एनटीपीसी लिमिटेड
(भारत सरकार का उद्यम)

एनटीपीसी
NTPC

NTPC LIMITED
(A Govt. of India Enterprise)

तालचेर थर्मल / Talcher Thermal
Ref. : TTPS/EMG/C-9/ 112
Date : 26.11.2019

To

Additional Principal Chief Conservator of Forests (C),
Ministry of Environment, Forest and Climate Change,
Regional Office (EZ), A/3, Chandersekharpur,
Bhubaneswar – 751023
Tel. No. 0674- 2301213, 2302432
Fax No.0674- 2302432
Email: roez.bsr-mef@nic.in

Sub: Half yearly Compliance of MoEF&CC Permission letter no.J-11015/276/2011-IA.II(M) dated. 19.04.2017.

Dear Sir,

Please find enclosed herewith Half yearly Compliance of MoEF&CC letter no. J-11015/276/2011-IA.II(M) dated. 19.04.2017 regarding permission for disposal of fly ash (1.2 MTPA) generated from 460 MW Talcher TPP of M/s. NTPC Ltd. into mine void of South Balanda OCP of M/s. Mahanadi Coalfields Ltd., in Talcher Coalfields, District, Angul, Odisha. Compliance period from April to September 2019.

Thanking you,

Yours faithfully,

Satpathy

(Ashutosh Satpathy)
AGM (TS)
NTPC/TTPS

<u>Encl</u> : As above.

CC: 1. Central Pollution Control Board
Kasba New Market, Sector E, East Kolkata Twp, Kolkata, West Bengal -700107

2. The Member Secretary,
SPCB, Odisha, Paribesh Bhawan,
A/118, Nilakantha Nagar, Unit- VIII, Bhubaneswar -751 012

Half yearly Compliance of MOEF&CC Environmental Clearance letter no. J-11015 / 276 /2011-IA.II (M) dated 19.04.2017

Compliance Period: April 2019 to September 2019

Half Yearly Compliance of Environmental Clearance dated 19.04.2017 for permission of disposal of fly ash (1.2 MTPA) generated from 460 MW Talcher TPP of M/s NTPC Ltd. into mine void of South Balanda OPC of M/s Mahanadi Coalfields Ltd., in Talcher Coalfields, District, Angul, Odisha.

Sr. No	EC Stipulation in EC letter dated 19.04.2017	NTPC Talcher TPP response as on 30.09.2019
10	The matter was placed before the Re-constituted Expert Appraisal Committee (Thermal Power) in its 4th Meeting held on 16.03.2017. In acceptance of the recommendation of the Re-constituted Expert Appraisal Committee (Thermal Power) and in view of the information / clarification furnished by you, with respect to the above project, the **Ministry hereby accords the permission to continue the disposal of fly ash for the maximum quantity of 1.2 MTPA on temporary basis for a further period of five years w.e.f. from 10.04.2017** subject to following conditions.	
i.	A pilot project shall be explored for implementation for Cenosphere extraction from flyash and manufacturing of by-products in consultation with organizations like CSIR, ISM (IIT) Dhanbad.	Awarded to NEERI, Nagpur. A Prototype unit of 10 Kg ash capacity has been fabricated by M/s NEERI.
ii.	As recommended by NEERI, Ash characterisation, hydro-geological studies, leachability of trace metals, monitoring of trace elements in the supernatant, pH of the water and the piezometers on a quarterly basis and reports shall be submitted to the Ministry and it's regional office annually.	Ash characterisation, hydro-geological studies, leachability of trace metals, monitoring of trace elements in the supernatant, pH of the water and the piezometers on a quarterly basis awarded to NEERI, Nagpur. Team collected samples in April '18, June '18 and November 18. Interim Report Submitted in February 19. (enclosed as **Annex.-A**.) 4th Qtr. Samples collected from 20th- 24th February 2019 and from 09.10.2019 to 14.10.2019.
iii.	Radio tracer studies shall be continued once in six months and the findings of the study shall be submitted to the Ministry and its Regional office annually.	Radio tracer studies awarded on 20.04.18 to BRIT, Mumbai, for study for a period of one year. Initially monitoring of spreading of radiotracer will be done regularly by BRIT, Mumbai. Interim Report also submitted in February 2019. Water samples submitted to M/s BRIT in June, July, August & September-2019.
iv.	Bioaccumulation and bio-magnification tests shall be conducted on surrounding flora and fauna (tree leaves, vegetation, crop yields and cattle population etc) during pre-monsoon	Bioaccumulation and bio-magnification tests have been conducted on surrounding flora and fauna awarded to NBRI, Lucknow. 1st year Report submitted in

Sr. No	EC Stipulation in EC letter dated 19.04.2017	NTPC Talcher TPP response as on 30.09.2019
	and post monsoon to find out any trace metals escaped through groundwater or runoff and the reports shall be submitted to the Ministry annually.	February 2019. (enclosed as **Annex.-C**.) Samples collected in May & September 2019.
v.	Surface runoff and supernatant water, in any case shall not be let into surroundings. It shall be collected by providing adequate drains around the mine. As proposed the supernatant water along with surface runoff shall be treated and re-used for ash mixing and plant operations. Surface and ground water quality along with existing piezometric wells shall be monitored quarterly and the reports shall be submitted to the Ministry annually.	As mentioned in (ii) above, Studies are awarded to NEERI, Nagpur. Team collected samples in April 2018, June 2018 and November 2018. Interim Report Submitted by NEERI in February 2019. 4th Qtr. Samples collected in February 2019. Samples collected from 4th to 9th June 2019 for 1st quarter of 2019. 1st Initial Interim Report is enclosed as **Annex.-A**.
vi.	After the mine void reaches its full capacity, 30 cm sweet soil lining and proper compacting be provided on the top to avoid any wash off during rainy season. Reclamation activities along with greenbelt development shall be carried out in consultation with M / s MCL in accordance with approved Mine Closure Plan. An action plan in this regard shall be submitted to the Ministry and its Regional Office.	Shall be complied at the time of mine closure in consultation with M/s MCL in accordance Mine Closure Plan.
vii	Only decanted water from mine, make up water from treated effluents such as cooling tower blow down and treated sewage water shall be used from making ash slurry. Raw water withdrawal from Brahmani river for purpose of making ash slurry shall be minimized. Downstream impacts of water withdrawal from Brahmani River shall be studied and report submitted to the Ministry.	Decanted water from mine, make up water from treated effluents such as cooling tower blow down and treated sewage water are being used for making ash slurry. Raw water withdrawal from Brahmani river for purpose of making ash slurry has already been minimized/optimized. Study on downstream impacts of water withdrawal from Brahmani River awarded to NIH, Roorkee. Final report received on 03.08.2019. Copy of the report enclosed as **Annex-B.**
viii.	Mercury in fly ash shall be periodically monitored by Inductively Coupled Plasma Mass Spectrometry (ICP-MS)	Being studied with Sr. No.-ii under Ash characterisation, hydro-geological studies, leachability of trace metals, monitoring of trace elements in the supernatant.
ix.	Details of month-wise quantity of fly ash disposed and water consumption along with nature of water shall be submitted to Ministry.	Annual report of Ash utilization is being submitted to MOEF&CC. Beside this, Annual Environmental Statement containing ash utilization and Water consumption for various purposes is being submitted to SPCB, Odisha.
x.	Half-yearly Compliance report for all the stipulated condition in this permission shall	Being complied.

Sr. No	EC Stipulation in EC letter dated 19.04.2017	NTPC Talcher TPP response as on 30.09.2019
	be submitted to the Ministry and its Regional Office	
xi.	The fly ash utilization shall be in compliance with Fly ash Notification and its amendments issued from time to time by the Ministry.	Fly ash is being used in preparation fly ash bricks and supply to other user industries. Balance ash is being utilized in filling of abandoned South Balanda Mine Voids of MCL.
xii.	Third party evaluation / Environment Audit shall be conducted annually form reviewing the compliance conditions stipulated in the clearances along with the baseline data / studies to be carried out during the period of temporary permission.	Third party Audit report will be submitted to Ministry.
xiii.	Compliance of EC / amendment conditions, Environment (Protection) Act. 1986, Rules and MoEF&CC Notifications issued time to time shall be done by an Environment Officer to be nominated by the Project Head of the Company who shall be responsible from implementation and necessary compliance timely.	Head (Env. Management Group/Ash Utilization) department is responsible for implementation & necessary compliance timely.
11.	All other studies & conditions prescribed in the earlier permissions dated 05.09.2013, 02.03.2015 and 11.04.2016 shall also be complied with by NTPC and other concerned, as applicable.	All other studies & conditions prescribed in the earlier permissions dated 05.09.2013, 02.03.2015 and 11.04.2016 are being complied.
12.	Any appeal against this permission shall lie with the National Green Tribunal, of preferred, within 30 days as prescribed under Section 16 of the National Green Tribunal Act. 2010.	Noted.

Annex.-A

Interim Report-II

Ash Characterization, its Leachability, Hydrogeological and Water Quality in and around Ash Filled South Balanda Mine Void

Submitted to

M/s. NTPC Limited, Talcher
Angul District, Odisha

CSIR-National Environmental Engineering Research Institute
Under Council of Scientific & Industrial Research
Nehru Marg, Nagpur – 440 020

NEERI
ISO 9001:2008

February 2019

Chapter 1: Introduction

1.1. Preamble

The NTPC-Talcher Thermal Power Station (TTPS) is a (4 × 60 MW and 2 × 110 MW) coal based power station situated about 15 km from the Angul town in Odisha. The power station was established by Odisha Power Generation Corporation Limited in the year of 1968. However, it was taken over by NTPC in the year of 1995.

The TTPS generates approximately 3500 tons of ash is generated per day. The potential use of fly ash for brick making in the region is insignificant. Only 1% of the fly ash is used for brick making and the rest is used for back filling of abandoned mine voids of South Balanda Open Cast Mines of Mahanadi Coalfields Limited since September 2005.

The unused fly ash and the bottom ash (in a ratio of about 80:20) are mixed with water in the ratio of 1:6 and the resultant slurry is brought to the abandoned South Balanda Mine void by large pipelines. After decantation, the supernatant water is recycled back to the project for further use in ash slurry making.

The South Balanda Mine void is spread over an area of 92.82 ha (**Figure 1.1**). The Mine void consists of three quarries, known as Quarry 2, 3A and 3B.

Figure 1.1: Ash disposal at the abandoned mine void (Quarry 3A) by Talcher Thermal Power Station (TTPS)

Before start of the ash filling, NTPC had undertaken various studies through The Central Mine Planning and Design Institute (CMPDI) in 2003. However, since intervention by Ministry of Environment, Forest and Climate Change (MOEF&CC) in 2011, NTPC engaged National Environmental Engineering Research Institute (NEERI) to undertake various studies related to Environmental Impacts of ash filling in mine voids. NEERI started studies in the South Balanda area in 2012 and since then, the study has been continuing every year during pre-monsoon and post-monsoon seasons. The studies have been undertaken in five phases as follows:

1. Impact assessment of ash fill sites of NTPC Ltd.,/ Talcher Thermal Power Station on water resources in the surrounding villages of South Balanda Mine Void and old ash pond area of Talcher Thermal Power Station (April 2012-March 2013),
2. Study of fly ash characterization of ash fill sites of Talcher Thermal Power Plant and leaching characteristics of mine void water at South Balanda mine void (October 2012-October 2013),
3. Impact Assessment of Ash Pond on Groundwater Quality in the Surrounding Area of South Balanda Mine Void of Talcher Thermal Power Station (November 2013-November 2014),
4. Monitoring of groundwater, surface water and soil in the vicinity of South Balanda Mine and old ash pond (May 2015-May 2016),
5. Integrated Hydrogeological, Geophysical, Hydrochemical and Groundwater flow and solute transport modelling studies around the ash filled South Balanda Mine Voids in Angul District, Odisha (May 2015-May 2016).

In addition, NTPC has also undertaken studies pertaining to impact on Flora, Fauna and Bio-accumulation & Bio-magnification of trace metals through NEERI and a Tracer Study through Bhabha Atomic Research Center (BARC), Mumbai. These reports were presented separately. Based on the above mentioned studies, the TTPS got Environmental Clearance to continue with the ash disposal at the mine void for a period of 5 years vide letter No: J-11015/276/2011-IA.II (M) dated 19.4.2017. The MoEF&CC has accord the permission to TTPS to continue disposal of fly ash for the maximum quantity of 1.2 MTPA on temporary basis for a further period of five years w.e.f. 10.04.2017 and directed to carry out certain studies. TTPS desired CSIR-NEERI to continue with the studies with the following scope of work for periods of 4 years vide Purchase order No4000197484-037-1027 dated 20.01.2018.

1.2. Objectives of the study

The broad objectives of the study are as follows:

- Ash characterization, hydro-geological studies, leachability of trace metals
- Periodical monitoring of Mercury in fly ash by inductively coupled Plasma Mass Spectrometry (ICP-MS)
- Monitoring of trace elements in the supernatant /decanted water, surface and ground water from nearby sources along with network of piezometric wells
- Monitoring of water quality (Physico-chemical) in the supernatant/decanted water, surface and ground water along with existing network of piezometric wells
- Nature of water used for ash slurry makeup

1.3. Scope of the work

The scope of the study includes the following aspects:

- Quarterly every year (including Pre and Post monsoon seasons) monitoring of Groundwater and Surface water quality for Physico-chemical Properties (pH, EC, TDS, Total Alkalinity, Ca, Mg, Na, K, Cl, SO_4, NO_3, and PO_4) and Trace metals (As, Ba, Cd, Co, Cr, Cu, F, Fe, Hg, Mn, Ni, Pb and Zn)
- Quarterly (every year) monitoring of chemical constituents of Fly Ash: SiO_2, Al_2O_3, Fe_2O_3, K_2O, TiO_2, CaO, MgO, Na_2O, P_2O_5, SO_3, Cr_2O_3, MnO_2, CuO, Rb_2O, SrO, Y_2O_3, Nb_2O_5 and BaO on percentage basis.
- Quarterly (every year) monitoring of Trace Elements in Fly Ash : As, Ba, Cd, Co, Cr, Cu, Fe, Mn, Ni, Pb and Zn (mg/kg, using TCLP Test)
- Quarterly (every year) monitoring of Mercury in Fly Ash using ICP-MS

1.4. Approach of the Study

The study includes the collection of Primary data (Field observations, sample collections, laboratory analysis and experiments) and secondary data (from different Govt. agencies, Reports and literature) keeping in view of the broader objectives of the project. The proposed methodology/approach for the study is described below:

a) Field visit to the study area and selection of observation wells.

b) A network of observation wells for water level measurement and groundwater sampling. The monitoring has to be done on quarterly basis which will also include the pre-monsoon and post-monsoon seasons.

c) Collection and analysis of groundwater samples of the study area for physico-chemical properties and trace metals.

d) Collection and analysis of surface water samples including samples of Mine Void supernatant/decanted water for physico-chemical properties and trace metals

e) Characterization of Ash – Analysis of chemical parameters, analysis of trace elements using Toxicity Characteristic Leaching Procedure (TCLP) test, and Mercury analysis on Inductive Coupled Plasma Mass Spectroscopy (ICP-MS)

f) Leachability studies through TCLP method

1.5. Layout of the report

The entire report has been presented in four chapters; the details of each chapter are given below:

Chapter 2: The study area details are presented.

Chapter 3: The methodology for data collection is discussed.

Chapter 4: The results for monitoring carried out in April 2018, June 2018 and November 2018 are presented in this Interim report.

Chapter 2: The Study Area

2.1. Location

The NTPC-Talcher Thermal Power Station (TTPS) lies in the study area between latitudes 20° 52' 00" N to 20° 59' 00" N and longitudes 85° 07' 30" E and 85° 15' 30" E. It is covered by Survey of India Toposheet (F45 T/1 and F45 T/5 on 1:50,000 scale). It is located in Talcher town in the Angul district of Odisha which is approximately 15 km from Angul city (**Figure 2.1**).

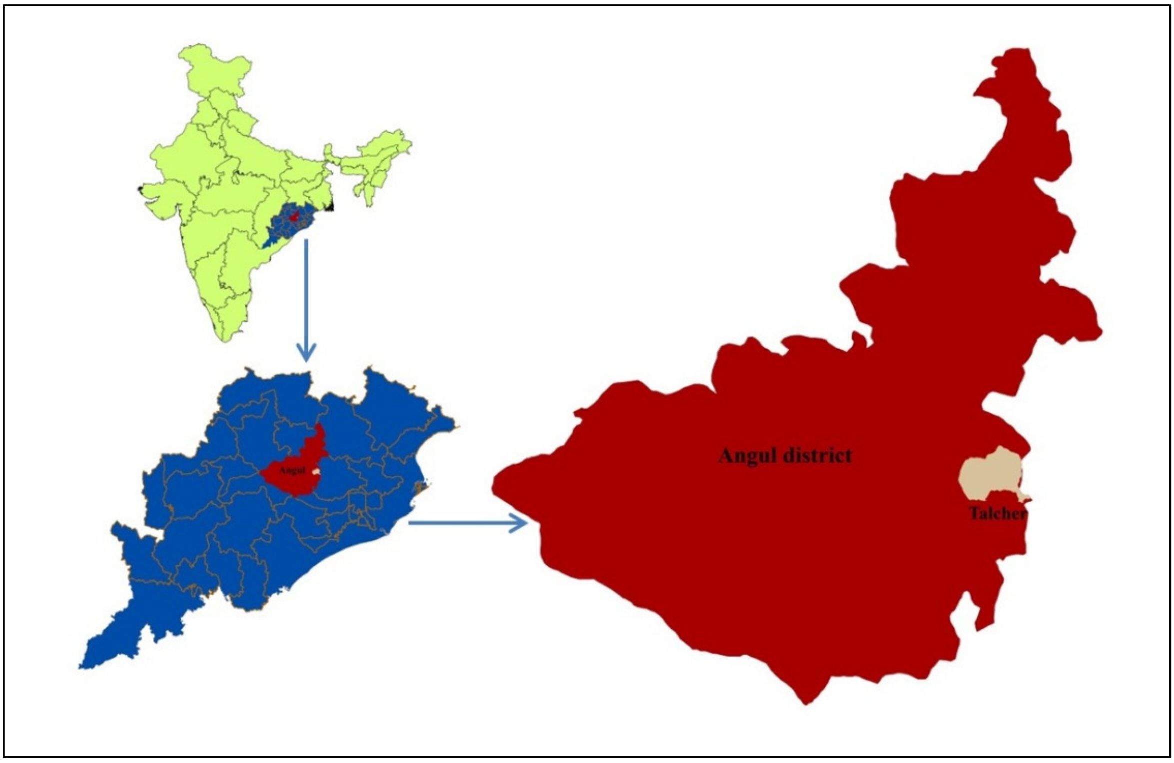


Figure 2.1: Location map of the study area

2.2. Climate

The study area experiences tropical monsoon climate with mild winter and hot summer. The average annual rainfall in the study area is approximately 1250 mm of which major amount is received during south west monsoon which is active during the period June to September.

2.3. Physiography and Land use

The study area constitutes northern part of Angul district. The area is mainly drained by the Brahmani River. The area constitutes various physiographic features such as alluvial plain, mountain ranges, flood plains and water bodies. The elevation of the area above mean sea

level (amsl) ranges from 49 m to 119 m and the slope is towards the south-east direction (**Figure 2.2**).

2.4. Geological setup

The study area is predominantly characterized by rocks of the Gondwana Super Group (**Figure 2.3**). The rock comprises of sandstone, carbonaceous shale and coal bands with pink clay and pebbly sandstones. Gondwana rocks are overlain by recent alluvium and valley fill materials at places. The abandoned South Balanda Mine is characterized by the Barakar formations underlain by pebbly sandstones and then the Karhabari formation (**Table 2.1**). The coal seams were found in the Barakar formations and the Karhabari formations. It is observed that granitoids appeared in South East and South West patches of the study area. Sandstone and Shale underlie the Karhabari formations (**Table 2.1**).

2.5. Hydrogeology

The area falls in the Brahmani tributary. The principal ground water reservoir in the area is consolidated crystalline rock of Precambrian age and semi consolidated Gondwana formations comprising of mainly sandstone and shale. The weathered and fractured sandstone form a good aquifer. Groundwater occurs under water table conditions in the weathered mantle, recent alluvium and the laterites and under semi-confined to confined condition in the fracture zone. The groundwater abstraction sources are mainly the open wells and India Mark-II hand pumps which are used to meet the domestic and drinking water requirements in the study area. The groundwater abstraction for agricultural requirement is almost insignificant.

Table 2.1: Local geology of South Balanda Block (CMPDI Report, 2003)

Age	Formation	Lithology	Thickness
Quaternary	Recent	Soil and sub-soil	0.86 m
Lower Permian	Baraker	Sandstone	6.1 m - 15.25 m
		Seam II	7.38 m - 48.92 m
		Pebbly sandstone	60 m (approx.)
Lower Permian	Karharbari	Sandstone	60 m -75 m
		Seam I	0.61 m - 18.16 m
		Sandstone	About 135m
Upper carboniferous to Lower Permian	Talchir	Sandstone and Shale	-

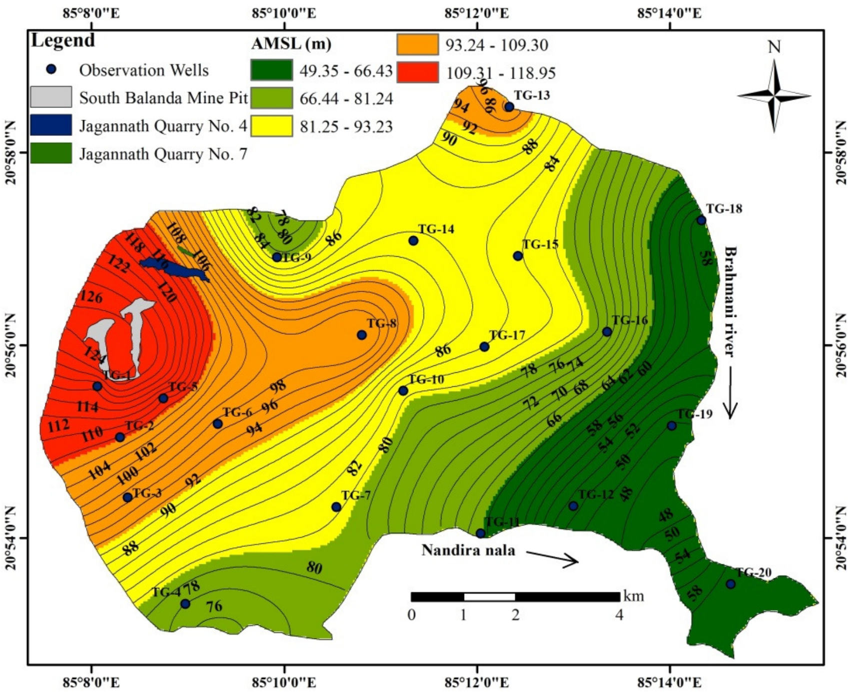


Figure 2.2: Elevation, location of observation wells and Mine Pits in the study area

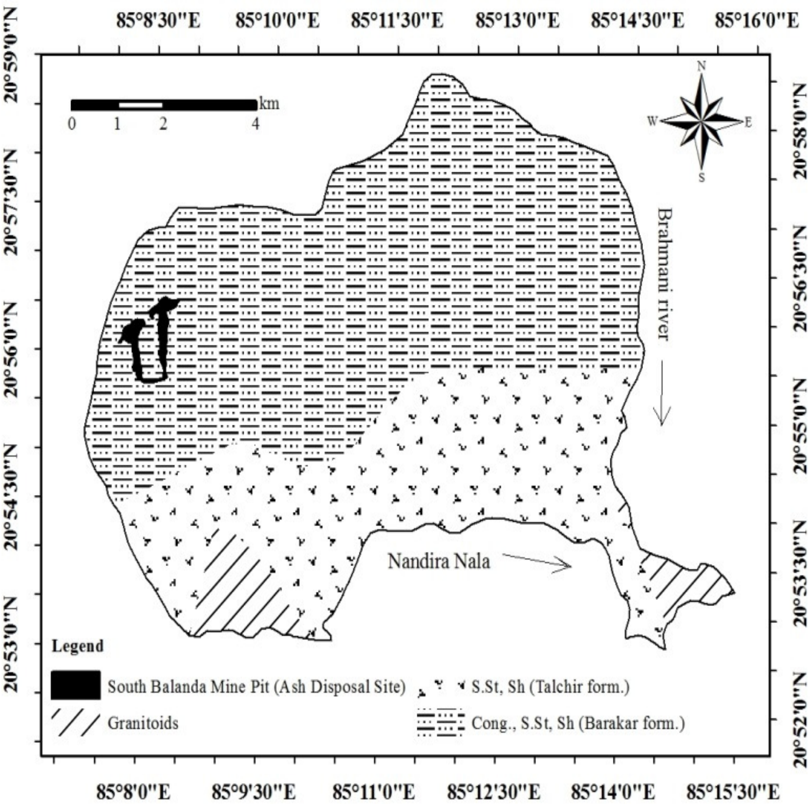


Figure 2.3: Geology map of the study area (after GSI, 2010)

Chapter 3: Methodology

3.1. General

The study envisages addressing the objectives by a holistic approach integrating the following aspects:

- Delineation of the study area on the basis of watershed principle and setting up a network of observation wells
- Measurement of groundwater levels in the study area
- Collection and analysis of groundwater samples in the study area
- Collection and analysis of Mine Void water samples
- Leachability studies through TCLP

3.2. Delineation of the study area and establishing observation well network

The study area has been delineated on the basis of watershed principle (**Figure 3.1**). The delineation is carried out by using the Survey of India Toposheet (F45 T/1 and F45 T/5 on 1:50,000 scale). A network of observation wells has been set up in the study area (Table 3.1). The observation well network includes India Mark-II hand pumps, open wells and piezometers installed by the TTPS. The study area covers an area of 89.52 sq. km. The co-ordinates (latitude/longitude) of the observation wells were noted with the help of hand held GPS of Garmin make. The details of the wells are presented in **Table 3.1**. It is ensured that the observation wells are located within 0.5 km, 1.0 km, 5.0 km and 10 km radius buffer zone (**Figure 3.1**). The Piezometers are located at a distance of 70m to 500m (**Figure 3.1**) from the Mine Void (

Table 3.2). The observation wells were identified in the study area in well representative manner so that the observation wells falls in all the land use pattern of the study area and during selection of observation wells it was also ensured that observation wells must cover the upstream and downstream area of the Ash ponds. Some of the sampling points were identified close to the disposal site i.e. the South Balanda Mine Void.

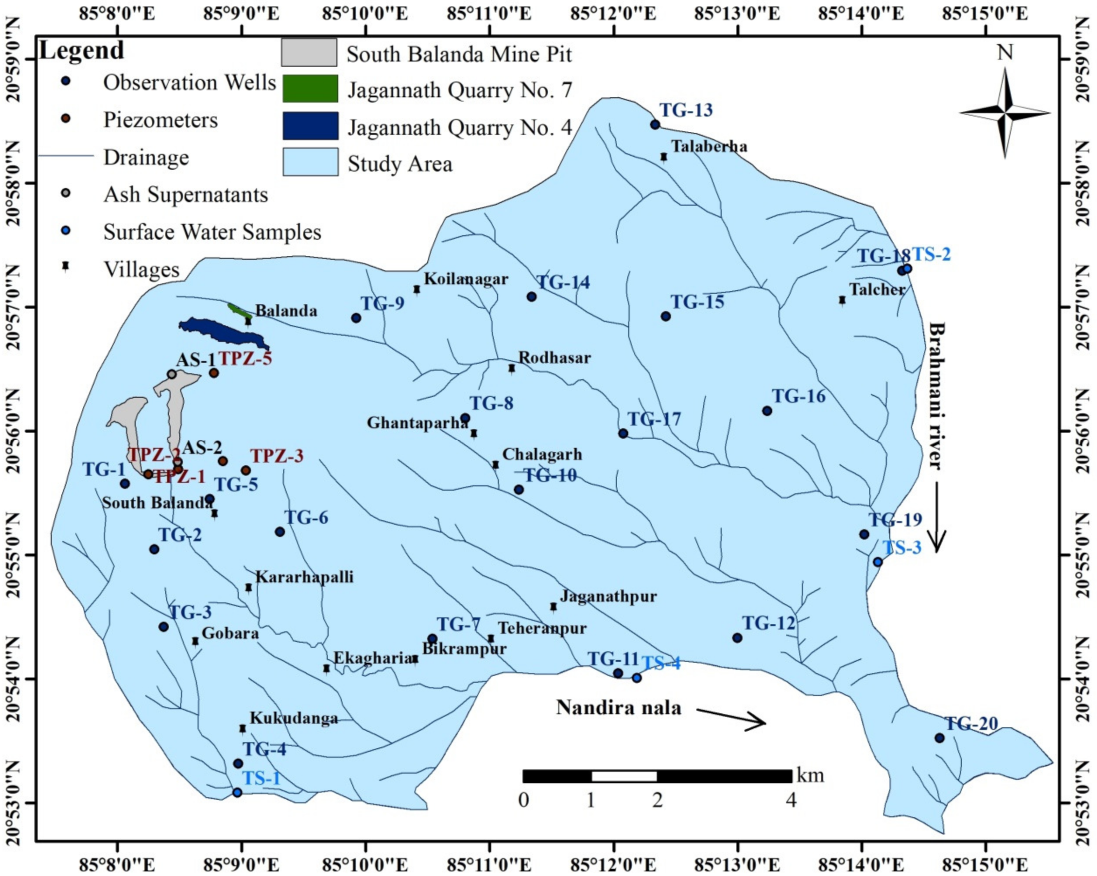


Figure 3.1: Base map of the study area

Table 3.1: Details of observation well network and surface water sampling locations in the study area

Source ID	Latitude	Longitude	Source	Description
TG-1	20° 55' 34.1"	85° 08' 03.6"	HP	Bharatpur gobara chowk, near truck garage, Temple
TG-2	20° 55' 02.2"	85° 08' 17.7"	HP	Chikkamunda village, Badasinghada, on the RHS of road from Bharatpur to Gobara
TG-3	20° 54' 25.2"	85° 08' 22.1"	HP	Gobara village center, after temple
TG-4	20° 53' 19.5"	85° 08' 57.9"	HP	Kukudanga village, LHS of the road towards Gobara, beside grinding mill

Source ID	Latitude	Longitude	Source	Description
TG-5	20° 55' 27.1"	85° 08' 44.6"	HP	MCL staff quarters, near Maa Tarini temple, south Balanda
TG-6	20° 55′ 11.0″	85° 09′ 18.4″	HP	Laxmanpur village near Balanda village, RHS of the road, beside the temple
TG-7	20° 54′ 19.4″	85° 10′ 32.0″	HP	RHS of the road towards NALCO, opposite to Shri Ganesh petrol pump, Bidyuth colony, Bikrampur
TG-8	20° 56′ 06.3″	85° 10′ 48.4″	HP	Ghantapada village, LHS of the road towards Chalagarh village, beside Pawan Biswal house
TG-9	20° 56′ 54.8″	85° 09′ 55.1″	HP	Dera village, inside primary school, LHS of the road towards Jagannath mine pit
TG-10	20° 55' 31.5"	85° 11' 14.1"	DW	On the Talcher-Chalagada road
TG-11	20° 54' 2.8"	85° 12' 02.0"	HP	Jagannathpur village, beside Madan Mahaparta village
TG-12	20° 54′ 19.5″	85° 12′ 59.5″	HP	LHS of the road towards TTPS, beside Talcher Thermal railway station
TG-13	20° 58′ 28.3″	85° 12′ 20.2″	HP	Talabeda village, RHS of the road towards Talcher road
TG-14	20° 57' 05.4"	85° 11' 20.1"	HP	Langida village, near Giridhar Maharana house
TG-15	20° 56' 56.2"	85° 12' 25.4"	HP	Deulabeda, in chouk near Shani Temple
TG-16	20° 56' 08.6"	85° 13' 20.7"	DW	Baghuabol village
TG-17	20° 55' 58.9"	85° 12' 04.9"	HP	On LHS of the road from Talcher station to Hatatota
TG-18	20° 57′ 17.7″	85° 14′ 19.7″	HP	Talcher town, beside Jagannath Mandir, LHS of the road towards Talabeda village
TG-19	20° 55′ 09.7″	85° 14′ 00.8″	HP	Santhapada village, RHS of the road towards Brahmani River
TG-20	20° 53' 30.9"	85° 14' 37.4"	HP	Village Jhadianba, near cowshed, besides drainage
TS-1	20° 53' 3.33"	85° 9′ 36.00″	SW	Upstream of Nandra Nala
TS-2	20° 57' 18.56"	85° 14′ 22.16″	SW	Upstream of Brahmani River
TS-3	20° 54' 56.47"	85° 14′ 7.98″	SW	Downstream of Brahmani River
TS-4	20° 54' 0.46"	85° 12′ 11.28″	SW	Downstream of Nandra Nala

* LHS-left hand side; RHS-right hand side; DW-dug well; HP-hand pump, SW-Surface water; NA-Not Available

Table 3.2: Piezometer locations near the South Balanda Mine Void

Piezometer ID	Latitude	Longitude
TPZ-1	20°55'38.90"N	85° 8'14.90"E
TPZ-2	20°55'41.40"N	85° 8'29.25"E
TPZ-3	20°55'40.70"N	85° 9'2.10"E
TPZ-4	20°55'45.30"N	85° 8'51.00"E
TPZ-5	20°56'28.10"N	85° 8'46.60"E

3.3. Groundwater level measurement

The water level from observation well network (**Figure 3.2**) was obtained using Electric Contact Gauze (KL010) manufactured by M/S OTT Pvt. Ltd (Germany). The groundwater level has been obtained with respect to below ground level (bgl).

Figure 3.2: Water level measurements in the study area

3.4. Groundwater and surface water sampling and analysis

The groundwater and surface water samples were collected during April 2018 from all the selected observation wells, piezometers and from surface water bodies (Brahmani River and Nandra Nala) (**Figure 3.3**). For physico-chemical parameters and metal analysis, samples were collected in pre-cleaned 500 ml and 100 ml polyethylene bottles respectively. Concentrated HNO_3 was added in the metal samples for preservation. Onsite parameters like pH, water temperature and Electrical Conductivity was measured in the field using probes. The physico-chemical parameters were analyzed by following the standard protocols (APHA, 2012). The trace metals (Fe, Mn, Zn, Pb, Cd, Cr and Cu) analysis was done by using ICP-OES (Model iCAP 6300 DUO, Make: Thermo Scientific). The detection limit for Fe, Mn, Zn, Pb, Cd, Cr and Cu is 0.0003 ppm, 0.018 ppm, 0.0002 ppm, 0.05 ppm, 0.009 ppm, 0.0006 ppm and 0.0004 ppm respectively. The parameters namely Na and K were analyzed by Flame Photometer (Model- CL361, Make: ELICO). The samples were also analyzed for the major cations and anions.

Figure 3.3: Surface water sampling from the Nandra Nala

3.5. Mine void water sampling

Supernatant samples were collected from the Mine void i.e. Quarry 2 and 3B. The samples were analyzed for the major cations, anions and trace metals.

3.6. Characterization of Ash

The fly ash samples were analyzed for the Toxicity Characteristic Leaching Procedure (TCLP) and total mercury concentration by digestion method.

3.6.1. Trace elements

The total leachable and non-leachable heavy metal concentration was determined by acid digestion method of EPA 3050B. The samples were taken in triplicates to avoid errors. After digestion the sample was filtered and analyzed by ICP-MS.

3.6.2. TCLP test

A commonly used test for the determination of the leaching characteristics of fly ash is the **Toxicity Characteristic Leaching Procedure (TCLP)** established by the US Environmental Protection Agency (US EPA, 1992). The TCLP is designed to determine the mobility of both organic and inorganic analytes present in liquid, solid and multiphase wastes. The procedure is carried out in an assembly which has an orbital shaker with fixed rotations per minute (RPM). This procedure provides a uniform method to compare the tendency of inorganic elements to leach out from fly ash samples into ***Moderate-to-highly acidic aqueous environments.*** The testing methodology is used to determine if ash is characteristically hazardous (D-List) or not. The extract is analyzed for substances appropriate to the protocol.

The toxicity characteristic leaching procedure (TCLP) was conducted as per United States Environmental Protection Agency protocol (US EPA SW-846 method, 1311). The fly ash and bottom ash sample was collected from the ash generation unit of NTPC-TTPS and analyzed using the TCLP test. Standard leaching procedure has been developed for the assessment of the mobility of hazardous substances into an aqueous phase and for the evaluation of their environmental impacts.

Table 3.3: Description of leaching test

Tests Condition	**EPA 3050B (Total concentration of trace elements)**
Heavy metal concentration	Leachable + Non-leachable
Leaching Solution	Nitric acid+ Hydrogen peroxide
Liquid to solid ratio	100:1
pH	< 2
Digestion/ Leaching time(h)	6 hrs
Temperature (˚C)	95
Number of samples	1

4.1. Groundwater Level

The groundwater level was monitored in the study area, from the identified hand pumps, dug wells and piezometers, in the month of April 2018, June 2018 and November 2018. The groundwater level in the study area ranges from **1.37 to 26.23 m bgl, 0.7 to 24.61 m bgl and 0.74 to 21.82** in the month of April 2018, June 2018 and November 2018 respectively (**Table 4.1**).

Table 4.1: Groundwater level data in the study area

Source ID	Well Type	BGL (m) April	BGL (m) June	BGL (m) November	Description
TG-1	HP	9.4	9.87	8.53	Bharatpur gobara chowk, near truck garage, Temple
TG-2	HP	NA	NA	NA	Chikkamunda village, Badasinghada, on the RHS of road from Bharatpur to Gobara
TG-3	HP	4.52	1.76	1.69	Gobara village center, after temple
TG-4	HP	7.55	6.39	3.09	Kukudanga village, LHS of the road towards Gobara, beside grinding mill
TG-5	HP	2.1	1.53	2.2	MCL staff quarters, near Maa Tarini temple, south Balanda
TG-6	HP	3.24	3.48	3.4	Laxmanpur village near Balanda village, RHS of the road, beside the temple
TG-7	HP	NA	24.61	21.82	RHS of the road towards NALCO, opposite to Shri Ganesh petrol pump, Bidyuth colony, Bikrampur
TG-8	HP	9.32	8.4	4.88	Ghantapada village, LHS of the road towards Chalagarh village, beside Pawan Biswal house
TG-9	HP	26.23	20.23	12.97	Dera village, inside primary school, LHS of the road towards Jagannath mine pit
TG-10	DW	2.83	0.7	0.91	On the Talcher-Chalagada road
TG-11	HP	NA	NA	NA	Jagannathpur village, beside Madan Mahaparta village
TG-12	HP	11.23	11.6	9.81	LHS of the road towards TTPS, beside Talcher Thermal railway station
TG-13	HP	5.07	21.15	15.06	Talabeda village, RHS of the road towards Talcher road
TG-14	HP	NA	NA	NA	Langida village, near Giridhar Maharana house
TG-15	HP	9.96	3.91	4.7	Deulabeda, in chouk near Shani Temple

Source ID	Well Type	BGL (m) April	BGL (m) June	BGL (m) November	Description
TG-16	DW	2.65	1.02	0.74	Baghuabol village
TG-17	HP	1.37	2.15	2.4	On LHS of the road from Talcher station to Hatatota
TG-18	HP	12.77	14.02	9.55	Talcher town, beside Jagannath Mandir, LHS of the road towards Talabeda village
TG-19	HP	18.30	14.85	14.61	Santhapada village, RHS of the road towards Brahmani River
TG-20	HP	11.19	10.9	8.55	Village Jhadianba, near cowshed, besides drainage

* LHS – left hand side; RHS – right hand side; DW – dug well; HP – hand pump; NA-Not Available

The piezometers installed in the study area had the groundwater level in the range of **0.73 to 7.69m bgl, 0.71 to 6.23 m bgl and 0.45 to 4.23 m bgl** in the month of April 2018, June 2018 and November 2018 **(Table 4.2)**.

Table 4.2: Groundwater level data of Piezometers installed in the study area

Piezometer ID	Latitude	Longitude	BGL (m) April	BGL (m) June	BGL (m) November
TPZ-1	20°55'38.90"N	85° 8'14.90"E	0.73	0.95	0.45
TPZ-2	20°55'41.40"N	85° 8'29.25"E	1.21	NA	NA
TPZ-3	20°55'40.70"N	85° 9'2.10"E	2.95	0.71	0.89
TPZ-4	20°55'45.30"N	85° 8'51.00"E	5.13	4.83	4.23
TPZ-5	20°56'28.10"N	85° 8'46.60"E	7.69	6.23	3.82

4.2. Ground water and Surface water quality

A total of 31 water samples were collected from nearby groundwater sources, surface water and from piezometers installed in the study area for the analysis of physico-chemical properties and trace metal concentrations. The water quality results were compared with the acceptable and permissible limits of drinking water specification BIS 10500:2012.

4.2.3. Physico-chemical Analysis

The physicochemical results of the water samples collected in the month of April 2018 **(Table 4.3 (a))**, June 2018 **(Table 4.3 (b))** and November 2018 **(Table 4.3 (c))** shows that some of the collected samples do not meet the overall drinking water specification BIS 10500:2012. The results of physico-chemical analysis for each parameter are as follows:

pH-

pH in April 2018

The pH **(Table 4.3 (a))** of all the collected groundwater and surface water samples taken in the month of April 2018 was found well within acceptable limits of BIS 10500:2012 drinking water specification.

pH in June 2018

The pH **(Table 4.3 (b))** for samples TG-17, TG-19 and TG-20 taken in the month of June 2018 were more than acceptable limit of BIS 10500:2012.

pH in November 2018

The pH **(Table 4.3 (c))** for the samples TG-9, TG-17 and TPZ-2 taken in the month of November 2018 showed below acceptable limit of BIS 10500;2012.

Total Dissolved Solids (TDS)-

April 2018

The TDS **(Table 4.3 (a) & Figure 4.3 (a))** in water samples collected in the month of April 2018 with code: TG-3, TG-4, TG-3, TG-6, TG-7, TG-11, TG-12, TG-17, TG-19, TPZ-3-T and TPZ-8-T were found above acceptable limit whereas all other samples were well within acceptable and permissible limits of BIS 10500:2012 drinking water specification.

June 2018

The TDS **(Table 4.3 (b) & Figure 4.3 (b))** in water samples with code: TG-3, TG-4, TG-6, TG-7, TG-11, TG-12, TG-13, TG-17, TG-19, TG-20, TPZ-3 and TPZ-5 were found above acceptable limit of BIS 10500:2012, whereas all other samples were well within the permissible limits of BIS 10500:2012 drinking water specification.

November 2018

The TDS **(Table 4.3 (c) & Figure 4.3 (c))** in water samples with code: TG-2 was the only one found to be above acceptable limit of BIS 10500:2012, whereas all other samples were well within acceptable and permissible limits of BIS 10500:2012 drinking water specification.

Turbidity-

April 2018

The turbidity **(Table 4.3 (a))** in most of the samples was found above acceptable/permissible limit of BIS 10500:2012 drinking water specification. The turbidity in samples with sample code: TG-4, TG-12, TG-13, TPZ-2B, TPZ-2T, TPZ-4T, TPZ-5T were found above acceptable limit.

June 2018

The turbidity **(Table 4.3 (b))** in all of the samples was found above acceptable limit of BIS 10500:2012 and most of them were above the permissible limit of BIS 10500:2012 drinking water specification. The only two samples that were below the permissible are TG-3 and TG-12, remaining all were above the permissible limit.

November 2018

The turbidity **(Table 4.3 (c))** in all of the samples was found above acceptable limit of BIS 10500:2012 and the samples TG-1, TG-2, TG-3, TG-4, TG-5, TG-6, TG-7, TG-8, TG 9, TG 13, TG 14, TG 15, TG 18, TG 20, TPZ-1, TPZ-4 and TPZ-5 was found above the permissible limit of BIS 10500:2012 drinking water.

Total Hardness as $CaCO_3$-

April 2018

The total hardness **(Table 4.3 (a))** in the samples (TG-1, TG-8, TG-12, TG-14, TG-15, TG-16, TG-19, TG-20, TPZ-4T, and TPZ-4B) was under acceptable limit. All other samples were detected with higher total hardness as compared to BIS 10500:2012 drinking water specification. All the surface water samples were found well within acceptable limit of BIS 10500:2012 drinking water specification for total hardness.

June 2018

The total hardness **(Table 4.3 (b))** of the samples TG2, TG3, TG 4, TG 6, TG 11, TG 13, TPZ 4 and TPZ 5 were above the acceptable limit of BIS 10500:2012. However, all the samples were well within the permissible limit as prescribed in 10500:2012.

November 2018

The total hardness **(Table 4.3 (c))** of the samples TG2, TG3, TG 6, TG 9, TG 10, TG 13, TG 19, TPZ-4 and TPZ-5 were above the acceptable limit of BIS 10500:2012. However, all the samples except TG 13 were well within the permissible limit as prescribed in 10500:2012.

Total alkalinity as $CaCO_3$-

April 2018

The total alkalinity (**Table 4.3 (a)**) in samples (TG-2, TG-3, TG-4, TG-6, TG-7, TG-11, TG-12, TG-13, TG-17, TG-19, TG-20, TPZ-2T, and TPZ-4T) was exceeding the acceptable limit of drinking water specification BIS: 10500:2012. However, all the surface water samples were found well within acceptable limit of BIS 10500:2012 drinking water specifications for total alkalinity.

June 2018

The total alkalinity **(Table 4.3 (b))** in the samples (TG-2, TG-3, TG-4, TG-6, TG-7, TG-11, TG-12, TG-13, TG-17, TG-19, TG-20 and TPZ-2) was exceeding the acceptable limit of drinking water specification BIS: 10500:2012. However, all the surface water samples were found well within acceptable limit of BIS 10500:2012 drinking water specifications for total alkalinity.

November 2018

The total hardness samples **(Table 4.3 (c))** TG2, TG3, TG 6, TG 9, TG 10, TG 13, TG 19, TPZ 5 and TPZ-5 were above the acceptable limit of BIS 10500:2012. However, all the samples except TG 13 were well within the permissible limit as prescribed in 10500:2012.

Fluoride-

April 2018

Fluoride **(Table 4.3 (a) & Figure 4.3 (a))** concentration was analyzed and the samples TG-7, TG-19, and TG-20 detected with higher fluoride concentration than the acceptable limit of BIS 10500:2012 drinking water specification.

Fluoride concentration in two surface water samples (TS-1 and TS-4) were also found above acceptable limit of drinking water specification BIS 10500:2012. Whereas all other surface water samples were under acceptable limit of drinking water specification BIS 10500:2012.

June 2018

Fluoride **(Table 4.3 (b) & Figure 4.3 (b))** concentration was analyzed in all of the samples and all of them had a result below the acceptable limit as prescribed by the BIS 10500:2012.

November 2018

Fluoride **(Table 4.3 (c) & Figure 4.3 (c))** concentration for samples TG 7, TG 11, TG-20 was above the permissible limit set in BIS: 10500:2012 All the other samples were within the permissible limit.

Nitrate-

April 2018

The concentration of Nitrate **(Table 4.3 (a) & Figure 4.3 (a))** in all the collected samples (groundwater sources, piezometers, and surface water) was found well within acceptable limit of drinking water specification BIS 10500:2012.

June 2018

The concentration of Nitrate **(Table 4.3 (b) & Figure 4.3 (b))** in all the collected samples (groundwater sources, piezometers, and surface water) was found well within acceptable limit of drinking water specification BIS 10500:2012.

November 2018

The concentration of Nitrate **(Table 4.3 (c) & Figure 4.3 (c))** in all the collected samples (groundwater sources, piezometers, and surface water) was except sample 2 samples (TG 9 and TG 17) found well within acceptable limit of drinking water specification BIS 10500:2012.

Sulphate-

April 2018

The sulphate **(Table 4.3 (a) & Figure 4.3 (a))** concentration in all the samples were well within acceptable limit of drinking water specification BIS 10500:2012 except samples with sample code TG-11 and TPZ-5T. The predicted Sulphate concentration within the study area (based on Sulphate concentration analyzed in collected groundwater sources including piezometers) is presented in **Figure 4.10**. Sulphate concentration in all the surface water samples was well within acceptable limits of drinking water specification BIS 10500:2012.

June 2018

The sulphate **(Table 4.3 (b) & Figure 4.3 (b))** concentration in the samples was well within acceptable limit of drinking water specification BIS 10500:2012. Samples that exceeded the acceptable limit are TG 11, TPZ-3, TPZ-4 and TPZ-5.

November 2018

The sulphate **(Table 4.3 (c) & Figure 4.3 (c))** concentration in the samples was well within acceptable limit of drinking water specification BIS 10500:2012. Samples that exceeded the acceptable limit are TG 19, Q2S, TPZ-3, TPZ-4 and TPZ-5.

Chloride-

April 2018

The concentration of chloride **(Table 4.3 (a) & Figure 4.3 (a))** in all the samples was also well within acceptable limit drinking water specification BIS 10500:2012 except sample with sample code TG-11. The predicted Chloride concentration within the study area (based on Chloride concentration measured in collected samples) is presented in **Figure 4.13**.

June 2018

The concentration of chloride **(Table 4.3 (b) & Figure 4.3 (b))** in all the samples was also well within acceptable limit drinking water specification BIS 10500:2012.

November 2018

The concentration of chloride **(Table 4.3 (c) & Figure 4.3 (c))** in all the samples was also well within acceptable limit drinking water specification BIS 10500:2012.

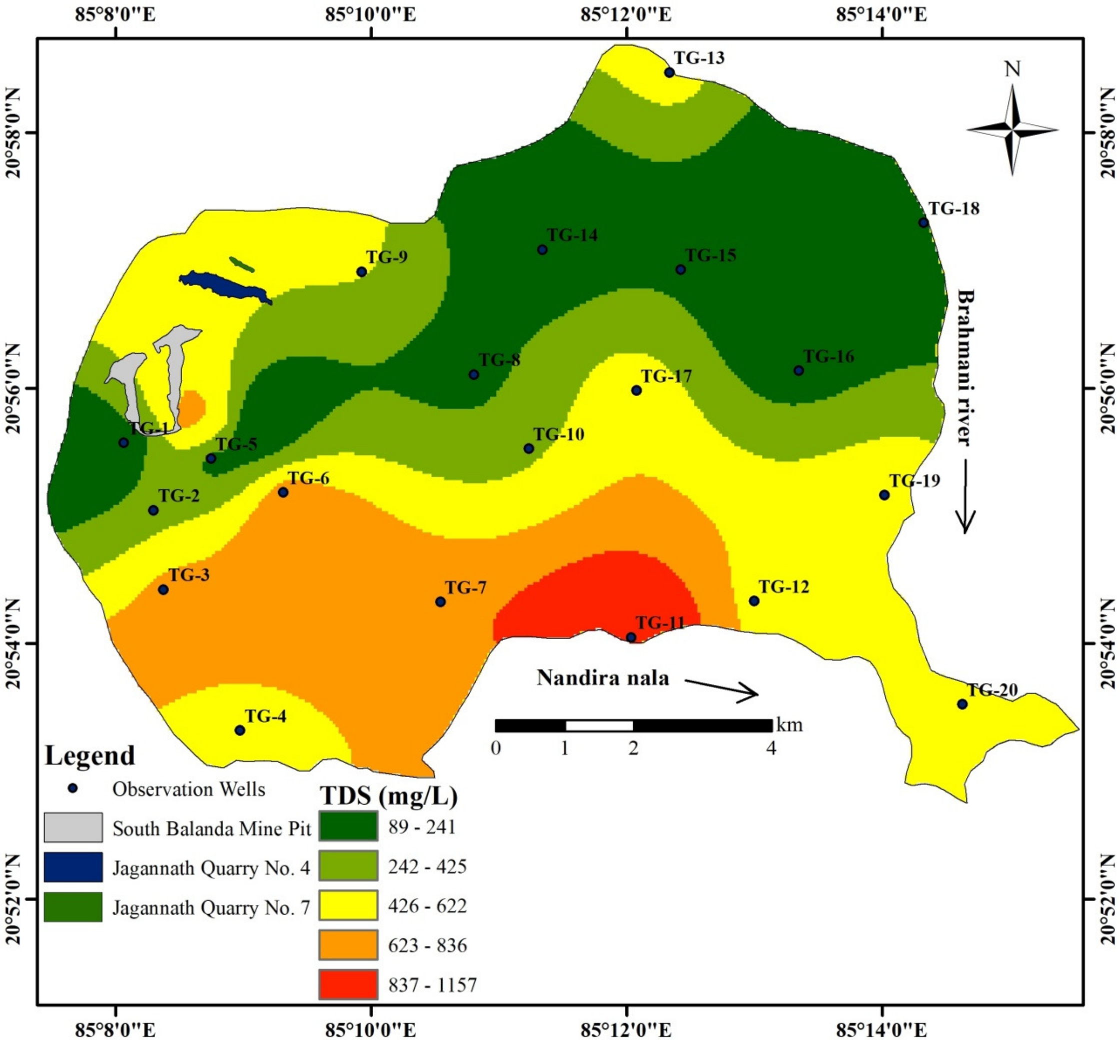


Figure 4.1 (a): TDS concentration in groundwater of the study area in April 2018

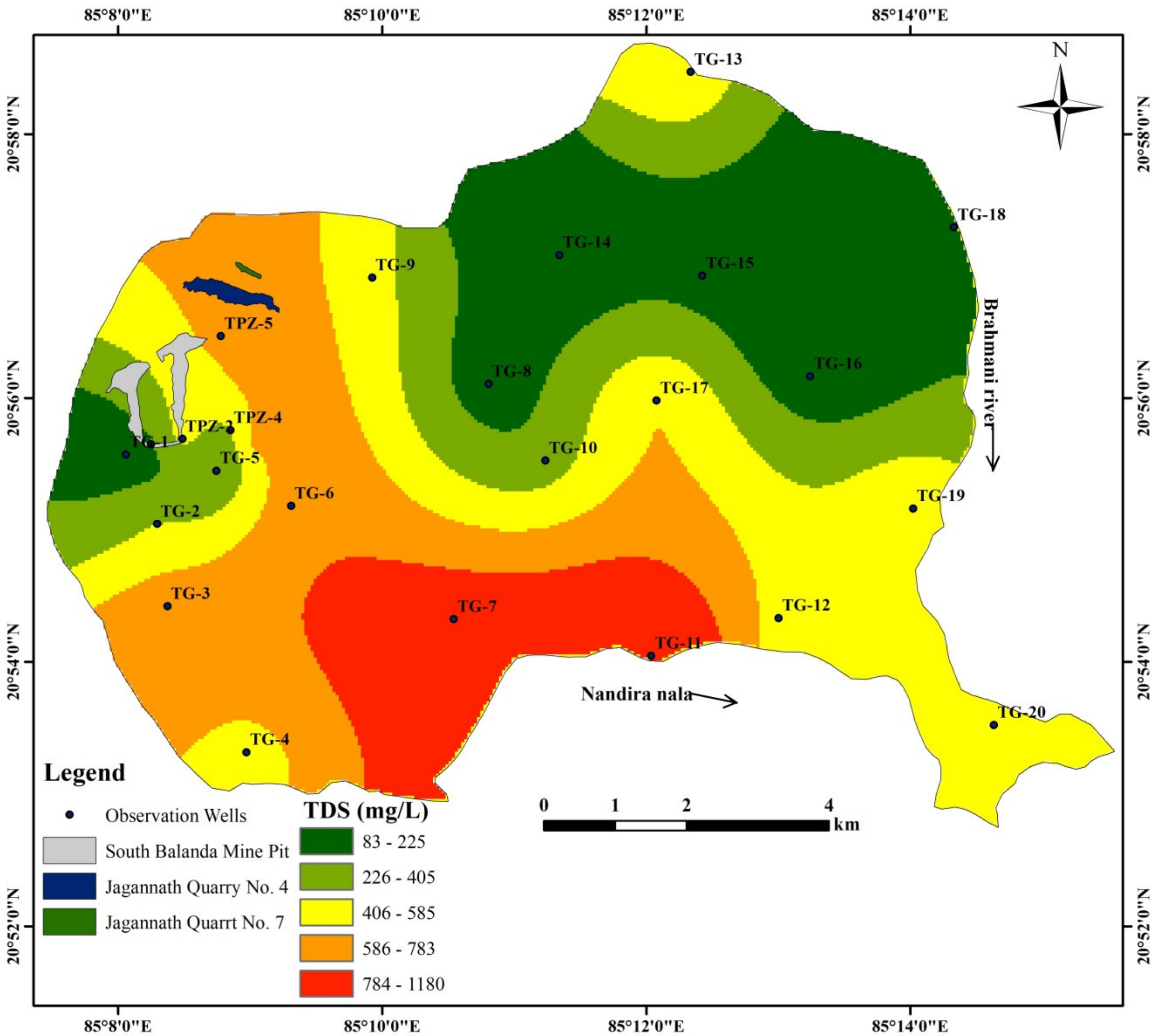


Figure 4.2 (b): TDS concentration in groundwater of the study area in June 2018

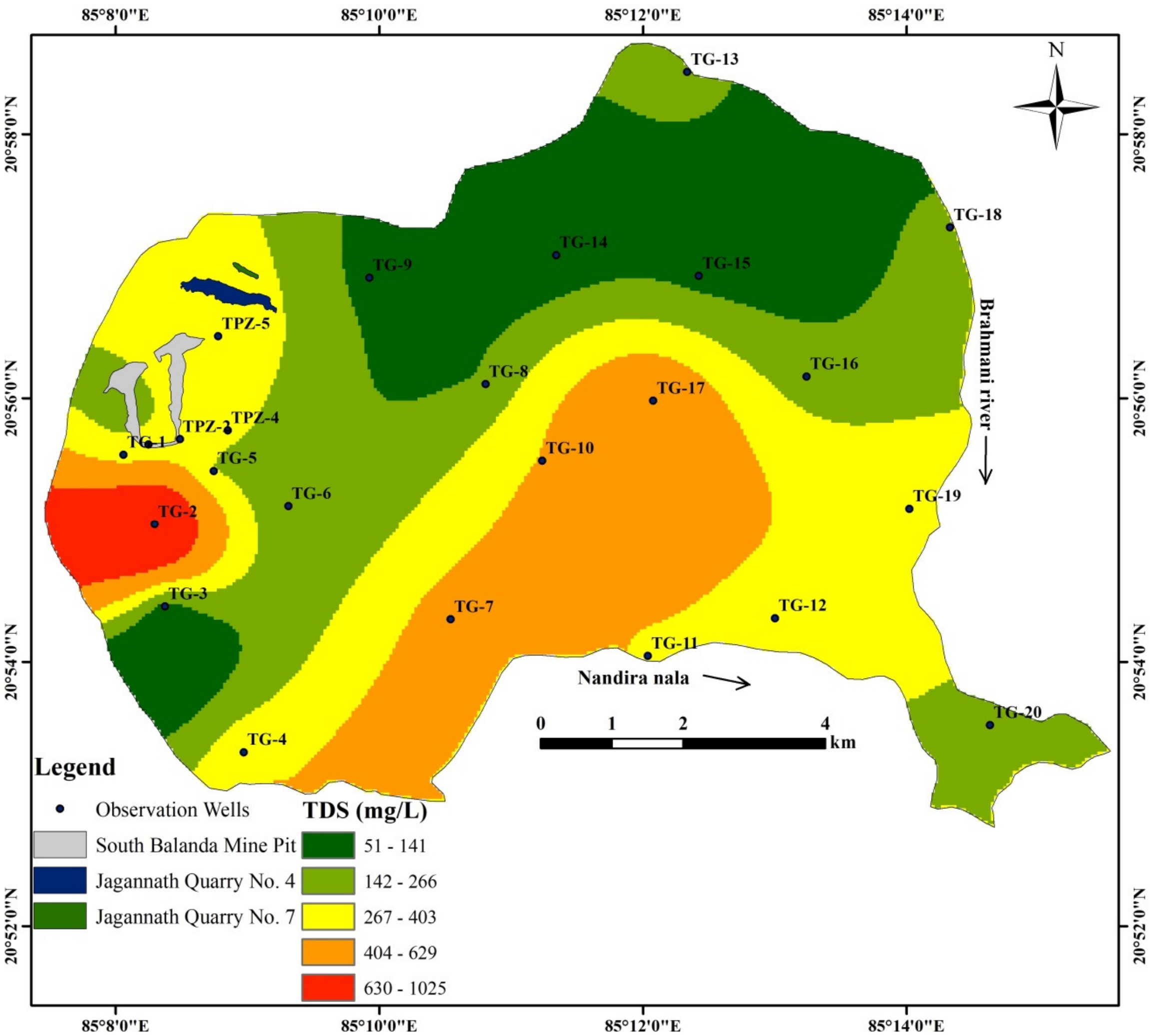


Figure 4.3 (c): TDS concentration in groundwater of the study area in November 2018

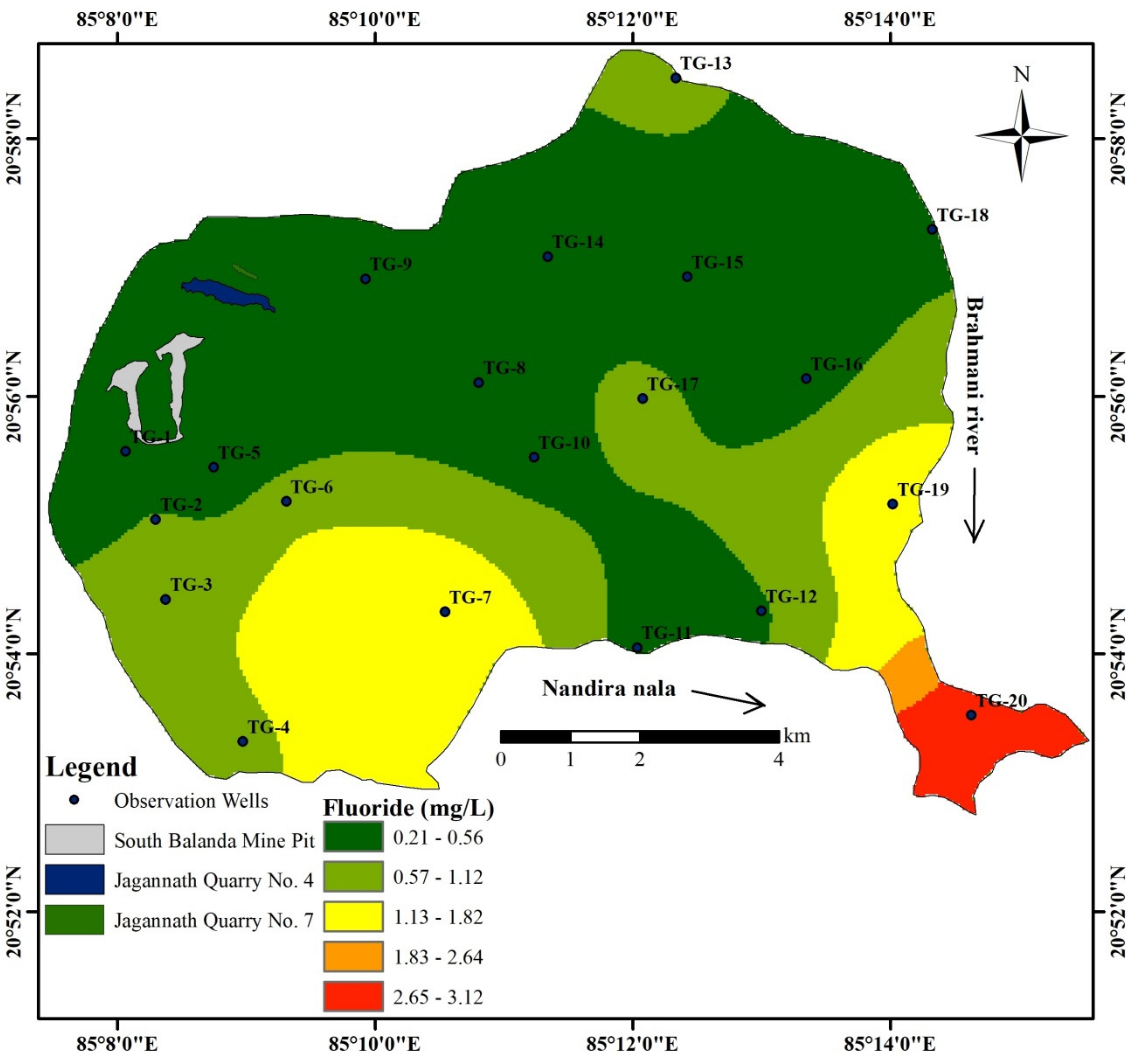


Figure 4.4 (a): Fluoride concentration in the groundwater of the study area in April 2018

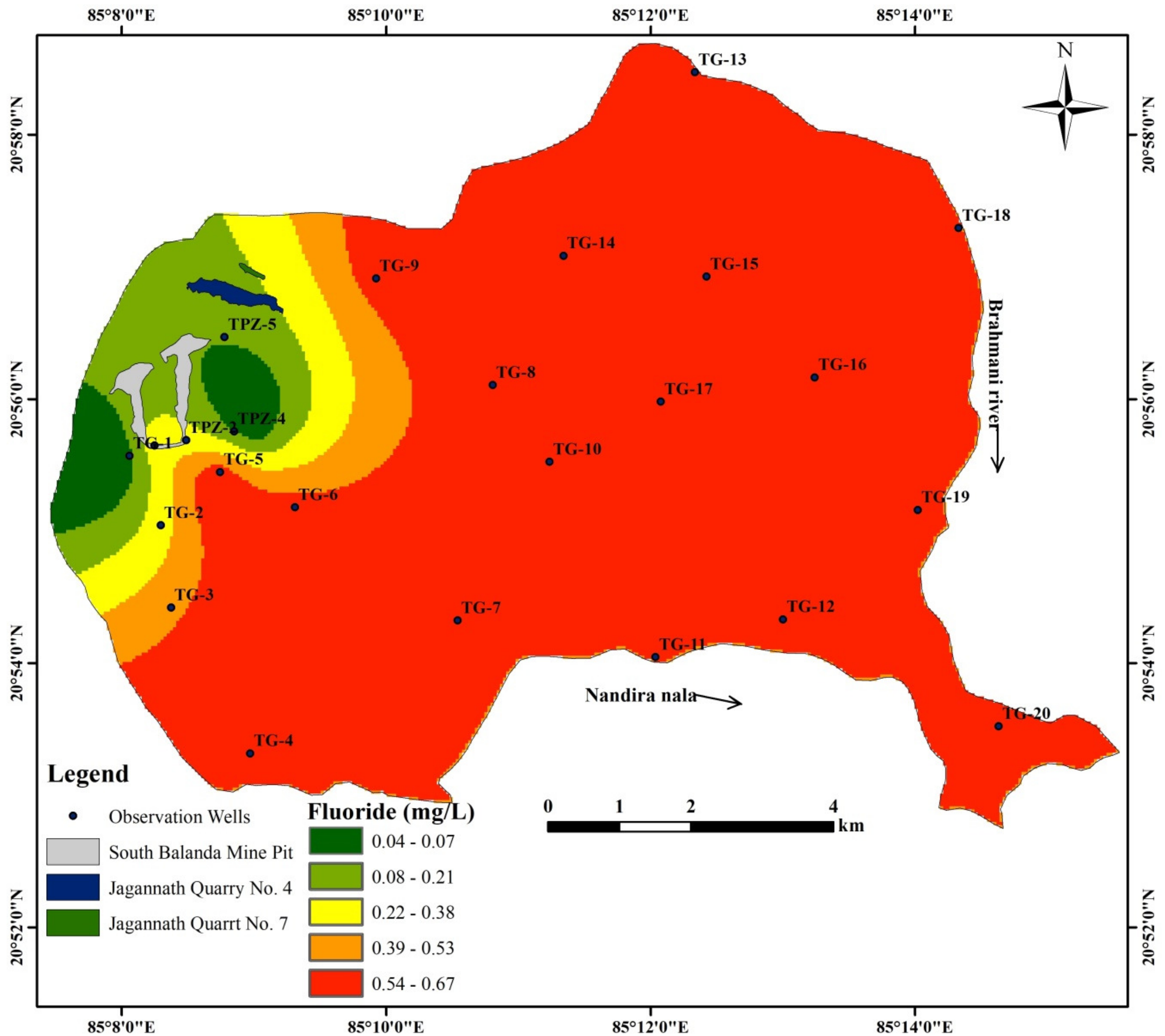


Figure 4.5 (b): Fluoride concentration in the groundwater of the study area in June 2018

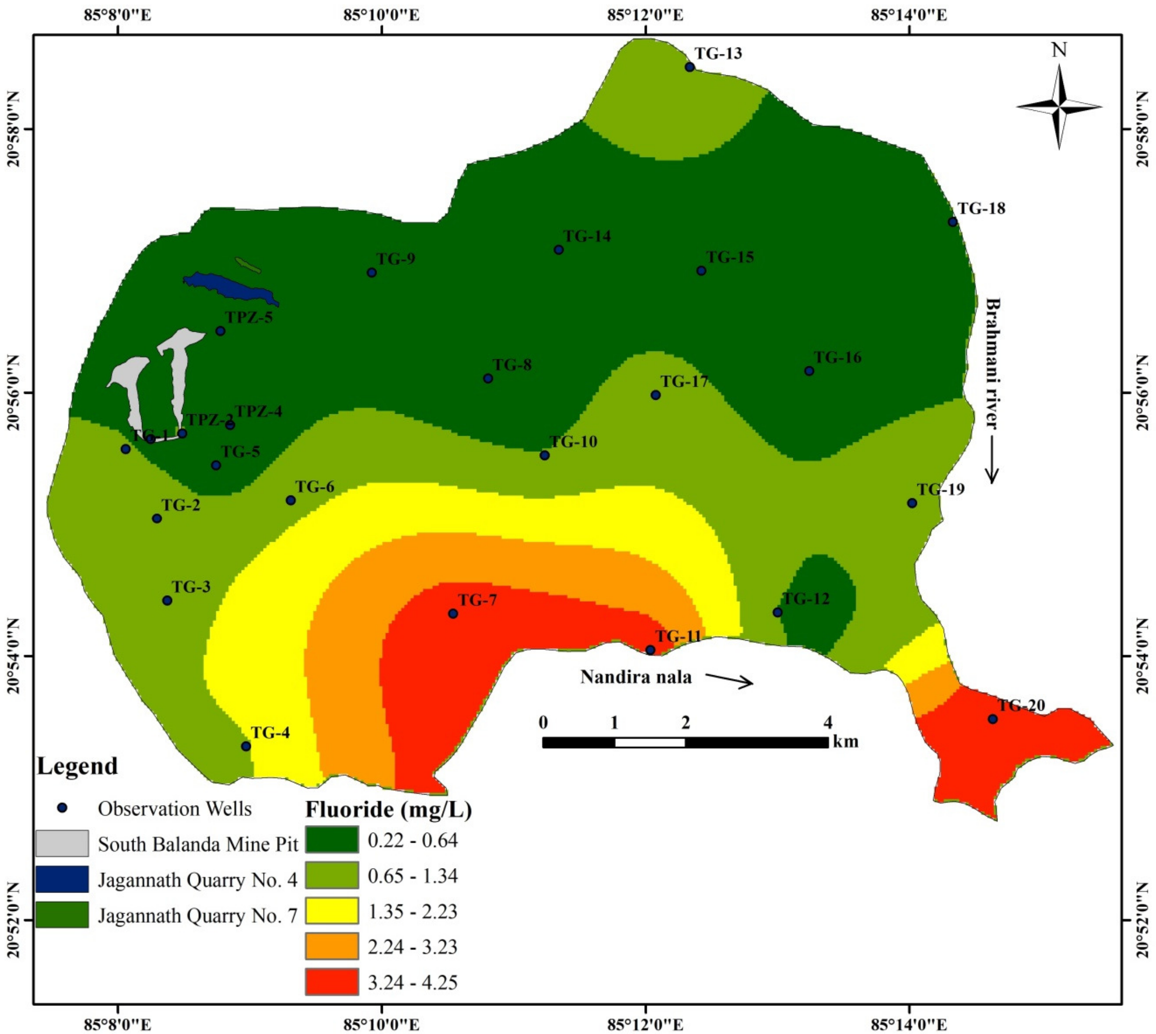


Figure 4.6 (c): Fluoride concentration in the groundwater of the study area in November 2018

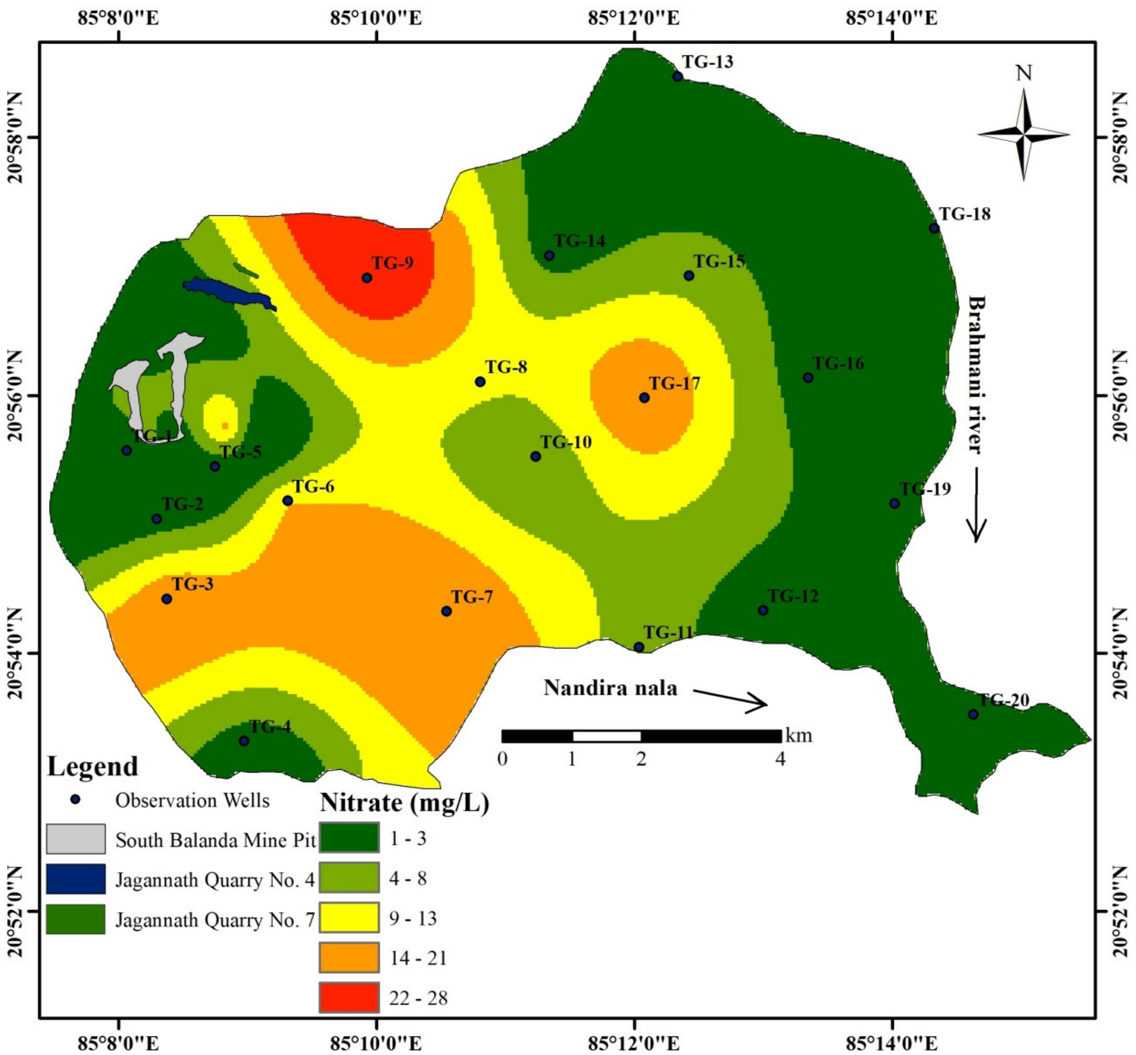


Figure 4.7 (a): Nitrate concentration in the groundwater of study area in April 2018

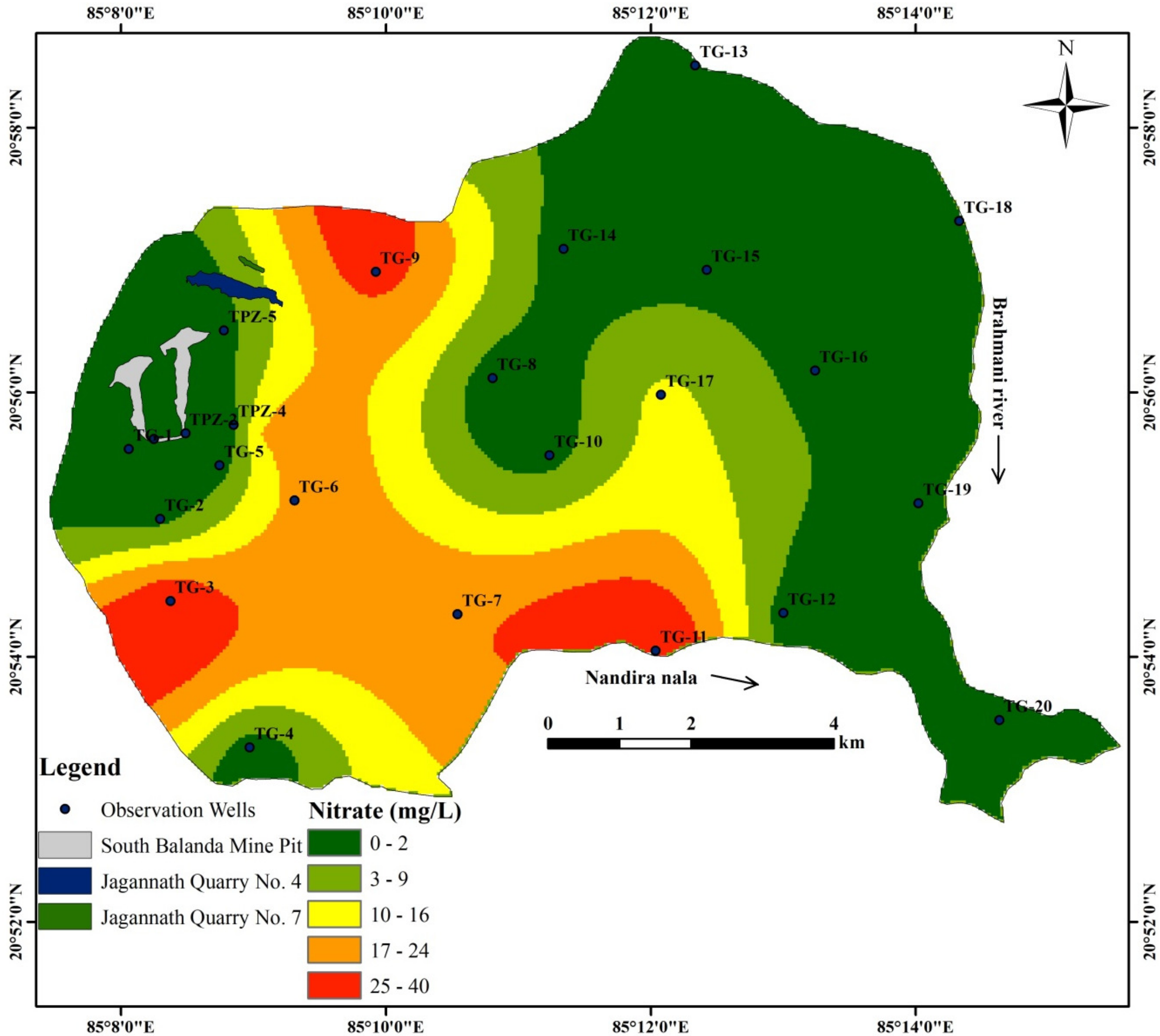


Figure 4.8 (b): Nitrate concentration in the groundwater of study area in June 2018

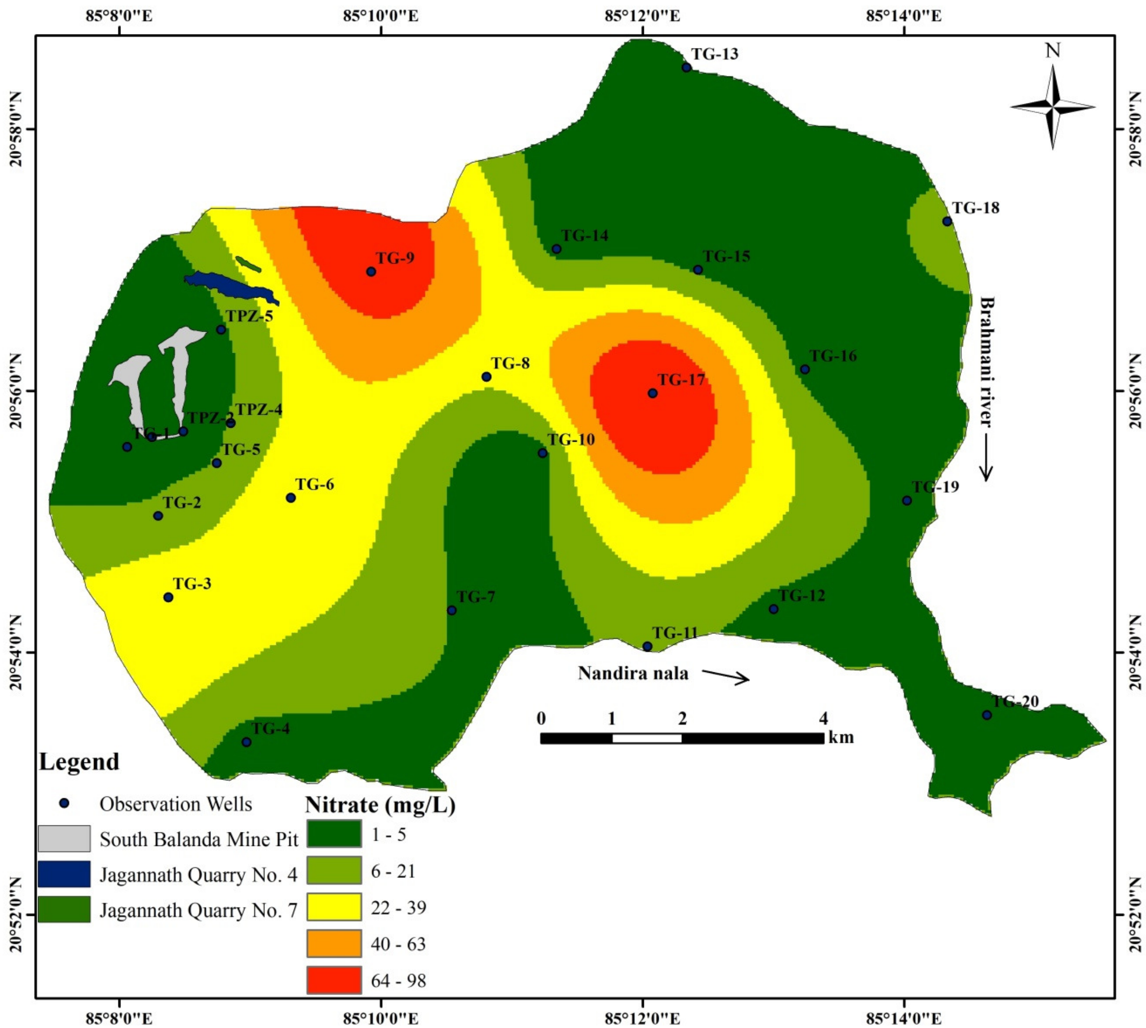


Figure 4.9 (c): Nitrate concentration in the groundwater of study area in November 2018

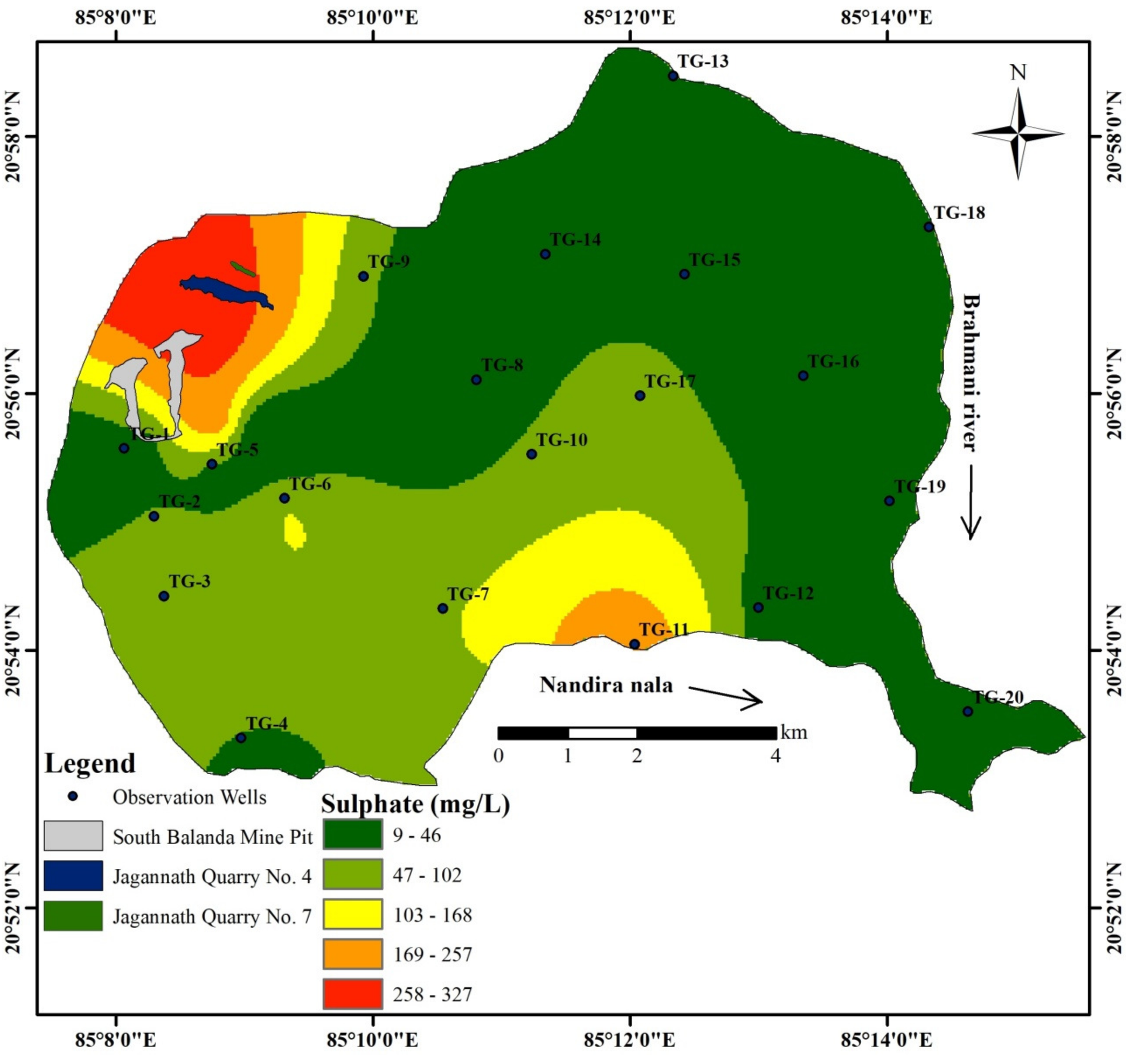


Figure 4.10 (a): Sulphate concentration in groundwater of the study area in April 2018

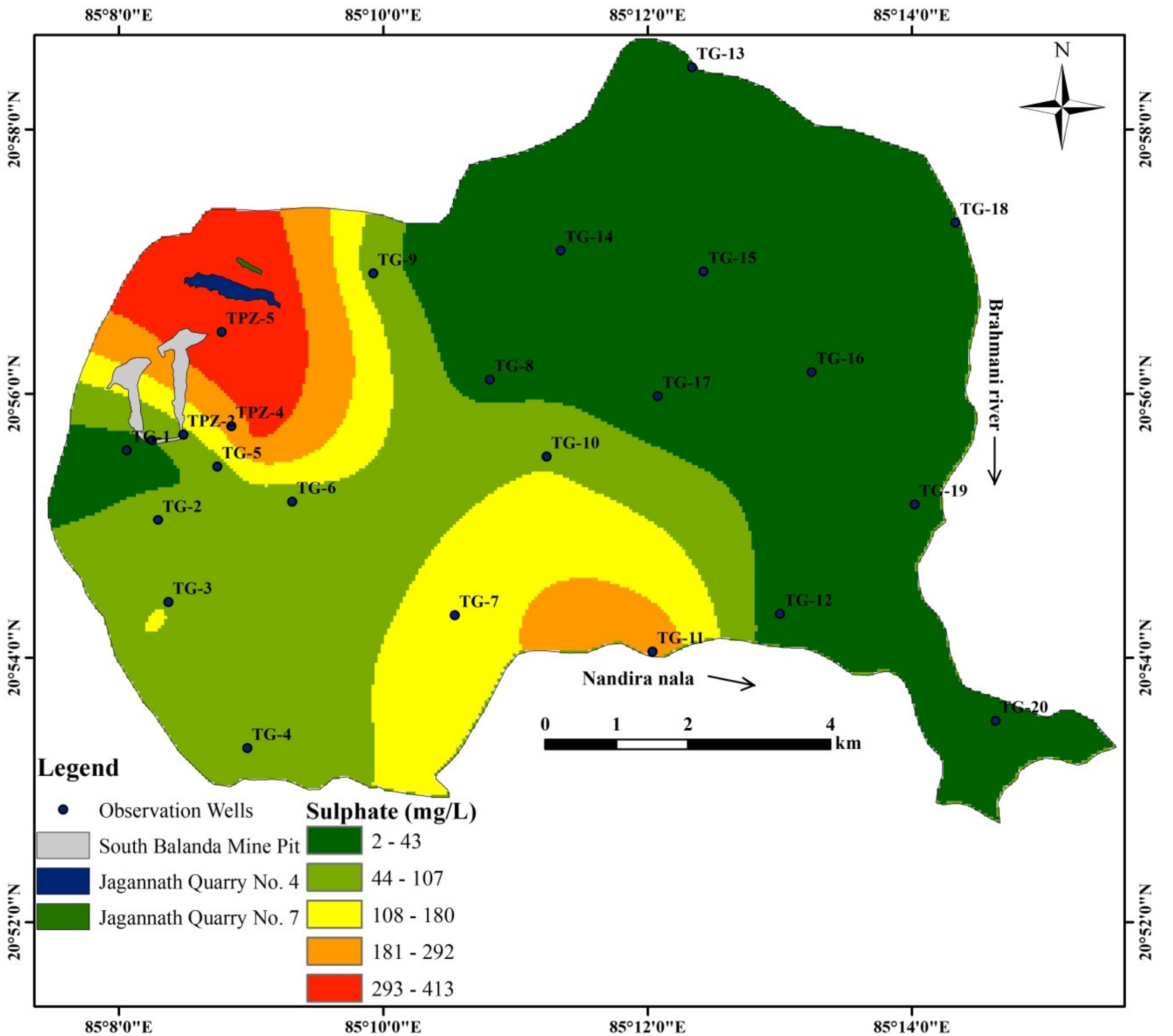


Figure 4.11 (b): Sulphate concentration in groundwater of the study area in June 2018

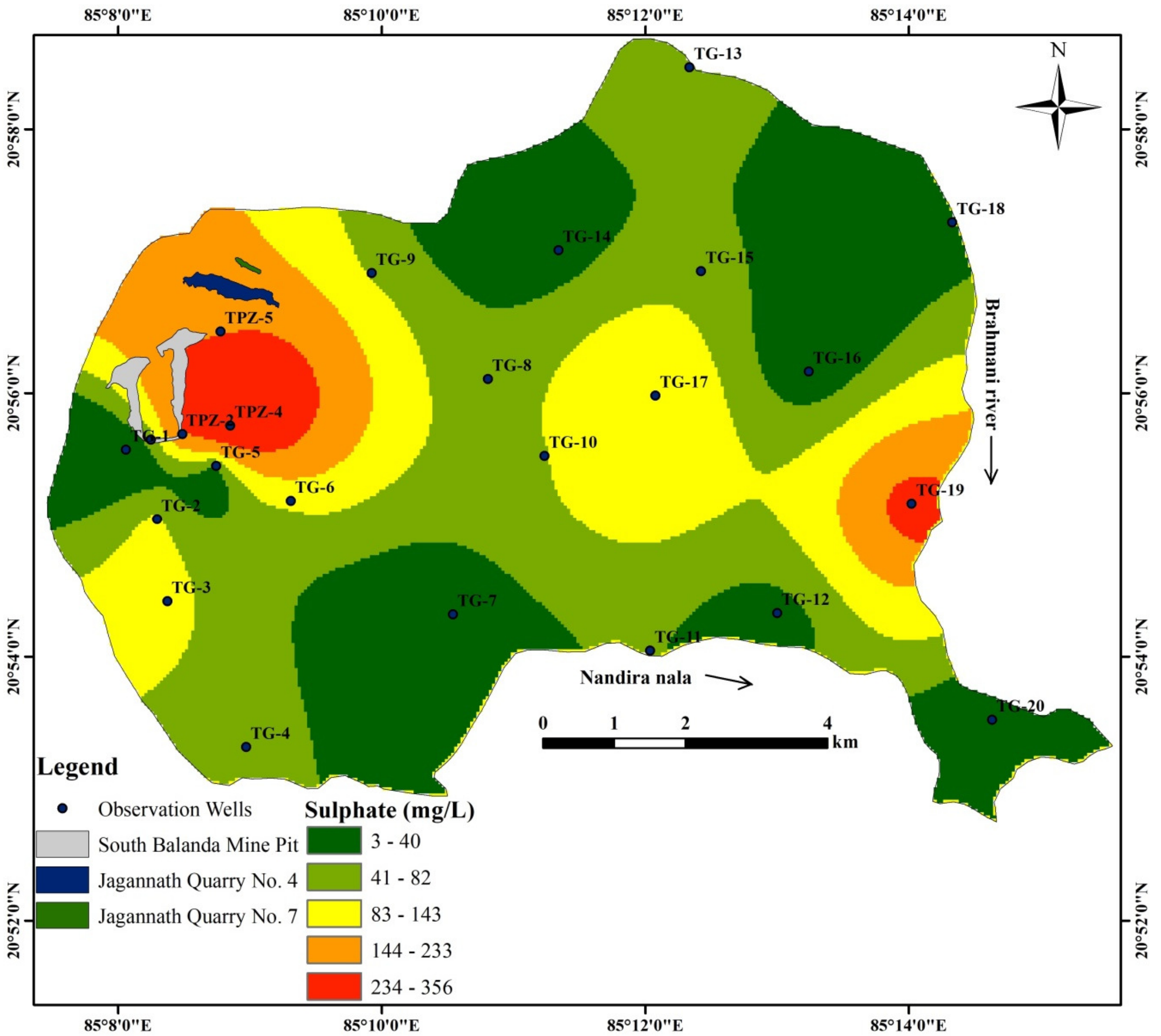


Figure 4.12 (c): Sulphate concentration in groundwater of the study area in November 2018

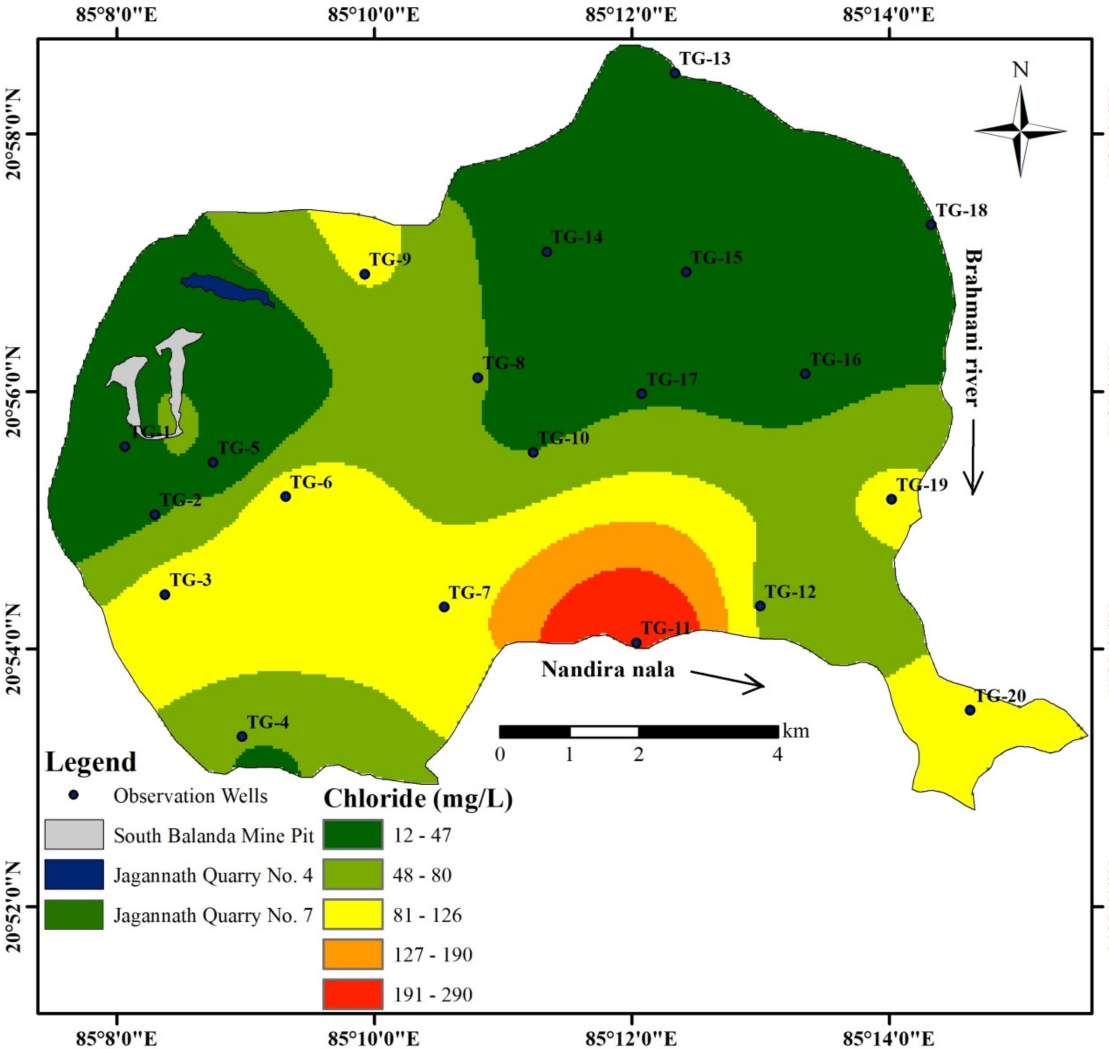


Figure 4.13 (a): Chloride concentration in groundwater of the study area in April 2018

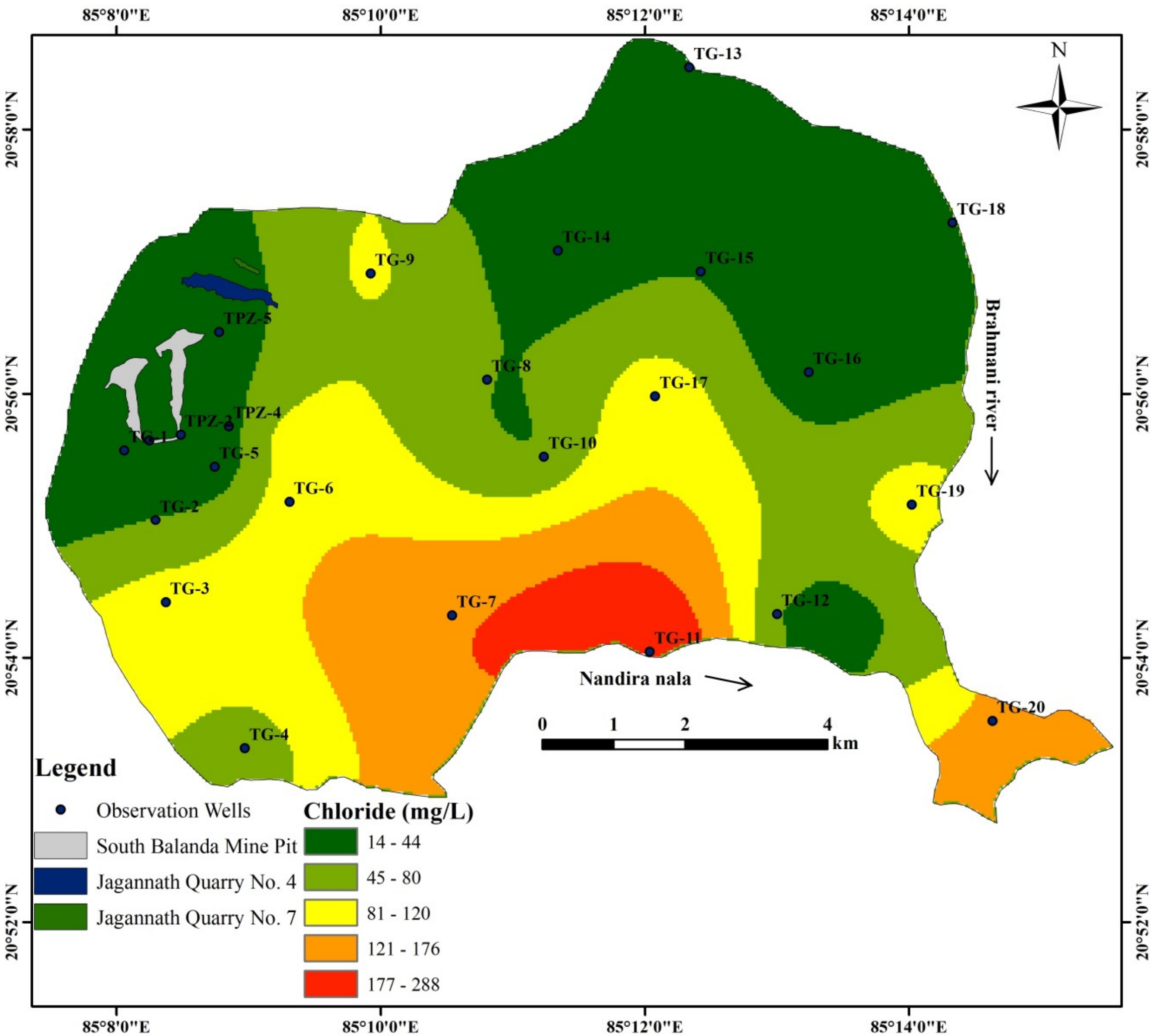


Figure 4.14 (b): Chloride concentration in groundwater of the study area in June 2018

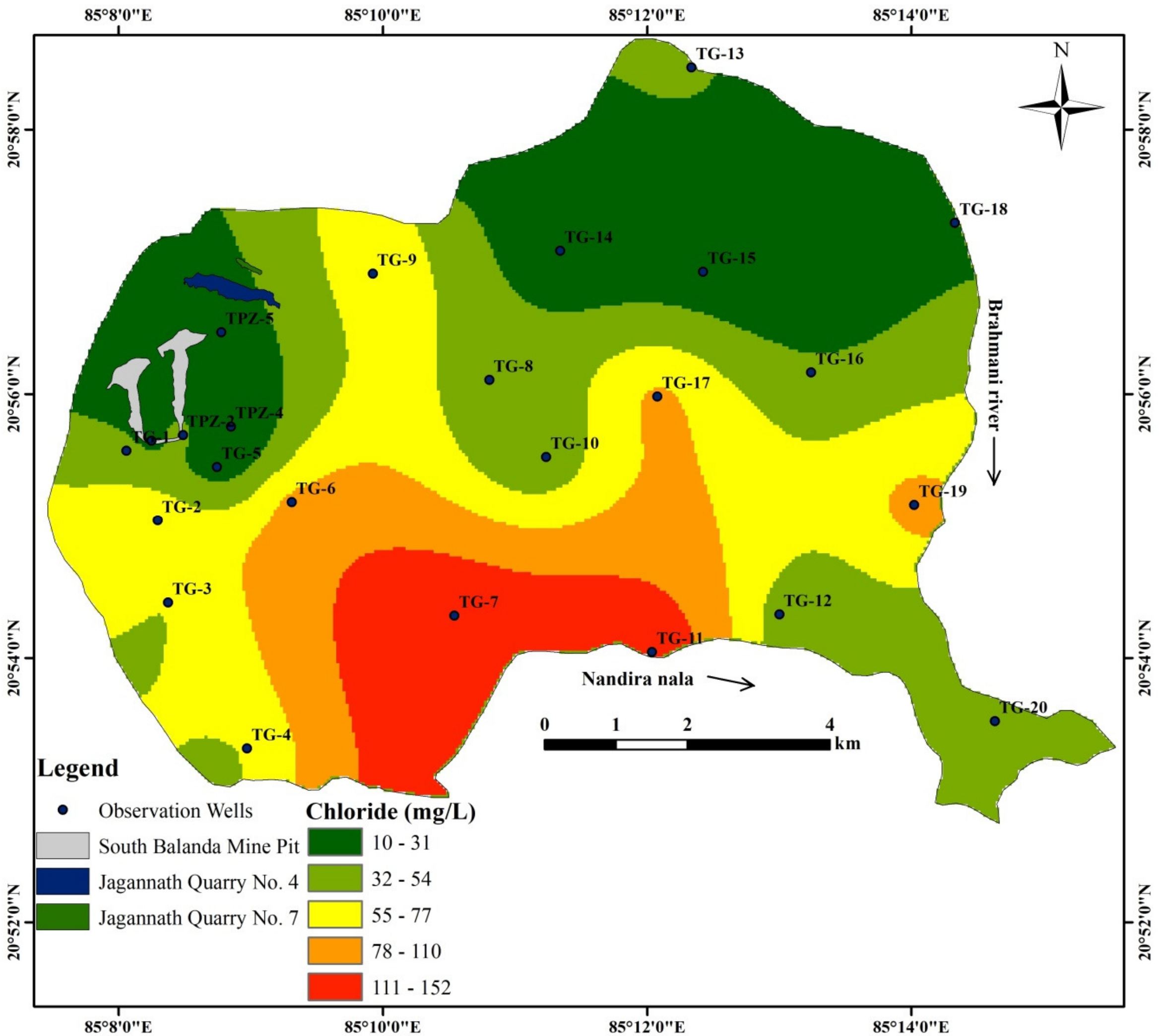


Figure 4.15 (c): Chloride concentration in groundwater of the study area in November 2018

Table 4.3 (a): Physico-chemical results of collected groundwater samples and surface water samples (April 2018)

Sr. No	Sample code	pH	EC	TDS (mg/l)	Turbidity	Total Hardness as $CaCO_3$	Calcium as Ca^{2+}	Magnesium Mg^{2+}	Sodium	Potassium	Total alkalinity as $CaCO_3$	Phosphate as PO_4^{-2}	Fluoride as F^-	Nitrate NO^{3-}	sulphate	chloride
Units	**-**	**-**	**µS/cm**	**mg/L**	**NTU**	**mg/L**										
BIS 10500:2012 (Acceptable/ Permissible limit)		**6.5/8.5**	**-**	**500/ 2000**	**1/5**	**200/ 600**	**75/200**	**30/100**	**-**	**-**	**200/600**	**-**	**1.0/1.5**	**45**	**200/400**	**250/ 1000**
1	TG-1	6.3	287	172	**17**	116	37	6	10	4	105	0.2	0.2	0	25	20
2	TG-2	7.7	549	329	0.9	**276**	83	16	10	1	**210**	0.4	0.6	1	51	44
3	TG-3	7.8	1121	**673**	0.6	**416**	99	40	87	5	**325**	0.3	0.9	18	95	100
4	TG-4	7.5	855	**513**	**1.1**	**300**	54	39	80	1	**400**	0.2	1.0	1	45	52
5	TG-5	6.9	363	218	**6.6**	**204**	46	21	7	2	125	0.2	0.2	0	48	20
6	TG-6	7.4	1205	**723**	0.4	**368**	85	37	102	2	**450**	0.3	0.9	13	92	110
7	TG-7	7.4	1282	**769**	0.5	**412**	72	56	132	1	**475**	0.9	**1.7**	20	96	100
8	TG-8	6.3	332	199	**18**	120	37	7	14	7	50	0.9	0.2	10	23	50
9	TG-9	6.7	723	434	**10**	**240**	56	24	40	31	100	0.9	0.2	28	61	84
10	TG-10	7.6	626	376	0.9	**280**	58	33	20	1	150	0.8	0.4	5	55	48
11	TG-11	7.1	1928	**1157**	0.9	**660**	173	55	84	1	**400**	0.9	0.4	6	**210**	**290**
12	TG-12	7.7	927	**556**	**1.6**	184	42	19	136	2	**325**	0.9	0.5	1	30	74
13	TG-13	7.3	968	**581**	**2.9**	**448**	69	66	36	20	**475**	0.9	1.0	1	28	46
14	TG-14	6.3	151	90	**5.5**	144	24	20	4	6	75	1.0	0.2	2	20	24
15	TG-15	7.7	338	203	0.8	100	29	7	29	16	75	0.9	0.2	7	25	46
16	TG-16	6.8	207	124	0.8	116	30	10	6	2	60	1.2	0.2	2	9	26
17	TG-17	7.2	905	**543**	1.0	**332**	75	35	60	6	**310**	0.9	0.7	19	66	44
18	TG-18	6.7	225	130	**11**	**292**	24	18	4	5	120	0.9	0.4	0	12	12
19	TG-19	7.4	981	**589**	0.6	200	69	7	114	1	**355**	0.9	**1.6**	2	21	90
20	TG-20	7.5	813	488	**22**	180	45	16	133	2	**285**	0.9	**3.1**	0	27	110
21	TPZ-1-T	7.9	446	268	**5.6**	**236**	67	16	10	11	150	0.9	0.5	4	39	30
22	TPZ-1-B	7.3	460	276	**4.7**	**256**	48	8	14	11	150	0.2	0.4	2	42	30
23	TPZ-2-T	7.2	998	**599**	**2.6**	**464**	163	13	59	1	**300**	0.1	0.3	1	132	68
24	TPZ-3-T	7.2	149	89	**21**	112	35	2	5	5	65	0.5	0.2	0	10	14
25	TPZ-3-B	7.1	140	84	**28**	96	35	2	5	5	60	0.3	0.1	0	12	14

Sr. No	Sample code	pH	EC	TDS (mg/l)	Turbidity	Total Hardness as $CaCO_3$	Calcium as Ca^{2+}	Magnesium Mg^{2+}	Sodium	Potassium	Total alkalinity as $CaCO_3$	Phosphate as PO_4^{-2}	Fluoride as F^-	Nitrate NO^{3-}	sulphate	chloride
Units	**-**	**-**	**µS/cm**	**mg/L**	**NTU**	**mg/L**										
BIS 10500:2012 (Acceptable/ Permissible limit)		**6.5/8.5**	**-**	**500/ 2000**	**1/5**	**200/ 600**	**75/200**	**30/100**	**-**	**-**	**200/600**	**-**	**1.0/1.5**	**45**	**200/400**	**250/ 1000**
26	TPZ-4-T	6.9	821	493	**1.6**	**360**	104	24	38	4	**250**	0.1	0.4	14	179	12
27	TPZ-5-T	6.8	845	**507**	**4.0**	**384**	**117**	22	45	5	95	0.1	0.4	1	**327**	28
28	TS-1	8.4	499	299	0.9	152	38	13	37	13	110	0.3	**2.1**	8	75	52
29	TS-2	7.9	109	65	**1.3**	56	18	3	6	1	55	0.3	0.2	0.6	3	10
30	TS-3	7.8	109	65	**1.2**	64	19	4	5	1	50	0.2	0.2	0.7	5	8
31	TS-4	8.0	500	300	0.8	188	48	16	35	9	150	0.2	**2.5**	3	92	40

Table 4.4 (b): Physico-chemical results of collected groundwater samples (June 2018)

Sr. No	Sample Code	pH	EC	TDS (mg/l)	Turbidity	Total Hardness as CaCO3	Calcium as Ca2+	Magnesium Mg2+	Sodium	Potassium	Total alkalinity as CaCO3	Phosphate as PO4-2	Fluoride as F-	Nitrate NO3-	sulphate	chloride
Units	-	-	µS/cm	mg/L	NTU	mg/L										
BIS 10500:2012 (Acceptable/ Permissible limit)		6.5/8.5	-	500/ 2000	1/5	200/ 600	75/200	30/100	-	-	200/600	-	1.0/1.5	45	200/400	250/ 1000
1	TG-1	5.6	290	174	600	112	26	12	22	7	112	0.03	0.04	0	30	20
2	TG-2	6.7	648	389	33	284	35	47	40	2	208	0.05	0.3	0	68	44
3	TG-3	6.9	1176	706	4.7	272	24	51	114	25	332	0.02	0.5	33	106	102
4	TG-4	6.9	855	513	5.9	316	18	65	91	1	328	0.08	0.6	0	73	60
5	TG-5	6.8	420	252	450	200	40	24	24	5	132	0.03	0.6	0	84	22
6	TG-6	7.2	1134	680	6.1	204	16	39	104	4	312	0.10	0.6	18	66	98
7	TG-7	6.9	1561	937	19	128	64	77	134	4	392	0.05	0.6	23	141	166
8	TG-8	5.9	262	157	500	72	16	8	36	8	80	0.02	0.6	0	27	46
9	TG-9	6.4	787	472	95	148	50	30	70	32	132	0.05	0.6	28	83	84
10	TG-10	6.9	502	301	7.5	192	48	17	36	8	136	0.05	0.6	0	96	50
11	TG-11	6.8	1967	1180	45	300	147	98	99	5	392	0.05	0.6	40	239	288
12	TG-12	7.4	857	514	2.1	116	8	23	141	2	404	0.04	0.6	0	11	50
13	TG-13	6.6	948	569	60	248	8	55	60	22	420	0.02	0.6	0	10	42
14	TG-14	5.4	138	83	650	60	10	9	30	8	68	0.09	0.6	0	18	20
15	TG-15	6.3	256	154	130	48	10	6	47	18	80	0.05	0.6	0	6	42
16	TG-16	5.9	179	107	16	60	21	2	14	4	68	0.02	0.6	0	10	24
17	TG-17	7.1	944	566	7.7	200	21	36	90	7	336	0.03	0.6	10.1	11	100
18	TG-18	6.7	264	158	500	128	18	20	8	6	148	0.01	0.6	0	2	20
19	TG-19	7.2	962	577	21	100	27	16	113	10	332	0.0	0.6	0	8	100
20	TG-20	7.2	861	517	60	124	18	19	138	4	272	0.02	0.6	0	4	130
21	TPZ-1	6.2	338	203	60	160	46	11	18	11	124	0.04	0.3	0	45	14
22	TPZ-2	6.6	725	435	40	200	43	22	39	7	232	0.01	0.3	0	88	26
23	TPZ-3	6.2	1034	620	150	376	88	37	18	7	108	0.02	0.08	15	300	66
24	TPZ-4	6.0	669	401	120	460	59	75	27	12	172	0.04	0.07	0	224	24
25	TPZ-5	5.9	1050	630	550	280	26	60	60	22	120	0.02	0.09	0	413	22

Table 4.5 (c): Physico-chemical results of collected groundwater samples (November 2018)

Sr. No	Sample Code	pH	EC	TDS (mg/l)	Turbidity	Total Hardness as CaCO3	Calcium as Ca2+	Magnesium Mg2+	Sodium	Potassium	Total alkalinity as CaCO3	Phosphate as PO4-2	Fluoride as F-	Nitrate NO3-	sulphate	chloride
Units	-	-	µS/cm	mg/L	NTU	mg/L										
BIS 10500:2012 (Acceptable/ Permissible limit)		6.5/8.5	-	500/ 2000	1/5	200/ 600	75/200	30/100	-	-	200/600	-	1.0/1.5	45	200/400	250/ 1000
1	TG-1	7.6	566	340	300	104	24	2	85	13	148	0.08	0.72	2	12	40
2	TG-2	7.4	1709	1025	12	200	35	45	38	2	256	0.37	0.96	8	83	70
3	TG-3	6.5	214	128	7.3	300	30	54	75	24	272	0.25	1.1	37	97	56
4	TG-4	7.5	583	350	6.3	192	42	21	95	6	360	0.14	1.3	1	62	56
5	TG-5	6.9	460	276	200	128	34	11	17	10	128	0.07	0.34	6	57	20
6	TG-6	6.5	294	176	50	268	35	43	97	5	348	0.23	1.1	35	96	82
7	TG-7	7.2	767	460	8.2	124	24	15	102	3	108	0.42	3.7	5	19	142
8	TG-8	7.4	273	164	320	128	35	10	24	13	92	0.10	0.22	25	58	46
9	TG-9	6.4	176	105	7.8	328	32	34	41	42	72	0.27	0.29	81	78	64
10	TG-10	6.9	687	412	2.3	220	19	41	43	6	192	0.27	0.67	2	80	36
11	TG-11	7.4	633	380	3.1	136	40	9	111	6	116	0.16	3.9	8	42	152
12	TG-12	7.4	563	338	3.0	112	18	16	152	6	380	0.24	0.66	1	25	46

Sr. No	Sample Code	pH	EC	TDS (mg/l)	Turbidity	Total Hardness as CaCO3	Calcium as Ca2+	Magnesium Mg2+	Sodium	Potassium	Total alkalinity as CaCO3	Phosphate as PO4-2	Fluoride as F-	Nitrate NO3-	sulphate	chloride
Units	**-**	**-**	**µS/cm**	**mg/L**	**NTU**	**mg/L**										
BIS 10500:2012 (Acceptable/ Permissible limit)		**6.5/8.5**	**-**	**500/ 2000**	**1/5**	**200/ 600**	**75/200**	**30/100**	**-**	**-**	**200/600**	**-**	**1.0/1.5**	**45**	**200/400**	**250/ 1000**
13	TG-13	7.9	350	210	6.1	520	21	112	41	24	460	0.07	1.3	1	80	40
14	TG-14	7.7	85	51	15	68	16	7	11	7	72	0.03	0.25	2	22	12
15	TG-15	7.5	174	104	7.1	160	45	12	23	15	132	0.11	0.27	3	65	16
16	TG-16	8.0	341	205	1.5	72	19	6	12	3	56	0.31	0.22	2	13	36
17	TG-17	7.0	950	570	1.2	180	118	15	68	9	316	0.19	0.90	98	135	80
18	TG-18	6.4	294	177	39	108	32	7	18	14	96	0.09	0.31	13	29	26
19	TG-19	7.2	634	380	4.1	284	35	47	296	8	364	0.20	1.2	2	268	84
20	TG-20	7.3	367	220	21	88	29	19	32	1	200	0.38	4.0	2	3	50
24	TPZ-2	5.8	524	315	2.9	176	96	11	45	7	192	0.29	0.66	2	217	36
25	TPZ-4	7.2	493	296	<u>20</u>	272	58	31	48	12	104	0.22	0.32	6	356	10
26	TPZ-5	7.0	583	350	<u>55</u>	380	101	31	13	7	84	0.26	0.23	3	220	20

4.3. Trace metal concentration

The water samples were collected from nearby groundwater sources and piezometers in the study area for the analysis of heavy metals concentration in the months of April 2018, June 2018 and November 2018. The concentration of different metal concentration in samples is presented in **Table 4.4 (a), 4.4 (b) and 4.4 (c)**. ***The metal concentrations in all the collected groundwater and surface water samples were found well within acceptable limit of BIS 10500:2012 drinking water specifications.***

Table 4.6 (a): Trace metal concentration in collected groundwater and surface water samples (April 2018)

Sr. No	Sample Code	Al	As	Cd	Cr	Cu	Fe	Mn	Ni	Pb	Zn	Hg
BIS 10500:2012 Acceptable Limit (mg/L)		**0.03**	**0.01**	**0.003**	**0.05**	**0.05**	**0.3**	**0.10**	**0.02**	**0.01**	**5.0**	**0.001**
BIS 10500:2012 Permissible Limit (mg/L)		**0.20**	**0.05**	**-**	**-**	**1.5**	**-**	**0.30**	**-**	**-**	**15**	**-**
ICP detection Limit (mg/L)		**0.002**	**0.007**	**0.0001**	**0.01**	**0.0004**	**0.0003**	**0.0001**	**0.005**	**0.009**	**0.001**	**0.000075**
BDL-Below Detection Limit, ND-Not Detected												
1	TG-1	0.002	BDL	ND	BDL	BDL	0.11	BDL	BDL	BDL	2.3	BDL
2	TG-2	BDL	BDL	ND	BDL	BDL	0.012	0.004	ND	ND	0.1	BDL
3	TG-3	BDL	BDL	BDL	BDL	BDL	0.004	0.003	BDL	BDL	ND	BDL
4	TG-4	BDL	BDL	BDL	BDL	BDL	0.015	0.01	ND	BDL	ND	BDL
5	TG-5	BDL	BDL	BDL	BDL	BDL	0.10	0.06	ND	BDL	ND	BDL
6	TG-6	BDL	BDL	BDL	BDL	BDL	0.05	0.005	ND	BDL	BDL	BDL
7	TG-7	BDL	BDL	BDL	BDL	ND	0.004	0.001	ND	BDL	0.5	BDL
8	TG-8	BDL	BDL	BDL	BDL	BDL	0.05	0.004	ND	BDL	BDL	BDL
9	TG-9	BDL	BDL	BDL	BDL	BDL	0.001	0.007	ND	BDL	ND	BDL
10	TG-10	BDL	BDL	BDL	BDL	BDL	0.001	0.006	BDL	BDL	0.4	BDL
11	TG-11	BDL	BDL	BDL	BDL	BDL	0.04	0.001	BDL	BDL	2.6	BDL
12	TG-12	BDL	BDL	BDL	BDL	BDL	0.01	0.005	BDL	BDL	0.05	BDL
13	TG-13	BDL	BDL	BDL	BDL	BDL	0.0007	BDL	BDL	0.0001	ND	BDL
14	TG-14	BDL	BDL	ND	BDL	BDL	0.012	BDL	BDL	BDL	0.9	BDL
15	TG-15	BDL	BDL	ND	BDL	BDL	0.08	0.001	ND	ND	1.1	BDL
16	TG-16	BDL	BDL	BDL	BDL	BDL	0.04	0.005	BDL	BDL	0.6	BDL
17	TG-17	BDL	BDL	BDL	BDL	BDL	0.005	0.002	ND	BDL	0.56	BDL
18	TG-18	BDL	BDL	BDL	BDL	BDL	0.006	0.004	ND	BDL	0.1	BDL
19	TG-19	BDL	BDL	BDL	BDL	BDL	0.01	0.1	BDL	BDL	2.1	BDL

Sr. No	Sample Code	Al	As	Cd	Cr	Cu	Fe	Mn	Ni	Pb	Zn	Hg
BIS 10500:2012 Acceptable Limit (mg/L)		**0.03**	**0.01**	**0.003**	**0.05**	**0.05**	**0.3**	**0.10**	**0.02**	**0.01**	**5.0**	**0.001**
BIS 10500:2012 Permissible Limit (mg/L)		**0.20**	**0.05**	**-**	**-**	**1.5**	**-**	**0.30**	**-**	**-**	**15**	**-**
ICP detection Limit (mg/L)		**0.002**	**0.007**	**0.0001**	**0.01**	**0.0004**	**0.0003**	**0.0001**	**0.005**	**0.009**	**0.001**	**0.000075**
BDL-Below Detection Limit, ND-Not Detected												
20	TG-20	BDL	BDL	BDL	BDL	ND	0.0004	0.04	BDL	BDL	3.7	BDL
21	TPZ-1-Top	BDL	BDL	BDL	BDL	BDL	0.004	0.1	ND	BDL	0.8	BDL
22	TPZ-1-Bottom	BDL	BDL	BDL	BDL	BDL	0.1	0.09	BDL	BDL	ND	BDL
23	TPZ-2-Top	BDL	BDL	BDL	BDL	ND	0.003	0.03	BDL	BDL	BDL	BDL
24	TPZ-3-Top	BDL	BDL	BDL	BDL	BDL	0.001	0.02	ND	BDL	0.04	BDL
25	TPZ-3-Bottom	BDL	BDL	BDL	BDL	BDL	0.005	0.05	ND	BDL	0.005	BDL
26	TPZ-4-Top	BDL	BDL	BDL	BDL	ND	0.07	BDL	BDL	BDL	1.4	BDL
27	TPZ-5-Top	BDL	BDL	BDL	BDL	ND	0.04	BDL	BDL	BDL	2.1	BDL
28	TS-1	BDL	BDL	BDL	BDL	BDL	0.2	0.02	BDL	BDL	2.5	BDL
29	TS-2	BDL	BDL	BDL	BDL	ND	0.04	0.0003	BDL	BDL	0.6	BDL
30	TS-3	BDL	BDL	BDL	BDL	0.1	0.04	0.001	ND	BDL	0.8	BDL
31	TS-4	BDL	BDL	BDL	BDL	0.005	0.01	0.04	BDL	BDL	2.2	BDL

Table 4.7 (b): Trace metal concentration in collected groundwater and surface water samples (June 2018)

Sr.No	Sample code	As	Cd	Cr	Cu	Fe	Mn	Ni	Pb	Zn	Hg
	BIS Limit (ppm)	**0.01-0.05**	**0.003**	**0.05**	**0.05-1.5**	**0.3-1.0**	**0.10-0.30**	**0.02**	**0.01**	**5.0-15**	**0.001**
	ICP detection Limit (ppm)	**0.007**	**0.0001**	**0.01**	**0.0004**	**0.0003**	**0.0001**	**0.005**	**0.009**	**0.001**	**0.000075**
1	TG-1	ND	ND	BDL	BDL	0.005	0.1	BDL	BDL	BDL	0.00001
2	TG-2	ND	ND	BDL	0.001	0.01	0.1	BDL	BDL	0.7	BDL
3	TG-3	ND	ND	BDL	0.001	0.01	0.01	BDL	BDL	0.8	ND
4	TG-4	ND	ND	BDL	0.04	0.001	0.02	BDL	BDL	0.1	ND
5	TG-5	ND	ND	BDL	0.001	0.004	0.03	BDL	BDL	BDL	0.0002
6	TG-6	ND	ND	BDL	BDL	0.06	0.08	BDL	BDL	BDL	0.00004
7	TG-7	ND	ND	BDL	BDL	0.005	0.01	BDL	BDL	BDL	ND
8	TG-8	ND	ND	BDL	ND	0.004	0.1	BDL	BDL	5.4	ND
9	TG-9	ND	ND	BDL	ND	0.07	0.05	BDL	BDL	3.3	ND
10	TG-10	0.02	0.001	BDL	0.01	0.06	0.1	BDL	BDL	0.1	ND
11	TG-11	0.008	ND	BDL	0.002	0.001	0.2	BDL	BDL	0.1	ND
12	TG-12	ND	ND	BDL	ND	0.006	BDL	BDL	BDL	BDL	ND
13	TG-13	ND	ND	BDL	BDL	0.1	0.2	BDL	BDL	BDL	ND
14	TG-14	ND	ND	BDL	ND	0.07	0.1	BDL	BDL	2.5	ND
15	TG-15	ND	0.001	BDL	0.001	0.1	0.7	BDL	BDL	0.1	ND
16	TG-16	ND	ND	BDL	BDL	0.1	0.06	BDL	BDL	1.9	ND
17	TG-17	ND	ND	BDL	BDL	0.04	0.01	BDL	BDL	BDL	ND
18	TG-18	ND	ND	BDL	BDL	0.01	0.04	BDL	BDL	0.1	ND
19	TG-19	ND	ND	BDL	ND	0.04	0.1	BDL	BDL	0.3	ND

20	TG-20	ND	ND	BDL	BDL	0.01	0.05	BDL	BDL	BDL	ND
21	TPZ-1	ND	ND	BDL	ND	0.005	0.1	BDL	BDL	5.4	ND
22	TPZ-2	ND	ND	BDL	ND	0.004	0.04	BDL	BDL	3.3	ND
23	TPZ-3	ND	ND	BDL	BDL	0.07	0.01	BDL	BDL	BDL	ND
24	TPZ-4	ND	ND	BDL	ND	0.06	0.05	BDL	BDL	5.4	ND
25	TPZ-5	ND	ND	0.02	ND	0.01	0.02	BDL	BDL	3.3	ND

Table 4.8 (c): Trace metal concentration in collected groundwater and surface water samples (November 2018)

Sr.No	Sample code	Al	Cd	Cr	Cu	Fe	Mn	Ni	Pb	Zn	Hg
	BIS Limit (ppm)	**0.03-0.2**	**0.003**	**0.05**	**0.05-1.5**	**0.3-1.0**	**0.10-0.30**	**0.02**	**0.01**	**5.0-15**	**0.001**
	ICP detection Limit (ppm)	**0.00001**	**0.0001**	**0.01**	**0.0004**	**0.0003**	**0.0001**	**0.005**	**0.009**	**0.001**	**0.000075**
1	TG-1	2.894	ND	0.036	ND	63.53	0.3839	ND	0.0032	0.0468	ND
2	TG-2	0.098	ND	ND	0.0053	0.8668	0.0286	ND	0.0003	0.3639	ND
3	TG-3	7.228	BDL	ND	0.0015	0.8323	0.0174	0.0002	0.0011	0.315	BDL
4	TG-4	6.338	ND	ND	0.06857	1.929	0.058	ND	0.0003	0.152	ND
5	TG-5	0.053	ND	0.016	ND	33.63	0.1817	ND	0.0009	2.341	ND
6	TG-6	0.065	ND	ND	0.0127	0.379	0.135	0.0014	ND	0.5967	0.00004
7	TG-7	0.057	0.0001	0.007	ND	20.03	0.721	0.0135	0.0016	8.474	BDL
8	TG-8	ND	ND	ND	0.0359	2.77	0.04612	0.0132	0.0003	1.038	BDL
9	TG-9	0.063	ND	ND	0.0055	4.50	0.1307	0.00017	ND	0.0969	BDL
10	TG-10	6.90	ND	ND	ND	0.775	0.024	0.00017	ND	0.505	0.00005
11	TG-11	0.059	ND	ND	0.0007	0.769	0.0366	0.00014	0.0009	0.4033	0.00001
12	TG-12	0.229	ND	0.0054	ND	17.81	0.094	ND	ND	4.716	BDL
13	TG-13	3.76	ND	0.021	ND	43.04	0.4137	0.0051	0.0009	3.826	BDL
14	TG-14	1.40	ND	0.0002	ND	9.01	0.1384	0.0002	ND	0.078	ND
15	TG-15	6.712	ND	ND	ND	0.31	0.116	0.0014	0.0015	0.014	0.00004
16	TG-16	13.92	ND	ND	0.0021	1.17	0.119	0.0006	ND	0.0931	0.00005
17	TG-17	0.906	ND	0.0062	ND	12.93	0.118	0.0021	0.0009	0.6598	BDL
18	TG-18	4.561	ND	ND	ND	0.300	0.024	0.0006	0.0006	1.300	BDL
19	TG-19	0.573	0.0009	ND	ND	2.05	0.0837	ND	0.0003	0.229	BDL
20	TG-20	5.465	0.0009	ND	ND	0.088	0.619	0.0751	0.0005	0.0954	0.00002
21	TPZ-1	0.241	ND	ND	ND	14.78	3.36	0.014	0.0008	0.4494	ND

22	TPZ-2	6.306	ND	0.0035	ND	14.77	3.36	0.014	0.0008	0.4494	BDL
23	TPZ-4	0.1589	ND	0.0185	ND	36.47	1.692	0.0092	0.001909	0.5043	0.0007
24	TPZ-5	0.0342	ND	ND	0.00133	0.3303	0.0747	0.0010	0.00115	0.03986	BDL

4.4. Ash characterization

The collected Ash Sample was analyzed for its leaching behaviour of trace elements by TCLP method and the concentration of mercury was also analysed by using ICP-MS.

4.4.1. Concentration of Mercury in Fly Ash

The fly ash sample was analyzed for the mercury concentration by acid digestion method of EPA 3050B using ICP-MS and it was found to be 0.0444 ppb.

4.4.2. Results of TCLP test

The TCLP test was conducted as per US EPA SW-846, method-1311. TCLP is an important study to examine the leaching behaviour of trace elements of concern. TCLP was carried out for the sample collected from the ash generation unit. The concentration of all the metals was found within regulatory level of **USEPA-RCRA-D List (Table 4.9 (a), 4.5 (b) and 4.5 (c)).**

The TCLP results shows that the ash sample was non-hazardous in nature as per RCRA guidelines (U.S. EPA, 1986). TCLP carried out in the previous studies (NEERI report 2014 and 2016) also and the leaching behaviour of toxic metals was under the regulatory level as per the USEPA-RCRA-D list.

Table 4.9: **TCLP trace metal concentrations (June 2018)**

Trace Elements	Concentration in Fly Ash (mg/L)	ICP Detection Limit (ppm)	Regulatory level by USEPA-RCRA-D List (mg/L)
Al	0.9480	0.002	-
As	0.0210	-	5
B	0.1240	-	100
Ba	0.0650	0.0001	-
Cd	0.0010	0.0001	1
Co	0.0043	0.0004	-
Cr	0.0421	0.01	5
Cu	1.0800	0.0004	-
Fe	0.4060	0.0003	-
Mn	0.1580	0.0001	-
Ni	0.0432	0.005	-
Pb	0.0010	0.009	5
Zn	0.0605	0.001	-
Se	0.0329	-	-
Hg	0.0001	-	-

4.4.3. Chemical constituents of Fly ash

The chemical constituents of fly ash were analyzed by using XRF instrument and the results were given in **Table 4.6.**

Table 4.6 Chemical parameters of ash (June 2018)

Sample Code	SiO_2 (%)	Al_2O_3 (%)	Fe_2O_3 (%)	K_2O (%)	TiO_2 (%)	CaO (%)	MgO (%)	Na_2O (%)	P_2O_5 (%)	SO_3 (%)	Cr_2O_3 (%)	MnO_2 (%)
Ash	62.99	27.02	3.57	0.95	1.76	0.92	0.38	0.10	0.54	0.08	0.02	0.03

Sample Code	CuO (%)	Rb_2O (%)	SrO (%)	Y_2O_3 (%)	ZrO_2 (%)	Nb_2O_5 (%)	BaO (%)	Cl (%)	NiO (%)	LOI (%)
Ash	0.01	0.006	0.01	0.006	0.04	0.005	0.02	0.01	0.01	1.34

4.5. Planning for future work

- The monitoring in April 2018, June 2018 and November 2018 has been completed and the analysis is being completed and analyzed.
- The next phase of sampling will be carried out in February 2019.

Annex.-B

Interim Report

on

RADIOTRACER STUDY

of

Fly-ash disposal into fly ash pond

of

M/s. TTPS

By

Isotope Application Services
Board of Radiation & Isotope Technology
Department of Atomic Energy
Government of India
February 2019

CONTENTS

1. INTRODUCTION

1.1 Introduction to BRIT

Board of Radiation and Isotope Technology (BRIT) was carved out of Bhabha Atomic Research Centre, Department of Atomic Energy, Government of India to undertake commercial activities of radioisotope and radiation applications. In other words it is a commercial wing of Department of Atomic Energy. Few of the industrial applications of radioisotopes like Gamma column scanning, blockage, void, corrosion detection in pipelines, identification of location of leakage in underground pipelines, residence time distribution analysis in reactor vessels of any kind, flow rate estimation and flow-meter calibration, effluent dispersion studies in surface waters and sediment transport studies on river/sea bed, bore-well interconnection studies for groundwater, studies for the enhanced recovery of oil from the oil wells, reservoir development, interconnection between oil wells, monitoring secondary recovery of oil and its effectiveness, etc are undertaken by BRIT. BRIT also supplies industrial irradiators for the irradiation of surgical items for sterilization, food grains for removal of pests and enhancement of their shelf life, etc. Gamma chambers of various capacities are supplied for research purposes. Indigenous radiography cameras (Industrial gamma radiography exposure device) are supplied for industrial radiography and the radioisotopes are provided for the imported radiography camera. For diagnosis and therapy, radioisotopes are produced and supplied to the hospitals in India and abroad. BRIT has laboratories for radiopharmaceutical distribution at various locations throughout India.

Out of the above activities undertaken by BRIT/BARC, radiotracer studies for dilution and dispersion of pollutants in surface waters is helping various agencies to decide upon the outfall design and its efficacy.

1.2 Theory of Radiotracer Study

The basic principle of tracer investigation is to label a substance, an object or a phase and then to follow it through a system or to carry out a quantitative assay of the tracer after it has left the system. The requirements of tracer are that: it should behave in the same way as the material under investigation, it should be easily detectable at low concentrations, detection should be unambiguous, injection, detection and/or sampling should be performed without disturbing the system, the residual concentration in the system after the study period should be minimal. All these criteria can be met using radioisotopes as tracer and by careful selection of the most appropriate tracer for a particular application. Factors which are important in the selection of radiotracer are: Half life – should be long enough to allow time to transfer the tracer from the nuclear reactor to the work site, prepare the tracer for use and complete the measurements. In order to reduce the level of residual tracer in the system short or optimum half-life tracer is desirable. Type and energy of radiation – should be detectable at lower concentrations either by sampling or in-situ detection, will have direct bearing on the total amount of activity which can be accommodated safely within given system. After injection, self-absorption by water present in the system may reduce the level of radiation to the levels which should be within the legal limits. Physico-chemical form – should be compatible with the material being traced both in physical form and chemical form and preferably behave same as the material being traced in the system. The ideal tracer in these circumstances is undoubtedly the irradiated material itself i.e. irradiated fly ash.

The final choice of radiotracer for an investigation is made after consideration of all of the above factors, many of which may be mutually exclusive.

Preferably, highly sensitive detectors which are pre-calibrated are used to track the progress and strength of the radiotracer. In the current scenario, in order to understand and establish the transport of heavy metals and other trace elements from the fly-ash to the surrounding environment, irradiated fly ash powder containing Zinc-65 (with half-life of 244 days and emitting 0.557MeV and 1.12MeV gamma rays) and Scandium-46 (with half-life of 84 days and emitting 0.887MeV and 1.119MeV gamma rays) is selected as a radiotracer.

Radioactive methods can help in investigating suspended sediment dynamics, providing important parameters for better designing, maintaining and optimizing disposal of suspended load in to the surface water bodies. Radioisotopes as tracers and sealed sources have been useful and often irreplaceable tools for such studies.

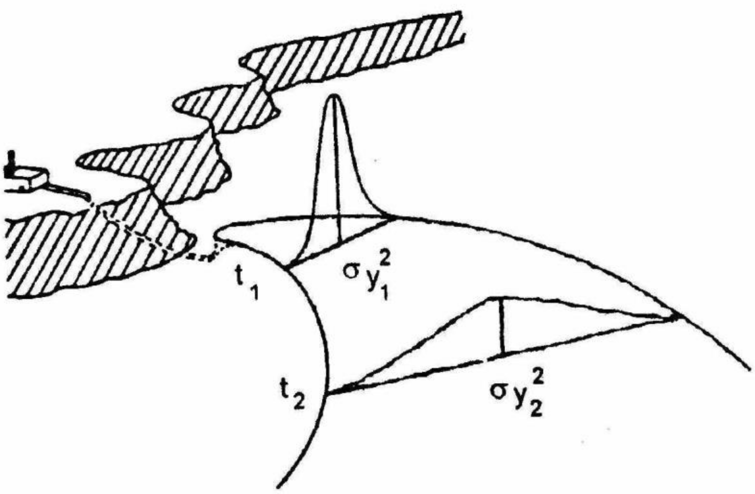
For the study of the behavior of the suspended load, the material being disposed is labeled with the radioactive isotopes such as Au-198/Sc-46 and injected in the water body. In this study the fly ash was labeled with Sc-46 isotope in chloride form. The detection of the radioactive cloud is achieved by towing immersed detectors at different depths.

There are three main transport mechanisms active in the transport of suspended particles:

1. Advection(currents)
2. Dispersion(turbulences)
3. Decantation(specific weight and volume of particles)

1.2.1 Dispersion Coefficient

Dispersion coefficient can be calculated by the method of moments:



Assuming the obtained steady state cross plume concentration profiles follows normal distribution (Gaussian), then lateral dispersion coefficient between two section, Dy is defined as:

$$Dy = \frac{\sigma y_2^2 - \sigma y_1^2}{2(t_2 - t_1)} m^2/s$$

Where σy_2^2 and σy_1^2 are the variance of cross plume concentration profiles at the sections 1 & 2 and t_1 & t_2 are time elapsed from the discharge point to the corresponding section.

Similarly, longitudinal dispersion coefficient can also be estimated using method of moments.

1.2.2 Decantation rate

The quantity of suspended matter at any moment can be obtained from

$$M(t) = M_0 . e^{\frac{-w(t-t_0)}{H.\varphi}}$$

Where: t=time

t0= time of injection

w= sinking speed of suspension particles

H=water depth

M0=total mass of suspension tracer

Φ= dimensionless function in Rouse's theory

$$\Phi = \int_{\frac{a}{H}}^{1} [\frac{\frac{a}{H}}{\left(1-\frac{a}{H}\right)} . \frac{(1-z''')^{\frac{w}{k.u}}}{z'''} dz$$

z'=z/H reduced height above bed

a= height of detector above bed

k= van Karman coefficient

u= shear stress velocity

Variation of M with respect to time gives decantation rate:

$$\theta = \frac{1}{M}\left|\frac{dM}{dt}\right| \text{ gm/sec-ton suspension}$$

Case studies show that flocs are formed during slack water. When currents induced due to wind are active, flocs disintegrate and tend to become homogenous.

1.2.3 Transport Velocity

From the iso-count contours, a plot between cumulative of product of count rate© and length of lateral spread (Y)(i.e. $C1 = \sum C.y$) for different locations(x) along the axis of movements is plotted against x, so that contour map is reduced to one dimension. The count distribution diagram so generated are called as 'transport diagrams'. For each diagram, the location of the weighted centre of gravity along the axis movements is found out using

$$X = \frac{\int C1.x.dx}{\int C1.dx}$$

Successive tracking in time make it possible to establish many centers of gravity and the mean velocity of movement (Vm) is calculated from the shifts in the centre of gravity between two successive trackings.

Radioactive tracers are the only unequivocal method of direct real time assessment of distribution of suspended matter in the surface water as well as ground water. Radiotracers are more sensitive and provide more accurate parameters than conventional tracers. In recent decades, many radiotracer studies for the investigation of suspended sediment transport in natural systems have been conducted worldwide, and various techniques for tracing and monitoring the suspended sediment have been developed by Isotope Application Services of BRIT. In addition to radiotracers, sealed source techniques can provide information on the density of suspended sediments in a channel of navigation as well as on the concentration of sediments circulating in suspension.

The environmental, economic and social benefits from the application of radiotracer and sealed source techniques can be enormous.

1.3 Advantages and Disadvantages of using radiotracer technique

Radiotracer technique is carried out without disturbing the system i.e. online. The radiotracer as the name suggests is used in trace quantity in comparison with the material in the system as it can be detected at very low concentrations using the highly sensitive radiation detectors. The detection does not depend upon physical or chemical changes during the study period as the nuclear properties of the radiotracer do not change during the course of the study. Since the properly selected radiotracer either in the same form of the material being traced or labeled on the traced material follows intended flow paths and undergoes same changes as the material being traced, ideally it follows the same flow dynamics of the mother material including leaching, sorption, desorption, flocculation, de-flocculation, floatation and settling. The conventional tracers like dyes, salts, fluorescents, etc. often are interfered by other physical or chemical parameters but radiotracers have no such adverse effect of the suppressing parameters.

Disadvantage of using radiotracers is, it requires trained manpower, additional training for handling of radioisotopes and knowledge of radiation safety. Contamination due to the use of radiotracers in powder as well as liquid form requires huge efforts to deal with.

1.4 Safety Issues

Since the water body of mine void is huge and the labeled fly ash being disposed should truly represent the bulk fly ash, the quantity of radiotracer theoretically arrived at is about 5 Ci. The selected radiotracer i.e. irradiated fly ash in sealed aluminum can needs to be brought to the site by road in a lead container weighing about 800kg. with proper regulatory approvals of transportation and usage. The vehicle transporting this will be properly labeled with necessary safety signs.

After it arrives at the site it will be kept secured in a locked room. The handling will be done using long handled tongs. The radioactive powder will be remotely transferred to can cutting machine and powder from the cut open can will be transferred to fly ash slurry tank. After sufficient time given for mixing the fly ash will be disposed off in to ash pond through the pipeline .

In general principle of ALARA (as low as reasonably achievable) will be strictly followed while performing the entire operation. Similarly the operations of handling the radiotracers will be carried out in minimum possible time, keeping the safe distance between source and personnel and using maximum possible shielding wherever required.

2. SCOPE OF THE WORK

2.1 Description about the Site

M/s. Talcher Thermal Power Station (TTPS) is located in Angul District of Odisha and about 170 km from Bhuvaneshwar in Odisha.

The pipelines are lead from the plant up to ash pond to directly deliver fly ash slurry in the pond. Depending upon the volume of the slurry being disposed, the location of disposal in to the pond is changed so as to distribute the slurry evenly all around.

2.2 Narrative of the problem

Safe disposal of fly ash is a major issue as it contains several toxic chemical constituents which may pollute the environment. Although, utilizing fly-ash for manufacturing bricks and cement could take care of this issue partially, the cost of transporting fly-ash to concerned factories limits its utility.

Ministry of Environment and Forest (MoEF) has accorded permission for disposal of fly ash in to the ash pond. The mine void is located at about 25km from TTPS. The fly-ash generated in TTPS is disposed into the mine void after making 60% slurry with water. In order to assess the environmental impact of the fly-ash disposal in the vicinity of the mine void, TTPS approached Board of Radiation and Isotope Technology (BRIT) to carry out the Radiotracer study to understand the leaching of heavy metals from fly ash in to the surface water and surrounding ground water.

2.4 Targeting the task

A preliminary site visit was carried out by BRIT scientists to understand the problem and to observe the study area as well as surroundings. There was ASH POND surrounded by thick vegetation.

On the upstream side there is decantation zone wherein excess water from the slurry is sucked through the pump and returned to the power plant as a recycled water to conserve the quantity of water.

Since the fly ash is disposed off in to the ash pond alongwith water, the fly ash may leach in to the void water. The leachates may contain heavy metals which could get percolated in to the ground water contaminating the ground water in the surrounding bore wells. To study the extent of leached heavy metals with respect to time, radiotracer was disposed in the same way as bulk fly ash while disposing it in to the ash pond and to study its spatial and temporal distribution in the water of the pond and its subsequent progress in to the surrounding bore wells.

3. EXPERIMENTAL

Inside the TTPS plant the regular practice is to gather slurry in a tank, homogenise it and pump it through the pipeline towards the ash pond. Hence it was decided to cut open the can, empty the contents in to the slurry tank while the churning is continued. Accordingly, on 18/12/2018 using long handled tongs the cans were removed from transport container directly from the truck and was placed in an automatic can cutter with perspex cover. Electromechanically, the can was cut open and 21 such cans were emptied out in the tank. After mixing and holding the slurry for about 2 hours, the pump was started and the radiotracer was disposed off in to the ash pond.

While disposing the slurry constant water flushing was done Water flushing was continued till the radioactivity level in the tank was brought down to the background level.

Radiation Safety monitoring

Before starting the preparations, all the personnel present and would be involved in the operations were given thorough briefing of the total activity planned. Wherever the radioactivity was in use, the polythene sheets were spread and covered with absorbent sheets. From beginning to the end of the entire operation, radiation monitoring was continuously carried out. After the radioactive handling job was finished all the personnel and area under use was specifically monitored.

The area was thoroughly flushed with copious amount of water so that there are no traces of radioactivity.

Since the radiotracer was disposed off on 18/12/2018 in the void, the monitoring of its spread in ash pond was carried out on 19/12/2018. 1″ diameter x1″ height sodium iodide scintillation detector connected by about 100 meters long cable to a scaler-ratemeter was used for monitoring the spread of the radiotracer in the pond.

The detector was moved from surface to the different depths at various locations in the water and the corresponding count rate was recorded with respect to the position of the monitoring boat. The position was determined by

GPS device. Thus the count-rate data was obtained at various lateral and longitudinal locations and at various depths.

Schedule of ground water sampling

In the bore wells already available and specially drilled for monitoring the frequency of sampling was decided to be every month till the breakthrough is achieved. After the breakthrough, this frequency could be increased to once in a day till the depletion in the count rate observed in each of the bore well sample.

Radiotracer tracking

Tracking of the radiotracer in the ash pond and decantation zone was carried out on 19/12/2018 and on 12/02/2019. The data is being mathematically treated and analysed. Isocount contours will be drawn and the sample analysis from the bore wells would also be carried out. The results will be incorporated in the subsequent report.

Annex.-C

Bioaccumulation and bio-magnification study on flora and fauna of surrounding the ash filled South Balanda Mine Void" NTPC, Talcher, Odisha

I year report
(2018-2019)

submitted to

Talcher Thermal Power Station
Angul district, Odisha

CSIR-NATIONAL BOTANICAL RESEARCH INSTITUTE, LUCKNOW (INDIA)

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(iii) Project Title:	Bioaccumulation and bio-magnification study on flora and fauna of surrounding the ash filled South Balanda Mine Void
(iv). Project duration a. Date of start of the project b. Date of Completion	4 years 20 Jan, 2018 19 Jan, 2022
(v) Total cost of Project	**Rs. 1,09,24875/-**

Bioaccumulation and bio-magnification study on flora and fauna of surrounding the ash filled South Balanda Mine Void, NTPC, Talcher, Odisha

1. Introduction

Talcher Thermal Power Station (TTPS) is located in Angul district of Odisha. This power plant is operated by NTPC and its installed capacity is 460 MW. All units of this power station are coal fired. TTPS is filling its fly ash in to quarries situated at a distance of about 12 kms from power station. Fly ash is brought to the quarry through pipes in the form of ash slurry.

CSIR-National Botanical Research Institute, Lucknow, U.P. is to monitor trace elements in fly ash, soil and water in 500 m zone around the fly ash filling quarries. Moreover CSIR-NBRI has to carry out biomonitoring, bioaccumulation and biomagnifications studies in flora and fauna. Metals to be estimated are As, Ba, Cd, Co, Cr, Cu, F, Fe, Hg, Mn, Ni, Pb, Zn.

2. Scope of work

The studies shall be based on primary survey (sample collection and laboratory analysis) undertaken at representative sites for flora (tree leaves, fruits, vegetation, fodder, crop yields etc.) and fauna (meat, scat and urine) for bio-accumulation and bio-magnification of trace elements during pre and post-monsoon seasons.

Number of sampling locations proposed and the parameters to be analysed are as follows:

Zone :

500 m Zone around Quarries 2, 3A and 3B and/ or nearest habitations from the mine voids.

No. of Sampling Locations:

Core Zone: 01 nos.

Buffer Zone: 05 nos. in surrounding areas up-to 500 m and/ or nearest habitations from the mine voids in all directions

Parameters to be analysed at each location :

• Analysis of trace elements in mine void supernatant, piezeometers and surface water samples. Trace elements shall include As, Ba, Cd, Co, Cr, Cu, F, Fe, Hg, Mn, Ni, Pb, Zn.

•Analysis of trace elements in Flora (in leaves, fruits, fodder, agricultural produce etc.), Fauna (Meat, Scat, Urine) and the invertebrates

•Analysis of trace elements in aquatic fauna from the mine void filled with fly ash.

The data generated above shall be analysed to establish the evidence of bio-accumulation or biomagnifications of the elements.

3. Study area location

Talcher Thermal Power station (TTPS) is located in Talcher sub-division of Angul district in the state of Odisha(Fig. 1). The power plant is one of the coal-based plants of NTPC. The coal for the power plant is sourced from Jagannath Mines of Mahanadi Coalfields Limited. Source of water for the plant is from Brahmani River. The nearest commercial airport is at Bhubaneshwar at an aerial distance of 90 km approx. and about 150 km by road.

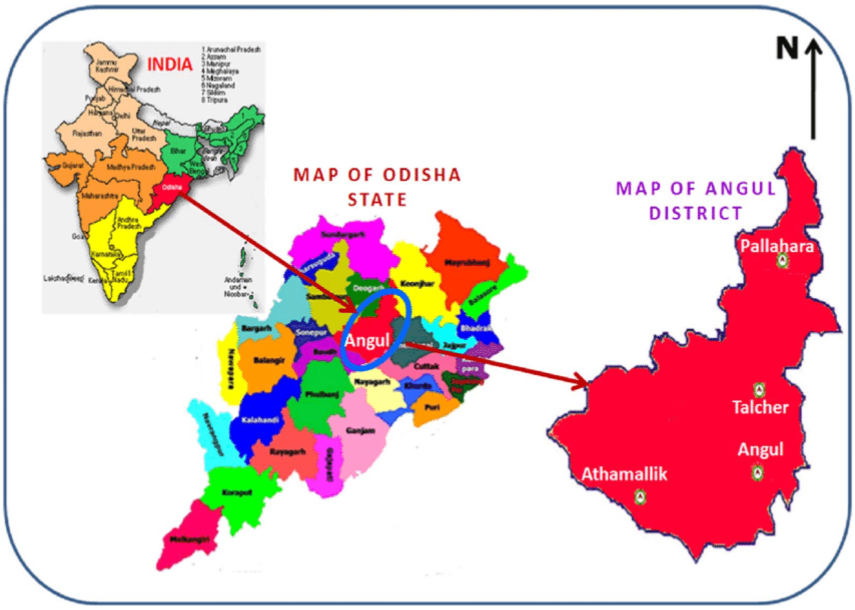

Fig 1. Location map of study area

Fig 2. Sampling locations (★ → Sites, S-I = Check Dam Mine Void 2; S-II = L- Shape Dam Ist Position; S-III = L-Shape Dam IInd Position; S-IV = Core Pond On The Fly Ash Dykes; S-V = Check Dam 3B; S-VI = Reservoir Pond)

3. Climate

The study area experiences tropical monsoon climate with mild winter and hot summer. The average annual rainfall of the study area is approximately 1250 mm of which major amount is received during the four months extending from June to September.

4. Description of the study area

Talcher Thermal Power plant (TPP) is situated in Talcher sub-division of Angul district in the Indian state of Odisha. The coal for the power plant is sourced from Jagannath Mines of Mahanadi Coalfields Limited. Source of water for the TPP is from Brahmani River. The TPP is owned and operated by Odisha state government and total generating capacity of Thalcher

TPP is 460 MW. There is a proposal for expansion of Thalcher TPP by two units of 660 MW, each fired by coal and the combined capacity of plant after the expansion is to be 1780 MW. Brahmani river water is used for making steam and also as a coolant for vital machinery. The discharge from the TPP may also contaminate the river water by leaching of heavy metals from fly ash. Fly ash, water (surface and ground) and plant species (terrestrial and hydrophyte plants) were taken in the range of ten km from the TPP. Samples were collected from six selected sites (Fig. 2) namely:

1. Check dam mine void 2
2. L shape dam Ist position
3. L shape dam IInd position
4. Core pond on the fly-ash dykes
5. Check dam 3B
6. Reservoir pond

6. Methodology

6.1 Surface and ground water sampling

Groundwater samples and surface water samples have been collected from the identified sources. The samples were collected in clean 100 ml polyethylene bottles. The heavy metal analysis was done by using ICP-MS (Model: 7500X Make: Agilent). The detection limit for As, Cd, Co, Cr, Cu, Fe, Mn, Ni, Pb, Zn is 0.001 ppm.

6.2 Plant sampling

Plant samples were washed thoroughly tap water and de-ionized water for removing the sticking fly ash/soil particles. After washing plant samples were oven dried at 80 °C for 72 hours and divided into root and leaves. The dried samples of the plants [root (150mg) and leaves (300mg)] were taken for the acid digestion with HNO_3:$HCLO_4$ (3:1 v/v) for the heavy metal analysis in the samples. All the samples of fly ash water and plants were digested through the hot plate. The digested samples were further diluted in Milli-Q water and subjected to the Inductively Coupled Plasma-Mass Spectrometry (ICP-MS) (Fig 3).

Fig 3. ICP-MS instrument used for metal analysis

6.3 Plant collection and identification

Different sites were visited during pre- and post monsoon seasons to collect the plant samples. From each location we tried to collect as much as plant species which were commonly growing in that area. The plants were collected in good quantity and kept in zipped polythene bags and later on they were properly dried and prepared for chemical analysis. Some of the plants were also preserved for preparing voucher/herbarium specimens for future record. The plants retained for herbarium preparation were collected either in flowering or fruiting or in both conditions for their correct identification along with the data on their habits and habitats and placed them in blotting papers for drying. The standard herbarium procedures out lined by Jain & Rao (1976) were followed for preparing voucher herbarium specimens. The identification of species was carried out with the help of Floras, existing regional monographs/ revisions and other authentic specimens deposited at NBRI, Lucknow herbarium, LWG.

The dominating associates of different study sites are given in Tables 1-6, however further identification is under progress.

7.1. Plant species found at different sites

Table 1. Major plant associates at site 1

S. No.	Locality	Distance from site (in metre)	Botanical name	Common name	Family
SITE -I	**Chek dam mine void - 2**	50 m	*Syzygium cumini*	Java plum, Jamun	Myrtaceae
		100 m	*Syzygium cumini*	Java plum, Jamun	Myrtaceae
		50 m	*Albizia julibrissin*	Persian silk tree	Fabaceae
		250 m	*Albizia julibrissin*	Persian silk tree	Fabaceae
		500 m	*Azadirachta indica*	Neem	Meliaceae
		100 m	*Syzygium cumini*	Java plum, Jamun	Myrtaceae
		100m	*Eucalyptus tereticornis*	Forest red gum, Blue gum	Myrtaceae
		100 m	*Eupatorium cannabinum*	Hemp-agrimony	Asteraceae
		10 m	*Microcystis*		Microcystaceae
		10 m	*Microphylla*	Fukien Tea,	Urticaceae
		10 m	*Mimosa pudica*	Lajwanti, Chui- mui	Fabaceae
		10 m	*Solanum nigrum*	Black nightshade	Solanaceae
		10 m	*Calotropis procera*	Aak, Madaar	Apocynaceae
		10 m	*Sparsiflora*		Brassicaceae
		50 m	*Ziziphus nummularia*	Jhar Beri	Rhamnaceae
		10 m	*Croton bonplandianum*	Rushfoil	Euphorbiaceae

Table 2. Major plant associates at site II.

S. No.	Locality	Distance from site (in metre)	Botanical name	Common name	Family
SITE - II	**L shape dam - Ist position**	50 m	*Bambusoideae*	Bamboo	Poaceae
		50 m	*Dalbergia sissoo*	Sisau, Sheesham	Fabaceae
		50 m	*Eucalyptus tereticornis*	Forest red gum, Blue gum	Myrtaceae
		50 m	*Cassia fistula*	Golden rain tree	Fabaceae
		50 m	*Prosopis juliflora*	Vilayati babool	Fabaceae
		50 m	*Eupatorium cannabinum*	Hemp-agrimony	Asteraceae
		20 m	*Hyptis spp*	Vilaiti tulsi	Lamiaceae
		20 m	*Indigofera*	True Indigo	Fabaceae
		20 m	*Yerba (llex)*		Aquifoliaceae
		20 m	*Senna occidentalis*	Coffee Senna	Fabaceae
		20 m	*Cynodon dactylon*	Dhoob	Poaceae
		20 m	*Euphorbia hirta*	Bara dudhi, Asthma Weed	Euphorbiaceae
		20 m	*Evolvulus*	Visnukrantha	Convolvulaceae

Table 3. Major plant associates at site III.

S. No.	Locality	Distance from site (in metre)	Botanical name	Common name	Family
SITE-III	**L shape dam - IInd position**	50 m	*Dalbergia sissoo*	Sisau, Sheesham	Fabaceae
		50 m	*Eucalyptus tereticornis*	Forest red gum, Blue gum	Myrtaceae
		50 m	*Saccharum spontanium*	Kans grass	Poaceae
		50 m	*Leucaena leucocephala*	White leadtree	Fabaceae
		50 m	*Eucalyptus tereticornis*	Forest red gum, Blue gum	Myrtaceae
		50 m	*Saccharum spontanium*	Kans grass	Poaceae

Table 4. Major plant associates at site IV.

S. No.	Locality	Distance from site (in metre)	Botanical name	Common name	Family
SITE-IV	**Core pond on the fly ash dykes**	50 m	*Azadirachta indica*	Neem	Meliaceae
		50 m	*Delonix regia*	Flame of the forest	Fabaceae
		50 m	*Saccharum spontanium*	Kans grass	Poaceae
		50 m	*Hyptis spp*	Vilaiti tulsi	Lamiaceae
		50 m	*Eupatorium cannabinum*	Hemp-agrimony	Asteraceae
		50 m	*Leucaena leucocephala*	White leadtree	Fabaceae
		50 m	*Mallotus*	Kumkum tree	Euphorbiaceae
		50 m	*Prosopis juliflora*	Vilayati babool	Fabaceae
		50 m	*Dalbergia sissoo*	Sisau, Sheesham	Fabaceae
		50 m	*Bambusoideae*	Bamboo	Poaceae
		50 m	*Mangifera indica*	Mango	Anacardiaceae
		50 m	*Artocarpus heterophyllus*	Jackfruit	Moraceae

Table 5. Major plant associates at site V.

S. No.	Locality	Distance from site (in metre)	Botanical name	Common name	Family
SITE-V	**Check dam 3B**	100 m	*Albizia julibrissin*	Persian silk tree	Fabaceae
		100 m	*Azadirachta indica*	Neem	Meliaceae
		100 m	*Tectona grandis*	Indian-Oak, Teak	Lamiaceae
		100 m	*Eucalyptus tereticornis*	Forest red gum, Blue gum	Myrtaceae
		20 m	*Casuarina equisetifolia*	Whistling Pine	Casuarinaceae
		20 m	*Dalbergia sissoo*	Sisau, Sheesham	Fabaceae
		20 m	*Cassia fistula*	Golden rain tree	Fabaceae
		20 m	*Hyptis spp*	Vilaiti tulsi	Lamiaceae
		20 m	*Eupatorium cannabinum*	Hemp-agrimony	Asteraceae
		20 m	*Centella asiatica*	Brahmi	Apiaceae

Table 6. Major plant associates at site VI.

S. No.	Locality	Distance from site (in metre)	Botanical name	Common name	Family
SITE-VI	**Reservoir pond**	50 m	*Lagerstroemia*	Common Crape Myrtle	Lythraceae
		50m	*Ficus hispida*	Hairy Fig	Moraceae
		50m	*Calotropis procera*	Aak, Madaar	Apocynaceae
		50 m	*Bambusoideae*	Bamboo	Poaceae
		50 m	*Leucaena leucocephala*	White leadtree	Fabaceae
		50 m	*Ficus benghalensis*	Banyan tree	Moraceae
		10m	*Lantana camara*	Raimuniya	Verbenaceae
		10 m	*Ziziphus*	Ber	Rhamnaceae

			jujuba		
		10 m	*Ficus hispida*	Hairy Fig	Moraceae
		10 m	*Nelumbo nucifera*	Lotus	Nelumbonaceae
		10 m	*Hydrilla verticillata*	Hydrilla	Hydrocharitaceae
		10 m	***Diploginup***		
		10 m	*Pteris vittata*	Ladder brake	Pteridiaceae
		10 m	*Marsilea*	Water clover	Marsileaceae
		10 m	*Typha*	Patera	Typhaceae
		10 m	*Leucaena leucocephala*	White leadtree	Fabaceae
		10 m	*Acacia spp*	Babul	Fabaceae

Some of plants collected at the sites

Hyptis suaveolens

Zizyphus numularia


Eupatorium adenophorum


Passiflora foetida

Indigofera linifolia

Collection of samples

Table 7. Concentration of heavy metals in water samples (ppm)

Sites	As	Ba	Cd	Co	Cr	Cu	F	Fe	Hg	Mn	Ni	Pb	Zn
Site I (Peizometer)	0.08	0.09	0.005	0.001	0.08	0.005	0.92	1.93	BDL	0.095	0.059	BDL	0.043
Site I (Surface water)	0.009	0.10	0.009	0.003	1.06	0.005	0.93	2.18	BDL	0.11	0.084	BDL	0.019
Site II (Slurry water)	0.04	0.18	0.005	0.09	2.04	0.09	1.19	4.59	BDL	2.39	0.19	BDL	1.02
Site III (Peizometer)	0.008	0.06	0.007	0.009	0.07	0.005	0.88	0.93	BDL	0.098	0.038	BDL	0.048
Site V (Surface water)	BDL	0.08	0.004	0.007	0.06	2.06	1.27	1.11	BDL	0.049	0.028	BDL	0.038
Site VI (reservoir water)	BDL	0.02	0.008	0.002	0.03	1.07	0.93	1.09	BDL	1.27	0.019	BDL	0.19

Note: BDL=Below detection limit

<u>Concentration of heavy metals in water samples (ppm)</u>

Arsenic was within the permissible limits of BIS for all the samples (Table 1). The concentrations of other heavy metals (Table 7) such as Cd, Co, Cr, Cu, F, Fe, Mn. Ni and Zn were also within the permissible limit as per BIS standard. **It needs to be mentioned that Hg and Pb was not detected in any of the samples.**

<u>Phytoplankton</u>

In general 4 groups comprising 6 genera were observed in water samples. The members of Chlorophyceae, Cyanophyceae and Cryptophyceae were most common. The group Chlorophyceae was represented by 2 genera viz. *Chlorella* and *Coelastrum*. Cyanophyceae was represented by 2 genera viz. *Oscillatoria* and *Microcystis*. The group Bacillariophyceae and Cryptophyceae were represented by single genera viz. *Nitzschia* and *Cryptomonas*, respectively.

7.2 Heavy metals concentration in plants

The results of analysis for heavy metals concentration in the trees are presented in Tables 8-13.

Arsenic (As): The concentration of As was mostly found to be within the permissible limits. Its concentration ranged from 0.00 – 3.89 mg kg^{-1}. In *Saccharum spontanium* root at site III its concentration was 3.54 mg kg^{-1}. However, *Pteris vittata* accumulated maximum 3.89 mg kg^{-1} As because it is a arsenic accumulator plant (Table 13).

Barium (Ba): Barium concentration ranged from 2.19-65.32 mg kg^{-1}. The maximum concentration of Ba was found in *Azadirachta indica* at Site I (Table 8).

Cadmium (Cd): The concentration of cadmium ranged between 0.00 and 1.23 mg kg^{-1} dry weight. The average concentration was 1.02 mg/kg dry weight in all the plant species. It was found that all studied plants have cadmium below the normal limit set by WHO. The high concentration of cadmium was found in leaves of *Zizyphus numularia* (1.23 mg/kg) at site VI (Table 13).

Cobalt (Co): The average concentration level of cobalt was 0.79 mg/kg dry weight. The highest concentration of Co was found in *Holarrhena antidysenterica* (4.52 mg/kg dry weight) at site IV (Table 11). There are no standard limits for plants set by WHO/FAO.

Chromium (Cr): The concentration of chromium ranged between 0.14 -5.29 mg/kg dry weight. The average concentration was 1.03 mg/kg dry weight. The maximum Cr was found in leaves of *Lantan camara* (5.29 mg/kg) at site VI (Table 13), followed by *Ficus religiosa* (4.23 mg/kg in leaf) at same site.

Copper (Cu): It is an essential trace element which is necessary for optimum activities of many enzymes. It plays an important role in normal growth and development of plants. The highest t concentration of copper was 30.81 mg/kg in leaves of *Prosopis juliflora* at site II (Table 9)and lowest in 0.33 mg/kg in Azadirachta indica at site V (Table 12). It was found below the permissible limit set by WHO.

Fluroide (F): Industrial activities may cause F pollution. In our study F was found to be in the normal range. Maximum concentration (5.76 mg/kg) was found in root of *Acacia auriculiformis* at site IV (Table 11)followed by Lanatna camara (5.23 mg/kg in stem) at site II (Table 9).

Iron (Fe): It is the most abundant metal. It is an essential constituent for all plants and animals. The results showed that highest concentration of iron was found in two Ficus spp at site VI (Table 13) viz., *Ficus hispida* (1830 mg/kg dry weight) and *F. benghalensis* (1839 mg/kg dry weight). The average iron concentration was more may be due to high level of iron content in soil as the study area has lateritic soil.

Mercury (Hg): It is to be noted that Hg was below detection limit in all plant samples.

Manganese (Mn): It is a trace heavy metal and very essential for plants and animals growth. Results revealed that manganese concentration was found high in all plant samples.
The highest concentration of manganese was found in Delonix sps leaves (512 mg/kg)
at site IV (Table 11). Ranges of Mn were found below the permissible limit set by WHO.

Nickel (Ni): It is an essential element needed for plants and animals. The maximum and minimum concentration of nickel was *Lanatan camara* (23.14 mg/kg) at site IV (Table 11) followed by *Leucaena leucophila* pod (8.20 mg/kg) at site III (Table 10). It was found below the permissible limit set at most of the sites.

Lead (Pb): It is a non-essential trace metal. The concentration of lead ranged between 0.02 and 5.88 mg/kg dry weight. It was found below the permissible limit set by WHO. The maximum concentration was found in *Prosopis juliflora* stem (5.88 mg/kg) at site II (Table 9)followed by stem of *Lantana camara* (4.11 mg/kg) at site II (Table 9).

Zinc (Zn): It is an essential micro-nutrient to plants. The zinc concentration ranged between 0.48 to 140.87 mg/kg dry weight in *Delonix sps* at site IV (Table 11). It was found below the permissible limit set by WHO.

Table 8. Heavy Metals concentrations in plant samples collected from Site I

Site - I Check Dam Mine Void - 02														
Plants Name	**Parts**	**Metal conc. (mg kg^{-1}DW)**												
		Cr	**Mn**	**Fe**	**Co**	**Ni**	**Cu**	**Zn**	**As**	**Hg**	**Cd**	**Pb**	**F**	**Ba**
Syzygium cumini	Stem	0.99	3.68	189.58	0.08	2.08	2.88	4.19	0.08	BDL	0.01	0.15	2.35	43.27
	Leaf	2.37	48.48	104.35	0.04	3.53	6.53	12.89	0.11	BDL	0.09	3.24	1.99	24.28
Zizyphus nummularia	Stem	1.52	3.64	106.62	0.04	1.33	2.23	7.05	0.06	BDL	0.01	0.27	1.89	32.76
	Leaf	1.52	28.15	88.28	0.01	2.04	4.09	11.43	0.12	BDL	0.14	0.60	1.28	18.29
Cassia fistula	Stem	2.80	8.65	113.20	0.14	0.71	2.17	14.65	0.09	BDL	0.01	1.15	2.10	38.94
	Leaf	1.38	5.99	119.05	0.06	0.78	2.79	14.92	0.08	BDL	0.05	1.11	1.29	25.34
Albizia julibrissin	Stem	1.50	42.33	42.89	0.10	1.18	5.50	16.97	0.06	BDL	0.01	0.46	0.45	44.32
	Leaf	0.98	56.83	59.76	0.07	0.28	1.68	9.49	0.09	BDL	0.01	0.47	0.18	37.39
	Pod	1.32	21.28	55.53	0.06	2.83	3.38	15.53	0.04	BDL	0.01	0.21	0.09	12.76
Azadirachta indica	Leaf	2.31	29.44	213.07	0.17	2.77	2.88	26.14	0.15	BDL	0.07	0.79	1.22	43.28
	Stem	1.18	5.32	110.33	0.10	0.88	3.50	8.24	0.06	BDL	0.15	0.38	2.33	65.32
	Fruit	1.25	16.31	70.52	0.37	0.78	12.33	19.56	0.07	BDL	0.09	2.13	0.12	21.32
Mimosa pudica	Leaf	1.82	60.92	113.75	0.02	3.82	5.76	17.35	0.07	BDL	0.08	3.92	1.29	35.38
	Stem	2.05	12.31	78.71	0.03	3.53	4.86	7.11	0.89	BDL	0.01	0.45	2.34	54.32
Eucalyptus tereticornis	Leaf	2.26	63.94	143.96	1.40	12.98	3.38	60.75	0.15	BDL	0.07	0.14	1.18	37.98
	Stem	1.96	90.50	65.75	0.29	5.84	6.42	41.49	0.27	BDL	0.11	0.87	2.67	43.65
Eupatorium adenophorum	Leaf	3.15	95.17	530.80	0.95	11.20	13.27	73.32	1.00	BDL	0.06	0.21	2.11	31.28
	Stem	1.70	83.70	163.17	0.27	2.49	6.53	30.01	0.10	BDL	0.03	0.36	3.28	54.22
	Inflorescence	3.24	86.04	212.83	0.79	9.55	9.91	37.12	0.19	BDL	0.08	2.24	0.92	12.23
Holarrhena antidysenterica	Leaf	3.56	115.77	152.95	0.19	10.30	22.40	50.63	0.07	BDL	0.10	1.73	1.11	24.88
	Stem	1.75	94.62	76.65	0.07	3.38	7.41	31.29	0.04	BDL	0.02	0.42	2.45	42.21

Note: BDL=Below detection limit

Table 9. Heavy Metals concentrations in plant samples collected from Site II

Site - II L - Shape Dam (First Position)														
Plants Name	**Parts**	**Metal conc. (mg kg^{-1}DW)**												
		Cr	**Mn**	**Fe**	**Co**	**Ni**	**Cu**	**Zn**	**As**	**Hg**	**Cd**	**Pb**	**F**	**Ba**
Azadirachta indica	Leaf	2.24	178.84	213.96	0.19	2.50	3.82	67.32	1.87	BDL	0.08	0.52	2.12	29.54
	Stem	1.91	15.66	58.75	0.00	2.31	5.22	23.15	0.21	BDL	0.10	1.77	2.33	37.98
Dalbergia sissoo	Leaf	2.27	31.71	77.26	0.13	5.08	5.13	26.93	2.52	BDL	0.01	0.35	1.98	35.22
	Stem	1.50	9.32	46.27	0.02	2.22	3.81	7.20	0.18	BDL	0.04	0.80	2.76	45.33
Lantana camara	Leaf	2.61	62.25	240.34	0.87	3.85	15.51	36.60	0.83	BDL	0.12	0.77	4.67	54.33
	Stem	1.31	14.02	104.87	0.15	0.80	1.09	8.30	0.50	BDL	0.07	4.11	5.23	57.22
Eucalyptus tereticornis	Leaf	2.01	35.93	97.71	0.07	4.04	3.34	17.26	0.16	BDL	0.01	0.38	1.38	23.12
	Stem	1.74	7.33	62.41	0.02	2.13	5.01	14.12	0.12	BDL	0.01	0.29	2.99	32.54
Cassia fistula	Stem	1.89	207.62	176.98	0.56	3.37	4.02	16.09	0.38	BDL	0.02	0.45	2.49	21.77
	Leaf	2.07	175.17	956.61	0.93	2.28	4.23	21.83	0.75	BDL	0.03	0.46	1.88	13.45
	Branch	2.06	17.70	100.83	0.14	1.19	4.79	20.28	0.16	BDL	0.04	2.10	1.97	11.21
	Flower	2.22	162.06	427.52	2.04	5.47	5.01	28.26	0.47	BDL	0.06	1.98	0.67	3.27
Zizyphus nummularia	Stem	1.88	15.71	82.81	0.12	2.61	4.09	16.37	0.15	BDL	0.16	0.67	2.11	34.28
	Leaf	1.13	97.43	112.48	0.30	2.73	4.22	35.68	0.36	BDL	0.09	0.17	1.89	12.87
Prosopis juliflora	Leaf	1.07	95.65	135.81	0.39	4.23	30.94	30.40	0.13	BDL	0.06	0.51	2.66	32.34
	Stem	1.27	13.43	72.54	0.36	3.24	7.29	17.08	0.18	BDL	0.11	5.88	3.28	43.57
Mimosa pudica	Stem	1.40	43.69	193.91	0.42	2.47	2.78	5.78	0.30	BDL	0.05	0.51	3.28	21.26
	Leaf	1.57	100.87	627.62	0.52	2.26	1.87	8.30	0.48	BDL	0.19	2.94	1.99	11.64
Eupatorium adenophorum	Leaf	1.51	71.26	206.26	0.89	4.52	22.64	41.04	0.76	BDL	0.13	0.41	3.14	23.65
	Stem	1.52	14.20	45.24	0.31	2.66	4.81	14.67	0.14	BDL	0.03	0.31	4.26	44.32
Hyptis suaveolens	Stem	1.04	131.51	50.59	2.76	2.84	14.58	25.16	0.19	BDL	0.05	0.59	3.67	21.27
	Leaf	0.55	57.29	56.19	0.98	3.21	2.56	34.57	0.23	BDL	0.02	2.26	2.11	7.37
	Inflorescence	1.19	23.33	177.62	0.79	2.38	5.02	12.07	0.38	BDL	0.00	0.13	0.65	2.19
Sida cordifolia	Leaf	1.32	27.68	137.13	0.25	0.55	5.70	7.07	1.08	BDL	0.05	0.11	1.87	23.27
	Stem	0.48	8.72	98.69	0.25	0.56	3.43	10.35	0.20	BDL	0.05	0.07	2.17	16.98
	Flower	0.51	55.35	60.65	0.63	5.01	7.08	36.01	0.60	BDL	0.06	0.22	0.32	2.19
Syzygium cumini	Leaf	0.70	89.51	94.30	0.20	3.17	9.63	36.97	0.17	BDL	0.05	0.11	1.87	34.95
	Stem	0.59	13.71	34.67	0.16	1.74	4.80	27.43	0.03	BDL	0.03	0.20	2.99	45.87

Note: BDL=Below detection limit

Table 10. Heavy Metals concentrations in plant samples collected from Site III

Site - III L - Shape Dam (Second Position)														
Plants Name	**Parts**	**Metal conc. (mg kg^{-1}DW)**												
		Cr	**Mn**	**Fe**	**Co**	**Ni**	**Cu**	**Zn**	**As**	**Hg**	**Cd**	**Pb**	**F**	**Ba**
Dalbergia sissoo	Bark	1.10	49.54	814.67	0.55	0.91	1.56	44.73	0.14	BDL	0.07	0.33	0.77	9.11
	Leaf	0.56	148.18	47.49	0.77	6.00	3.47	28.80	0.41	BDL	0.03	0.07	1.23	17.92
	Stem	0.70	37.40	48.49	0.36	2.71	4.01	21.82	0.19	BDL	0.01	0.12	1.99	25.94
Eucalyptus tereticornis	Leaf	0.79	68.86	62.35	0.22	1.22	1.09	11.87	1.16	BDL	0.03	0.11	1.11	18.02
	Stem	0.70	41.01	40.24	0.31	3.20	2.82	6.88	0.48	BDL	0.20	0.08	1.67	34.29
Acacia auriculiformis	Leaf	0.94	220.78	195.02	0.34	5.11	3.16	29.27	0.97	BDL	0.12	0.27	1.09	12.978
	Pod	0.89	87.23	48.89	0.24	6.98	3.74	33.33	0.60	BDL	0.09	0.34	0.09	36.90
	Stem	0.68	33.80	32.59	0.16	1.54	1.81	18.34	0.47	BDL	0.09	0.22	1.94	44.60
Zizyphus nummularia	Leaf	0.83	280.36	91.41	0.53	4.42	2.54	27.69	0.71	BDL	0.01	0.08	1.34	23.89
	Stem	0.68	44.72	79.54	0.45	2.82	2.76	24.43	0.44	BDL	0.03	0.22	1.45	34.80
Saccharum spontanium	Root	0.80	0.77	261.03	0.11	1.02	2.37	9.66	3.54	BDL	0.03	0.07	2.34	45.89
	Leaf	0.74	31.80	85.01	0.46	1.14	3.06	4.02	3.36	BDL	0.06	0.07	1.98	34.90
	Stem	0.92	39.00	128.62	0.25	0.41	3.69	25.23	0.89	BDL	0.04	0.15	2.11	32.99
Lantana camara	Flower	0.99	29.31	312.51	0.26	2.69	2.89	9.66	1.44	BDL	0.08	0.19	1.24	10.09
	Stem	1.01	46.05	102.70	0.53	4.26	4.34	39.91	0.89	BDL	0.20	0.07	3.29	23.95
	Leaf	1.40	22.56	154.56	0.58	3.81	3.23	9.50	1.86	BDL	0.03	0.06	2.19	19.67
Leucaena leucocephala	Pod	0.55	20.75	53.94	0.62	8.20	4.32	19.56	0.09	BDL	0.00	0.14	0.17	8.90
	Leaf	0.86	44.13	123.54	1.18	2.48	6.25	10.82	0.15	BDL	0.00	0.10	1.76	25.89
	Stem	0.57	13.69	46.61	0.53	2.50	2.68	16.48	0.35	BDL	0.00	0.13	2.18	34.85

Note: BDL=Below detection limit

Table 11. Heavy Metals concentrations in plant samples collected from Site IV

Site - IV Core Pond														
Plants Name	**Parts**	**Metal conc. (mg kg^{-1}DW)**												
		Cr	**Mn**	**Fe**	**Co**	**Ni**	**Cu**	**Zn**	**As**	**Hg**	**Cd**	**Pb**	**F**	**Ba**
Eucalyptus tereticornis	Leaf	0.80	23.25	170.26	0.16	1.28	0.72	6.84	1.47	BDL	0.19	0.45	2.36	23.78
	Stem	0.33	3.75	18.18	0.12	0.27	0.46	2.00	0.10	BDL	0.16	0.12	3.69	38.56
Acacia auriculiformis	Leaf	0.99	28.96	81.21	0.23	1.83	2.03	7.06	1.35	BDL	0.14	0.21	3.21	32.87
	Pod	0.54	15.56	38.29	0.16	3.42	1.33	5.67	0.15	BDL	0.09	0.21	0.87	1.98
	Stem	0.45	10.77	39.89	0.14	0.82	1.13	12.00	0.37	BDL	0.37	0.05	4.23	43.56
	Root	0.41	3.11	16.13	0.15	0.75	1.35	9.06	1.10	BDL	0.25	0.11	5.76	32.04
Terminalia bellirica	Leaf	0.40	20.59	68.54	0.23	0.86	1.42	5.00	0.58	BDL	0.11	0.12	1.87	21.94
	Stem	0.25	1.62	14.38	0.11	0.84	0.85	1.93	0.03	BDL	0.10	0.09	2.19	34.65
Azadirachta indica	Leaf	0.72	150.64	61.94	1.30	3.06	1.82	29.68	0.07	BDL	0.00	0.09	1.89	34.57
	Stem	0.27	32.45	14.87	1.31	3.50	1.81	14.98	0.00	BDL	0.01	0.05	3.18	44.98
Delonix Sp.	Flower	0.77	82.39	16.78	0.21	1.21	0.82	0.85	0.01	BDL	0.01	0.04	0.32	1.93
	Leaf	0.51	512.01	55.36	1.75	7.41	2.59	140.87	0.03	BDL	0.05	0.11	2.32	26.94
	Branch	0.58	91.02	195.46	0.53	5.06	1.15	28.17	0.00	BDL	0.15	0.14	2.98	34.87
	Stem	0.72	74.60	70.95	0.32	3.13	1.75	28.55	0.01	BDL	0.15	0.10	3.18	47.43
Saccharum spontanium	Leaf	0.71	68.31	72.99	0.11	0.79	2.04	6.61	0.29	BDL	0.16	0.17	1.87	43.85
	Stem	0.43	23.62	39.05	0.12	0.61	0.81	11.36	0.00	BDL	0.19	0.17	3.28	55.94
	Root	0.28	13.65	46.75	0.22	1.70	2.42	6.49	0.08	BDL	0.17	0.13	4.28	24.95
Hyptis suaveolens	Flower	0.30	28.40	16.27	1.28	6.61	2.22	11.20	0.00	BDL	0.26	0.14	0.94	11.21
	Leaf	0.58	12.28	44.12	0.38	1.01	0.85	1.11	0.06	BDL	0.14	0.05	1.87	23.86
	Stem	0.36	279.21	8.11	2.60	2.40	4.25	36.65	0.01	BDL	0.16	0.05	2.18	32.78
	Root	0.26	58.33	64.58	1.03	1.41	3.48	32.04	0.00	BDL	0.20	0.15	2.98	43.32
Eupatorium adenophorum	Leaf	0.60	35.81	1.51	1.34	8.49	1.45	0.00	0.05	BDL	0.14	0.05	2.87	32.93
	Stem	0.27	28.47	18.56	0.16	2.11	0.87	10.33	0.00	BDL	0.16	0.11	3.95	21.46
Leucaena leucocephala	Leaf	0.61	13.01	14.77	0.35	2.48	2.25	3.29	0.12	BDL	0.19	0.06	2.87	12.38
	Stem	0.19	5.43	32.71	0.07	0.66	1.56	4.07	0.01	BDL	0.22	0.07	3.76	18.05
Lantana camara	Leaf	0.44	76.33	56.32	1.95	23.14	3.33	79.09	0.01	BDL	0.15	0.07	3.87	21.03
	Stem	0.52	15.41	69.26	1.32	1.78	1.11	26.89	0.00	BDL	0.15	0.12	4.86	45.02
Prosopis juliflora	Leaf	0.48	30.80	63.78	0.06	1.15	2.52	9.70	0.08	BDL	0.19	0.09	2.87	26.04
	Stem	0.50	4.60	37.99	0.05	1.57	1.72	8.77	0.00	BDL	0.16	0.11	4.38	34.05
Dalbergia sissoo	Leaf	0.58	25.22	51.18	0.08	2.55	1.77	22.09	0.32	BDL	0.22	0.08	2.76	24.05
	Pod	0.60	14.57	51.49	0.07	5.37	2.83	21.75	0.11	BDL	0.17	0.12	0.45	11.09
	Stem	0.54	5.87	30.82	0.04	2.34	1.30	8.46	0.04	BDL	0.25	0.07	3.28	38.69
Syzygium cumini	Leaf	0.65	71.72	36.75	0.41	1.29	1.15	3.68	0.00	BDL	0.14	0.10	1.76	23.29
	Stem	0.31	62.81	39.86	2.94	2.98	1.71	23.64	0.00	BDL	0.15	0.08	2.77	43.86
Bamboo sps	Leaf	0.38	21.49	66.66	0.15	1.99	2.33	7.75	0.00	BDL	0.12	0.08	3.29	34.05
	Stem	0.24	1.86	24.47	0.01	0.36	0.63	2.85	0.00	BDL	0.14	0.08	4.54	54.23
	Branch	0.70	5.31	17.63	0.02	0.64	1.23	7.64	0.02	BDL	0.15	0.41	3.33	43.67
Holarrhena antidysenterica	Flower	0.73	349.88	54.96	4.52	12.16	4.35	74.76	0.00	BDL	0.41	0.20	0.44	11.10
	Leaf	0.37	353.10	50.76	3.56	7.04	2.78	113.33	0.02	BDL	0.18	0.09	1.89	21.04

	Stem	0.44	73.36	31.82	0.79	7.01	1.44	32.80	0.01	BDL	0.15	0.06	3.29	37.20

Note: BDL=Below detection limit

Table 12. Heavy Metals concentrations in plant samples collected from Site V

Site - V Check Dam - 3B														
Plants Name	**Parts**	**Metal conc. (mg kg^{-1}DW)**												
		Cr	**Mn**	**Fe**	**Co**	**Ni**	**Cu**	**Zn**	**As**	**Hg**	**Cd**	**Pb**	**F**	**Ba**
Leucaena leucocephala	Stem	0.64	3.38	35.12	0.04	0.76	1.19	8.31	0.00	BDL	0.13	0.07	2.18	23.67
	Leaf	0.67	13.38	106.69	0.13	2.67	3.31	25.51	0.03	BDL	0.14	0.09	1.12	18.21
Albizia julibrissin	Stem	0.55	6.66	32.60	0.01	0.45	1.70	8.93	0.53	BDL	0.08	0.02	1.29	43.27
	Leaf	0.49	9.56	67.99	0.00	0.37	1.77	7.36	0.11	BDL	0.08	0.03	1.22	32.89
Azadirachta indica	Stem	0.14	0.42	32.47	0.00	0.13	0.33	0.48	0.00	BDL	0.19	0.02	1.34	23.45
	Leaf	0.27	2.01	67.07	0.00	0.20	1.25	1.78	0.00	BDL	0.20	0.08	0.92	16.85
Tectona grandis	Leaf	0.29	2.41	73.44	0.00	1.76	6.96	9.84	0.00	BDL	0.20	0.04	2.43	12.98
	Stem	0.21	1.15	37.49	0.00	1.25	5.47	6.05	0.00	BDL	0.20	0.05	1.94	25.98
Eucalyptus tereticornis	Stem	0.15	0.96	9.47	0.00	0.24	0.75	1.60	0.00	BDL	0.22	0.07	1.82	32.95
	Leaf	0.21	2.53	41.53	0.00	0.65	1.15	18.56	0.00	BDL	0.20	0.09	0.19	23.19
Casuarina equisetifolia	Leaf	0.39	22.10	34.66	0.10	1.00	0.96	3.29	0.00	BDL	0.20	0.11	1.11	12.94
	Stem	0.35	14.98	51.52	0.00	0.46	0.73	3.59	0.01	BDL	0.20	0.04	1.78	32.87
Zizyphus nummularia	Leaf	0.70	16.86	58.01	0.00	0.42	0.91	4.42	0.00	BDL	0.20	0.16	0.93	21.98
	Stem	0.63	0.83	40.48	0.00	0.35	0.75	5.04	0.00	BDL	0.19	0.02	1.11	34.98
Dalbergia sissoo	Pod	0.70	3.92	50.68	0.00	1.06	2.36	3.51	0.00	BDL	0.20	0.02	0.23	9.87
	Leaf	0.77	12.20	61.48	0.00	0.51	1.56	7.61	0.00	BDL	0.20	0.15	1.11	12.86
	Stem	0.49	3.13	31.38	0.00	0.62	2.79	6.05	0.00	BDL	0.20	0.02	1.98	32.97
Cassia fistula	Leaf	1.15	4.57	58.17	0.00	1.16	1.44	5.44	0.00	BDL	0.20	0.03	1.11	23.86
	Stem	0.48	1.09	17.00	0.00	0.78	1.30	4.62	0.00	BDL	0.20	0.04	1.98	45.89
Hyptis suaveolens	Leaf	1.15	14.63	355.20	0.00	0.32	1.49	6.28	0.02	BDL	0.20	0.02	1.23	22.98
	Inflorescence	0.94	11.57	107.38	0.07	0.80	5.30	14.24	0.00	BDL	0.25	0.14	0.09	9.43
	Stem	0.54	9.93	57.06	0.01	0.31	4.10	7.43	0.00	BDL	0.19	0.02	1.99	25.98
Eupatorium adenophorum	Stem	0.73	7.96	31.29	0.00	2.00	1.37	6.28	0.00	BDL	0.21	0.09	2.76	43.87
	Leaf	0.95	24.42	159.37	0.00	1.13	3.28	6.15	0.00	BDL	0.20	0.04	1.43	16.08
Calotropis procera	Leaf	1.08	12.13	110.33	0.00	0.93	1.90	8.13	0.00	BDL	0.20	0.36	2.99	23.56
	Stem	1.12	19.74	62.74	0.00	1.04	1.69	10.38	0.00	BDL	0.20	0.06	3.57	43.08
Holarrhena antidysenterica	Leaf	1.04	11.61	83.14	0.00	2.01	3.48	9.11	0.00	BDL	0.20	0.05	0.95	26.58
	Stem	0.58	3.97	26.53	0.00	1.16	2.43	7.60	0.00	BDL	0.20	0.04	1.67	27.00

Note: BDL=Below detection limit

Table 13. Heavy Metals concentrations in plant samples collected from Site VI

Site - VI Reservoir Pond														
Sample no. Plant	**Part**	**Heavy metal concentrations (mg kg^{-1})**												
		Cr	Mn	Fe	Co	Ni	Cu	Zn	As	Hg	Cd	Pb	F	Ba
1. *Ficus hispida*	Leaf	2.98	48.19	1830	1.19	1.98	25.89	13.28	0.004	BDL	0.29	1.28	1.23	43.98
	Stem	3.29	25.90	920	1.32	1.11	18.98	10.23	0.09	BDL	0.11	0.78	0.89	55.98
2 *Calotropis procera*	Leaf	3.90	59.29	1726	2.91	2.45	24.90	28.10	0.007	BDL	0.32	1.98	0.21	43.98
	Stem	2.75	43.57	1093	1.98	1.46	32.97	32.98	0.09	BDL	0.87	2.89	1.76	54.89
3 *Leucaena leucocephala*	Leaf	1.99	46.56	739	1.04	1.82	15.98	22.91	0.003	BDL	0.19	0.84	1.28	21.87
	Stem	2.87	32.87	886	2.89	0.98	24.67	32.87	0.008	BDL	0.11	1.65	1.89	32.09
4 *Ficus religiosa*	Leaf	4.23	39.85	1839	2.84	2.22	17.19	19.18	0.05	BDL	0.39	0.83	1.29	35.78
	Stem	2.78	45.97	1278	1.18	1.98	11.12	23.89	0.1	BDL	1.21	1.98	1.11	54.98
5 *Lantana camara*	Leaf	5.29	29.28	829	2.11	3.18	14.87	18.11	0.07	BDL	0.54	2.22	2.81	24.98
	Stem	3.78	32.98	674	1.76	1.89	27.89	23.87	1.02	BDL	0.94	3.26	1.78	34.98
6 *Zizyphus nummularia*	Leaf	1.65	35.98	738	0.98	1.82	27.81	11.20	0.006	BDL	0.13	0.28	1.02	23.67
	Stem	0.34	54.65	346	1.11	2.76	18.96	7.32	0.004	BDL	0.23	2.19	1.12	43.27
7 *Pteris vittata*	Leaf/frond	3.90	21.94	839	1.76	1.82	19.49	27.18	3.89	BDL	0.11	0.22	2.10	54.22
8 *Acacia auriculiformis*	Leaf	1.09	25.03	638	2.09	1.27	18.98	21.98	0.004	BDL	0.32	0.83	1.92	23.59
	Stem	2.12	32.45	436	1.28	0.93	21.98	32.85	0.03	BDL	0.18	0.72	1.11	32.86
9 *Lagerstroemia Sps*	Leaf	3.29	18.09	748	1.98	1.78	11.98	12.38	0.09	BDL	0.17	0.28	1.09	43.22
	Stem	2.16	12.98	1198	1.21	0.93	25.92	32.98	0.11	BDL	0.23	0.65	1.11	54.32
10 *Hydrilla verticillata*	Leaf	1.04	34.98	364	0.98	0.93	1.58	13.18	0.02	BDL	0.09	0.19	1.28	1.98
11 *Azadirachta indica*	leaf	2.13	24.54	410	1.10	1.24	3.29	1.47	0.01	BDL	0.12	0.06	1.32	32.87
	Stem	1.11	32.85	290	1.87	2.89	4.98	1.11	0.08	BDL	0.22	0.09	1.11	45.38

8. Faunal diversity and analysis of heavy metals

Different groups of faunal samples including Insecta, Arachnids, butterflies and bovinae were collected from study sites (Fig. 4). The collected species mostly consist of Insecta followed by butterflies. In general, Site-IV had maximum ranges of species availability as compared to other sites. Apart from the live-animal collections, various animal-parts like cow-milk, cow-dung, and tail hair were also collected from the study sites.

Identification of faunal samples

The faunal samples were further identified by means of enumerating various morphological attributes (Fig. 4). Abnormalities of any morphological features were also recorded.

Processing of the samples

The dried samples were acid digested with HNO_3:$HCLO_4$ (3:1 v/v) for the heavy metal analysis. The digested samples were analysed with Inductively Coupled Plasma-Mass Spectrometry (ICP-MS) (Table 14).

Acraca terpsicose

Beetle

Argiope anasuja

Diplacodes trivialis

Fig 4. View of selected faunal samples collected from different sites

Metal content in faunal samples

Chromium (Cr) content-

Maximum concentration of Cr was observed in butterfly sample at site I followed by dragon fly at site V and dragon fly at site IV (Table 14).

Manganese (Mn) content-

Butterfly sample at site I showed maximum concentration of Mn followed by dragon fly at site III and dragon fly at site V (Table 14).

Iron (Fe) content

Maximum Fe concentration was found in dragon fly at site III and at site V followed by butterfly at site I (Table 14).

Cobalt (Co) content

Maximum Co content was found in dragon fly at site IV followed by spider at site III and ant at site VI (Table 14).

Nickel (Ni) conetnt

Maximum Ni concentration was observed in dragon fly at site V followed by site II (Table 14).

Copper (Cu) content

It was maximum in dragon fly (74.65 mg kg^{-}1) at site V followed by spider (66.24 mg kg^{-}1) at site I and dragon fly (60.48 mg kg$^{-1)}$ at site IV (Table 14).

Zinc (Zn) content

Maximum amount of Zn (413.53 mg kg^{-1}) was found in dragon fly sample at site V, and at site IV (195.25 mg kg^{-1}) and in Sand hopper (138.51 mg kg^{-1}) at site VI (Table 14).

Arsenic (As) content

Its concentration was maximum in dragon fly (1.08 mg kg^{-1}) at site V, followed by dragon fly (0.83 mg kg^{-}1) at site IV (Table 14).

Cadmium (Cd) content

Concentration of Cd was below detection limit in most of the samples however dragon fly at site IV had Cd of 5.80 mg kg^{-}1 followed by spider (1.69 mg kg^{-}1) at site III (Table 14).

Lead (Pb) content

Maximum Pb was found in dragonfly (72.81 mg kg^{-1}) at site III followed by dragonfly (37.60 mg kg^{-1}) at site IV (Table 14).

Barium (Ba) content

Maximum Ba was found in cow dung (1.78 mg kg^{-1}) at site I followed by dragon fly (0.92 mg kg^{-1}) at site VI and dragon fly (0.88 mg kg^{-1}) at site IV (Table 14).

Fluoride and mercury were found to be below detection limit in all the samples.

Table 14 . Heavy Metals concentrations in faunal samples collected from different sites

Locations	Animal	Concentration of metals (mg kg^{-1})										
		Cr	Mn	Fe	Co	Ni	Cu	Zn	As	Cd	Pb	Ba
Site - I	*Argiope anasuja* **(Spider)**	0.08	0.78	304.63	0.04	1.61	56.24	42.36	0.32	0.00	0.83	0.78
	Pantala flavescens **(Dragon fly)**	0.49	35.84	372.23	0.00	0.71	22.61	46.48	0.13	0.00	7.35	0.62
	Cow dung	0.53	18.92	266.99	0.00	0.29	5.74	70.58	0.23	0.00	4.31	1.78
	Acraca terpsicose **(Butter fly)**	4.27	110.24	660.25	1.19	2.11	7.88	27.67	0.15	0.00	1.09	0.60
Site - II	**Lady bird beetle**	0.04	0.66	15.60	0.00	0.03	0.66	3.14	0.00	0.00	0.32	0.31
	Pantala flavescens **(Dragon fly)**	1.28	16.62	391.21	0.24	10.81	17.73	64.01	0.08	0.00	31.43	0.32
Site - III	*Pantala flavescens* **(Dragon fly)**	1.84	73.18	790.50	1.66	3.29	18.90	55.75	0.20	1.53	72.81	0.37
	Argiope anasuja **(Spider)**	2.26	17.37	781.55	18.14	1.51	14.90	73.51	0.44	1.69	31.65	0.32
Site - IV	*Pantala flavescens* **(Dragon fly)**	2.53	3.38	446.00	78.45	4.88	60.48	195.25	0.83	5.80	37.60	0.88
Site - V	**Cow hairs**	0.04	2.78	48.22	0.00	0.03	0.41	6.91	0.00	0.00	0.00	0.00
	Pantala flavescens **(Dragon fly)**	3.99	58.22	691.40	0.00	19.12	74.65	413.53	1.08	0.00	21.35	0.63
Site - VI	*Argiope anasuja* **(Spider)**	0.00	0.00	604.63	0.00	2.61	66.24	32.36	0.41	0.00	0.00	0.81
	Pantala flavescens **(Dragon fly)**	0.23	12.00	470.00	0.14	2.53	2.20	32.16	0.55	0.00	5.03	0.92
	Beetle	0.88	44.31	461.15	0.00	1.74	10.30	96.85	0.21	0.00	16.89	0.21
	Sand hopper	0.74	14.67	302.38	0.00	0.25	28.85	138.51	0.10	0.00	2.42	0.18
	Ant	0.00	0.00	0.00	11.15	0.00	0.00	0.00	0.10	0.00	0.002	0.21

Note= F and Hg were below detection limit

Table 15: Guidelines for Metals in foods, Vegetables and plants

Metals (mg kg^{-1})	WHO/FAO	EC/CODEX	Normal range in plants
As	1.0	-	-
Cd	1	0.2	<2.4
Co	-	-	-
Cr	1.30	-	-
Cu	30	0.3	2.5
Fe	48	-	400-500
Mn	500	-	
Ni	10	-	0.02-50
Pb	2	0.3	0.5-30
Zn	60	<50	20-100

Observations of the first year study

- The fluoride content in the ground and surface water within 0.5 km of the ash dumping area is <1.0mg/L which is well within the norms.
- It is noted that arsenic was within the permissible limits of BIS standards in all the samples except *Pteris vittata* at site VI. This may be because this plant is arsenic hyper accumulator. Another grass *Sacchraum spontaneuma* also showed high As levels. The reason could be that this grass is known to be a good phyto-remediator for many metals.
- It is to be noted that Hg was not found in any of the samples.
- The trace element concentration in the plant species has been found to be within limits.
- In general , plants growing at site IV seems to accumulate/sequester more targeted metals among all the sites.
- On the other hand, site VI exhibited maximum plant diversity and also showed less concentration of targeted metals.

Bioaccumulation and Bio-magnification studies

Bioaccumulation

Bioaccumulation is the process of accumulation of substances in living organisms and takes places over a certain length of time. These accumulated substances include chemicals, pesticides and heavy metals and they usually enter the systems through food chains. The levels at the lower tropic levels of food chains tend to gather or accumulate less concentration of substances than the levels above. Looking at the above bioaccumulation process, the first year data will serve as baseline data for targeted metals among different floral and faunal components. The tabulated values of floral and faunal samples represent real time metal concentrations for the sampling period.

Further to understand biomagnifications of selected metals in plant and animal systems, we need to quantify and compare respective metal concentrations for seasonal and inter-annual variations and quantitative analysis for bio-magnification, if any during the study period.