxicity in respect of amine and all other chemicals should be found out and monitoring arrangement should be made. A copy of report should be sent to the Ministry's Regional Office at Shilong.

xxx. Company shall ensure good housekeeping at the drilling site.

xxxi. Company shall have own Environment Management Cell having qualified persons with proper background. Full fledged laboratory facilities must be set up to carry out the environmental management and monitoring functions.

B. GENERAL CONDITIONS:

i. The project authorities must strictly adhere to the stipulations made by the Assam Pollution Control Board (APCB), State Government and any other statutory authority.

ii. No further expansion or modification in the project shall be carried out without prior approval of the Ministry of Environment & Forests. In case of deviations or alterations in the project proposal from those submitted to this Ministry for clearance, a fresh reference shall be made to the Ministry to assess the adequacy of conditions imposed and to add additional environmental protection measures required, if any.

iii. The project authorities must strictly comply with the rules and regulations under Manufacture, Storage and Import of Hazardous Chemicals Rules, 2000 as amended subsequently. Prior approvals from Chief Inspectorate of Factories, Chief Controller of Explosives, Fire Safety Inspectorate etc. must be obtained, wherever applicable.

iv. The overall noise levels in and around the plant area shall be kept well within the standards by providing noise control measures including acoustic hoods, silencers, enclosures etc. on all sources of noise

generation. The ambient noise levels shall conform to the standards prescribed under EPA Rules, 1989 viz. 75 dBA (daytime) and 70 dBA (nighttime).

v. A copy of clearance letter shall be sent by the proponent to concerned Panchayat, Zila Parishad / Municipal Corporation, Urban Local Body and the local NGO, if any, from whom suggestions / representations, if any, were received while processing the proposal. The clearance letter shall also be put on the web site of the company by the proponent.

vi. The project proponent shall upload the status of compliance of the stipulated environment clearance conditions, including results of monitored data on their website and shall update the same periodically. It shall simultaneously be sent to the Regional Office of the MOEF, the respective Zonal Office of CPCB and the APCB. The criteria pollutant levels namely; PM_{10}, SO_2, NOx, HC (Methane & Non-methane), VOCs (ambient levels as well as stack emissions) or critical sectoral parameters, indicated for the projects shall be monitored and displayed at a convenient location near the main gate of the company in the public domain.

vii. The project proponent shall also submit six monthly reports on the status of the compliance of the stipulated environmental conditions including results of monitored data (both in hard copies as well as by e-mail) to the Regional Office of MOEF, the respective Zonal Office of CPCB and the APCB. The Regional Office of this Ministry / CPCB / APCB shall monitor the stipulated conditions.

viii. The environmental statement for each financial year ending 31st March in Form-V as is mandated to be submitted by the project proponent to the concerned State Pollution Control Board as prescribed under the Environment (Protection) Rules, 1986, as amended subsequently, shall also be put on the website of the company alongwith the status of compliance of environmental conditions and shall also be sent to the respective Regional Offices of the MOEF by e-mail.

ix. The Project Proponent shall inform the public that the project has been accorded environmental clearance by the Ministry and copies of the clearance letter are available with the APCB and may also be seen at Website of the Ministry of Environment and Forests at http:/envfor.nic.in. This shall be advertised within seven days from the date of issue of the clearance letter, at least in two local newspapers that are widely circulated in the region of which one shall be in the vernacular language of the locality concerned and a copy of the same shall be forwarded to the Regional office.

x. Project authorities shall inform the Regional Office as well as the Ministry, the date of financial closure and final approval of the project by the concerned authorities and the date of commencing the land development work.

8.0 The Ministry may revoke or suspend the clearance, if implementation of any of the above conditions is not satisfactory.

9.0 The Ministry reserves the right to stipulate additional conditions if found necessary. The Company in a time bound manner shall implement these conditions.

10.0 The above conditions shall be enforced, inter-alia under the provisions of the Water (Prevention & Control of Pollution) Act, 1974, the Air (Prevention & Control of Pollution) Act, 1981, the Environment (Protection) Act, 1986, Hazardous Wastes (Management and Handling) Rules, 2003 and the Public (Insurance) Liability Act, 1991 along with their amendments and rules.

(Dr. P. B. Rastogi)
Director

Copy to:

1. Principal Secretary, Department of Environment & Forest, Govt. of Assam, Guwahati, Assam.
2. The Chief Conservator of Forests, Regional Office (North-East Zone, Shillong) Upland Road, Laitumhran Shillong-793003.
3. The Chairman, Central Pollution Control Board Parivesh Bhavan, CBD-cum-Office Complex, East Arjun Nagar, New Delhi - 110 032.
4. The Chairman, Assam Pollution Control Board, Bamunimaidam, Guwahati – 21 Assam.
5. Adviser, IA II(I), Ministry of Environment and Forests, Paryavaran Bhavan, *CGO* Complex, New Delhi.
6. Monitoring Cell, Ministry of Environment and Forests, Paryavaran Bhavan, *CGO* Complex, New Delhi.
7. Guard File/Monitoring File/Record File.

(Dr. P. B. Rastogi)

Director

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GOVERNMENT OF INDIA
MINISTRY OF ENVIRONMENT, FOREST & CLIMATE CHANGE
NORTH EASTERN REGIONAL OFFICE
LAW-U-SIB, LUMBATNGEN, SHILLONG-793021
TEL. 0364-2537278; FAX. 0364-2536041
E-mail: moefro.shillong@gov.in

No. RO-NE/E/IA/AS/MI/53/ 731-33 Date: 30th June, 2020

To,

1. The Member Secretary, Industry-II,
   Ministry of Environment, Forest and Climate Change,
   Indira Paryavaran Bhawan, Jor Bagh Road,
   Aliganj, New Delhi-110003;

2. The Director, Monitoring Cell, IA Division,
   Ministry of Environment, Forest and Climate Change,
   Indira Paryavaran Bhawan, Jor Bagh Road,
   Aliganj, New Delhi-110003.

Sub: Information regarding Baghjan Blow Out in Tinsukia district, Assam- regarding.

Ref: **i.** EC No. J-11011/1255/2007-IA. II (I) dated 01.11.2011 entitled "Drilling of Development Well (26 Nos.) and Exploratory Well (15 Nos.) at N. Hapjan-Tinsukia-Dhola Area in District Tinsukia Assam by M/s Oil India Limited";
ii. Letter No. OMEC/MKY/BGN-5/2020/L01/46 dated 27.06.2020 by One Man Enquiry Committee, Government of Assam.

Sir/Madam,

In inviting a reference to the above, I am directed to state that this office received letter No. OMEC/MKY/BGN-5/2020/L01/46 dated 27.06.2020 under reference (ii) by email from the office of the One Man Enquiry Committee, Tinsukia, Government of Assam seeking comments on the last sentence of Clause 2 of the EC under reference (i) which reads "**No National Park/Wildlife Sanctuary/Eco-Sensitive Area are located within 10 km**". A copy of said letter is enclosed herewith. For the said project, appraisal for grant of Environmental Clearance was done by Ministry. Hence, all documents/records are available with Ministry.

In view of the above, the information sought is forwarded to Ministry for kind immediate necessary action as the Committee has sought reply within 6th July, 2020 please.

Yours faithfully,

(Dr. H. Tynsong)
Scientist 'D'

Encl: As stated.
Copy to:

1. Shri M. K. Yadava, IFS, Addl. PCCF (WL) & CWLW and One Man Enquiry Committee, Government of Assam, Room No. 08, Circuit House, Tinsukia, Assam-786126

30/6/2020
Scientist 'D'

Reaction Type 1

see eqn 11 & 12

$$[C_xH_y + qCO_2 + jN_2] + b[O_2 + 3.76N_2] \rightarrow$$

(LHS)

$$\longrightarrow \eta x CO_2 + \eta\frac{y}{2}H_2O + [1-\eta]xCO + [1-\eta]\frac{y}{2}H_2 + dO_2 + jN_2 + \underbrace{qCO_2}_{\text{RHS}} + 3.76\,bN_2 \quad \text{—(11)}$$

~~Applying Balancing the equation (11)~~

you get $q = \left[x\left(\frac{1}{2} - \frac{\eta}{2}\right) + y\left[\frac{1}{2} - \frac{\eta}{4}\right]\right]$ —(12)

(NB) η controls/regulates the distribution of CO_2 and CO in the product of combustion. It is known that the higher η (combustion efficeney), the lower CO in the product.

step 1 Determine all coefficients, known and Unknown in the LHS of equation (11)

LHS: C_xH_y is determined using eqn 18 and 19 and data from Table 1

$$C_x = B_1C_1 + B_2C_2 + B_3C_3 + B_4C_4 + B_5C_5 + \ldots + B_nC_n$$

$$C_x = 0.92506(1) + 0.0278(2) + 0.016582(3) + 0.007791(4) + 0.002971(5).$$

C_1 C_2

$\therefore C_x = C_{1.076}$

$\Longrightarrow$ $x = 1.076$, $y = 4.11$, $q = 0.00218$, $j = 0.0011$ } All SOKU.

$b = ?$ 2.06

To get b } use eqn 8 – 10

Set $\eta = 0.98$ and $f = 0.98$ } Table 3 results

η = Combustion efficeney

f = percentage of air available for combustion.

$\therefore$ at $f = 1$ {Complete Combustion}.

NB: $\therefore f = \frac{b}{1c}$ — eqn 8

$f = 0.98$ — This means Incomplete combustion as air available for combustion is only 98% of air available for Complete Combustion.

$K = (x + \frac{y}{z})$ — from eqn (9).

$K = (1.076 + \frac{4.11}{4}) = 2.1035$ { for SOKy }.

NB: "z" here is small letter.

$z = 4$

Interpretation: This means it will take Cathy from SOKy K air (i.e 2.1035 mole/or unit) air to achieve complete Combustion.

NB: at $z=4$, $b=K$. ⇒ which implies complete combustion.

However, our focus is incomplete combustion at $\delta = 0.98$

∴ from eqn 8, $b = \delta K$

$b = 0.98 \times 2.1035 = 2.0614$ See air column in Table 3 under SOKy

RHS

— $\eta x CO_2 + qCO_2$ = values under CO_2 in Table 3 at $\delta = 0.98$ & $\eta = 0.90$ — for reaction Types 1, 3 and 5.

$= 0.90 x CO_2 = [0.90 \times 1.076 \cdot [12+32]] + [0.00218 \times [12+32]]$

$= 42.774$ kg.

— Values under $CO = [1-\eta] x CO$ +

$= (1-0.90)(1.076)(12+32) = 3.441$

— values under $H_2O = \eta \frac{y}{2} H_2O$ +

$= 0.90 \times \frac{4.11}{2} [2+16] = 33.291$ (not shown in table)

— values under $H_2 = [1-\eta] \frac{y}{2} H_2$

$= (1-0.9) \times \frac{4.11}{2} \times [2] = 0.411$ (not shown)

— values under N_2

$= jN_2 + 3.76\, bN_2$

$= [0.0011 \times N_2] + [3.76 \times 2.0614 \times N_2]$ (not shown)

— values under $NO = 0$ } eqn 11 which is for reaction Type 1 does not have NO and NO_2 on the RHS

— values under $NO_2 = 0$ }

— value under $O_2 = dO_2$

But $d = \left[x\left(\frac{1}{2} - \frac{\eta}{2}\right) + y\left[\frac{1}{2} - \frac{\eta}{4}\right]\right] b$

∴ To get z, $b = \frac{x+y}{z}$,

but $b = 2.0614$ at $\delta = 0.98$ — See air column in Table 3 for SOLN.

$\therefore z = \frac{y}{b-x} = \frac{4.11}{2.0614 - 1.076} = 4.17$

$\therefore d = \left[x\left(0.5 - \frac{0.90}{2}\right) + y\left(\frac{1}{4.17} - \frac{0.90}{4}\right)\right]$

$= \left[(1.076 \times 0.05) + (4.11 \times 0.0148)\right]$

$= 0.0538 + 0.0608$

$d = 0.1146$

Therfore Value under dO_2 in Table 3 (not shown)

$= dO_2 = 0.1146 \times 32 = 3.6672$

To get values under R5 (i.e Reaction type 5 in Table 3 for SOLN)

— use eqn (16) —

$[C_x H_y + q CO_2 + j N_2] + b(O_2 + 3.76 N_2)$

$\longrightarrow \eta x CO_2 + n\frac{y}{2} H_2O + (1-\eta) x CO + (1-\eta)\frac{y}{2} H_2$

$+ \frac{d}{4} O_2 + j N_2 + q CO_2 + \left(3.76 - \frac{d}{2}\right) N_2$

$+ \frac{d}{2} NO + \frac{d}{2} NO_2$ ——— (16)

$d = 0.1146$ { for SOLN at $\delta = 0.98, \eta = 90$ }

Value under NO — $\frac{d}{2} \cdot NO = \frac{0.1146}{2}(28+16) = 2.52$ ✗

Mass of Nitrogen used was 28 instead of 14

$\therefore$ — $\frac{d}{2}(NO) = \frac{0.1146}{2}(14+16) = 1.72$ ✓

Value under $NO_2 = \frac{d}{2}(NO_2) = \frac{0.1146}{2}(28+32) = 3.44$ ✗

Using Mass of Nitrogen as 14

$= \frac{0.1146}{2}(14+32) = 2.64$ ✓

Using equation (14) for values under R3 in Table 3

$d_{NO} = 0.1146 \times [28+16] = 5.04$ ✗ wr

Page 4. use $d_{NO} = 0.1146 \times [14+16) = 3.44$ ✓

Please take note of the following typing errors I suppose.

1 — Coefficients of H_2O in equations 1, 2, 5, 11, 13, 14, 15, 16 and 17 is

$\eta \frac{y}{2}$ and not $\eta \frac{y}{z}$

2 — The molar mass/Mass of Nitrogen should be 14 and not 28 ~~for~~ except for N_2 {i.e molecular mass}
This will affect ~~the~~ values of NO & NO_2 & N_2 in the results tables

3 — This was embedded in my code already and was not changed. ~~Since the focus was mostly on~~

$$d = \left[x\left(\frac{1}{2} - \frac{\eta}{2}\right) + y\left(\frac{1}{2} - \frac{\eta}{4}\right) \right] \quad -12$$

Hope this helps

Konrad.

Umkhon Godsgift Ezaine

~~Ezaine~~







