ENVIRONMENTAL IMPACT OF FLY ASH DISPOSAL SITES OF MAJOR THERMAL POWER PLANTS IN ODISHA

Submitted to

STATE POLLUTION CONTROL BOARD ODISHA
A/118, Nilakanthanagar, Bhubaneswar – 751 012

VEER SURENDRA SAI UNIVERSITY OF TECHNOLOGY BURLA
Sambalpur, Odisha -768018
March, 2018

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VSSUT Burla

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Dr. R. R. Dash

Dr. P. K. Pradhan

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ABBREVIATIONS

AAQ	:	Ambient Air Quality
AAS	:	Atomic absorption spectrophotometer
ASTM	:	American society for testing and materials
BARC	:	Bhaba Atomic Research Centre
BIS	:	Bureau of Indian Standards
CFA	:	Coal fly ash
CMPDI	:	Central Mine Planning and Design Institute
CPP	:	Captive Power Plant
CSIR	:	Council of Industrial and Scientific Research
EC	:	Electrical Conductivity
ESP	:	Electrostatic Precipitator
FFA	:	Class-F fly ash
FA	:	Fly ash
HCSD	:	High Concentration Slurry Disposal
HDPE	:	High Density Poly Ethylene
ICP-MS	:	Inductively Coupled Plasma Mass Spectroscopy
ISE	:	Ion Selective Electrode
ISO	:	International Standard Organization
LCSD	:	Lean Concentration Slurry Disposal
LDPE	:	Low Density Poly Ethylene
MCL	:	Mahanadi Coalfield Limited
MoEF	:	Ministry of Environment & Forest
MSL	:	Mean Sea Level
MTPA	:	Million Ton per Annum
MW	:	Mega Watt
NALCO	:	National Aluminium Company
NH	:	National Highway
NEERI	:	National Environmental Engineering Research Institute
NTPC	:	National Thermal Power Corporation
OCP	:	Open Cast Project
PM	:	Particulate Matter
PPM	:	Parts Per Million
SADT	:	Sulfuric Acid Digestion Test
SEM		Scanning Electron Microscope
TCLP	:	Toxicity Characteristics Leachate Procedure
TOR	:	Term of Reference
TPA	:	Ton per Annum
TPD	:	Ton per Day
TPP	:	Thermal Power Plant
WLT	:	Water Leachate Tests
WTP	:	Water Treatment Plant
XRD	:	X-ray Diffraction

Chapter 1

Introduction and Methodology

1.1 Introduction

Coal is a major source of energy in Odisha, and its consumption is predicted to increase in the future in order to meet the continuous demand for electric power generation. With the increasing use of coal, disposal of coal combustion waste products (known as ash) become a serious environmental problem. The Ministry of Environment and Forest (MoEF) Government of India stipulates various conditions to be implemented while issuing environmental clearance to the Thermal Power Plants. Some of the main stipulations related to ash disposal are

(a) 100% fly ash utilization

(b) Safe ash dyke design

(c) Preventing ground water contamination

(d) Control of fugitive dust.

(e) Area limitation for Ash disposal.

For utilizing and disposing the ash, the facilities to be provided for ash utilization and disposal management is planned at the conceptual stage. The design, planning of disposal system and ash utilization should fulfil the requirement of plant and comply with the MoEF norms. One of the major challenges in ash management is to protect the environment with safe disposal. For this purpose, it is necessary to have a well-planned design, construction, continuous monitoring and safe ash disposal management in place. The general guidelines for the design and maintenance of fly ash pond is enclosed as Appendix-A.

The environmental aspects of fly ash disposal aim at minimizing air and water pollution. The fly ash produced in Thermal Power Plants can cause all three environmental risks - air, soil, surface water and groundwater pollution. The pathways of pollutant movement through all these modes are schematically represented in **Fig. 1.1.**

Fly ash is an alumino silicate glass consisting of the oxides of Si, Al, and Fe with minor amounts of Ca, Mg, Na, K, Zn and S and various trace elements. The concentration associated with the ash may be either adsorbed on the surface of particle or incorporated into matrix.

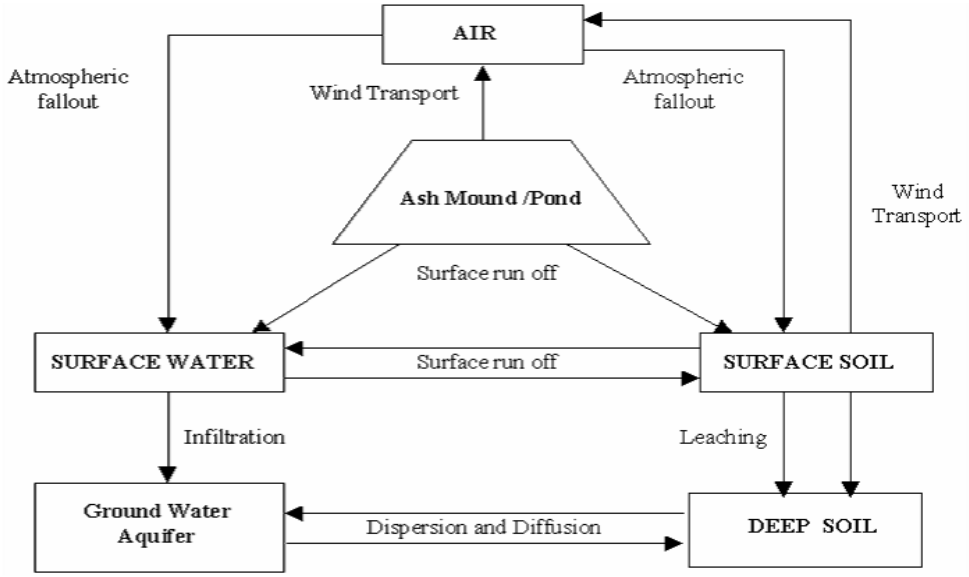


Fig. 1.1 Pathways of Pollutant Movement around Ash Disposal Site

A mechanism that appears to be common for all kind of ash during their formation is the condensation of metal and metalloid vapours on refractory core materials. As the ash particles and gas stream exit from the combustion chamber as flue gas, this results in locally higher concentrations of many trace elements at the surface of ash particles.

Difference in the heavy metal concentration in fly ash among the Thermal Power Plants (TPPs) can mainly be attributed to the use of different types of coal. The difference between the fly ash and bottom ash samples from the same power plant may be due to the difference in the mass of the elements. Elements (Cu, Zn) having lower mass can be carried and precipitated with the fly ash while elements having higher mass (Co) may settle rapidly after combustion and be enriched in bottom ash. Some elements, like Ni, however show no such preference. It has also been reported that the composition of trace elements in fly ash even from a single coal fired power plant may vary measurably on a daily basis.

At present, all most all the Thermal Power Plants are facing problem in getting land and other suitable place for ash disposal. The fly ash disposal sites of TPPs are here potential impact on the health hazard, and likely detoriate surface and ground water quality. There is a demand to study the impact of ash pond/mound on its surroundings and build up novel technologies for suitable disposal or the handling of ash and its effective recovery, reuse and recycling potential of fly ash.

1.2 Scope of the study

Since the fly ash disposal in ash pond or/and ash mound have potential to contaminate the ground water, surface water and soil in nearby areas, SPCB Odisha has awarded a project to study the environmental impact of fly ash disposal sites of following nine major Thermal Power Plants operating in Odisha.

(i) **Angul-Talcher Area**

- (a) CPP,National Aluminum Company Ltd (NALCO), Angul
- (b) Talcher Thermal Power Station (TTPS), Talcher
- (c) Talcher Super Thermal Power Station(TSTPS), Kaniha
- (d) Bhushan Energy Ltd, Dhenkanal

(ii) **Sambalpur-Jharsuguda Area**

- (a) Hindalco Industries Ltd. Hirakud
- (b) Bhushan Steel & Power Ltd, Rengali
- (c) OPGC, Bnaharpali
- (d) Vedanta Ltd., Jharsuguda
- (e) NTPC-SAIL Power Co. Ltd., Rourkela

Locations of Thermal Power Plants in Angul-Talcher area and Sambalpur-Jharsuguda area are presented in **Figure 1.2 and 1.3** respectively. Power generation capacity along with the fly ash generation and capacity of ash disposal sites for each plant is given in **Table 1.1**.

Table 1.1 Power Generation Capacity, Fly Ash Generation and Capacity of Ash Disposal Sites

S. N.	Name of Power Plant	Installed Capacity (MW)	Fly Ash Generation in Million tons (2016-17)	Capacity of ash disposal sites(Acre)
1	CPP, National Aluminum Company Ltd (NALCO), Angul	1200	2.3	519
2	Talcher Thermal Power Station (TTPS), Talcher	460	1.2	229(Mine voids) 281(Contingency)
3	Talcher Super Thermal Power Station (TSTPS), Kaniha	3000	7.1	1700
4	Bhushan Energy Ltd., Dhenkanal	300	0.50	294(Mine voids) 42 (Quarry voids)
5	Hindalco Industries Ltd. Hirakud	467.5	0.75	135.4
6	Bhushan Steel & Power Ltd, Rengali	370	0.63	155 (Ash mound) 1.44 acres (Quarry voids)
7	OPGC, Bnaharpali	420	1.2	250 (Exhausted) 150 (Operational)
8	Vedanta Ltd., Jharsuguda	3615	6.0	335
9	NTPC-SAIL Power Co. Ltd., Rourkela	120	0.46	71.5

Fig 1.2 Location Map Showing TPPs in Angul-Talcher Area

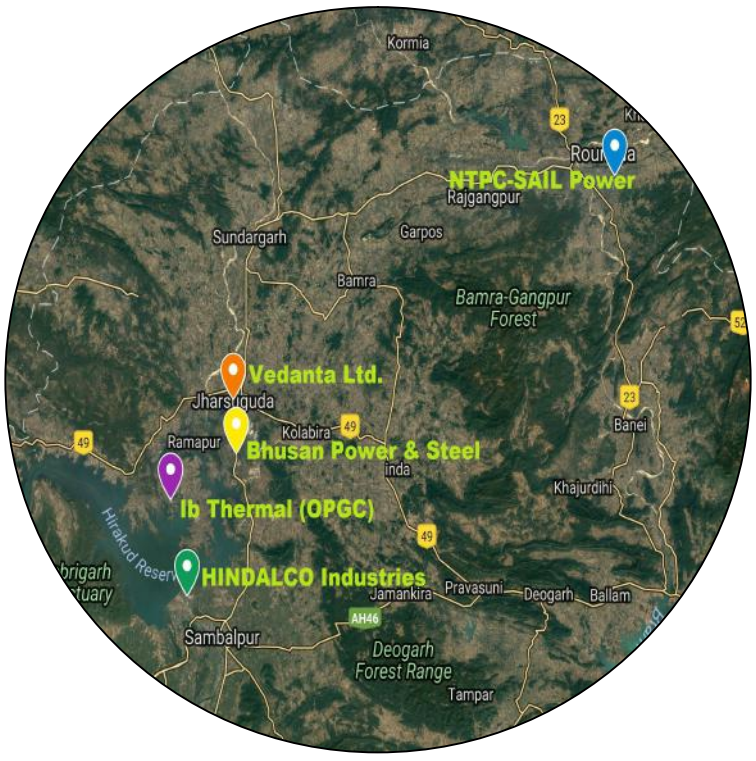


Fig 1.3 Location Map Showing TPPs in Sambalpur-Jharsuguda Area

As per the terms of reference, the following aspects have been taken for study.

- Scrutiny and verification of data submitted by the Thermal Power Plants (TPPs) in respect of ash disposal sites
- Inventory of ash disposal sites
- Characterization of fly ash with its leaching potential
- Collection and Analysis of air, surface & ground water & soil samples within 2 km of ash disposal sites
- Collection, compilation & interpretation of past data of air, water & soil quality around ash disposal area
- Assessment of volume of the allotted quarry voids for ash disposal.
- Assessment on present practices of ash management adopted by TPPs

The above industries were visited to collect data during Feb 2016 to May 2016 and Nov 2016 to January 2017.

The primary objective of an EIA study includes determining the present environmental status of the fly ash disposal sites of major Thermal Power Plants in Odisha and recommending necessary environmental control measures to mitigate the impacts and improve the environment.

EIA study, thus necessarily includes collecting detailed information on the existing environmental scenario or baseline data and establishing baseline data and establishing related data of the proposed activity.

The EIA is aimed at determining the environmental impacts on the study area surrounding the fly ash disposal sites, which encompasses all areas falling around the site. The major environmental disciplines to be studied include soils, surface and ground water quality, air quality etc. The report consists of field data generated over an annual cycle along with relevant secondary data collected from various agencies on the above disciplines. The report also consists of proposed pollution control measures, ash management and other recommended mitigatory measures.

1.3 Objective of the EIA Study

The objective of the study is to determine the environmental impact of fly ash disposal sites of major Thermal Power Plants in Odisha.

1.4 Methodology of study

The methodology of sampling of fly ash, surface water, ground water, air quality and soil etc are as follows;

- Fly ash was collected from ash disposal area were stored in a polyethylene bottle and kept in a refrigerator (4ºC) until the leaching tests were performed and heavy metal analysis were carried out.
- Ground water from the tube/dug wells from the villages and surface water from streams/rivers within 2.0 km of ash disposal sites were collected & stored in polyethylene bottles and kept in a refrigerator (4ºC) until the leaching tests were performed and heavy metal analysis were carried out.
- Soil sample collection: Top soil (0-5) cm samples were collected around the ash disposal site of all the plants. Samples were stored in a polyethylene bottle and kept in a refrigerator (4ºC) until the leaching tests were performed and heavy metal analysis were carried out.
- Air quality monitoring: Ambient air from the nearby villages around 2.0 km of ash disposal sites were collected &gravimetric analysis were performed for particulate matter analysis.

1.5 Analysis procedure

Physical properties of ash

The physical properties that are of particular interest are particle size distribution, specific gravity, and bulk density etc. The bulk density (ρ) is determined and the specific gravity (G) of fly ash and pond ash samples is determined by water pycnometer as per standard IS: 2386 (Part III). The porosity (ϕ) is calculated by using the following relationship:

$$\Phi = [1-(\rho/G)] \text{ X } 100\% \quad (1)$$

The coefficient of permeability is determined by a constant-head permeameter as per standard ASTM D-2434. The particle morphology of the fly ash and pond ash samples are analyzed from the micrographs obtained with a JEOL JSM-5800 Scanning Electron Microscope (SEM).

Chemical and mineralogical composition of ash

Element analysis of the ash sample was conducted by XRF instrument. In XRF analysis, pellets of various samples were produced by 30 tonne pressure and using polyvinyl acetate as a non-additive binder. After the preparation of pellets, they were placed into the XRF instrument for analysis. Mineralogical characteristics were determined by X-ray diffraction using Cu-Kα

radiation, where a properly dried sample were crushed with the help of motar pastel kept in a glass slide which was exposed to X ray in XRD instrument.

Trace elements

Strong acid digest test

The total leachable and non-leachable heavy metal concentration was determined by acid digestion method. A direct acid digestion test was carried out for determination of total concentrations of elements. Ash samples passing through 200 mesh (75 µm) were dried in an oven at about 110 °C for an hour. 0.5 g of the oven-dried ash sample was taken in a conical flask, and 2 ml of 40 % hydrofluoric acid (HF) was added followed by 10 ml of 69 % nitric acid (HNO_3) then, the mixture was heated to dryness on a hot plate. Again, 2 ml of 40 % HF was added followed by 10 ml of 69 % HNO_3 into the dry residue left in the conical flask and again heated to dryness on a hot plate. This process was repeated until no undigested residue was left in the conical flask. The completely digested ash in the conical flask was poured then with 100 ml of distilled water to get the digested ash dissolved in water. Finally, the solution was filtered by Whatman No. 42 filter paper and analyzed by inductively coupled plasma mass spectrometer (ICP-MS).

Toxicity characteristics leachate procedure

The toxicity characteristic leachate procedure (TCLP) requires the use of an extraction fluid made of buffered acidic medium to run the test. For this the selection of the extraction fluid is made prior to conducting the test. Acetic acid is used as an extraction liquid; pH is maintained at 4.99 as per USEPA procedure. A 5 g fly ash sample was taken and then extraction fluid equal to 20 times the amount of sample taken added to it. The system was tightly closed and then placed on the orbital shaker for 18 hours, rotating at 30 ± 2 rpm at a room temperature. The leachate samples were filtered and acidified with 2 ml of nitric acid and and analyzed by ICP-MS.

Other parameters

- Calcium: Flame photometer
- Fluoride: The fluoride in soil and water were determined by ion selective electrode (ISE).
- Reactive silica: determined by IS 3812 (Part-1) 2013 method.

Chapter 2

National Aluminium Company Ltd, Angul

2.1 Introduction

M/s National Aluminium Company Ltd. (NALCO) had set up a power plant at Angul way back in the year 1984 and the power generation from the first unit of the Captive Power Plant (CPP) was started in September 1986. Subsequently, it has increased its power generation capacity in stages and at present the power generation capacity of the CPP is 1200 MW (10x120MW). The plant is situated at a distance of 150 km from Bhubaneswar towards Sambalpur along NH 55. The topography of the area is more or less flat with gentle undulating with paddy field. The general elevation of the area varies from 105 m to 125 m above mean sea level. The area gets an annual rainfall of around 1400 mm and the water table in the region is shallow. The predominant winds are mostly from West followed by South and East direction. Calm conditions prevailed for about 32% of the total time

2.2 Ash management

All the units # 1 to 10 generate ash approx. 45 tph (ESP Fly Ash@33tph + Bottom Ash @12 tph) per unit. The total ash generated from the plant was about 2.3 million tons during the year 2016-17. At present the power plant generates about 5000 TPD of ash out of which 3800 TPD of ash is being sent to ash pond and the rest is supplied to fly ash brick, asbestos manufacturers and for low lying land development etc.

The Unit # 1 to 6 of the plant is having lean slurry disposal system. These units consume water at the rate of about 450tph/unit; thus generating slurry approx 500tph/unit. The fly ash from these units along with bottom ash is pumped to ash pond as lean slurry (ash to water ratio of 10:90). Every two units of the plant have a slurry pump house with two ash pumps. Each pump house has 3 series of pump with two pumps in each series (Pump capacity:850 m^3/hr). One series of pump is in continuous operation; another is in intermittent operation while 3rd series is standby. Each pump house is connected to the ash pond through 2 MS pipeline of 350 mm diameter each. The length of each pipeline is approx. 7 km. Total 8 no of pipelines are laid for pumping lean ash slurry to ash pond.

Unit # 7 to 10 has dry ash collection system. Dry fly ash from Unit # 7 to 10 is sent to ash Pond-IV in High Concentration Slurry Disposal (HCSD) mode (ash to water in ratio of 60:40).

Bottom ash of the units sent to ash pond I or II in lean slurry mode. 2 nos of HCSD pipe lines are laid for pumping in HCSD mode. The TPPs have also installed 4 ash silos of 500T capacity each and 2 silos of 1500T capacity each for storage of dry fly ash for subsequent utilization in making ash based products.

Fig. 2.1 shows the location of ash ponds. The industry has constructed its ash pond in an area of 800 acres which is located at a distance of 3.5-4.0 km from the plant. Ash pond is 3 pond system having ash pond I (210 acre), ash pond II (211.5 acre) and ash pond III (51.5 acre). Ash pond I and II function as sedimentation ponds while ash pond III functions as overflow lagoon. The ash pond IV with HDPE lining (46 acre) has also been constructed near existing ash pond having volume 5.5 lakh m^3. The overflow from the ash ponds is taken to clarifier from where it is recycled back to the plant for use in ash make-up water.

Fig. 2.1 Ash pond of M/s NALCO, Angul

A garland drain has been provided around the ponds, besides the overflow channel existing down the spillway. The overflow occurring in the rainy season is reportedly discharged to Nandira river. The location of the ash disposal site and its features are presented in **Table 2.1** and **Table 2.2** respectively.

Table 2.1 Location of Ash Disposal Site, NALCO CPP

Sl No	Details	Distance
1	Location of Ash pond	Angul village
2	Distance from the plants	3.5 km to the North of NALCO CPP
3	Distance from human habitation	Balaramprasad: 0.5 km in NE direction Kurdole:0.4km in SW direction Kukudanga: 0.4 km in NW direction
4	Distance from water bodies	100 m: Nandira river in North direction
5	Distance from educational institutions/ commercial infrastructures	Balaramprasad UP school: 1.0 km in NE direction Giranga Square: 1.0 km in SW direction
6	Distance from forest cover	Hill forest: 0.1 km East of pond 1,2,3 & South of pond -4
7	Distance from roads and railway line	Angul-Talcher Rly line: 0.2 km in South direction Angul- Thermal Road: 0.3 km in North and SE direction
8	Distance from heritage site	NA

Table 2.2 Features of Ash Disposal Site, NALCO CPP

Name of Ash Disposal Sites	Pond I	Pond II	Pond IV
Area (acre)	210	211.5	46
Type of lining	Clay	Clay	HDPE
Over flow Lagoon (OFL)	← 51.5 →		
Design height of each raising(m)	3.00	4.00	5.00
No. of raising designed for	6	6	6
Present stage of raising	6th	6th	1st
No. of pipelines	4	4	2
Distance from plant (km)	3.5	4.0	3.5
Volume of ash stored(million m^3)	17.54	17.53	0.361
Operating since	01.01.1997	01.08.2003	01.06.2009

The volume of ash ponds may be calculated using the following formula.

$$V = \frac{h}{3} \times (B_1 + B_2 + \sqrt{B_1 \times B_2})$$

For ash pond-1, Bottom area= 210 acre, top area= 200 acre and height= 20 m

For ash pond-1, Bottom area= 211 acre, top area= 210 acre and height= 20 m

The current status of ash ponds is as follows;

Ash pond - I is divided into two compartments known as Part-A and Part-B. The dyke raising of Part-A and Part-B from 110m RL to 113m RL has been completed and Part A was in active state. Similarly, Ash Pond - II is divided into two compartments A and B. The industry has made ash mound on Part-B only by evacuating the pond ash from ash pond-I (Part A & B) and Part A of pond-II. It was reported that construction of ash mound will be done by raising mound heights in two stages. First phase of ash mound has been completed from 107m RL to 111m RL in part B of ash pond-II.

With a quantity of 15 lakh cum of ash by which an equivalent space of 15 lakh cum for lean slurry disposal in existing pond was created. 2nd phase of ash mound work from 111m RL to 115m RL shall create a space of another 15 lakh cum. With the present dyke raising of ash pond-I and ash mound over ash pond-II for a quantity of 15 lakh cum (2nd phase), the ash pond is exposed to cater for ash slurry disposal up to 2018. With construction of ash mound (3rd and 4th phase) for a total capacity of about 35 lakh cum, the industry is able to discharge ash slurry in ash pond up to 2020.

Ash Pond -IV is meant for HCSD discharge only. At present, around 2.5 lakh cum space is available for disposal which will cater up to 2018.

Apart from its usual disposal of fly ash in the ash ponds, the plant is also in process of using mine void of Bharatpur south quarry of MCL for ash disposal. The volume of mine void is approximately 13.1 million m^3. The lean slurry transportation system for mine void filling at Bharatpur South Quarry is about to be completed. It was observed that the CPP has conducted one rapid EIA by Central Mine Planning and Design Institute (CMPDI), Ranchi for transportation and backfilling of ash in abandoned mines of MCL in 2003 indicating safe disposal of ash in mine void.

The Ministry of Environment and Forests has given permission on 5th Sept, 2013 to M/s. NALCO for disposal of fly ash into mine void as pilot project for one year. However, it could not be implemented due to certain reasons. Further the CPP has made extensive studies such as permeability study through UPES, Dehradun, heavy metal studies and Nucleoid study of ash

pond through BARC. The studies made by different agencies reveal that the ash disposal in the ash pond is safe.

2.3 Sampling locations

Ground water, soil, fly ash and ambient air samples have been collected within 2 km from the boundary of the ash disposal site. **Fig. 2.2** shows the location of sampling sites. The description of sampling site and its distance from the ash disposal site are presented in **Table 2.3**.

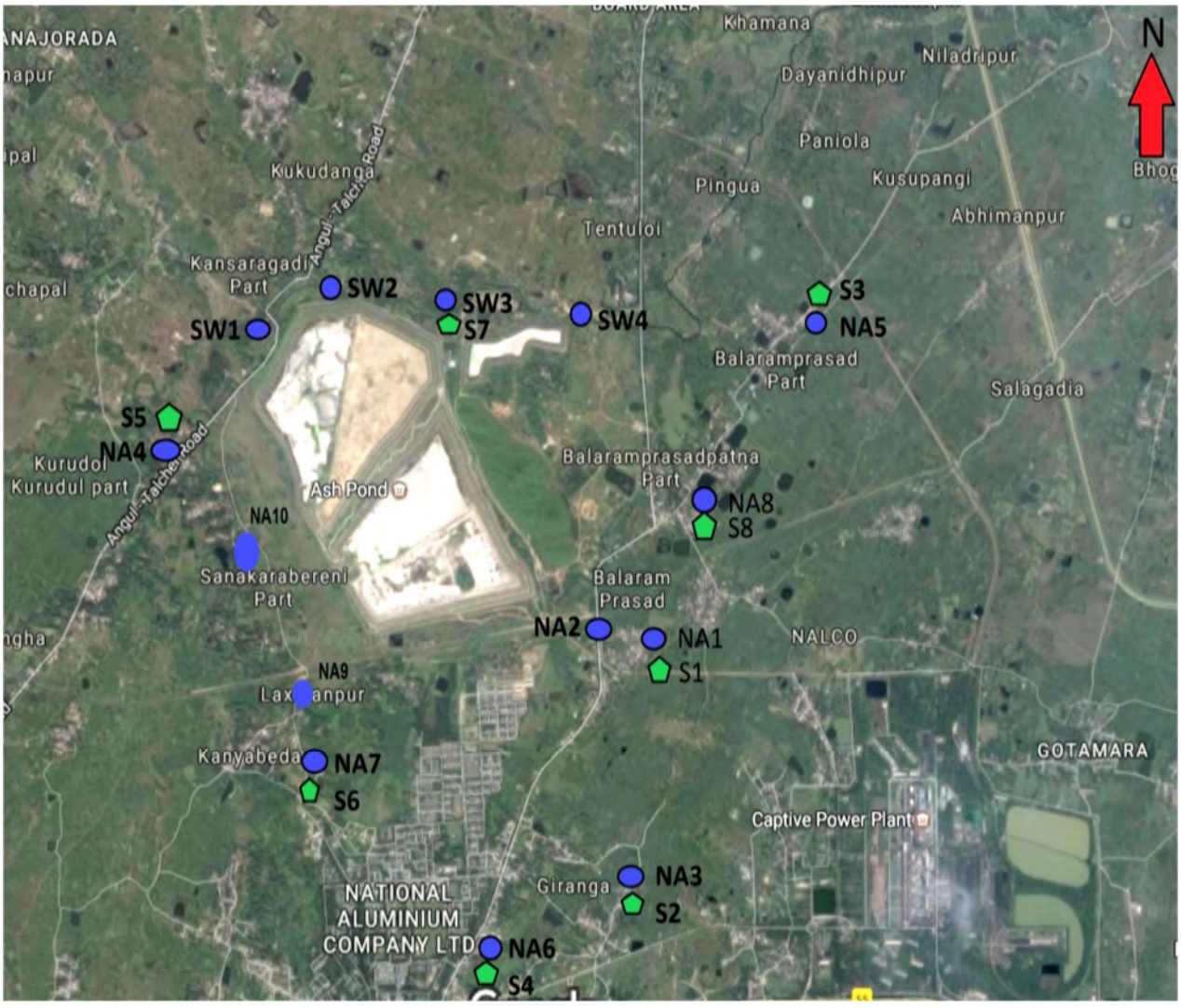


Fig. 2.2 Location of Sampling Points around Ash Pond of M/s NALCO CPP, Angul

Table 2.3 Details of Sampling Locations

Nomenclature	Description of sampling locations	Distance from Ash Pond (km)	Direction w.r.t. Ash Pond
Ground water			
NA1	Kendhudhipa	0.6	SE
NA 2	NALCO Bidyut colony	0.5	SE
NA 3	Girang (Sidheswar temple)	1.5	SE
NA 4	Kurdul, Matigudiasahi	1.0	NW
NA 5	KaifuliaSahi	1.0	N
NA 6	Nalco Township (Daily Market)	2.0	W
NA7	Kanyabeda	1.0	SW
NA8	Balaram Prasad Chhak	1.0	SE
NA9	Laxmanpur/Suniamunda	0.5	SW
NA9(OW)	Laxmanpur/Suniamunda	0.5	SW
NA10	Kurdul (Nuasahi)	0.6	W
NA10(OW)	Kurdul (Nuasahi)	0.6	W
Surface water			
SW1	Nandira river	0.2	N
SW2	Nandira river	0.1	N
SW3	Nandira river	0.2	N.
SW4	Nandira river	0.5	N
Ash			
A1	ESP Fly ash	0.0	-
A2	Ash Pond-I	3.5	W
A3	Ash Pond-II	4	W
Soil			
S1	Kendhudhipa	0.6	SE
S2	Girang(Sidheswar temple)	1.5	SE
S3	KaifuliaSahi	1.0	N
S4	Nalco Township (Daily Market)	2.0	W
S5	Kurdul, Matigudiasahi	1.0	NW
S6	Kanyabeda	1.2	SW
S7	Nandira river bed	0.2	N
S8	Balaram Prasad Chhak	1.0	SE
AAQ monitoring station			
NA1	Fly ash pond	0.1	E
NA2	NALCO Township	2.0	w

2.4 Results and discussion

The results of the physico-chemical & mineralogical characterization of fly ash and pond ash samples, heavy metal analysis in ground water, leachability studies of fly ash & soil are given as follows:

2.4.1 Physical properties

It is found that fly ash possesses a maximum mean particle diameter (D50= 36.8μm), whereas, pond ash with mean particle diameter (D50) of 43.44 μm. **Table 2.4** shows physical properties of the fly ash and pond ash samples. The results of the permeability test of ash samples show that the coefficient of permeability values of both the fly ash and pond ash samples is very low. The average specific gravity and bulk density of fly ash are found to be more than the pond ash samples.

Table 2.4 Physical Properties of the Fly Ash and Pond Ash Samples

Parameters	Color	Specific Gravity	Bulk density, g/cc	Porosity,%	Coefficient of permeability, k x 10^{-4} cm/s
Fly ash	Gray	1.95- 2.26	1.05 - 1.08	50-54	1.58 - 1.77
Pond ash	Dark Gray	1.94 - 2.14	1.03 - 1.05	51-58	3.67 - 4.42

The scanning electron micrographs of fly ash and pond ash at ×1000 magnification are shown in **Figs. 2.3 (a& b)**. The micrographs reveal that the fly ash samples consist of mostly spherical particles. Comparatively, the pond ash particles are coarser in size, highly irregular in shape and porous in nature than the fly ash particles.

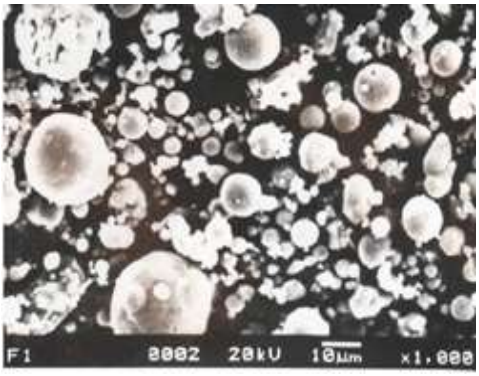


Fig. 2.3 (a)SEM of Fly Ash Sample

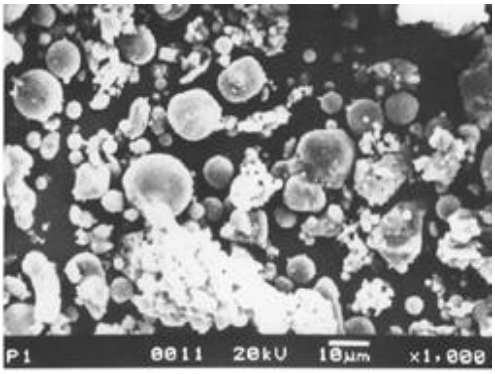


Fig. 2.3 (b)SEM of Pond Ash Sample

2.4.2 Chemical and mineralogical compositions

The chemical compositions (element oxides) of ash samples are presented in **Fig. 2.4 (a & b)**. The results of the chemical composition (element oxides) show that the ash samples are enriched predominantly with silica (SiO_2) and alumina (Al_2O_3). In addition, they also contain small amounts of iron oxide (Fe_2O_3), TiO_2, K_2O, CaO and MgO. The rest of the compounds present in the ash samples are in minor concentrations. The sum of SiO_2, Al_2O_3 and Fe_2O_3account for more than 90% of the total composition in fly ash and pond ash samples. The fly ash and pond ash samples possess more or less similar physico-chemical and mineralogical properties. The reactive silica content in fly ash is found to be in the range of 16-18%.

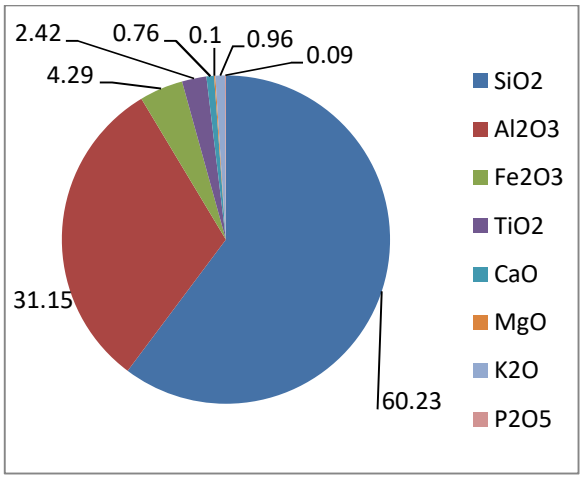


Fig. 2.4 (a) Element Oxides of Fly Ash

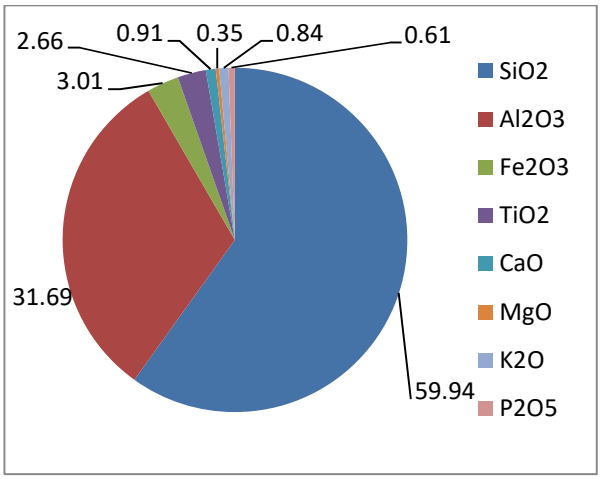


Fig. 2.4 (b) Element Oxides of Pond Ash

2.4.3 *Heavy metal analysis in water samples*

The pH of the fly ash and soil was determined in 1:5 solutions (1fly ash/soil: 5water). The variation of pH with time is presented in **Fig. 2.5**. The pH value of fly ash is acidic in nature after one hour of measurement and the value increases as the time passes. This behaviour of fly ash may be mainly due to presence of alumina (in form of Al_2O_3) which exhibits amphoteric character. When fly ash is mixed with water, alumina present in fly ash initially slower pH of the slurry as alumina has 56% basic constituents and 44% acidic constituents. As acidic constituents are generally more soluble in water, pH of the sample falls immediately after mixing with water. As the time passes, basic constituents neutralises acidic fraction and pH of the sample gradually increases and equilibrium is reached.

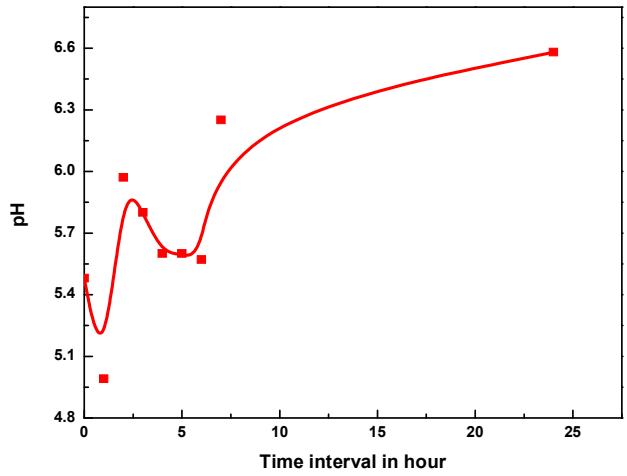


Fig. 2.5 Variation of pH with Time

Small amount of alkali present in fly ash also neutralises the acidic fraction of alumina. The final pH value of the samples is observed as 6.67, when equilibrium is reached. It was also observed that the pH of the soil of the study area ranges between 6.5 and 7.5.

The ground water analysis was performed on the water samples collected from the bore wells and open wells from different locations in the area around fly ash dumpsite. Details of concentration of heavy metals in the groundwater and surface water samples near the ash ponds and at the surrounding villages are given in **Table 2.5** and **Table 2.6**. **Fig. 2.6** and **2.7** show the concentration of heavy metal in pre & post-monsoon respectively.

Ground Water Quality

Pre-monsoon Season 2016

- The analysis results indicate that the pH values in the range of 6.85 to 7.8, which is well within the specified standard of 6.5 to 8.5.
- The EC was observed in the range of 215 mg/l to 702 mg/l, the maximum TDS value was observed at Kanyabeda (NA7) and whereas minimum value was observed at Girang (NA3).
- The Ca was observed in the range of 42 mg/l to 87 mg/l exceeding the permissible levels of BIS guidelines
- The F was observed in the range of 0.73 mg/l to 1.27 mg/l, the maximum value was observed at Girang (NA3) and whereas minimum value was observed at Kendudhipa (NA1). Fluoride concentration was observed to be above the standard mostly in pre-monsoon.
- The metal concentrations except Al were found to be within acceptable limit of BIS guidelines.

Table 2.5 Analysis Result of Groundwater Sample

Sample ID	Season	pH	EC	Ca	Al	Cr^{+6}	T. Cr.	Cd	Pb	Cu	Zn	Hg	F^-
NA1	Premonsoon	6.85	452	72	0.046	0.022	0.11	BDL	0.014	0.02	1.46	0.00011	0.73
	Postmonsoon	7.35	665	122	0.02	0.018	0.180	BDL	0.01	BDL	0.76	BDL	0.41
NA2	Premonsoon	7.10	586	42	0.048	0.030	0.180	0.0001	0.015	0.02	1.61	0.00021	0.97
	Postmonsoon	7.28	865	67	0.021	0.026	0.171	BDL	0.01	BDL	0.91	BDL	0.65
NA3	Premonsoon	7.13	215	57	0.011	0.011	0.112	0.0002	0.009	0.016	0.14	0.00021	1.27
	Postmonsoon	7.60	612	83	0.04	0.031	0.182	BDL	BDL	BDL	0.18	BDL	1.15
NA4	Premonsoon	6.88	445	36	0.022	0.038	0.193	BDL	0.003	0.009	0.35	0.00028	0.87
	Postmonsoon	7.28	478	61	0.05	0.031	0.186	BDL	BDL	BDL	0.55	BDL	0.65
NA5	Premonsoon	7.10	360	67	0.033	0.032	0.129	0.0003	0.034	0.023	0.79	BDL	0.88
	Postmonsoon	7.25	315	115	0.018	0.033	0.188	BDL	0.021	BDL	0.59	BDL	0.79
NA6	Premonsoon	6.90	302	65	0.044	0.017	0.048	BDL	0.009	0.012	0.17	BDL	1.19
	Postmonsoon	7.41	412	105	0.030	0.019	0.050	BDL	0.004	BDL	BDL	BDL	0.93
NA7	Premonsoon	6.91	702	87	0.007	0.015	0.049	BDL	BDL	0.016	0.81	BDL	1.10
	Postmonsoon	7.70	813	107	BDL	0.039	0.151	BDL	BDL	BDL	0.61	BDL	0.84
NA8	Premonsoon	7.17	686	45	0.015	0.032	0.118	BDL	0.003	0.018	0.61	BDL	1.15
	Postmonsoon	7.39	786	55	0.018	0.036	0.162	BDL	BDL	BDL	0.41	BDL	0.74
NA9	Premonsoon	7.15	334	48	0.041	0.035	0.121	BDL	0.015	0.02	0.117	BDL	0.98
	Postmonsoon	7.75	456	62	0.031	0.038	0.178	BDL	BDL	BDL	BDL	BDL	0.89
NA9 (OW)	Premonsoon	7.31	478	58	0.007	0.018	0.045	BDL	0.010	0.008	0.052	BDL	1.09
	Postmonsoon	7.81	897	65	BDL	0.02	0.041	BDL	BDL	BDL	BDL	BDL	0.93
NA10	Premonsoon	7.55	453	42	0.011	0.02	0.050	BDL	BDL	0.016	0.268	BDL	1.12
	Postmonsoon	8.10	675	62	0.028	0.046	0.182	BDL	BDL	BDL	BDL	BDL	0.89
NA10 (OW)	Premonsoon	7.80	654	60	0.010	0.026	0.108	BDL	BDL	0.013	0.051	BDL	0.95
	Postmonsoon	8.2	976	117	0.018	0.039	0.153	BDL	BDL	BDL	BDL	BDL	0.64
	AL	**6.5-8.5**	**-**	**75**	**0.03**	**-**	**0.05**	**0.003**	**0.01**	**0.05**	**5.0**	**0.001**	**1.0**
	DL	-	-	-	0.002	-	0.01	0.0001	0.002	0.004	0.002	0.00007	-

Unit of all parameters is mg/l except pH and EC; Unit of EC is µS/cm; pH has no unit; AL: Acceptable Limit as per IS 10500:2012; DL: Detectable limit

Table 2.6 Analysis Result of Surface Water Sample

Sample ID	Season	pH	EC	Ca	Al	Cr^{+6}	T. Cr.	Cd	Pb	Cu	Zn	Hg	F^-
SW1	Premonsoon	6.72	435	22	0.045	0.012	0.12	BDL	0.023	0.02	0.86	BDL	1.80
	Postmonsoon	6.88	835	47	0.112	0.003	0.08	BDL	0.011	BDL	0.46	BDL	1.12
SW2	Premonsoon	7.19	886	35	0.058	0.010	0.113	BDL	0.03	0.02	0.88	BDL	1.80
	Postmonsoon	7.19	886	65	0.113	0.003	0.083	BDL	0.012	BDL	0.41	BDL	1.11
SW3	Premonsoon	7.13	815	41	0.056	0.011	0.112	0.001	0.042	0.02	0.81	BDL	1.85
	Postmonsoon	7.18	815	61	0.118	0.003	0.086	BDL	0.012	BDL	0.41	BDL	1.10
SW4	Premonsoon	7.23	598	66	0.061	0.031	0.113	BDL	0.043	0.02	0.85	BDL	1.82
	Postmonsoon	7.33	898	86	0.127	0.008	0.095	BDL	0.013	BDL	0.46	BDL	1.20

Unit of all parameters is mg/l except pH and EC; Unit of EC is µS/cm; pH has no unit; AL: Acceptable Limit as per IS 10500:2012; DL: Detectable limit

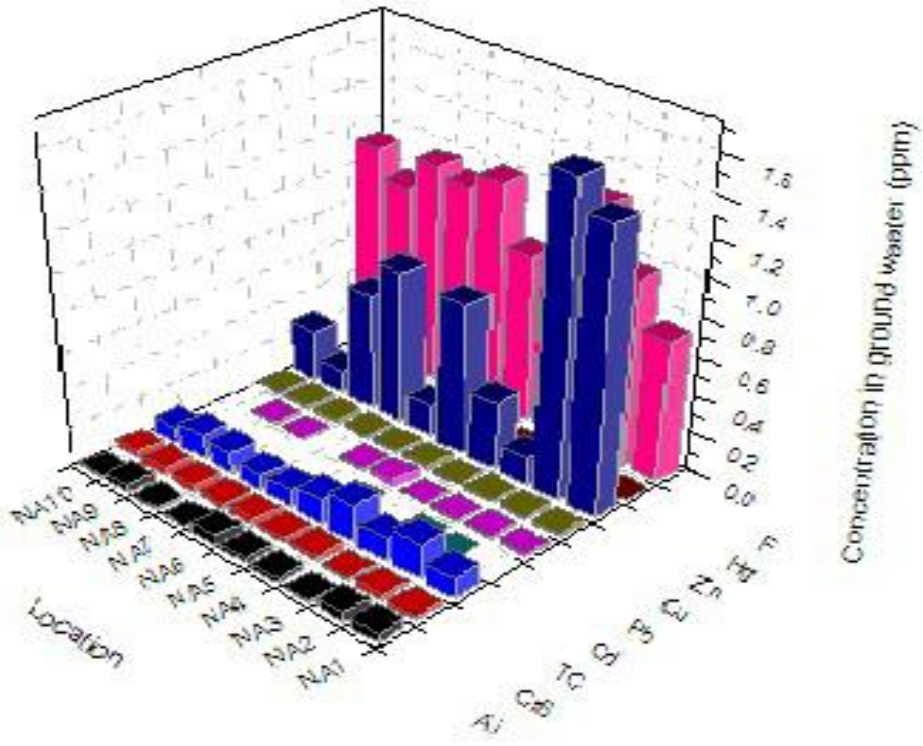


Fig. 2.6 Metal Concentration in Pre-Monsoon

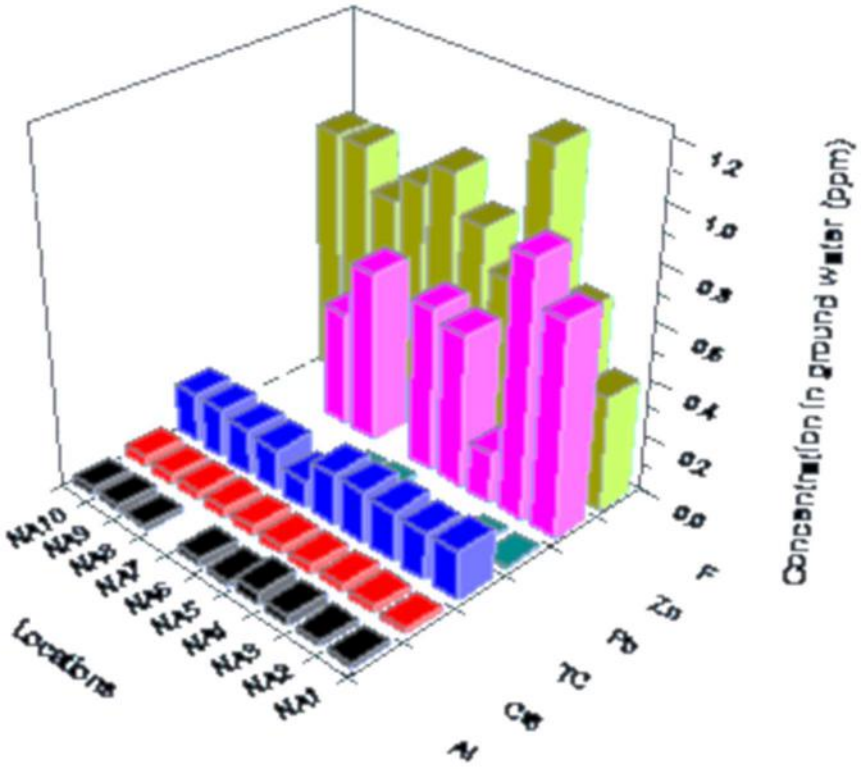


Fig. 2.7 Metal Concentrations in Post-Monsoon

Post Monsoon Season 2016

- The analysis results indicate that the pH values in the range of 7.25 to 7.75, which is well within the specified standard of 6.5 to 8.5.
- The EC was observed in the range of 315 mg/l to 976 mg/l, the maximum TDS value was observed at Kurdul (NA10) and whereas minimum value was observed at Nalco Township (NA5).
- The Ca was observed in the range of 55 mg/l to 122 mg/l exceeding the permissible levels of BIS guidelines
- The F was observed in the range of 0.41 mg/l to 1.15 mg/l, the maximum value was observed at Girang (NA3) and whereas minimum value was observed at Kendudhipa (NA1).
- The metal concentrations except Al were found to be within acceptable limit of BIS guidelines.

Surface Water Quality of Nandira River

Most of the villages in the project area have hand pumps which are used for drinking and other domestic uses. Nandira is one of the river which almost surrounds the ash ponds. The river water data of pre and post monsoon season are as follows;

Pre-monsoon Season 2016

- The analysis results indicate that the pH values in the range of 6.72 to 7.23.
- The EC was observed in the range of 435 mg/l to 886 mg/l.
- The Ca was observed in the range of 22 mg/l to 66 mg/l.
- The F was observed in the range of 1.80 mg/l to 1.85 mg/l.
- The metal concentrations except Cd, Cu and Hg were found in the Nandira water samples.

Post Monsoon Season 2016

- The analysis results indicate that the pH values in the range of 6.88 to 7.33.
- The EC was observed in the range of 815 mg/l to 898 mg/l.
- The Ca was observed in the range of 47 mg/l to 86 mg/l.
- The F was observed in the range of 1.10 mg/l to 1.20 mg/l, the maximum value was observed at SW4 and whereas minimum value was observed at SW3.
- The metal concentrations except Cd, Cu and Hg were found in the water samples.

Few pre and post-monsoon groundwater quality parameters of two villages surrounding NALCO ash ponds were compared with the previous studies conducted by other researchers to find out the trends of the parameters which are presented in **Fig. 2.8 and 2.9**. It is evident from the figures that the EC of groundwater has increased over the years. Further the groundwater quality

parameters in and around NALCO was compared with the data of another researcher which was presented in **Table 2.7**. The table shows that there is not much difference in results except EC.

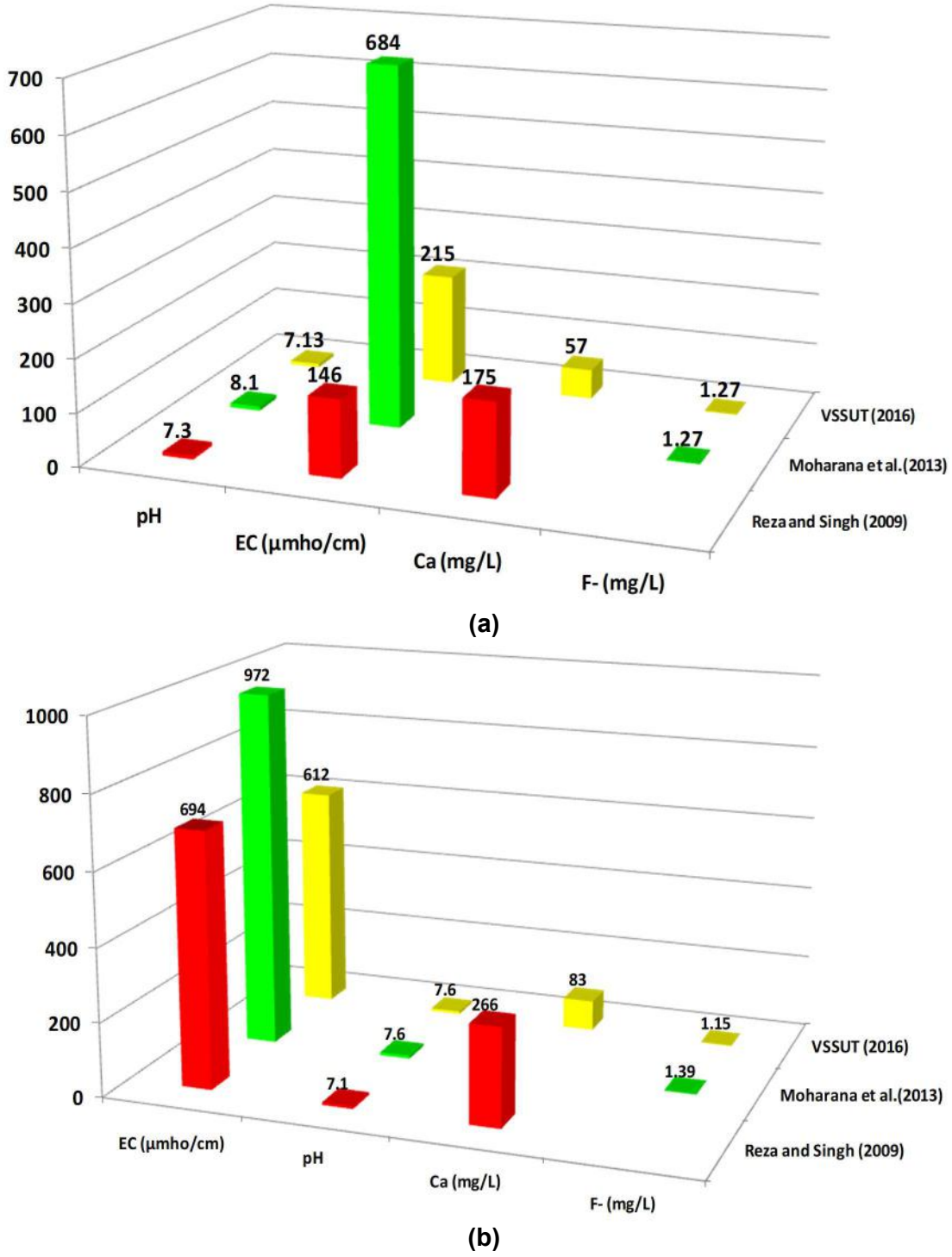
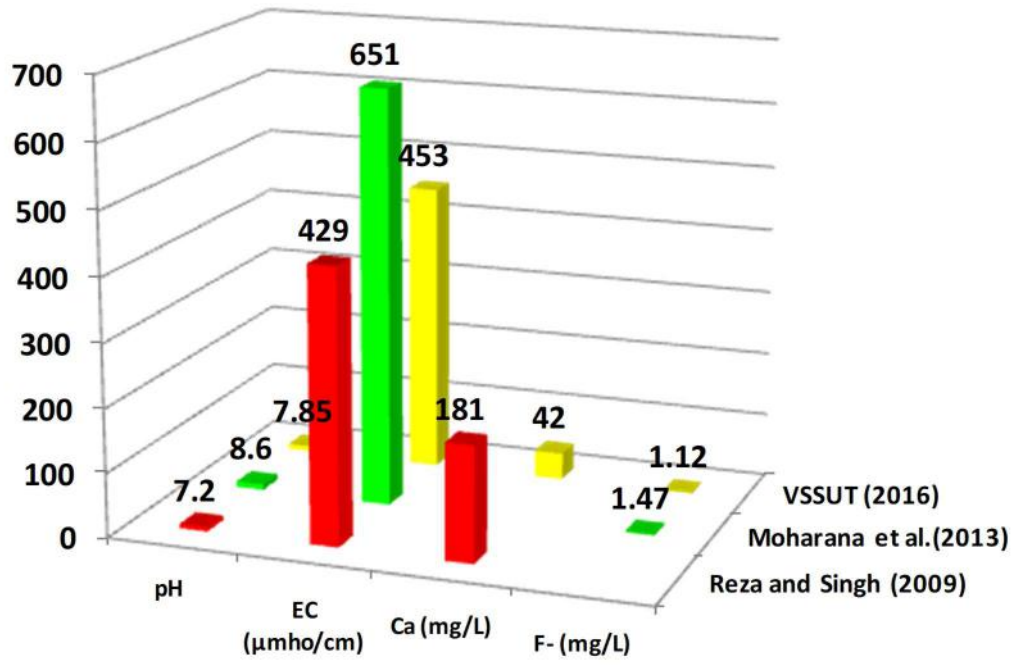


Fig. 2.8 Comparison of (a) Pre and (b) Post Monsoon Groundwater Quality Parameters at Giranga (NA3)



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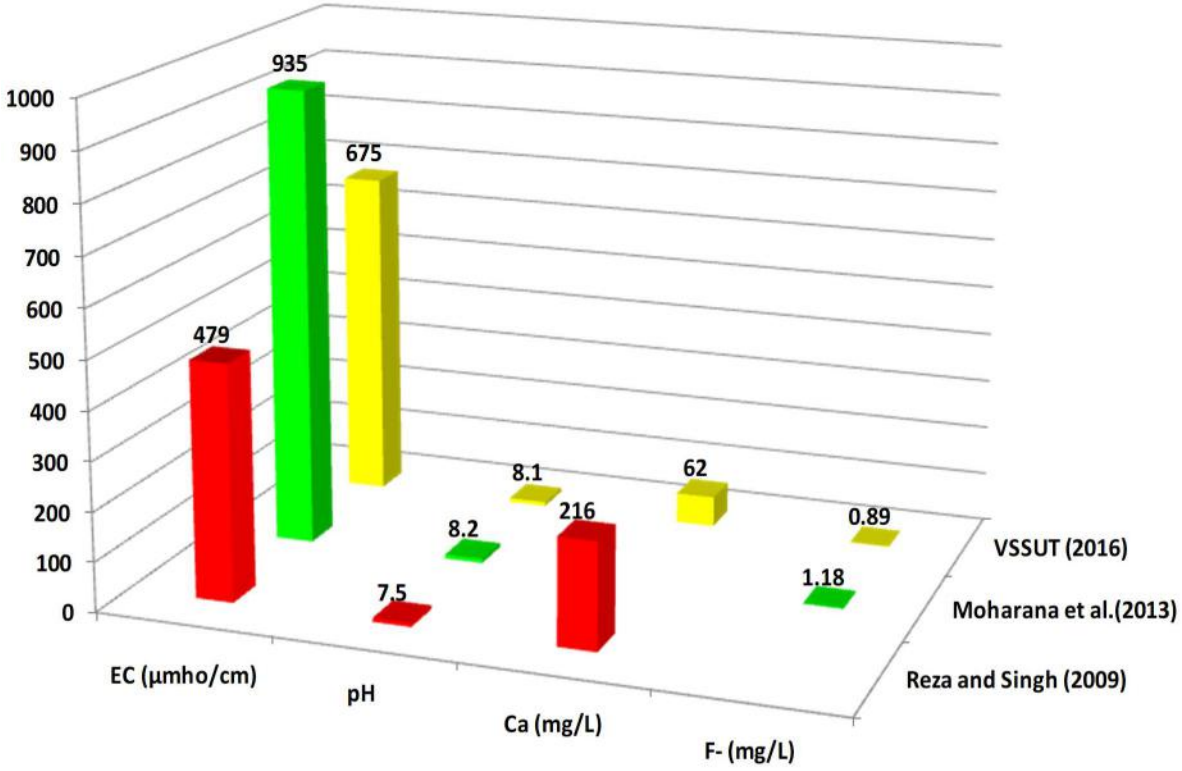


(b)

Fig. 2.9 Comparison of (a) Pre & (b) Post Monsoon Groundwater Quality Parameters at Nuasahi (NA10)

Table 2.7 Comparison of Parameters in Ground Water in and around NALCO

Parameters	Year and authors	Winter (Post monsoon)		Summer (Pre monsoon)	
		Min	Max	Min	Max
PH	2003 (Dash and Patra)	7.23	7.78	7.45	7.83
	2016 (VSSUT)	7.25	7.75	6.85	7.80
EC	2003 (Dash and Patra)	1063	2669	1187	2992
	2016 (VSSUT)	315	976	215	702
Ca	2003 (Dash and Patra)	49.4	74.9	46	68.5
	2016 (VSSUT)	55	122	42	87
F	2003 (Dash and Patra)	0.565	1.71	0.618	1.498
	2016 (VSSUT)	0.41	1.15	0.73	1.27
Cr^{+6}	2003 (Dash and Patra)	0.006	0.021	0.006	0.028
	2016 (VSSUT)	0.018	0.046	0.011	0.042

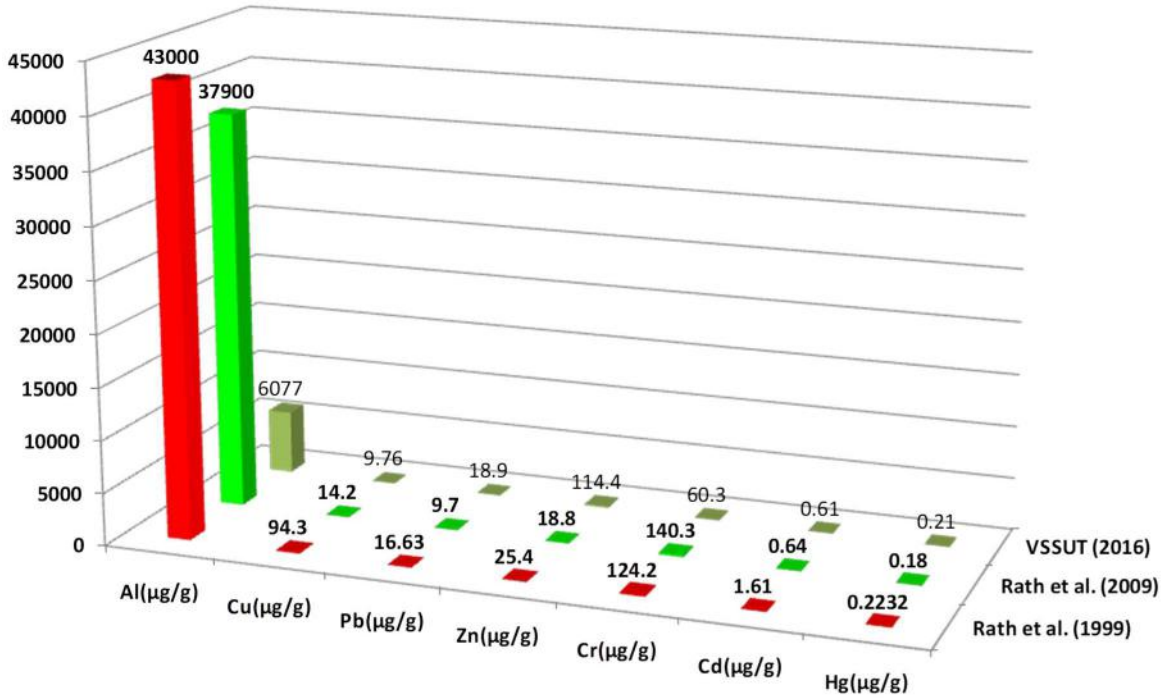
2.4.4 Heavy metal analysis in ash and soil samples

Acid digestion data of fly ash and surrounding soil provide the total available concentration levels of trace elements in fly ash & soils which is shown in **Table 2.8**. The results obtained from TCLP were found significantly lower in composition compared to acid digestion test. This is because; metal solubility generally decreases with increasing pH. Concentrations of Ca were found significantly high as compared to other elements. Cd concentration was found significantly low in the acid digestion test; therefore, the leaching of Cd was found BDL in the TCLP test. The low leaching of metals in the TCLP test compared to acid digestion test, indicates a strong bonding of metals with the other compounds of ashes. The results reveal that concentrations of heavy metals in pond ash are less than the fly ash indicating some leachability of metals. The overall analysis result of soil suggests that the local soil is not that much contaminated with fly ash. Few soil quality parameters of Nandira river bed sediments and soil quality at Kurdul were compared with the previous studies conducted by other researchers to find out the trends which are presented in **Fig. 2.10**. It is evident from the figures that although Nandira river bed sediments (S7) contain all heavy metals indicating the settlement of ash in river bed, no significant increase in metal concentration compared to previous data is observed.

Table 2.8 Concentration of Elements in Ash and Soil Sample

Sample ID	Testing Procedure	Ca	Al	Cr^{+6}	T. Cr	Cd	Pb	Cu	Zn	Hg	F^-
A1	SADT	3220	6640	BDL	242	4.21	95	102	161	1.24	-
	TCLP	2817	34.24	BDL	0.43	0.0016	0.026	0.28	0.72	BDL	15.2
A2	SADT	2307	6185	BDL	202	3.93	84	49.87	142	0.54	-
	TCLP	1808	32.8	BDL	0.33	0.0011	0.018	0.13	0.50	BDL	8.41
A3	SADT	3707	5702	BDL	206	3.95	86	55.87	148	0.84	-
	TCLP	2741	25.8	BDL	0.33	0.0011	0.024	0.14	0.52	BDL	13.3
S1	SADT	2460	3212	BDL	2.51	BDL	1.800	11.56	20.2	BDL	-
	TCLP	1905	16.58	BDL	BDL	BDL	BDL	BDL	BDL	BDL	1.08
S2	SADT	2440	3137	BDL	3.16	BDL	1.440	5.88	13.6	BDL	-
	TCLP	2089	21.25	BDL	BDL	BDL	BDL	BDL	BDL	BDL	1.76
S3	SADT	2400	2916	BDL	BDL	BDL	BDL	5.76	14.4	BDL	-
	TCLP	1929	14.87	BDL	BDL	BDL	BDL	BDL	BDL	BDL	1.24
S4	SADT	2103	2830	BDL	BDL	BDL	BDL	BDL	9.8	BDL	-
	TCLP	1808	14.17	BDL	BDL	BDL	BDL	BDL	BDL	BDL	1.56
S5	SADT	2460	2285	BDL	BDL	BDL	1.618	1.56	8.2	BDL	-
	TCLP	2150	11.18	BDL	BDL	BDL	BDL	BDL	BDL	BDL	1.08
S6	SADT	2440	2791	BDL	1.16	BDL	1.540	5.88	13.6	BDL	-
	TCLP	1889	13.25	BDL	BDL	BDL	BDL	BDL	BDL	BDL	0.76
S7	SADT	7400	6077	BDL	60.3	0.61	18.9	9.76	11.4	0.21	-
	TCLP	2929	30.07	BDL	0.08	BDL	BDL	BDL	BDL	BDL	4.24
S8	SADT	2103	3254	BDL	BDL	BDL	BDL	BDL	9.8	BDL	-
	TCLP	1508	15.17	BDL	BDL	BDL	BDL	BDL	BDL	BDL	0.86

Unit of all parameters is mg/kg



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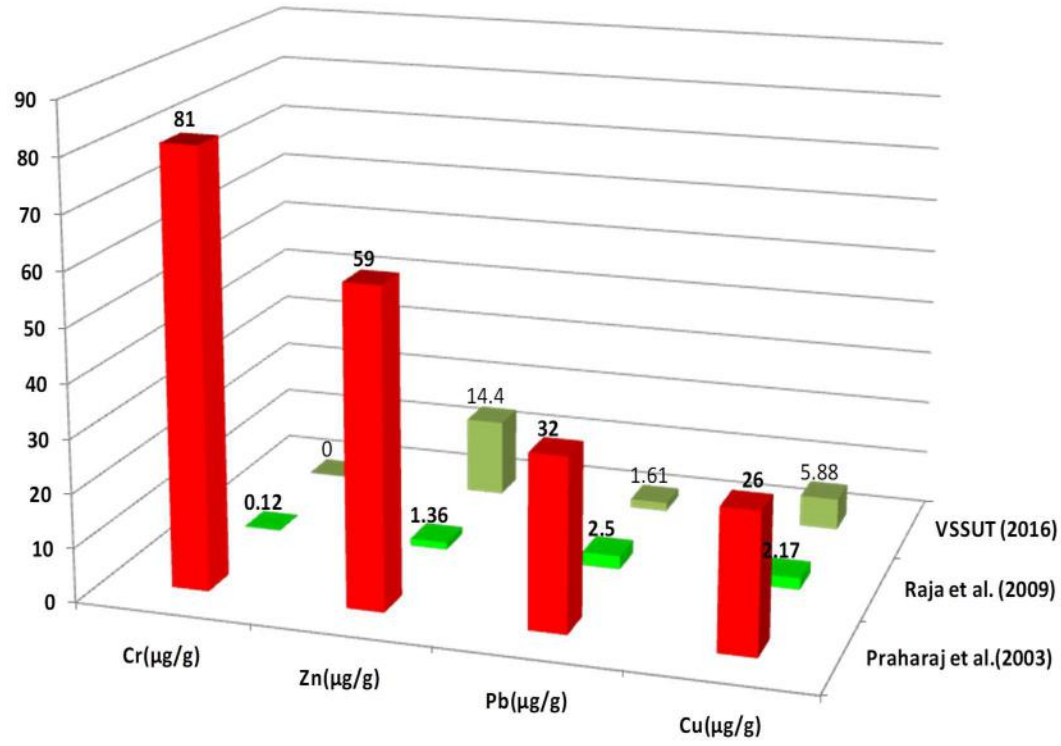


(b)

Fig. 2.10 Comparison of (a) Nandira River Bed Sediment(S7) (b) Soil Quality at Kurdul

2.4.5 Ambient air quality

Ambient air quality in respect of PM_{10}at fly ash pond and NALCO Township was found to be 125 $\mu g/m^3$ and 88 $\mu g/m^3$ respectively. The ambient air quality monitoring at nearby villages could not be conducted due to public protest. It was reported by the public that severe dust pollution happens in the locality at the time of dyke raising of ash ponds.

2.5 Conclusion

On the basis of the study, following conclusion are drawn:

- The ash characterization results indicate that the fly ash comes under the class F.
- Analytical results of ground water samples collected from different locations show that the physico-chemical parameters are within the permissible levels of BIS guidelines except Ca, Al, and F^-. The higher concentration of fluoride and Aluminium in ground water may be due to fluoride and Aluminium bearing minerals in the study area. The reason of high concentration of chromium and lead in ground water could be due to the geogenic factors. Heavy metals like Cu, Zn were observed to be within the standard limit prescribed for drinking water.
- Fluoride concentration was observed to be above the standard limit mostly in pre-monsoon. However, this value decreases below the standard in post-monsoon.
- No cadmium and mercury were detected in the surface water sample.
- As per the results obtained from leachate tests, the leaching of metals may occur only under extremely acidic conditions in laboratory. Under normal environmental conditions, the leaching of the heavy metals is insignificant.
- The hydraulic conductivity values indicate that the ash has very poor permeability. However, it will be substantially less at the bottom where it is more compacted preventing the movement of leachate into aquifer.

The following suggestions are made for better management of ash in the plant.

- The industry shall make lucrative policy for fly ash users for large scale utilization of fly ash before exploring the option like quarry and mine void filling.
- The plant must convert the lean concentration slurry disposal method into high concentration slurry disposal (HCSD) for the units 1 to 6. Since this disposal is highly viscous the method shall reduce the probability of leaching from ash.
- The industry must install permanent sprinkler system in the ash dyke to control fugitive ash during ash pond dyke raising.

- The Thermal Power Plants must monitor the ground water quality on quarterly basis around the ash disposal sites and at other strategic location to predict future trend.
- The surface of the pond ash may be sprinkled with the waste water treatment plant sludge. This has the advantages of controlling the fugitive emissions by forming a thin film on the surface; enhancing the fertility of ash for growth of vegetation and ground cover and thirdly by providing a disposal option for the WTP (water treatment plant) sludge.
- Planting of saplings having tolerance to warm slurry water and heavy metals may be considered to be the most ideal mitigation measure, since the biomass can also adsorb toxic metals as nutrients and provide obstruction for windblown particulates.

Chapter 3

Talcher Thermal Power Station (TTPS), NTPC, Talcher

3.1 Introduction

M/s Talcher Thermal Power Station (TTPS), NTPC, Talcher is the first Thermal power station in the State of Odisha established by Govt. of Odisha which was commissioned with its Unit-I on 17.12.1967. However, it was taken over by National Thermal Power Corporation (NTPC) on 03.06.1995. At present, the plant is having six units and total installed capacity of 460 MW (4 x 60 MW in Stage-I and 2 x 110 MW in Stage-II). The plant uses the coal of Jagannath Mines of MCL. The area is gently undulating and the general slope is towards North-East. The elevation of the area varies from 97.0 m to 140 m above MSL. The drainage is controlled by perennial Brahmani river. Wind usually blows from South West and North West directions in the monsoon. In the post monsoon and cold season, wind blows between the West and the North. In the summer months the winds become variable in direction.

3.2 Ash management

All the units # 1 to 6 generated 1.2 Million Ton of total ash in the year 2016-17 (Approx. 3,300 TPD). The TPPs have also installed 2 ash silos of 100T capacity each for storage of dry fly ash for subsequent utilization in making ash based products. The unit is required to install more number of silos to contain the ash of all units. The plant uses fly ash in its captive fly ash brick plants (3nos) inside its premises and also supplies to 18 outside fly ash brick plants. About 20 TPD of dry ash is utilized for fly ash brick manufacturing and about 80 TPD is supplied to asbestos plants. Balance ash is used in mine void filling.

The plant was using its own ash pond located at Santhapada for disposal of ash. However, the pond is not active since 2005. **Fig. 3.1** shows the ash pond of the industry. The plant has been using abandoned coal mine void of South Balanda coal mine(MCL) for ash filling. The mine void is spread over an area of 92.82 ha consisting of three quarries, known as Quarry 2, 3A and 3Bhaving total volume14.73 Mm^3. The void filling was started since 2005 and the estimated life of this void is 14 years. The unused fly ash and the bottom ash are mixed with water in the ratio of 1:6 and the resultant slurry is pumped to the mine void by pipe lines. After decantation, the supernatant water is recycled back to the plant for further use in ash slurry making.

There are three ash slurry disposal pipelines (2 Working + 1 Standby) of about 9 kilometers length each for transportation of ash slurry to mine void. The ash slurry discharged at mine void travels through gravity towards a lower level and ash particles settle down while travelling. The decanted water is partly being circulated back to the plant and partly used for irrigation, as per the demand of farmers. The industry has been analyzing the decanted water samples quarterly and the quality of water is within the permissible limit. The mine void at South Balanda is shown in the schematic map at **Fig. 3.2**.

Fig. 3.1 Mine Void for Ash Disposal

Further TTPS has constructed two contingency ash ponds as Ash Dyke-I and Ash Dyke- II for disposal of ash in case of emergency.

(i) Ash Pond-I (Santhapada)

Dyke-I is located about 3.50 km from TTPS plant. The total area of the ash dyke is 131.485 acres. Out of which 52 acres area was exhausted during 2012. The industry has converted the balance area 79.485 acres in to contingency ash pond. The volume of this pond is 14 lakh cum. The industry has provided decantation well inside the ash pond and the water from the well moves through pipelines to the settling lagoon by gravity. After settling it is recycled to the plant by pumping for reuse in the plant. The plant uses this contingency pond when there is a problem in the submersible pump at South Balanda coal mine of MCL.

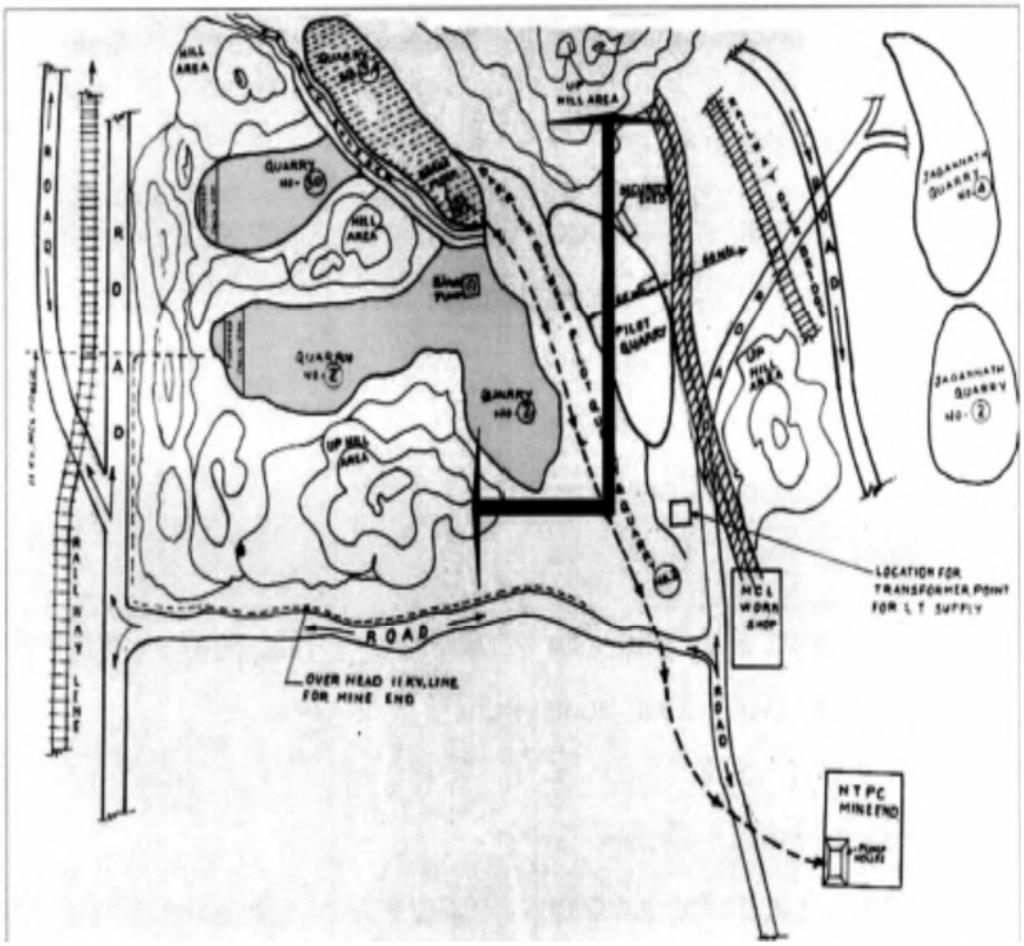


Fig. 3.2 Map of South Balanada Mine Void

(ii) Ash Pond-II (Jhadeamba)

Dyke-II,is located about 4.50 km from TTPS plant. The total area of the ash dyke is 150 acres. Volume of dyke under construction is 25 Lakh m^3 and the work to complete the ash pond is in

progress. **Table 3.1** presents the surrounding features of ash ponds and mine voids used for ash disposal. The capacity of new ash pond-1 (76 + 56 acres) & 2 (156 acres) with two raisings in each dyke is about 11.5 M cum.

Table 3.1 Locations of Ash Pond

S. N	Location of the Site	South Balanda Mine void	Santhapada Ash Pond	Jadiamba Ash Pond
1	Distance from the plant	10 km NW of the plant	1.0 km SE of the plant	2.0 km SE of the plant
2	Distance from human habitation	Bharatpur Colony: 1.0 km SW of mine	Dasanali: 0.5 km NE of ash pond Digi: 0.4 km W of ash pond Santhapada: 1.0 km NE of ash pond	Jhadiamba: 0.6 km NW of ash pond Tolakalundi: 0.7 km W of ash pond
3	Distance from water bodies	-	Nandira: 0.1 km SW to S of ash pond Brahmani: 0.6 km E of ash pond	Nandira: 0.1 km S of ash pond Brahmani: 0.1 km N to NE of ash pond
4	Distance from educational institutions/ commercial infrastructures	NilakantheswaraVidyapitha: 3 km SE of mine South Balanda Market: 2.5 km SE of mine	DAV College: 0.8 km NW of ash pond Anandbazar market: 0.9 km NW of ash pond	DAV College: 1.8 km NW of ash pond Anandbazar market: 1.8 km NW of ash pond
5	Distance from forest cover	0.1 km E, W & NW of mine void	-	-
6	Distance from roads and railway line(if any)	Mines Road: 0.5 km S & SE of mine	Talcher-Thermal Rly line: 1.0 km NW of ash pond	Banarpal- Talcher Road: 1.5 km W of ash pond
7	Distance from heritage site	NA	NA	NA

It was noted that CMPDI Ranchi, CSIR-NEERI, BARC and others have made detailed studies on the impact of mine backfilling on the environment. All the reports reveal the concentration of heavy metals within limit in the ground and surface water surrounding the ash filled mine voids. As per the study conducted by CSIR-NEERI during 2012-14, titled "Study of Effects due to Ash Fill Sites of Talcher Thermal Power Plant on Flora and Fauna in the

surrounding area of South Balanda Mine Pit and Jagananth Mine Pit", there is no ecological sensitive flora or fauna in the study area. Leaf injury symptoms due to fly ash were also not observed. Although, dust deposition was observed on leaves, microscopic studies revealed that there were stomata indicating that deposition of dust / fly ash is not having an adverse impact on the flora surrounding the ash dumping sites. The features of the mine void site is presented in **Table 3.2**.

Table 3.2 Features ofSouth Balanda Mine Void used for Fly Ash Disposal

Name of Ash Disposal Sites	South Balanda Mine Void
Area (acre)	92.82 ha
Type of lining	-
Over Flow Lagoon (OFL)	NA
Design height of each raising(m)	NA
No. of raising designed for	NA
Present stage of raising	NA
No. of pipelines	4
Distance from plant (km)	10.0
Volume of ash stored(million m^3)	12.82
Operating since	Aug.2005

3.3 Sampling locations

Ground water, soil, fly ash and ambient air samples have been collected around the ash disposal site. **Fig. 3.3** shows the location of sampling sites around old ash pond and mine voids of South Balanda. **Table 3.3** shows description of sampling site and its distance from the ash disposal site.

Fig. 3.3 Location of Sampling Points around Old Ash Pond and Mine Voids of M/S TTPS, Talcher

Table 3.3 Details of Sampling Locations

Nomenclature	Description of sampling locations	Distance from Ash Pond (km)	Direction w.r.t. Santhapada Ash Pond
Ground water			
NNT1	Tolkolondi Village	1.0	SE
NTT2	Santhapada Village	0.5	E
NTT3	Jadiamba Village	0.5	SE
NTT4	Santhapda Village	2.0	N
NTT5	Gurujangli village	1.0	W
Surface water			
SW1	Nandira river	0.2	S
SW2	Nandira river	0.1	S
Ash			
A1	Fly Ash	-	-
A2	South balanda mine void	-	-
Soil			
S1	Tolkolondi Village	1.0	SE
S2	Santhapada Village	0.5	E
S3	Jadiamba Village	0.5	SE
S4	Santhapda Village	2.0	N
S5	Gurujangli village	1.0	W
AAQ monitoring station			
NA1	Raw water treatment plant	1.0	NW
NA2	Weather monitoring station	1.0	W
NA3	Township colony	0.8	W
Nomenclature	**Description of sampling locations**	**Distance from Ash Pond (km)**	**Direction w.r.t. Mine void**
Ground water			
NTT6	MCL staff quarters, near Maa Tarini temple, south balanda	2.0	SE
NTT7	South Balanda market	2.0	SE
NTT8	Near Birsamunta Square	2.0	E
NTT9	Bharatpur Gobara Chowk	1.0	S
NTT10	Chikkamunda village,	2.0	S
Soil			
S6	South Balanda market	2.0	SE
S7	Near Birsamunta square	2.0	SE

3.4 Results and discussion

The results of the physico-chemical & mineralogical characterization of fly ash and pond ash samples, heavy metal analysis in ground water, leachability studies of fly ash & soil are given as follows:

3.4.1 Physical properties

It is found that fly ash possesses a maximum mean particle diameter (D50=14.46 μm), whereas, pond ash with mean particle diameters (D50) of 33.44 μm. **Table 3.4** shows physical properties of the fly ash and pond ash samples. The results of the permeability test of ash samples show that the coefficient of permeability values of both the fly ash and pond ash samples is very low and equivalent to the permeability of silts. However, the permeability of the pond ash is higher than fly ash due to coarser particle size. Though there is little difference in the specific gravity value of fly ash and pond ash samples, comparatively, the average specific gravity and bulk density of fly ashes are found to be more than the pond ash samples.

The scanning electron micrographs at ×1000 magnification are shown in **Figs. 3.4 (a & b)** which reveal that the fly ash samples consist of mostly spherical particles compared to pond ash particles.

Table 3.4 Physical Properties of the Fly Ash and Pond Ash Samples

Parameters	Color	Specific Gravity(G)	Bulk density, g/cc	Porosity,%	Coefficient of permeability, k x 10^{-4} cm/s
Fly ash	Grey	2.06- 2.17	1.04 - 1.06	48.15-50.27	1.33 - 1.37
Pond ash	Dark Grey	1.97 - 2.15	1.04 - 1.05	49.16-51.21	3.35 - 4.14

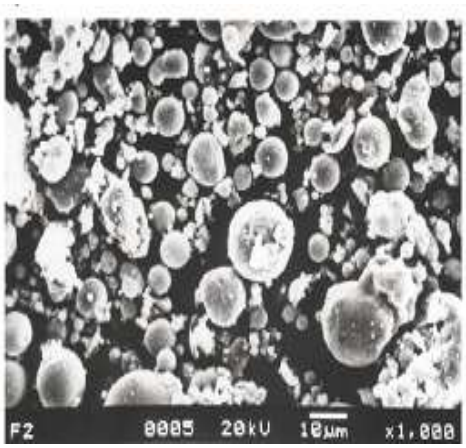


Fig. 3.4 (a) SEM of fly ash samples

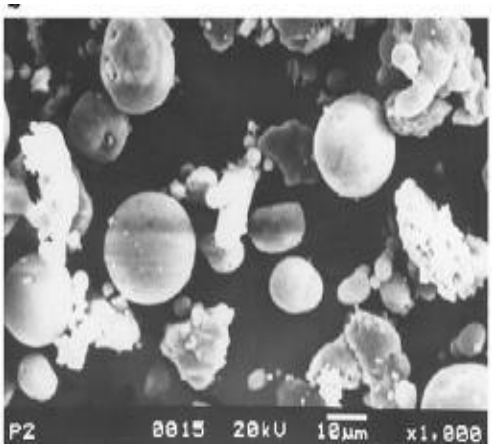


Fig. 3.4 (b) SEM of pond ash samples

3.4.2 Chemical and mineralogical compositions

The elemental and chemical compositions (element oxides) of ash samples are presented in **Fig. 3.5 (a & b)** and **Fig. 3.6 (a & b)** respectively. The results show that all the fly ash and pond ash samples are abundant in Si and Al, and possess minor concentrations of Fe, Ca, Mg, Mn, K, Ti and P. In the ash samples, the elements present in decreasing order of their abundance are O, Si, Al, Fe, Ti, K, Ca, P and Mg. The reactive silica content in fly ash is found to be in the range12-14 %.

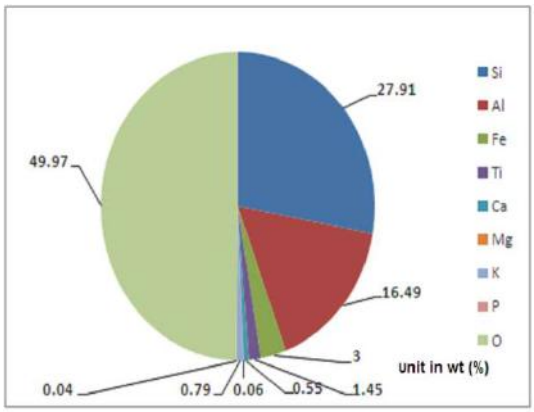


Fig. 3.5(a) Element Composition of Fly Ash

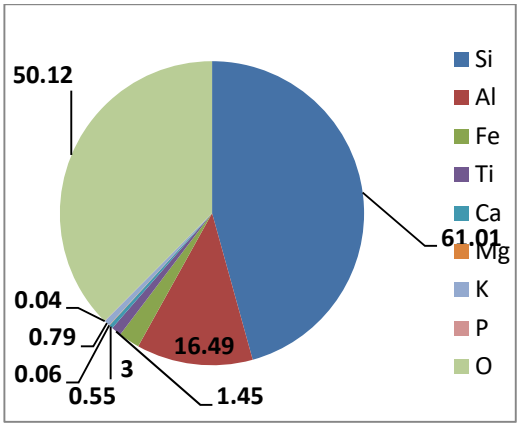


Fig. 3.5(b) Element Composition of Pond Ash

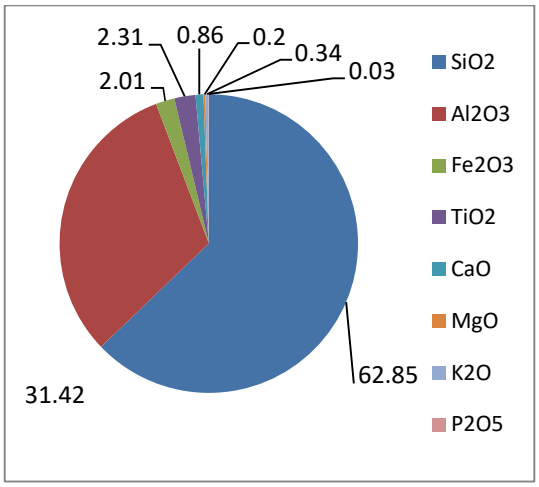


Fig. 3.6(a) Element Oxides of Fly Ash

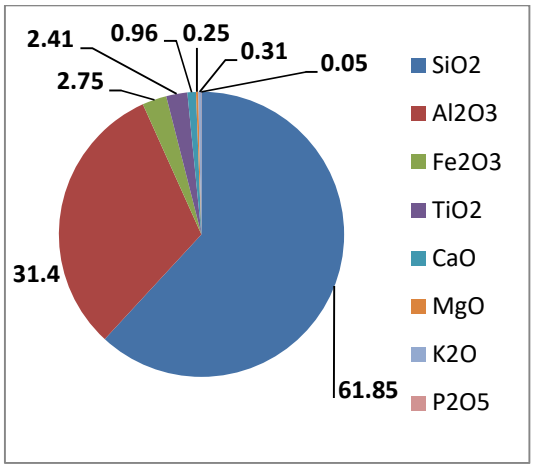


Fig. 3.6(b) Element Oxides of Pond Ash

The results of the chemical composition (element oxides) show that the ash samples are enriched predominantly with silica (SiO_2) and alumina (Al_2O_3). In addition, they also contain small amounts of iron oxide (Fe_2O_3), TiO_2, K_2O, CaO and MgO. The rest of the compounds present in the ash samples are in minor concentrations.

3.4.3 Heavy metal analysis in water samples

The ground water analysis was performed on the water samples collected from the bore wells from different locations in the area of fly ash dumpsite. Details of the concentration of heavy metals in the groundwater and surface water samples near the ash ponds and at the surrounding villages are given in **Table 3.5**. pH of the ground water sample ranged from 6.65 to 7.29, indicating alkaline nature of the water. The groundwater analysis results reveal that all the parameters except Al, Ca, Pb and F meet the drinking water standard prescribed in IS10500: 2012.The dug wells and tube wells at all sampling locations exhibited very high TDS values in the range 210-950 mg/l. Fluoride concentration was observed to be above the standard limit mostly in pre-monsoon. However, this value decreases below the standard limit in post-monsoon. Heavy metals like Cu, Zn were observed to be within the standard limit prescribed for drinking water. Metals like Cd and Hg were not detected anywhere in post-monsoon season. **Table 3.6 and 3.7** show the comparison of pre and post monsoon ground water result with NEERI findings. **Fig. 3.7** to **Fig. 3.11** show the comparison of pH, EC, Ca, F and Zn respectively. The comparison of pre-monsoon result (Present study and NEERI) reveals that there is hardly any difference in the values of pH, Zn and F at all locations. The water quality of the bore-well at MCL staff quarters (NTT6) almost match with NEERI finding in respect of pH, EC, Ca and Zn. The similar findings are also observed in the comparison of post monsoon results. **Table 3.8** presents the surface water quality of the area.

3.4.4 Heavy metal analysis in ash and soil samples

Acid digestion data of fly ash and surrounding soils provide the total available concentration levels of trace elements in fly ash & soils which is shown in **Table 3.9**. The results obtained from TCLP were found significantly lower in composition compared to acid digestion test. The results reveal that concentrations of heavy metals in pond ash are less than the fly ash indicating some leachability of metals. The overall analysis result of soil suggests that the local soil is not that much contaminated with fly ash.

Table 3.5 Analysis Result of Ground Water Sample

Sample ID	Monsoon	pH	EC	Ca	Al	Cr^{+6}	T. Cr.	Cd	Pb	Cu	Zn	Hg	F^-
NTT1	Pre	6.65	582	32	0.041	0.015	0.05	0.0001	0.01	0.02	0.67	0.0003	1.33
	Post	7.12	815	61	0.018	0.011	0.045	BDL	0.003	BDL	0.16	BDL	0.81
NTT2	Pre	7.18	389	35	0.039	0.012	0.133	BDL	0.068	0.031	0.81	0.0001	1.87
	Post	7.20	462	76	0.013	0.009	0.120	BDL	0.029	BDL	0.62	BDL	1.43
NTT3	Pre	6.83	515	53	0.067	0.031	0.118	0.001	0.058	0.024	0.19	0.0001	1.18
	Post	6.90	751	105	0.022	0.011	0.110	BDL	0.028	BDL	0.01	BDL	0.93
NTT4	Pre	6.78	865	65	0.060	0.043	0.128	BDL	0.049	0.016	0.55	0.00022	1.54
	Post	7.12	1076	45	0.040	0.011	0.116	BDL	0.033	BDL	0.45	BDL	1.32
NTT5	Pre	7.11	676	53	0.022	0.02	0.05	BDL	0.048	0.024	0.81	0.00013	0.64
	Post	7.20	877	65	0.020	0.011	0.048	BDL	0.028	BDL	0.62	BDL	0.55
NTT6	Pre	6.81	278	55	0.087	0.038	0.089	BDL	0.056	0.001	0.23	0.00024	0.64
	Post	7.11	312	89	0.034	0.018	0.045	BDL	0.048	BDL	0.12	BDL	0.33
NTT7	Pre	6.85	811	47	0.032	0.026	1.132	BDL	0.041	0.183	1.81	0.00025	1.09
	Post	7.05	1089	62	0.019	0.019	0.951	BDL	0.022	BDL	0.72	BDL	0.87
NTT8	Pre	7.17	986	54	0.044	0.032	1.118	BDL	0.054	0.009	2.61	0.00018	0.45
	Post	7.29	1368	83	0.018	0.016	0.902	BDL	0.029	BDL	1.21	BDL	0.23
NTT9	Pre	6.85	786	67	0.084	0.062	1.082	BDL	0.01	0.021	0.22	0.00011	0.85
	Post	7.18	1098	83	0.065	0.049	0.751	BDL	0.008	BDL	0.01	BDL	0.47
NTT10	Pre	7.12	888	67	0.054	0.072	0.678	BDL	0.044	0.004	0.72	0.00018	0.65
	Post	7.22	1187	82	0.021	0.026	0.402	BDL	0.038	BDL	0.43	BDL	0.44
AL		**6.5-8.5**	**-**	**75**	**0.03**	**-**	**0.05**	**0.003**	**0.01**	**0.05**	**5.0**	**0.001**	**1.0**
DL		-	-	-	0.002	-	0.01	0.0001	0.002	0.004	0.002	0.00007	-

Unit of all parameters is mg/l except pH and EC; Unit of EC is µS/cm; pH has no unit; AL: Acceptable Limit as per IS 10500:2012; DL: Detectable limit

Table 3.6 Comparison of Pre-Monsoon Ground Water Analysis

Sample ID	Pre-monsoon	pH	EC	Ca	Al	Cr^{+6}	T. Cr.	Cd	Pb	Cu	Zn	Hg	F^-
NTT1	May 2012	7.6	674	52	ND	ND	ND	ND	ND	ND	ND	ND	5.2
	May 2016	6.65	582	32	0.041	0.015	0.05	0.0001	0.01	0.02	0.67	0.0003	1.33
NTT2	May 2012	7.7	1610	90	ND	ND	ND	ND	0.02	ND	1.1	ND	1.0
	May 2016	7.18	389	35	0.039	0.012	0.133	BDL	0.068	0.031	0.81	0.0001	1.87
NTT3	May 2012	7.2	470	60	ND	ND	ND	ND	0.01	ND	3.0	ND	1.6
	May 2016	6.83	515	53	0.067	0.031	0.118	0.001	0.058	0.024	0.19	0.0001	1.18
NTT4	May 2012	7.6	438	44	ND	ND	ND	ND	ND	ND	0.30	ND	0.5
	May 2016	6.78	865	65	0.060	0.043	0.128	BDL	0.049	0.016	0.55	0.00022	1.54
NTT6	May 2012	6.9	180	44	ND	ND	ND	ND	ND	ND	ND	ND	0.10
	May 2013	7.4	223	52	0.045	ND	0.0012	0.0003	0.002	ND	0.24	ND	0.20
	May 2016	6.81	278	55	0.087	0.038	0.089	BDL	0.056	0.001	0.23	0.00024	0.64
NTT7	May 2012	6.4	159	52	ND	ND	ND	ND	ND	ND	2.0	ND	0.10
	May 2016	6.85	811	47	0.032	0.026	1.132	BDL	0.041	0.183	1.81	0.00025	1.09
NTT8	May 2012	5.6	105	16	ND	ND	ND	ND	ND	ND	3.0	ND	0.10
	May 2016	7.17	986	54	0.044	0.032	1.118	BDL	0.054	0.009	2.61	0.00018	0.45
NTT9	May 2012	6.9	337	41	ND	ND	ND	ND	ND	ND	12	ND	0.20
	May 2013	6.87	333	80	0.065	ND	0.005	0.005	0.03	0.001	19.6	ND	0.20
	May 2016	6.85	786	67	0.084	0.062	1.082	BDL	0.01	0.021	0.22	0.00011	0.85
NTT10	May 2012	7.6	579	94	ND	ND	ND	ND	ND	ND	1.0	ND	0.60
	May 2016	7.12	888	67	0.054	0.072	0.678	BDL	0.044	0.004	0.72	0.00018	0.65
AL		**6.5-8.5**	**-**	**75**	**0.03**	**-**	**0.05**	**0.003**	**0.01**	**0.05**	**5.0**	**0.001**	**1.0**
DL		-	-	-	0.002	-	0.01	0.0001	0.002	0.004	0.002	0.00007	-

Unit of all parameters is mg/l except pH and EC; Unit of EC is µS/cm; pH has no unit; AL: Acceptable Limit as per IS 10500:2012; DL: Detectable limit

Note: NEERI had analysed the data in the year 2012

Table 3.7 Comparison of Post-Monsoon Ground Water Analysis Data

Sample ID	Post monsoon	pH	EC	Ca	Al	Cr^{+6}	T. Cr.	Cd	Pb	Cu	Zn	Hg	F^-
NTT1	Nov2012	7.8	710	124	0.02	ND	ND	ND	ND	ND	0.10	ND	4.9
	Nov 2016	7.12	815	61	0.018	0.011	0.045	BDL	0.003	BDL	0.16	BDL	0.81
NTT2	Nov2012	7.3	990	208	ND	ND	ND	ND	0.01	ND	0.03	ND	1.1
	Nov 2016	7.20	462	76	0.013	0.009	0.120	BDL	0.029	BDL	0.62	BDL	1.43
NTT3	Nov2012	7.1	580	152	ND	ND	ND	ND	0.01	ND	3.0	ND	1.7
	Nov 2016	6.90	751	105	0.022	0.011	0.110	BDL	0.028	BDL	0.01	BDL	0.93
NTT4	Nov2012	7.4	450	104	ND	ND	ND	ND	ND	ND	0.3	ND	0.5
	Nov 2016	7.12	1076	45	0.040	0.011	0.116	BDL	0.033	BDL	0.45	BDL	1.32
NTT6	Nov2012	7.2	261	88	0.07	ND	ND	ND	ND	ND	0.10	ND	0.1
	Nov 2016	7.11	312	89	0.034	0.018	0.045	BDL	0.048	BDL	0.12	BDL	0.33
NTT7	Nov2012	6.6	160	48	0.08	ND	ND	ND	ND	ND	1.0	ND	0.10
	Nov 2016	7.05	1089	62	0.019	0.019	0.951	BDL	0.022	BDL	0.72	BDL	0.87
NTT8	Nov2012	5.9	133	32	0.09	ND	ND	ND	ND	0.01	2.2	ND	0.2
	Nov 2016	7.29	1368	83	0.018	0.016	0.902	BDL	0.029	BDL	1.21	BDL	0.23
NTT9	Nov2012	6.8	303	72	0.03	ND	ND	ND	ND	ND	7.2	ND	0.2
	Nov 2016	7.18	1098	83	0.065	0.049	0.751	BDL	0.008	BDL	0.01	BDL	0.47
NTT10	Nov2012	7.4	563	176	0.01	ND	ND	ND	ND	ND	1.7	ND	0.6
	Nov 2016	7.22	1187	82	0.021	0.026	0.402	BDL	0.038	BDL	0.43	BDL	0.44
AL		**6.5-8.5**	**-**	**75**	**0.03**	**-**	**0.05**	**0.003**	**0.01**	**0.05**	**5**	**0.001**	**1.0**
DL		-	-	-	0.002		0.01	0.0001	0.002	0.004	0.002	0.00007	-

Unit of all parameters is mg/l except pH and EC; Unit of EC is µS/cm; pH has no unit; AL: Acceptable Limit as per IS 10500:2012; DL: Detectable limit

Note: NEERI had analysed the data in the year 2012

Table 3.8 Analysis Result of Surface Water Sample

Sample ID	Season	pH	EC	Ca	Al	Cr^{+6}	T. Cr.	Cd	Pb	Cu	Zn	Hg	F^-
SW1	Premonsoon	6.85	715	33	0.05	0.041	0.123	0.003	0.051	0.033	0.76	BDL	1.81
	Postmonsoon	7.10	1112	21	0.123	0.011	0.095	BDL	0.032	BDL	0.41	BDL	1.21
SW2	Premonsoon	7.05	898	46	0.071	0.041	0.124	0.0032	0.053	0.025	0.88	BDL	2.12
	Postmonsoon	7.13	1232	66	0.131	0.011	0.083	BDL	0.033	BDL	0.49	BDL	1.31

Unit of all parameters is mg/l except pH and EC; Unit of EC is µS/cm; pH has no unit; AL: Acceptable Limit as per IS 10500:2012; DL: Detectable limit

Table 3.9 Concentration of Elements in Ash and Soil Sample

Sample ID	Testing Procedure	Ca	Al	Cr^{+6}	Total Cr	Cd	Pb	Cu	Zn	Hg	F^-
A1	SADT	3694	5605	BDL	319	7.69	104	101	200	1.24	-
	*TCLP	2835	23.24	BDL	0.43	0.0016	0.026	0.28	0.72	BDL	15.2
A2	SADT	3315	5240	BDL	316	7.61	106	95.87	173	0.74	-
	TCLP	2645	25.92	BDL	0.33	0.0011	0.024	0.14	0.52	BDL	12.2
S1	SADT	2100	2413	BDL	3.56	BDL	2.70	13.7	11.3	BDL	-
	TCLP	1609	21.17	BDL	BDL	BDL	BDL	BDL	BDL	BDL	0.4
S2	SADT	2420	2115	BDL	4.88	BDL	BDL	14.5	12.6	BDL	-
	TCLP	1808	21.27	BDL	BDL	BDL	BDL	BDL	BDL	BDL	2.0
S3	SADT	2260	2440	BDL	5.6	BDL	2.392	11.0	13.2	BDL	-
	TCLP	1710	12.84	BDL	BDL	BDL	BDL	BDL	BDL	BDL	2.6
S4	SADT	2020	2177	BDL	8.24	BDL	BDL	12.48	12.5	BDL	-
	TCLP	1667	11.58	BDL	BDL	BDL	BDL	BDL	BDL	BDL	0.6
S5	SADT	2434	2455	BDL	3.56	BDL	2.0	13.7	11.2	BDL	-
	TCLP	1910	12.47	BDL	BDL	BDL	BDL	BDL	BDL	BDL	1.5
S6	SADT	2263	2265	BDL	4.88	BDL	BDL	14.5	5.1	BDL	-
	TCLP	1610	11.27	BDL	BDL	BDL	BDL	BDL	BDL	BDL	0.6
S7	SADT	2354	2867	BDL	5.6	BDL	1.392	11.0	4.8	BDL	-
	TCLP	1957	13.84	BDL	BDL	BDL	BDL	BDL	BDL	BDL	0.4

Unit of all parameters is mg/kg

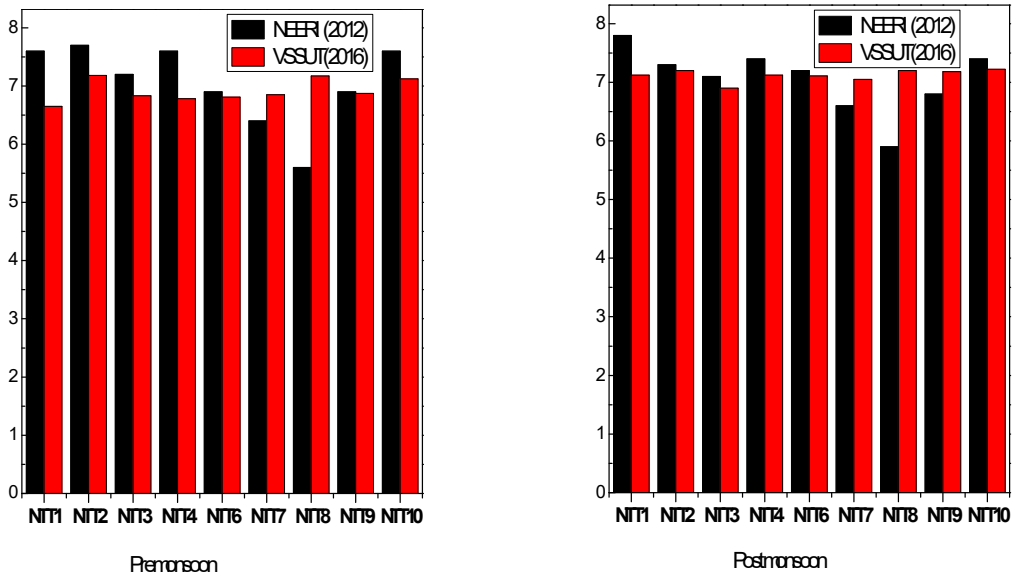


Fig. 3.7 Comparison of Pre & Post Monsoon pH in Groundwater

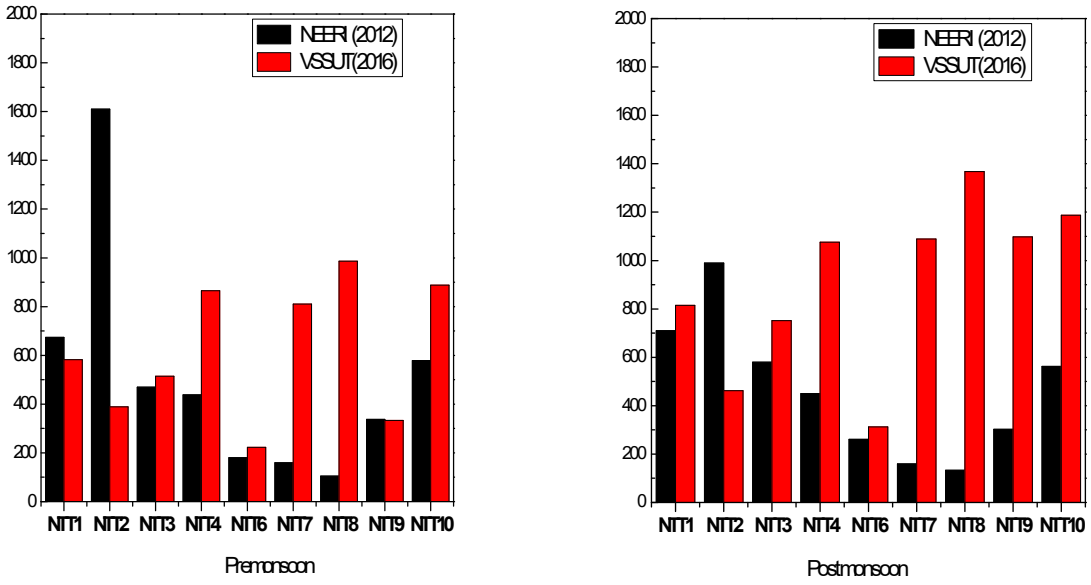


Fig. 3.8 Comparison of Pre & Post Monsoon EC in Groundwater

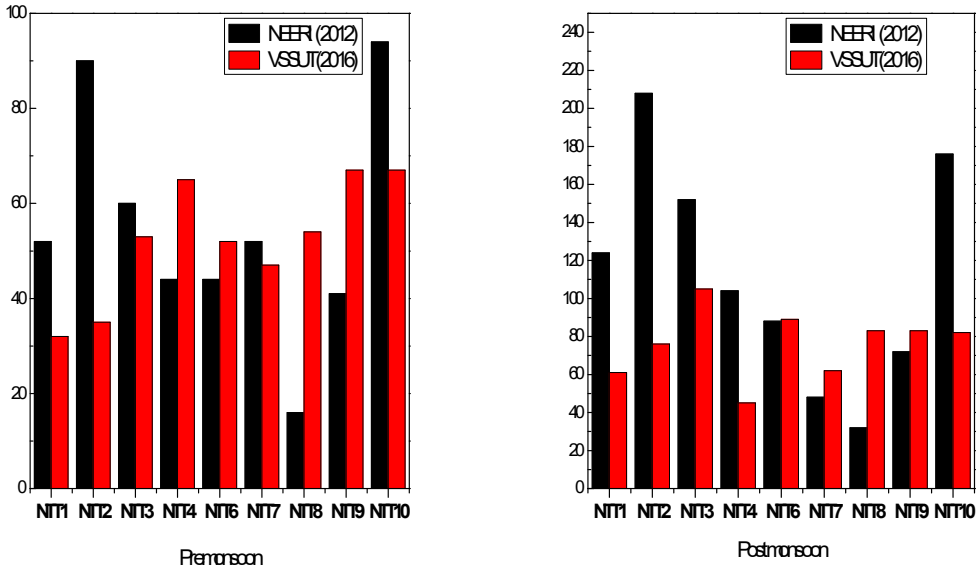


Fig. 3.9 Comparison of Pre & Post Monsoon Calcium in Groundwater

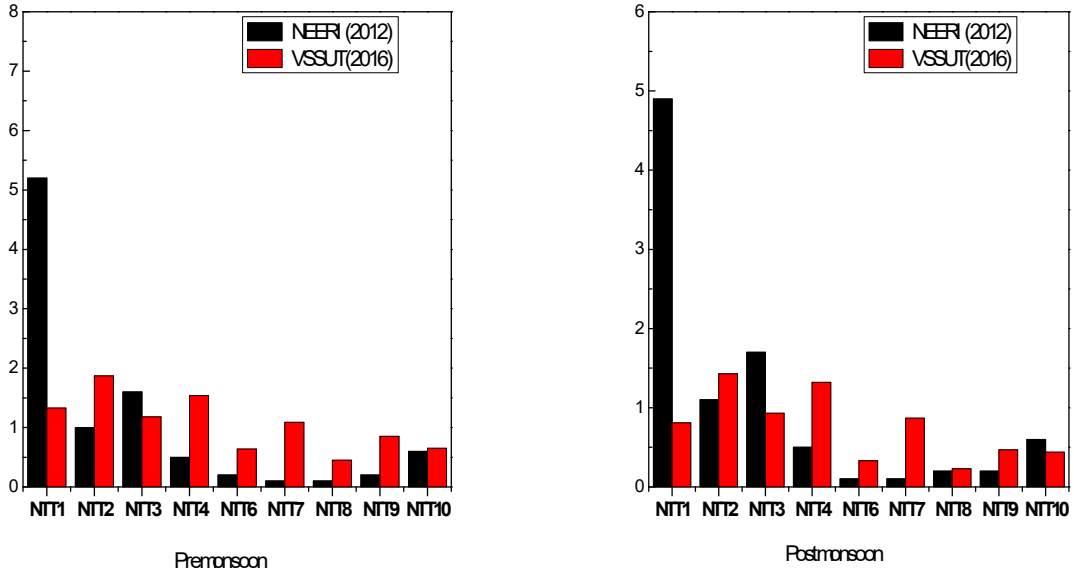


Fig. 3.10 Comparison of Pre & Post Monsoon Fluoride in Groundwater

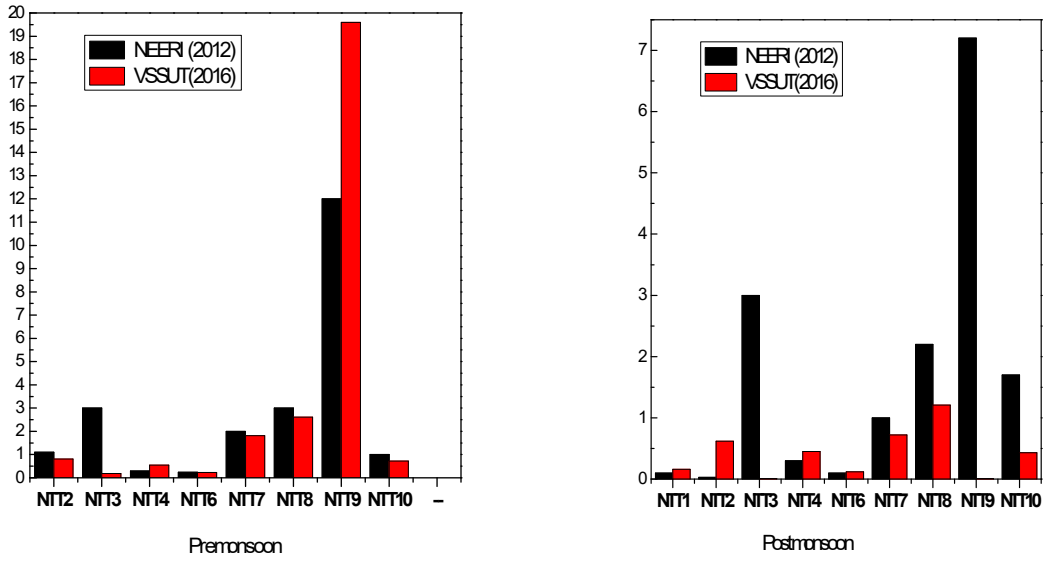


Fig. 3.11 Comparison of Pre & Post Monsoon Zinc in Groundwater

3.4.5 Ambient air quality

Ambient air quality in respect of PM_{10} at raw water treatment plant, weather monitoring station and township colony were found to be 112 µg/m^3, 75 µg/m^3 and 84 µg/m^3 respectively.

3.5 Conclusion

On the basis of the study, following conclusion are drawn:

- The ash characterization results indicate that the ash samples come under the class F. As per the results, the major constituents in the pond ash are Si, Al, Fe and Ti as prominent elements in the form of oxides, silicates and alumino-silicates.
- All the physico-chemical parameters are within the permissible levels of BIS guidelines except Ca, Al, Pb and F. Petrographic studies carried out by NEERI in 2014 had established the presence of *fluoride and Aluminium* bearing minerals in the study area.
- The comparison of present ground water study data with NEERI findings reveal that Zn, Pb and F are three important water quality parameters which need to be monitored frequently along with other parameters.
- No mercury was detected in surface water. Cadmium was detected only in pre-monsoon.
- As per the results obtained from leachate tests, the leaching of metals may occur only under extremely acidic conditions in laboratory. Under normal environmental conditions, the leaching of the heavy metals and trace elements is insignificant.
- The hydraulic conductivity values indicate that the ash has very poor permeability. This explains the low concentration of trace elements in the ground water. The hydraulic

conductivity for the ash collected at the top was found to be 10^{-7} cm/sec. However, it will be still less at the bottom where it is more compacted.

The following suggestions are made for better management of ash in the plant.

- The industry shall make lucrative policy for fly ash users for large scale utilization of fly ash before exploring the option like quarry and mine void filling.
- The industry shall install adequate number of silos for storage of ash.
- The industry shall take all preventive measures to prevent ground water or Nandira river contamination due to seepage of ash pond under construction at Jadiamba. The pond shall be lined with HDPE/LDPE lining or any other suitable impermeable media depending on permeability of soil at sites and leachability of ash to be filled.
- The industry must install permanent sprinkler system in the contingency ash dykes to control fugitive ash during ash dyke raising.
- The industry must monitor the ground water quality on quarterly basis around the South Balanda mine voids and contingency ash ponds at Santhapada and Jadiamba to predict future trend.

Chapter 4

Talcher Super Thermal Power Station, NTPC, Kaniha

4.1 Introduction

M/s Talcher Super Thermal Power Plant (TSTPP) is situated at Kaniha in the district of Angul and is the largest power-generating station in India with an installed capacity of 3000 MW (6 x 500 MW: 2 x 500 MW in Stage I + 4 x 500 MW in Stage-II). The unit-1 and 2 of the plant was commissioned in the February 1995 and March 1996 respectively. The other four units (Unit-4 to 7) were commissioned between 2004 to 2007.The source of coal and water is Coal Field (Lingaraj Area) and Samal Barrage Reservoir respectively. This plant has been accredited with ISO 18001, ISO 9001:2000 and ISO 14001 by the Bureau of Indian Standards. The topography and meteorology of the area is almost same as TTPS, Talcher.

4.2 Ash management

The power plant consumes about 17 million tonne of coal and the ash generation from the plant was about 7.1 million tonne during the year 2016-17. The average ash generation is 20,000 TPD. The industry has provided two nos of dry silos of 135 MT storage capacity each for stage-I (Unit -1 and 2). Similarly, two nos of dry ash silos of 750MT storage capacity each have been provided for stage-II (Unit-3 and 4) with 100% collection facility. About 200 TPD of fly ash is utilized for brick manufacturing (5 plants inside and 25 plants outside), about 80 TPD is supplied to asbestos units and 5,500 TPD of ash is used for dyke raising. Balance amount of ash is disposed off in the ash ponds in lean slurry form through pipelines. The utilisation of fly ash during 2016-17 was 42.7%.

The industry has two ash ponds as Stage-I (11 km away from plant) and Stage-II (13 km away from plant) and two nos of overflow lagoon for collection of ash ponds overflow water. The Stage-I was brought into operation in the year 1997 and Stage-II in the year 2003. The total area of Stage-I is 750 acres and Stage-II ash pond is 850 acres. The area of overflow lagoons of Stage-I and Stage-II ash pond is 45 acres and 56 acres respectively. Both the ash ponds are divided into two compartments i.e. Lagoon-I and Lagoon-II. The area of Lagoon-I of Stage-I and Stage-II ash pond is 230 acres and 144 acres respectively. Toe drains are provided along the periphery of the dyke to control seepage water in the ash dyke. **Fig. 4.1** shows the ash pond of the industry situated at Takua village.

In general, one lagoon is kept in service. Presently the Stage-I ash pond is in 7th raising and stage II ash pond is in 6th raising. They have installed 2 pump houses consisting of 36 ash slurry pumps for 6 Units. In addition to the above, the power plant has been allotted abandoned Quarry No.8 of Jagannath Coal mine of MCL having void capacity of 17.8 million m^3. The plant has initiated several studies and is in the process of obtaining various clearances for mine void filling. The location of the ash disposal site and its features are presented in **Table 4.1 and Table 4.2** respectively.

Fig. 4.1 Ash Pond of M/s TSTPP (NTPC), Kaniha

Table 4.1 Features of Ash Pond

Sl No	Details	Distance
1	Location of the Site	Takua Village (Stage-I) Derang Village(Stage-II)
2	Distance from the plants	North to NW of the industry
3	Distance from human habitation	Takua Village:0.2 km W of Stage-I ash pond Derang: 0.02 km W of Stage-II ash pond Kaniha: 0.4 km E of ash pond
4	Distance from water bodies	Tikira: 0.3 km N to E of ash pond BakuliJhor flows between Stage I and II (0.02 km)
5	Distance from educational institutions/ commercial infrastructures	Kaniha College: 1,0 km SE of ash pond Kaniha market : 0.8 km E of ash pond
6	Distance from forest cover	0.6 km in North direction
7	Distance from roads and railway line	Talcher -Rengali road: 0.5 km N& E of ash pond TTPS Rly line: 3.0 km E of ash pond
8	Distance from heritage site	NA

Table 4.2 Features of Ash Pond

Name of Ash Disposal Sites	Stage # I	Stage # II
Area (acre)	750	850
Type of lining	Clay	Clay
Over How Lagoon (OFL)	45	56
Others facilities (acre)	195	541
Design height of each raising(m)	3.00	5.00
No. of raising designed for	Seven	Nine
Present stage of raising	6th	4th
No. of pipelines	4	6
Distance from plant (km)	10.8	13.2
Volume of ash stored (million m^3)	352	348
Operating since	01.01.1997	01.08.2003

4.3 Sampling locations

Ground water, soil, fly ash and air samples have been collected around the ash disposal site. **Fig. 4.2** shows the location of sampling sites. **Table 4.3** shows description of sampling site and its distance from the ash disposal site.

Fig. 4.2 Location of Sampling Points around Ash Ponds of M/S NTPC, Kaniha

4.4 Results and discussion

The results of the physico-chemical & mineralogical characterization of fly ash and pond ash samples, heavy metal analysis in ground water, leachability studies of fly ash & soil are given as follows:

4.4.1 Physical properties

It is found from the analysis that fly ash possesses a maximum mean particle diameter (D50=34.46 μm), whereas, pond ash with mean particle diameters (D50) of 40.14μm. The values of the D30 and D60 for each sample are determined and the Coefficient of Uniformity (C_U) and Coefficient of Curvature (C_C) are calculated. Itis concluded that the fly ash samples are poorly graded.

Table 4.4 shows physical properties of the fly ash and pond ash samples. The results show that the coefficient of permeability values of both the fly ash and pond ash samples is very low and equivalent to the permeability of silts. The average specific gravity and bulk density of fly

ashes are found to be more than the pond ash samples. The porosity of bulk fly ash varies between 50.46 and 55%, whereas, in case of bulk pond ash, it varies in the range of 51-58%.

Table 4.3 Details of Sampling Locations

Nomenclature	Description of sampling locations	Distance from Ash Pond (km)	Direction w.r.t. Ash Pond
Ground water			
NTK1	Kaniha Market, Gandhi Statue	2.0	SE
NTK2	Masunihata near temple	1.0	SW
NTK3	Derang village near shiva temple	1.5	NW
NTK4	Takua Village	2.0	NE
NTK5	Badahira Village	1.0	SE
Ash			
A1	Fly ash from ESP	-	-
A2	ash from pond	-	-
Soil			
S1	Kaniha Market, Gandhi Statue	2.0	SE
S2	Masunihata near temple	1.0	SW
S3	Derang village near shiva temple	1.5	NW
S4	Takua Village	2.0	NE
S5	Badahira Village	1.0	SE
Ambient air			
NA1	Mahanadi Club	1.0	W
NA2	Shakti Dwar	1.5	NE

Table 4.4 Physical Properties of the Fly Ash and Pond Ash Samples

Parameters	Color	Specific Gravity(G)	Bulk density, g/cc	Porosity, %	Coefficient of permeability, k x 10^{-4} cm/s
Fly ash	Gray	2.09- 2.15	1.06	50.46-51	1.65 - 1.86
Pond ash	Dark Gray	2.07 - 2.11	1.03 - 1.04	51-58	2.85 - 4.02

The scanning electron micrographs at ×1000 magnification are shown in **Figs. 4.3(a& b)**. The figures reveal that the fly ash samples consist of mostly spherical particles and the bottom ash consists of the irregularly shaped particles.

Fig. 4.3(a) SEM of Fly Ash Samples

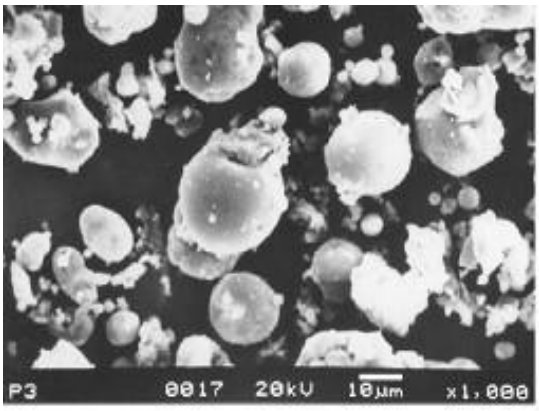


Fig. 4.3 (b)SEM of Pond Ash Samples

4.4.2 Chemical and mineralogical compositions

The elemental and chemical compositions (element oxides) of ash samples are presented in **Fig. 4.4 (a & b)**. The results show that all the fly ash and pond ash samples are abundant in Si and Al, and possess minor concentrations of Fe, Ca, Mg, Mn, K, Ti and P in the ash samples. The results of the chemical composition (element oxides) show that the ash samples are enriched predominantly with silica (SiO_2) and alumina (Al_2O_3). Since the sum total of SiO_2, Al_2O_3 and Fe_2O_3 is more than 90% in all fly ash and pond ash samples, they are classified as Class F fly ash according to the ASTM C-618 specifications. The fly ash and pond ash samples possess more or less similar physico-chemical and mineralogical properties. The reactive silica content in fly ash is found to be in the range 18-22%.

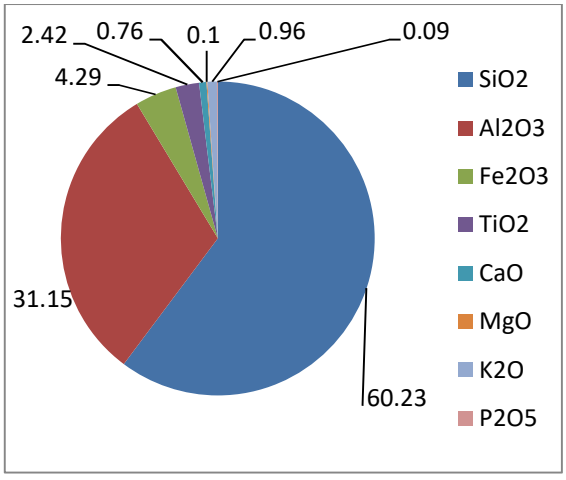


Fig. 4.4(a) Element Oxides of Fly Ash

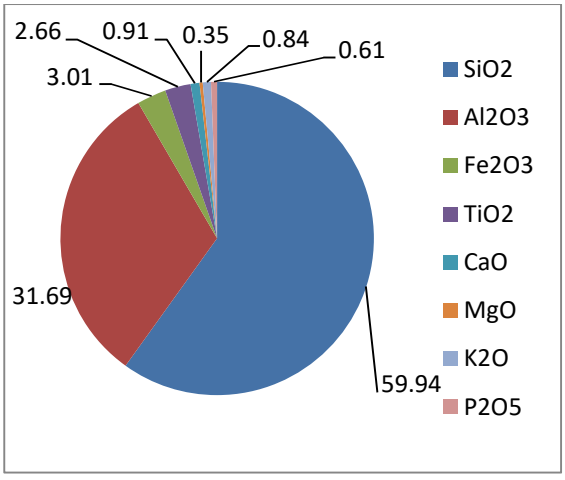


Fig. 4.4(b) Element Oxides of Pond Ash

4.4.3 Heavy metal analysis in water samples

The ground water analysis was performed on the water samples collected from the bore wells from different locations in the area of fly ash dumpsite. Details of the concentration of heavy metals in the groundwater samples near the ash ponds and at the surrounding villages are given in **Table 4.5**.

Ground Water Quality

Pre-monsoon Season 2016

- The analysis results indicate that the pH values in the range of 6.51 to 6.94, which is well within the specified standard of 6.5 to 8.5.
- The EC was observed in the range of 385mg/l to 776mg/l.
- The Ca was observed in the range of 16mg/l to 62mg/l exceeding the permissible levels of BIS guidelines
- The F was observed in the range of 0.56mg/l to 1.12mg/l, the maximum value was observed at Deranga (NTK3) and whereas minimum value was observed at Masunihata (NTK2). Fluoride concentration was observed to be above the standard mostly in pre-monsoon.
- The metal concentrations except Al were found to be within acceptable limit of BIS guidelines.

Post Monsoon Season 2010

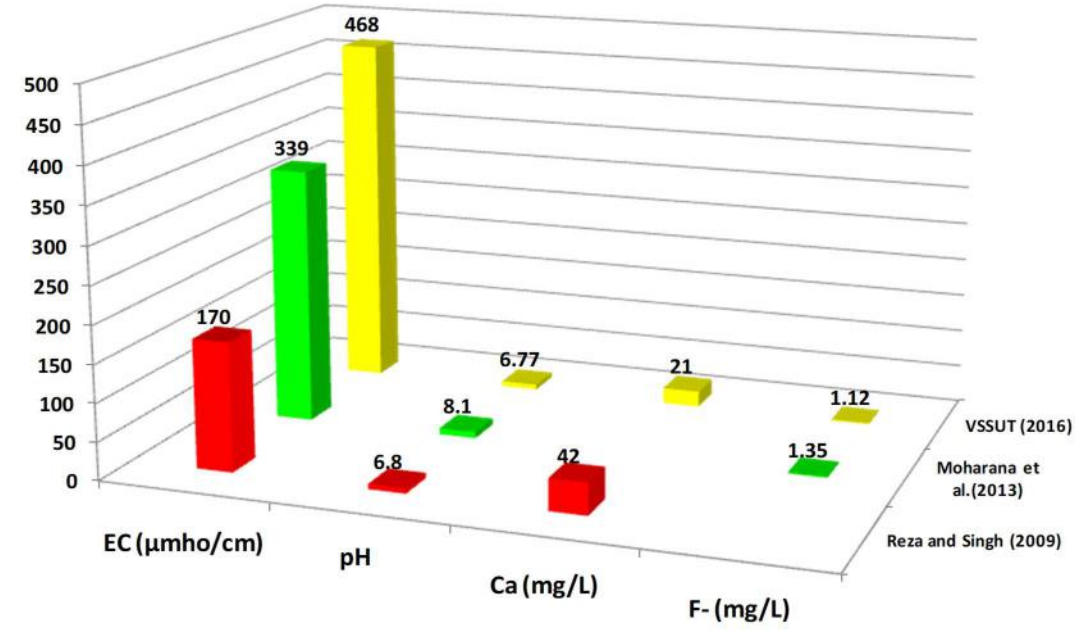
- The analysis results indicate that the pH values in the range of 7.2 to 7.8, which is well within the specified standard of 6.5 to 8.5.
- The EC was observed in the range of 565mg/l to 912mg/l, the maximum TDS value was observed at Deranga (NTK3) and whereas minimum value was observed at Badahira village (NTK5).
- The Ca was observed in the range of 21mg/l to 82mg/l exceeding the permissible levels of BIS guidelines
- The F was observed in the range of 0.47mg/l to 0.86mg/l.
- The metal concentrations except Al were found to be within acceptable limit of BIS guidelines. The concentrations of heavy metals in post monsoon are less compared to pre monsoon, probably due to dilution of ground water.

Table 4.5 Analysis Result of Ground Water Sample

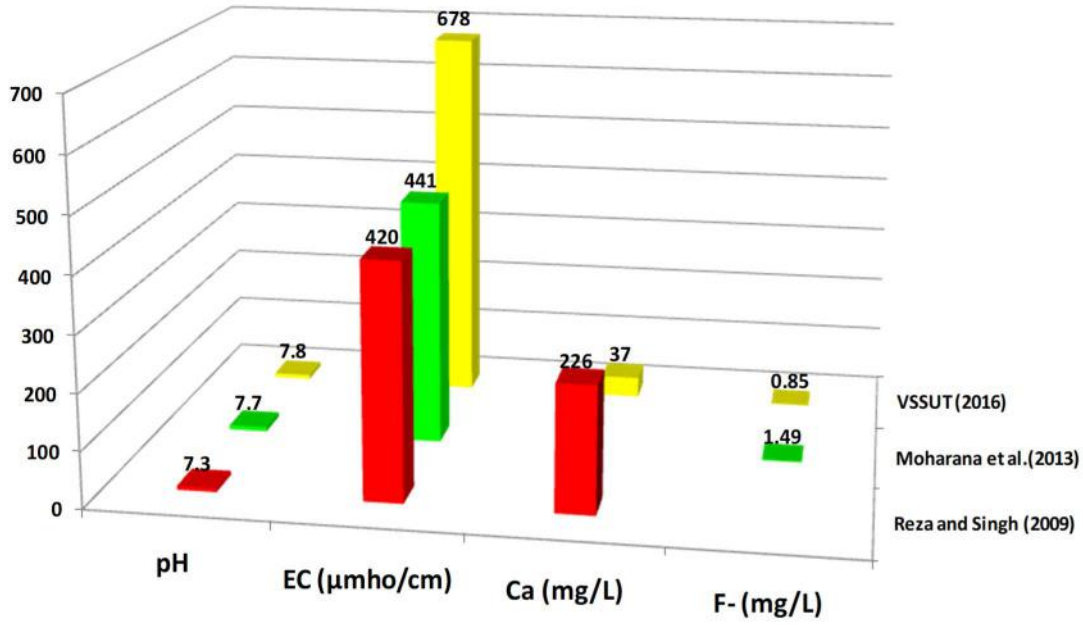
Sample ID	Season	pH	EC	Ca	Al	Cr^{+6}	T. Cr.	Cd	Pb	Cu	Zn	Hg	F^-
NTK1	Premonsoon	6.94	632	62	0.032	0.018	0.050	BDL	0.050	BDL	0.514	0.0002	0.88
	Postmonsoon	7.45	865	82	0.024	0.010	0.046	BDL	0.003	BDL	0.126	BDL	0.51
NTK2	Premonsoon	6.51	485	37	0.028	0.021	0.198	BDL	0.010	0.027	0.628	0.0001	0.56
	Postmonsoon	7.20	565	47	0.023	0.006	0.100	BDL	0.001	BDL	0.161	BDL	0.47
NTK3	Premonsoon	6.76	776	45	0.022	0.019	0.183	BDL	0.040	0.023	0.023	0.00041	0.71
	Postmonsoon	7.80	912	63	0.013	0.011	0.050	BDL	0.002	BDL	0.011	BDL	0.60
NTK4	Premonsoon	6.77	468	16	0.043	0.011	0.133	BDL	0.030	BDL	0.331	0.00048	1.12
	Postmonsoon	7.78	678	21	0.051	0.011	0.126	BDL	0.002	BDL	BDL	BDL	0.85
NTK5	Premonsoon	6.51	385	37	0.028	0.021	0.118	BDL	0.030	0.027	0.328	0.0001	0.86
	Postmonsoon	7.20	565	47	0.023	0.006	0.100	BDL	0.002	BDL	0.061	BDL	0.67
AL		**6.5-8.5**	**-**	**75**	**0.03**	**-**	**0.05**	**0.003**	**0.01**	**0.05**	**5**	**0.001**	**1.0**
DL		-	-	-	0.002	-	0.01	0.0001	0.002	0.004	0.002	0.00007	-

Unit of all parameters is mg/l except pH and EC; Unit of EC is µS/cm; pH has no unit; AL: Acceptable Limit as per IS 10500:2012; DL: Detectable limit

The pre and post-monsoon groundwater quality parameters such as pH, EC and Ca of village Takua were compared with the previous studies conducted by other researchers to find out the trends which are presented in **Fig. 4.5**. It is evident from the figures that the EC of groundwater has considerably increased over the years.



(a)



(b)

Fig. 4.5 Comparison of (a) Pre & (b) Post Monsoon Groundwater Quality Parameters at Takua Village

4.4.4 Heavy metal analysis in ash and soil samples

Acid digestion data of fly ash and surrounding soils provide the total available concentration levels of trace elements in fly ash & soils which is shown in **Table 4.6**. The results obtained from TCLP were found significantly lower in composition compared to acid digestion test. The results reveal that concentrations of heavy metals in pond ash are less than the fly ash indicating some leachability of metals. The overall analysis result of soil suggests that the local soil is not that much contaminated with fly ash.

Table 4.6 Concentration of Elements in Ash and Soil Sample

Sample ID	Testing Procedure	Ca	Al	Cr^{+6}	Total Cr	Cd	Pb	Cu	Zn	Hg	F^-
A1	*SADT	3780	7471	BDL	235	4.1	91	102	155	1.24	
	*TCLP	1668	31.2	BDL	0.43	0.0018	0.028	0.312	0.72	BDL	16.4
A2	SADT	3360	6585	BDL	198	3.8	81	55	150	0.74	
	TCLP	1647	35.4	BDL	0.33	0.0012	0.026	0.148	0.52	BDL	15.1
S1	SADT	2340	3028	BDL	12.2	BDL	1.843	17.8	12.3	BDL	
	TCLP	1998	24	BDL	BDL	BDL	BDL	BDL	BDL	BDL	1.0
S2	SADT	2052	2193	BDL	12.8	BDL	1.478	14.0	8.1	BDL	
	TCLP	1420	11.8	BDL	BDL	BDL	BDL	BDL	BDL	BDL	1.2
S3	SADT	2020	3656	BDL	19.16	BDL	BDL	14.8	14.6	BDL	
	TCLP	1502	17.63	BDL	BDL	BDL	BDL	BDL	BDL	BDL	1.36
S4	SADT	2440	3416	BDL	11.8	BDL	BDL	19.16	10.3	BDL	
	TCLP	1906	16.22	BDL	BDL	BDL	BDL	BDL	BDL	BDL	2.4

Unit of all parameters is mg/kg

4.4.5 Ambient air quality

Ambient air quality at Mahanadi club and Shakti Dwar for PM_{10} gives the value 75 µg/m^3 and 135 µg/m^3 respectively. It was reported by the public that severe dust pollution in the villages nearer to ash ponds occurs during ash pond dyke raising.

4.5 Conclusion

On the basis of the study, following conclusion are drawn:

- The ash characterization results indicate that the fly ash comes under the class F.
- Analytical results of ground water samples collected from different locations show that the physico-chemical parameters are within the permissible levels of BIS guidelines except Al. The higher concentration of Aluminium in ground water may be due to Aluminium bearing minerals in the study area. pH of the water sample ranged from 6.51 to 7.80, indicating alkaline nature of the water. The dug wells and tube wells at all sampling locations exhibited very high TDS values in the range 230-650 mg/l. Fluoride concentration was observed to be within the standard.

- No Cadmium was detected in any season.
- It is also noted that the on-line Emission monitoring devices and continuous AAQ monitoring stations have been installed by the power plant.
- As per the results obtained from leachate tests, the leaching of metals may occur only under extremely acidic conditions in laboratory. Under normal environmental conditions, the leaching of the heavy metals and trace elements is insignificant.
- The hydraulic conductivity values indicate that the ash has very poor permeability. This explains the low concentration of trace elements in the ground water. However, it will be still less at the bottom where it is more compacted.

The following suggestions are made for better management of ash in the plant.

- The industry shall make lucrative policy for fly ash users for large scale utilization of fly ash before exploring the option like quarry and mine void filling.
- The plant may adopt high concentration slurry disposal (HCSD) to reduce the formation of leachate from ash.
- The seepage from the ash ponds must be prevented into Bakulijhor leading to Tikira. The same must be recycled for reuse in ash slurry making.
- The industry must install a permanent sprinkler system in the ash dyke to control fugitive ash problem in the near-by villages during ash dyke raising.
- The Thermal Power Plant must monitor the ground water quality around the ash disposal sites and at other strategic location to predict future trend.
- The surface of the pond ash may be sprinkled with the waste water treatment plant sludge. This has the advantages of controlling the fugitive emissions by forming a thin film on the surface; enhancing the fertility of ash for growth of vegetation and ground cover and thirdly by providing a disposal option for the WTP (water treatment plant) sludge.
- Planting of saplings having tolerance to warm slurry water and heavy metals may be considered to be the most ideal mitigation measure, since the biomass can also adsorb toxic metals as nutrients and provide obstruction for windblown particulates.

Chapter 5

Bhushan Energy Ltd., Dhenkanal

5.1 Introduction

M/s Bhushan Energy Ltd is located in Banarpal block of Angul district which is 2.2 km due south of NH-55and nearly 6 km due south west of Brahmani river and bounded by the villages Narendrapur, Sibapur, Mitikapashi and Talabahal etc. The installed power generation capacity of the plant is 485MW (2 x 150 MW + 185 MW). Both the units of 150 MW the plant were commissioned in April 2010. The source of coal and water is MCL (Talcher Area) and Brahmani river respectively. The south-west monsoon is the principal source of the rain fall in the area. The average annual monsoon rain fall in the area is 1401 mm. Winds are mostly blown from southwest to northeast directions during monsoon period. In the cold season winds are mainly from west or north while in the summer wind blows from variable directions. Generally, wind speed varies from 16-22 km/hr for 240 days and rest of the days are calm.

5.2 Ash management

The industry generated 5,03,071tonne of ash during the year 2016-17. Earlier, the industry was disposing the ash in dry form at Sibpur ash mound in an area of 22 Acres. The mound has been reclaimed by maintaining the slopes and undertaking plantations. A garland drain with catch pits has also been provided around the ash mound for collection of the surface-run off. **Fig. 5.1** shows the location of old ash pond.

The plant is generating about 2,000 TPD of ash at present out of which about 100 TPD is used for brick manufacturing inside the plant premises. Remaining fly ash is being disposed off in filling of stone quarries and mine void in dry form. Both bottom ash and fly ash are being conveyed to respective ash storage silos by pneumatic conveying system prior to transport to disposal sites. The unloading of ash from silo is done through ash conditioner unit where ash is conditioned with water containing more than 20% moisture leaving no ash particles to be air borne. The ash is transported in covered vehicles to stone quarries and through bulkers in mine void.

The industry has obtained permission from competent authority to dispose the ash in six stone quarries having an area of 19.37 Acres located at Karanda village which is about 12 km by road from the plant. One of the stone quarries has already been filled up and stabilized.

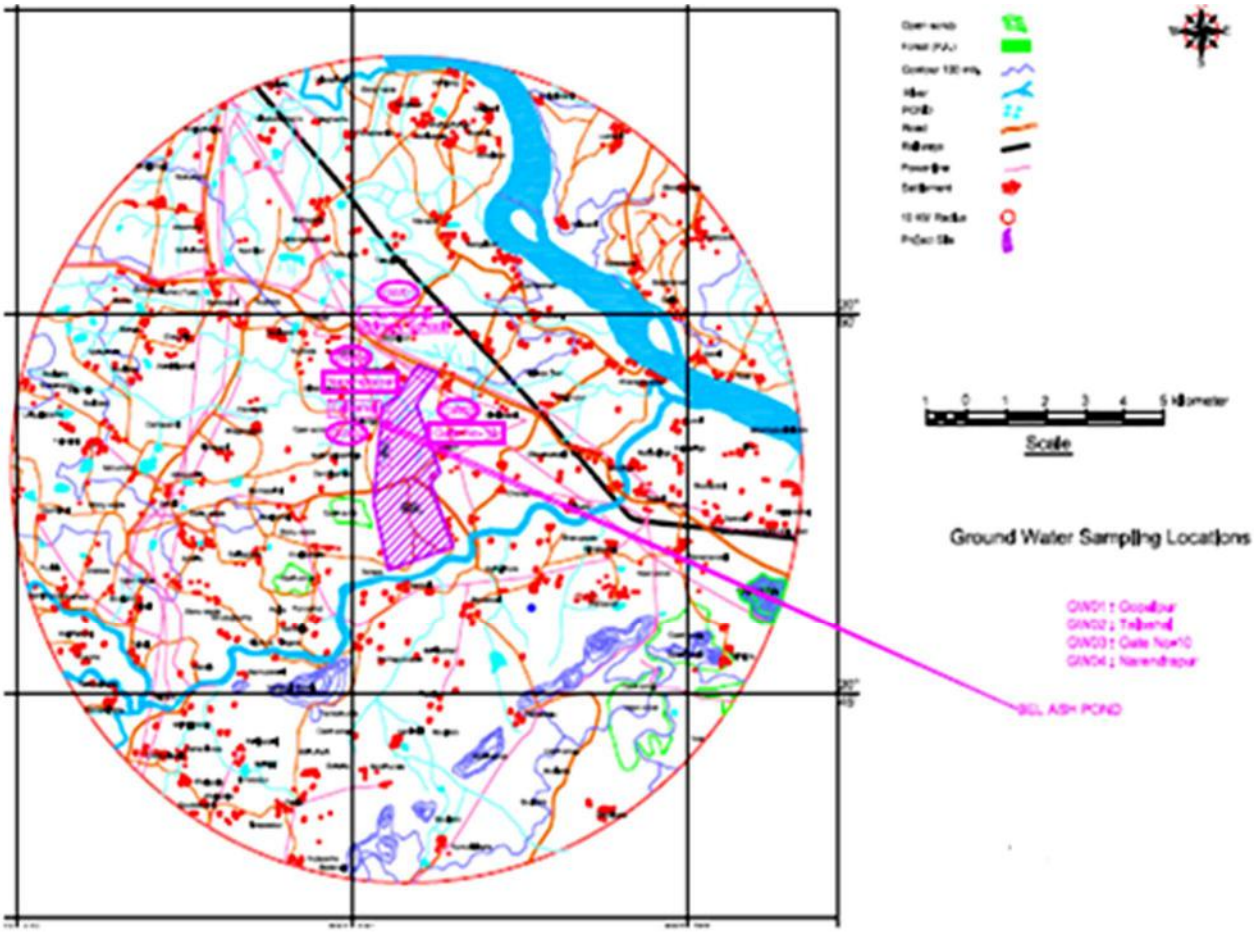


Fig. 5.1 Ash Pond of M/s BEL, Dhenkanal

Ash from the bulker is evacuated pneumatically on the site of mine void (Quarry-4 of Jagannath OCP) and is converted in to slurry in three mixers by adding water. The slurry is then released to the mine void by gravity. Water from the mine is used for slurry making. The distance of mine void is about 37 km by road. The area of mine void is 294.19 acres having capacity of 17 million M^3. The practice of mine void filling has started since 15th March, 2014. The detail of the ash disposal areas of the plant at Karanda and surrounding features of facilities at Sibpur & Karanda are given in **Table 5.1** and **5.2** respectively.

5.3 Sampling locations

Ground water, soil and fly ash samples have been collected around the ash disposal sites situated at Sibpur and Karanda. **Fig. 5.2** and **Fig. 5.3** show the location of sampling sites. **Table 5.3** shows description of sampling site and its distance from the ash disposal site.

Table 5.1 Details of Ash Disposal Sites

Name of the ash disposal sites	Area in Acre	Volume in m^3
Quarry no. 4 of Jagannath OCP, MCL	294.19	17000000
Stone quarry at Karanda	2.56	54149
Stone quarry at Karanda	4.71	99792
Stone quarry at Karanda	2.35	49778
Stone quarry at Karanda	2.93	61914
Stone quarry at Karanda	2.24	47350
Stone quarry at Karanda	4.58	96876
Ash moundat Sibpur	4.78	145102
Laterite Stone quarry at Baldiabandha	15.0	303450
Black Stone quarry at Tarakbeda(2 quarries)	3.0	94955

Table 5.2(a) Inventory of Ash Disposal Sites

1	Location of the Site	Sibpur	Karanda Black Stone Quarries	Baldiabndha laterite stone quarry	Tarkabeda Black Stone Quarries
2	Distance from the plants	1.5 km NW of the industry	20 km SE of industry	30 km N of industry	15 km SE of industry
3	Distance from human habitation	1.5 km (Sibpur)	Karanda: 1 km SW of site	Baldiabndha: 1.5 km S of site	Tarkabeda: 1.5 km SW of site
4	Distance from water bodies	KisindaJhor: 0.1 km E of site	Seasonal Nala: 1 km N of site	-	-
5	Distance from educational institutions/commercial infrastructures	Narendrapur Primary School: 2.0 km NW of site	Ghodadian School: 2 km N of site	OMFED Dhenkanal: 1.0 km W of site	Madhupur Primary School: 1.2 km N of site
6	Distance from forest cover	Nil	Nil	Nil	Nil
7	Distance from roads and railway line(if any)	NH 55: 0.5 km N of site SE Rly line: 2.5 km N of site	RD Road: 0.5 km W of site	NH 55: 0.5 km S of site	NH 55: 5 km N of site
8	Distance from heritage site	Nil	Nil	Nil	Nil

Table 5.2(b) Inventory of Quarry-4 of Jagannath OCP, MCL

S.N.	Features	Name	Distance (km)	Direction from site
1	Location of the Site and Details of the Landmarks	Jagannath OCP	25	NW
2	Distance from human habitation	Dera	1	E
3	Distance from water bodies	Nil		
4	Distance from educational institutions/commercial infrastructures	Central Hospital	2	SE
5	Distance from forest cover	Nil	-	-
6	Distance from roads and railway line(if any)	South Balanda RD road	2	SE
7	Distance from heritage site	Nil	Nil	NiL

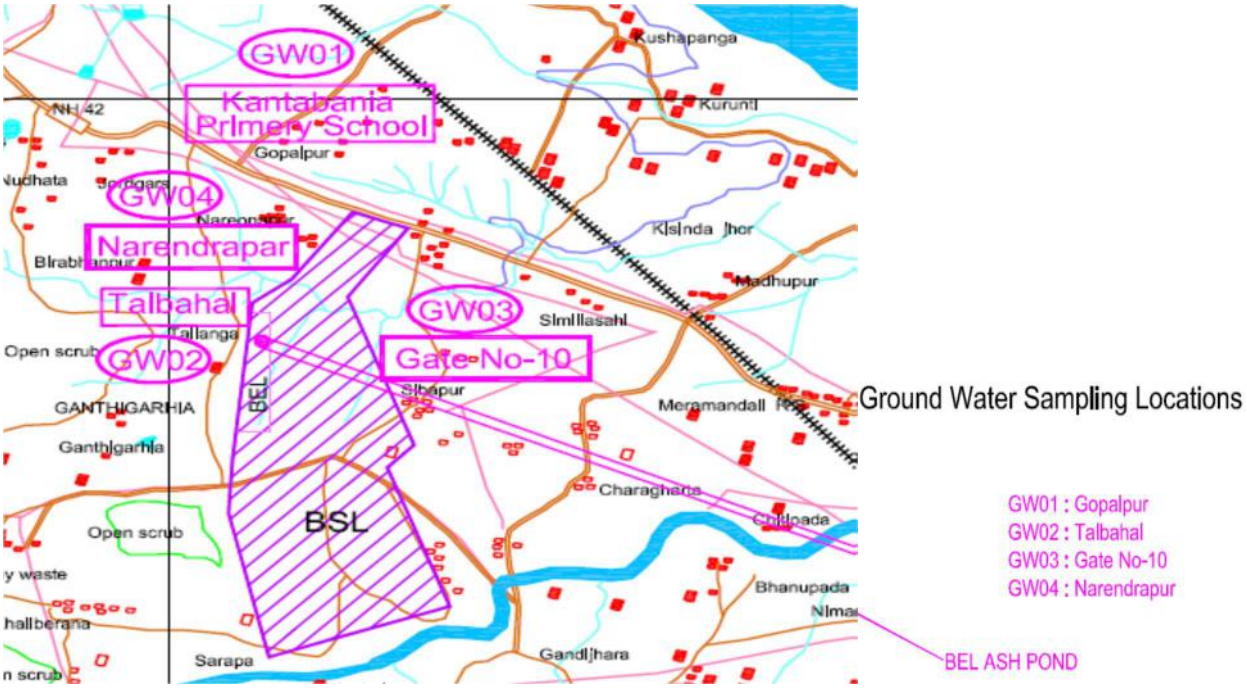


Fig. 5.2 Location of Sampling Points around Ash Pond at Sibpur of M/S BEL, Dhenkanal

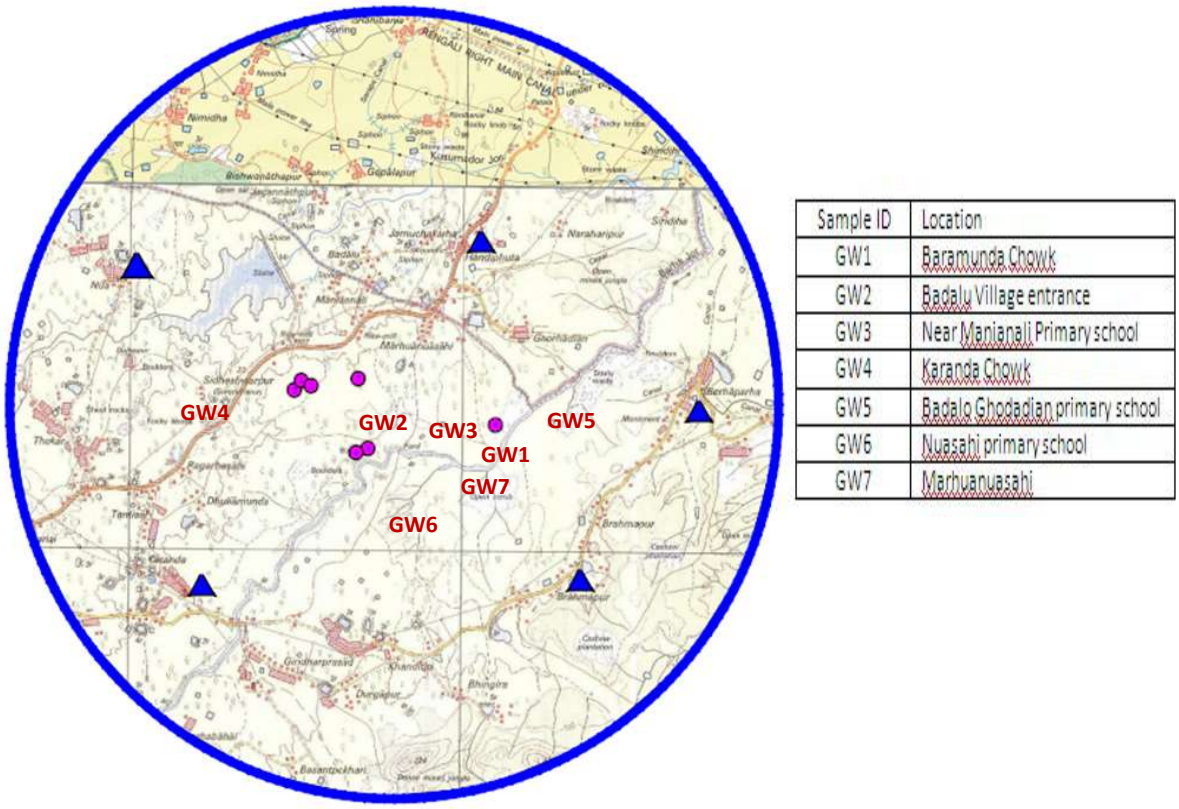


Fig. 5.3 Location of Sampling Points around Ash Pond at Karanda of M/S BEL, Dhenkanal

Table 5.3(a) Location Details of Sampling Stations at Sibpur Ash Mound

Nomenclature	Description of sampling locations	Distance from Ash Pond (km)	Direction w.r.t. Sibpur ash mound
Ground water			
GW01	Gopalpur (Kantabania Primary school)	1.5	NW
GW02	Talbahal Near Boundary wall	1 .5	SW
GW03	Gate No 10	1.5	W
GW04	Narendrapur village	1.5	NW
Ash			
A1	Fly ash		
A2	Ash from mine void		
Soil			
S1	Narendrapur Village	1.5	NW
S2	Talbahal Near Boundary wall	1 .5	SW

Table 5.3(b) Location Details of Sampling Stations at Karanda Stone Quarry

Nomenclature	Description of sampling locations	Distance from Ash Pond (km)	Direction w.r.t. Karanda stonequarry
Ground water			
GW1	BaramundaChowk	1.5	NE
GW2	Badalu village entrance	2.0	E
GW3	Near Manianali Primary School		
GW4	KarandaChowk	2,0	SW
GW5	BadaluGhodadian U.P school	2.0	N
GW6	BaramundaChowk	1.5	NE
GW7	Maruhanuasahi	1.5	NE
Soil			
S3	KarandaChowk	2.0	SW
S4	BaramundaChowk	1.5	NE

5.4 Results and discussion

The results of the heavy metal analysis in ground water, leachability studies of fly ash & soil are as follows:

5.4.1 Heavy metal analysis in water samples

Table 5.4 presents the analysis result of groundwater samples. The groundwater analysis results reveals that all the parameters except Ca, Al and F meet the drinking water standard prescribed in IS10500:2012. The concentrations of heavy metals in post monsoon are less compared to pre monsoon, probably due to dilution of ground water.

5.4.2 Heavy metal analysis in ash and soil samples

Acid digestion data of fly ash and surrounding soils provide the total available concentration levels of trace elements in fly ash & soils which is shown in **Table 5.5**. The results obtained from TCLP were found significantly lower in composition compared to acid digestion test. The results reveal that concentrations of heavy metals in mine void ash are less than the fly ash indicating some leachability of metals. The overall analysis result of soil suggests that the local soil is not much contaminated with fly ash.

5.5 Availability of quarry voids for ash disposal

The industry has obtained permission for disposal of fly ash at the following low lying areas. The detail features of the sites are presented below in **Table 5.6**. The area of the low lying areas at Bhudhapank and Kurinti-Malgalpur are 2.97 and 3.67 acre respectively. The volume of Bhudhapank site is 23600 m^3 and Kuinti-Mangalpur is 43500 m^3.

Table 5.4 Analysis Result of Ground Water Sample

Sample ID	Monsoon	pH	EC	Ca	Al	Cr^{+6}	T. Cr.	Cd	Pb	Cu	Zn	Hg	F^-
GW01	Pre	7.44	482	13	0.011	0.018	0.049	BDL	0.015	0.013	0.34	0.00021	0.32
	Post	7.60	882	113	0.011	0.018	0.041	BDL	BDL	BDL	0.24	BDL	0.12
GW02	Pre	7.47	687	52	0.012	0.021	0.293	BDL	0.013	0.018	0.21	0.00011	0.16
	Post	7.51	987	67	BDL	0.026	0.163	BDL	BDL	BDL	0.08	BDL	0.08
GW03	Pre	7.92	492	34	0.028	0.022	0.184	BDL	0.002	0.015	0.38	0.0004	0.42
	Post	8.11	535	78	BDL	0.032	0.113	BDL	BDL	BDL	0.28	BDL	0.28
GW04	Pre	7.73	456	98	0.042	0.028	0.173	BDL	0.013	0.008	0.27	0.00028	0.36
	Post	7.84	585	112	BDL	0.038	0.050	BDL	BDL	BDL	0.15	BDL	0.12
GW1	Pre	7.66	487	98	0.013	0.027	0.181	BDL	0.009	0.016	1.62	BDL	1.2
	Post	7.75	684	124	BDL	0.015	0.113	BDL	BDL	BDL	0.95	BDL	0.92
GW2	Pre	7.68	564	82	0.018	0.025	0.164	BDL	0.01	0.017	2.66	BDL	1.0
	Post	7.80	662	105	BDL	0.021	0.121	BDL	BDL	BDL	1.26	BDL	0.75
GW3	Pre	7.75	422	56	0.032	0.031	0.223	BDL	BDL	0.014	0.11	BDL	0.82
	Post	7.80	567	77	BDL	0.032	0.109	BDL	BDL	BDL	BDL	BDL	0.65
GW4	Pre	7.75	879	31	0.033	0.028	0.203	BDL	BDL	0.011	0.033	BDL	0.51
	Post	7.82	987	57	BDL	0.013	0.047	BDL	BDL	BDL	BDL	BDL	0.38
GW5	Pre	7.66	487	98	0.013	0.027	0.181	BDL	0.009	0.016	1.62	BDL	1.2
	Post	7.75	684	124	BDL	0.015	0.113	BDL	BDL	BDL	0.95	BDL	0.92
GW6	Pre	7.68	564	82	0.018	0.025	0.164	BDL	0.01	0.017	2.66	BDL	1.0
	Post	7.80	662	105	BDL	0.021	0.121	BDL	BDL	BDL	1.26	BDL	0.75
GW7	Pre	7.75	422	56	0.032	0.031	0.223	BDL	BDL	0.014	0.11	BDL	0.82
	Post	7.80	567	77	BDL	0.012	0.049	BDL	BDL	BDL	BDL	BDL	0.65
AL		**6.5-8.5**	**-**	**75**	**0.03**	**-**	**0.05**	**0.003**	**0.01**	**0.05**	**5.0**	**0.001**	**1.0**
DL		-	-	-	0.002	-	0.01	0.0001	0.002	0.004	0.002	0.00007	-

Unit of all parameters is mg/l except pH and EC; Unit of EC is µS/cm; pH has no unit; AL: Acceptable Limit as per IS 10500:2012; DL: Detectable limit

Table 5.5 Analysis Result of Ash and Soil Sample (SADT &TCLP)

Sample ID	Testing Procedure	Ca	Al	Cr	Cd	Pb	Cu	Zn	Hg	F^-
A1	SADT	6612	6672	BDL	4.20	93	98	128	0.62	-
	TCLP	5835	29.84	BDL	0.0015	BDL	BDL	BDL	BDL	14.1
A2	SADT	6425	6686	BDL	4.10	88	68	105	0.41	-
	TCLP	5945	32.4	BDL	0.0014	BDL	BDL	BDL	BDL	11.2
S1	SADT	2212	2129	BDL	BDL	BDL	2.24	8.1	BDL	-
	TCLP	1810	10.56	BDL	BDL	BDL	BDL	BDL	BDL	1.4
S2	SADT	2820	2235	BDL	BDL	BDL	1.51	12.3	BDL	-
	TCLP	2408	11.81	BDL	BDL	BDL	BDL	BDL	BDL	1.6
S3	SADT	2290	2156	BDL	BDL	BDL	3.21	18.0	BDL	-
	TCLP	1718	11.63	BDL	BDL	BDL	BDL	BDL	BDL	1.2
S4	SADT	2319	2434	BDL	BDL	BDL	2.54	14.1	BDL	-
	TCLP	1870	12.22	BDL	BDL	BDL	BDL	BDL	BDL	1.5

Unit of all parameters is mg/kg

Table 5.6 Inventory of Low Lying Area for Ash Disposal

1	**Location of the Site**	**Budhapanka**	**Mangalpur- Kurinti**
2	Details of the Landmarks	Budhapanka: 3.5 km NW from the plant	Kurinti: 1.0 km N from the plant
3	Distance from human habitation	Budhapanka: 1.5 km N of the site	Itapa: 0.6 km E of the site
4	Distance from water bodies	Nil	Reangali right canal: 0.2 km N of the site
5	Distance from educational institutions/commercial infrastructures	Budhapank High School: 0.15 km N of the site	Narendrapur Primary School: 1.0 km W of the site
6	Distance from forest cover	Nil	Nil
7	Distance from roads and railway line(if any)	NH55: 1.0 km S of the site	NH55: 0.05 km S of the site
8	Distance from heritage site	Nil	Nil

5.6 Conclusion

On the basis of the study, following conclusion are drawn:

- The reactive silica content in fly ash is found to be in the range 10-12%.
- Good vegetation was observed around all ash disposal sites. The industry has planted good number of trees at Sibpur dump area.
- Analytical results of ground water samples show that the physico-chemical parameters are within the permissible levels of BIS guidelines except Ca, Al and F.
- It has also been noted that the on-line Emission monitoring devices and continuous AAQ monitoring stations have been installed by the power plant.

The following suggestions are made for better management of ash in the plant.

- The industry shall make lucrative policy for fly ash users for large scale utilization of fly ash before exploring the option like quarry and mine void filling.
- The plant shall adopt lean concentration slurry disposal method to transport the ash to mine void instead of transporting the ash by bulkers.
- The industry must make the base and sides of laterite/black stone quarry/low lying filling sites impermeable by HDPE/LDPE lining or any other suitable impermeable media with appropriate thickness. Once any quarry is filled completely, it must be stabilized.
- The industry must provide water sprinkler system to control fugitive dust at the laterite/black stone quarry/low lying filling sites.
- The industry must monitor the ground water quality on quarterly basis around the mine voids of Jagannath OCP and other ash disposal sites to predict future trend.

Chapter 6

HINDALCO Industries Ltd (CPP), Hirakud, Sambalpur

6.1 Introduction

M/s Hindalco Industries Ltd is located at Hirakud, Sambalpur having aluminum smelting facility and power plant. The power generation capacity of the plant is 467.5 MW (1 X 67.5 + 4 X 100). Both bottom ash and fly ash are being conveyed to respective ash storage silos by pneumatic conveying system prior to transport to ash mound. The unloading of ash from silo is done through ash conditioner unit where ash is conditioned with water containing more than 20% moisture leaving no ash particles to be air borne. The ash is being transported in tarpaulin cover truck to ash mound and transported to ash dumping ground. The industry has constructed its ash disposal area in an area of 103 acres which is located at a distance of 5 km from the plant. The total ash generation from this plant was about 0.754 Million tons during the financial year 2016-17. At present, the Power Plant generates about 840 TPD of ash, out of which, about 3,800 TPD is being sent to the ash mound. Balance ash of about 0.39 million tons is supplied to fly ash brick manufacturers, cement manufacturers and for low lying land development.

6.2 Ash management

The ash mound of the industry is situated near Budhakanta village (**Fig. 6.1**). Location of Ash Disposal Sites are given in **Table 6.1**.

Table 6.1 Location of Ash Disposal Site at Hindalco

1. Name of the Site	Ash Mound
2. Location of the Site	Near village Budhakata at a distance of 3 km and larbhanga village at a distance of 1.5 km
3. Details of the Landmarks	Left bank dyke of Hirakud Dam Reservoir
4. Distance from human habitation	0.5 Km
5. Distance from water bodies	0.5 Km
6. Distance from educational institutions/commercial infrastructures	More than 8 Km
7. Distance from roads and railway line	More than 10 Km from NH 6 More than 10 Km from nearest railway line
8. Distance from heritage site	No heritage around

Details of the ash disposal site along with ash collection system and disposal are summarized in **Table 6.2** respectively.

Fig. 6.1 Ash Mound at Hindalco

Table 6.2 Features of Ash Disposal Site at Hindalco

1. Details of Ash Disposal Sites		
(a)	Name of the Ash Disposal Site	Ash mound
(b)	Area in acre	135.4
(c)	Quantity of ash disposed off	6356660 MT
2. Ash collection system		
(a)	Collection device used	Pneumatic conveying from ESPs to Ash silos and then mechanically unloading (in moistened condition) to trucks for transportation to ash mound
(b)	Capacity	09 Ash silos of 1300 MT capacity each
(c)	Frequency of collection	Continuous
3. Modes of Transportation		By covered trucks
4. Disposal		
(a)	Disposal modes	Dry disposal
(b)	Frequency of disposal	Continuous on daily basis

6.3 Studies carried out by the TPP on impact of ash on environment

The plant has carried out various environmental studies (provided by the plant), which are given below in **Table 6.3**.

Table 6.3 Studies Carried out by TPP on Impact of Ash on Environment

S.N.	Name of the study	Agency (Year)
1	Fly ash characterization	Bhagavathi Ana Labs Pvt. Ltd., Hyderabad (2013)
2	Reclamation vis-à-vis restoration of ash mounds of HINALCO power plant at Hirakud under various plantation stage	SambalpurUniveristy (2010)
3	Comprehensive Characterization of fly ash generated at HINDALCO, Hirakud	CPRI, Bangalore (2008)
4	Environmental Impact Assessment Report - Expansion of smelter and captive power plant	EMTRC Consultant Pvt. Ltd., Delhi (2006)
5	Environmental Impact Assessment Study for the proposed expansion of captive power plant by 100 MW	VIMTA Labs Ltd., Hyderabad (2005)
6	Rapid Environmental Impact Assessment Study Report for Augmentation of 1 x 77 MW captive power plant	Development Consultants Ltd., Kolkata (1997)

The above reports have been reviewed and the salient features of Fly ash characterization, Soil characterization at the stabilized ash disposal site and ground water monitoring are given in **Table- 6.4, 6.5 and 6.6** respectively.

Table 6.4 Fly Ash Characterization (Studies Carried out by TPP)

Parameters	Units	Bottom ash	Fly ash
Specific Gravity	--	2.7	2.11
Plasticity	--	Non Plastic	Non-plastic
Max Dry Density	g/cc	Sand Size Material	1.23
Optimum Moisture Content	%	Sand Size Material	28.0
Cohesion	KN/m^2	Negligible	Negligible
Angle of Internal Friction	Ø deg	38	37
Coefficient Index	Cc	--	0.23
Coefficient of consolidation Cv	cm^2/sec	--	$1.93x10^{-3}$
Permeability	cm/sec	$2.5x10^{-3}$	$3x10^{-6}$
Particle size Distribution			
Clay	%	0	9

Silt	%	0.38	50
Sand	%	97.98	41
Gravel	%	1.64	NIL
Coefficient of uniformity	--	15	8.8
Total Chromium as Cr, mg/l		0.04	0.04
Vanadium as V, mg/l		0.02	0.03
Copper as Cu, mg/l		0.03	0.04
Zinc as Zn, mg/l		0.08	0.10
Nickel as Ni, mg/l		0.05	0.04
Cobalt as Co, mg/l		<0.01	<0.01
Lead as Pb, mg/l		0.03	0.02
Cadmium as Cd, mg/l		<0.01	<0.01
Arsenic as As, mg/l		<0.01	<0.01
Mercury as Hg, mg/l		0.002	0.002
Selenium as Se, mg/l		0.04	0.03
Molybdenum as Mo, mg/l		0.01	0.02
Antimony as Sb, mg/l		0.01	0.01

Table 6.5 Soil Characterization (Studies Carried out by TPP)

Parameters	Ash disposal site (2005)
Soil Type	Loam
Colour	Brown
pH(40% aq.solution, soil water extract)	6.3-6.9
Electrical Conductivity (1:5 soil-water extract, micro Siemens/cm)	105.9-118.9
Bulk density, gm/cc	1.21
Porosity (%)	29
Sand (%)	35
Silt (%)	21
Clay (%)	44
Water holding capacity (%)	39-43
Loss of ignition (%)	18-21
Available Nitrogen as N (kg/ha)	97.8-104.1
Available phosphrous as P	68.6-73.4

Available Potassium as K	289.5-316.5
Cation exchange capacity(meq/100gm)	13.2
Sodium Absorption Ratio	0.19-0.22
Available Magnesium as Mg	18.3-18.8
Zinc (mg/kg)	1.8-2.0
Iron (mg/kg)	25.5-26.7
Copper (mg/kg)	6.2-7.2
Boron (mg/kg)	28.5-29.4

Table 6.6 Ground Water Quality Analysis (Studies Carried out by TPP)

Water Quality Parameters	Budhakanta Village* (1997)	Budhakanta Village* (2005)	Budhakanta* (2006)	Larbanga** (2005)	Larbanga** (2006)
pH value	7.1	7.0-7.3	6.33	7.04	7.04
Conductivity µS/cm		467-691	420	190	190
SS (mg/l)	NIL	NIL	6	NIL	NT
TDS (mg/l)	252	256-345	282	151-235	NT
Total Hardness(mg/l)	94	211 - 318	160	144 -177	80
fluorides(mg/l)	0.881	0.54-0.67	0.6	0.32-0.49	0.5
Boron (as B)(mg/l)	BDL	<0.01	NT	<0.01	NT
Arsenic(as As)(mg/l)	BDL	<0.01	NT	<0.01	NT
Barium(as Ba) (mg/l)	BDL	<0.01	NT	-	-
Sodium(as Na) (mg/l)	18	<0.01	NT	-	-
Cadmium(as Cd)(mg/l)	BDL	<0.01	NT	-	-
Lead(As Pb) (mg/l)	BDL	<0.01	NT	<0.01	NT
Copper(as Cu) (mg/l)	BDL	<0.01	NT	-	-
Chromium(as Cr)(mg/l)	BDL	<0.01	NT	<0.01	0.04
Mercury(as Hg) (mg/l)	BDL	<0.001	NT	<0.001	NT
Nickel(as Ni) (mg/l)	BDL	<0.01	NT	-	-
Zinc(as Zn)(mg/l)	0.08	<0.01	1.24	<0.01	0.76
Iron(as Fe)(mg/l)	0.38	<0.01	0.04	<0.01	NT

** Same location as HW 01 and ** same location as HW02 as described in* ***Table 6.7***

Ground water monitoring indicates that all the measured water quality parameters are within the permissible.

6.4 Sampling locations

Ground and surface Water (HW) samples, soil sample (HS), air sample (HA) were collected around the Thermal Power Plants ash disposal sites and Fly ash (HF) sample was collected from the ash mound. Ground water (blank sample) was also collected from an area which is at a distance of more than 8 km from ash mound. The description of sampling site and its distance from the ash disposal site are presented in **Table 6.7**. Photographs taken during sampling are given at **Fig. 6.2**. Details of sampling locations are shown in **Fig. 6.3**.

Table 6.7 Location of Sampling Stations

Sl. No.	Sampling Locations	Description of Sampling Locations	Distance from Ash Pond (km)	Direction w.r.t. Ash Pond
1	HW01	Bore well at Budhakanta village	3	S
2	HW02	Bore well at Larbhanga village	1.5	NE
3	HW03	Open pond at Larbhanga village	1	NE
4	HW04	Bore well at Alind Guest house	8	SW
5	HW05	Bore well at Indal colony	9	SW
6	HW06	Bore well near Larbhanga village	2.5	SW
7	HS01	Soil sample from Larbhanga at a distance of 1.5 Km	1.5	NE
8	HS02	Soil sample from Budhakanta village	2.5	S
9	HF01	Fly ash sample from ash mound first location	0	-
10	HF02	Fly ash sample from ash mound second location	0	-
11	HA01	Ambient air quality monitoring at Larbhanga	1.5	NE

6.5 Results and discussion

The results of the physico-chemical and mineralogical characterization of fly ash as well as water quality analysis for ground water are given as follows:

6.5.1 Physical properties

It is found that fly ash possesses a mean particle diameter i.e. D_{50} having 38.8 µm and Coefficient of uniformity i.e. C_u having 14. **Table 6.8** shows physical properties of the fly ash. The results of the permeability test show that the coefficient of permeability is very low.

Soil sample collection at Larbhanga

Soil sample collection at Larbhanga

Water sample collection from open pond

Ash disposal site

Fig. 6.2 Photographs of Ash Disposal Site taken during Sampling

Table 6.8 Physical Properties of the Fly Ash Sample

Parameters	Color	Specific Gravity	Maximum dry density, g/cc	Porosity, %	Coefficient of permeability, k x 10^{-6} cm/s
Fly ash	Grey	1.98- 2.18	1.04 - 1.08	50-56	2.5 – 3.5

6.5.2 Chemical and mineralogical compositions

The element oxides of ash samples are presented in **Fig. 6.4 (a & b)**. The results show that the ash samples are enriched predominantly with silica (SiO_2) and alumina (Al_2O_3). In addition, they also contain small amount of iron oxide (Fe_2O_3), TiO_2, K_2O, CaO and MgO. The rest of the compounds present in the ash samples are in minor concentrations. The sum of SiO_2, Al_2O_3 and Fe_2O_3 accounts for more than 90% of the total composition in all fly ash and pond ash samples. Since the sum total of SiO_2, Al_2O_3 and Fe_2O_3 is more than 70% in all fly ash and pond ash samples, they are classified as Class F fly ash according to the ASTM C-618.The reactive silica content in fly ash is found to be in the range13.5 -16 %.

Fig. 6.3 Location of Sampling Points at Hindalco Ash Mound

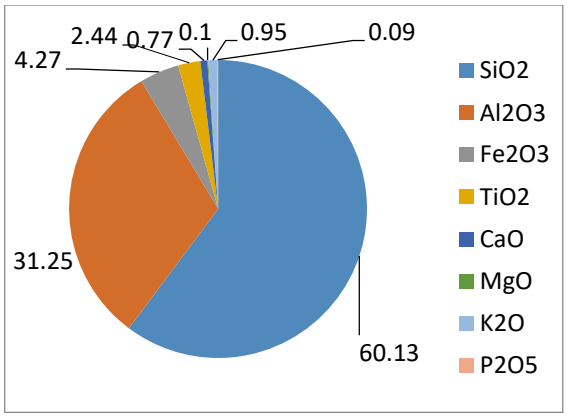


Fig. 6.4 (a) Element Oxides of Fly Ash-1

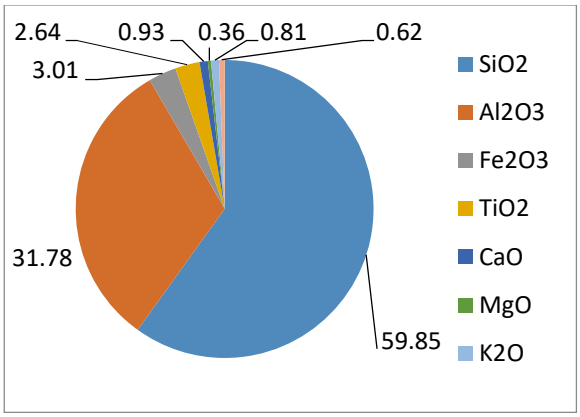


Fig. 6.4 (b) Element Oxides of Fly Ash-2

6.5.3 Ground Water Quality Analysis

The water quality analysis was performed on the water samples collected from the bore well as well as open pond from different locations in the area around fly ash dumpsite. Details of concentration of heavy metals and other water quality parameters in the groundwater samples near the ash disposal sites and at the surrounding villages are given in **Table 6.9**. Water quality analysis for the present study (**Table 6.9**) is compared with the water quality study done by TPP between 1997 to 2006 (**Table 6.6**) and the findings are discussed below:

- pH of the water sample ranged from 7.2 to 8.1, indicating alkaline nature of the water (present study). A neutral range of pH value (pH = 6.3 – 7.3) was found by the studies carried out by TPP. The difference in result is due to seasonal variations.
- Maximum value for electrical conductivity (EC) is 724 µS/cm and minimum value is 326 µS/cm for ground water sample (present study). Similar electrical conductivity values i.e. 190 - 691 µS/cm was found by the studies carried out by TPP. High fluctuations in EC values in different ground water samples are due to fact that some bore-wells (having lower EC values) are hydraulically connected to Hirakud reservoir and recharged by the reservoir water. EC values for the surface water is less than 200 µS/cm.
- Calcium (Ca in mg/l) of the ground water sample ranged from 24 to 72 mg/l for all the ground water samples (present study).
- Presence of Aluminum is found in all the six pre-monsoon samples and five out of the six post-monsoon samples within the range of 0.016 – 0.056 mg/l (present study).
- Concentrations of hexavalent chromium are below the detectable limit in all the ground water as well as surface water samples (present study). Total chromium is found in all

ground water and surface water samples collected during pre and post monsoon within the range of 0.015 – 0.042 mg/land are below acceptable limit (present study). Total chromium is found in one ground water sample (0.04 mg/l) tested by the TPP. Total chromium in rest of the samples tested by the TPP is below detectable limit (<0.01).

- Concentration of Cadmium (Cd in mg/l) is found in all samples with a minimum and maximum concentration of 0.0015 mg/l and 0.003 mg/l respectively (present study), which are within the acceptable limit. Studies carried out by TPP indicate the presence of cadmium below detectable limit (<0.01 mg/l) in all ground water samples.
- Concentration of Lead (Pb in mg/l) is found in all samples with a minimum and maximum concentration of 0.008mg/l and 0.045 mg/l respectively (present study). Studies carried out by TPP indicate the presence of lead below detectable limit (<0.01 mg/l) in all ground water samples.
- Concentration of Mercury (Hg in mg/l) in all the water samples (present study) as well as in the sample tested by the TPP is below detectable limit.
- Presence of Copper (Cu in mg/l) is found in all the ground water samples (0.032 – 0.05 mg/l) but not in the surface water sample (present study). However, the concentration of Copper is below the acceptable limit. Studies carried out by TPP indicate the presence of copper below detectable limit in all ground water samples (<0.01).
- Maximum value for Zinc concentration is 0.096 mg/l and minimum value is 0.015 mg/l for the water samples (present study). Studies carried out by TPP indicate the presence of Zinc in a range of <0.01 – 1.24 mg/l in ground water sample.
- Fluoride (F^- in mg/l) of the water sample ranged from 0.4 to 0.9 mg/l for all the ground water samples collected from five locations (present study) and the concentrations are within the acceptable limit. Surface water has higher concentration of fluoride in comparison to ground water (present study). Similar values (0.3 - 0.9 mg/l) for fluoride concentration in ground water were found by the studies carried out by TPP.

The groundwater analysis results reveal that pH, Cr^{+6}, Cd, Cu, Zn, Ca, Hg and F^- meet the drinking water standard prescribed in IS10500:2012. The concentrations of heavy metals in post monsoon samples are less compared to pre monsoon samples, probably due to dilution of ground water. No significance change was found in the ground water sample at a distance of more than 8 km (HW 04-Alind Guest house and HW 05-Indal colony) from ash disposal site in

comparison to other ground water sample collected (HW 01-Budhakanta village, HW 02 & HW 06-Larbhanga village) nearer to ash disposal site. Comparison of ground water quality between present study i.e VSSUT 2016 and study done by TPP at location HW 01-Budhakanta village and at location HW 02-Larbhanga village is shown in **Fig. 6.5-a, b** and **Fig. 6.6-a, b** respectively.

6.5.4 Heavy Metal Analysis in ash and soil samples

Acid digestion data of fly ash and surrounding soils provide the total available concentration levels of trace elements in fly ash & soils which is shown in **Table 6.10**. The results obtained from TCLP were found significantly lower in composition compared to acid digestion test. This is because; metal solubility generally decreases with increasing pH. Concentrations of Ca and Al was found significantly high as compared to other elements. The leaching of metals which were found low in the TCLP test, but found high in the acid digestion test, indicating a strong bonding of metals with the other compounds of ashes.

6.5.5 Air quality survey

Ambient air quality monitoring done at Larbhanga village for particulate matter (24 hr sampling period) gives the maximum value as 144.6 μg/m^3 and minimum value as 53.2 μg/$m^3$for PM_{10} and maximum value as 46.8 μg/m^3 and minimum value as 18.4 μg/$m^3$for $PM_{2.5}$.

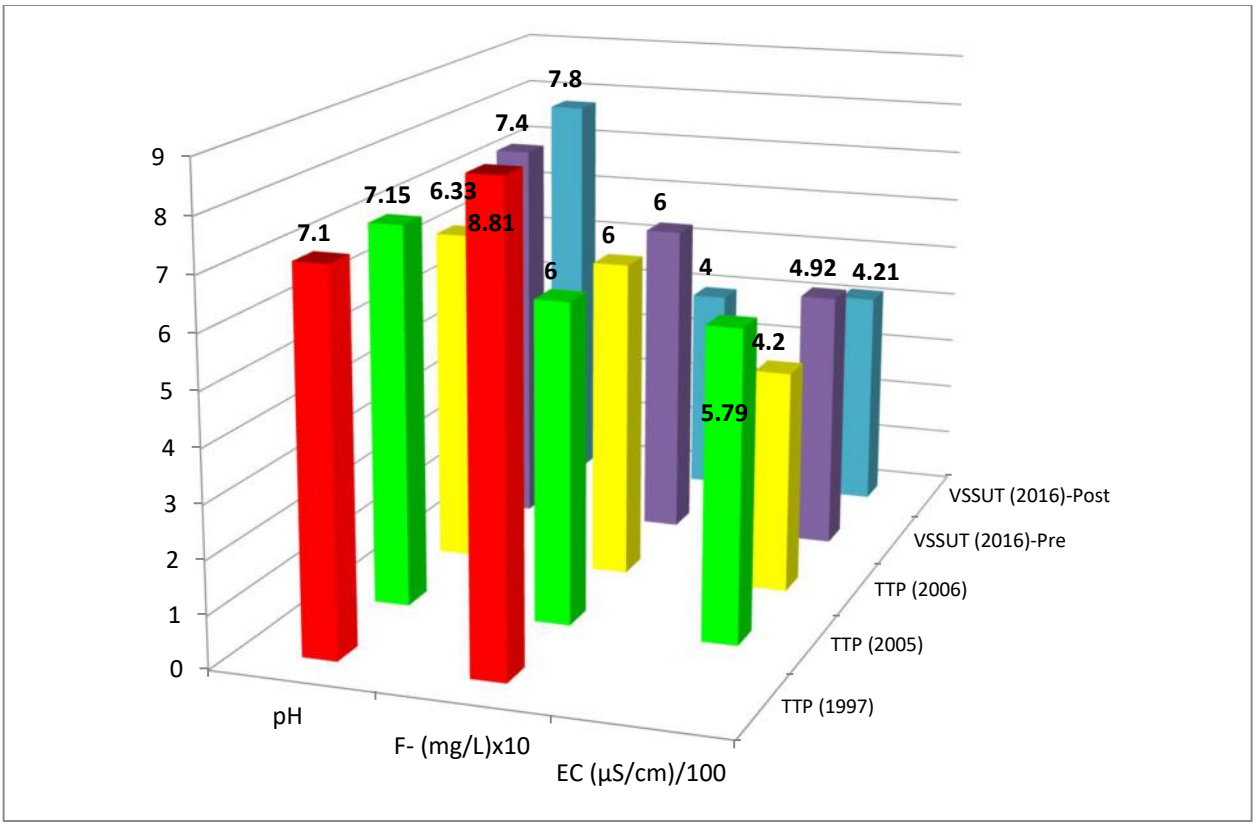
6.6 Conclusions

On the basis of the study, following conclusions were drawn:

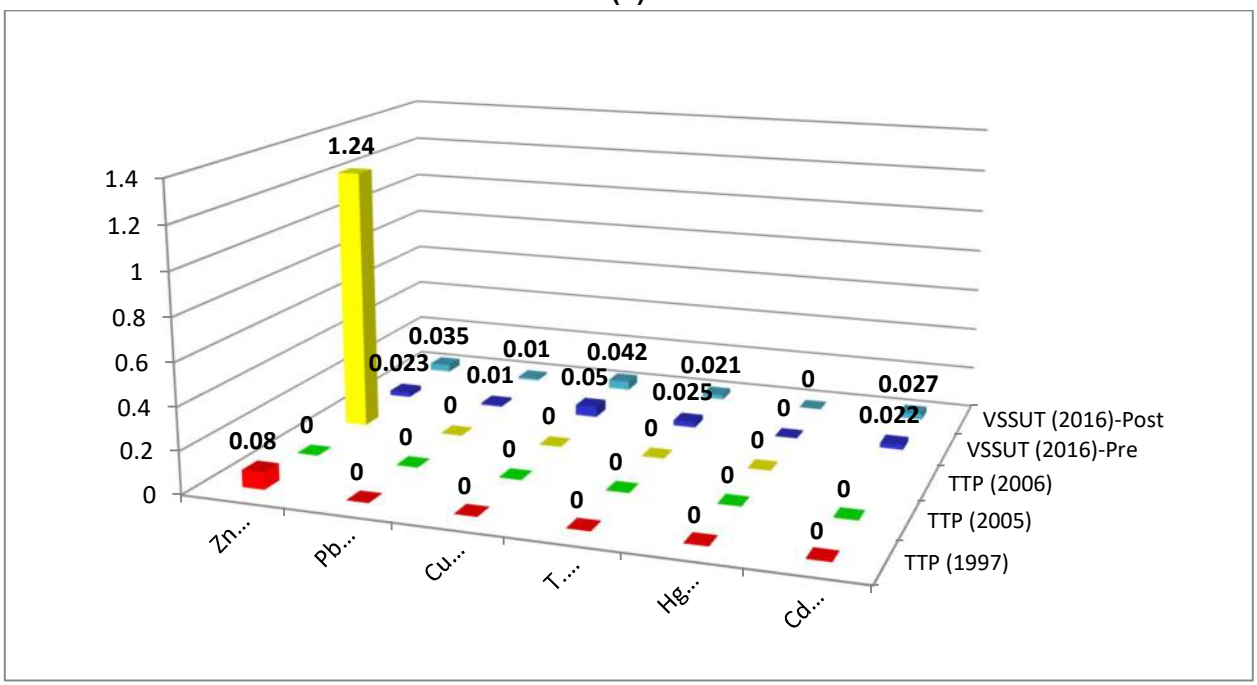
- Analytical results of ground water collected from 5 locations show that the values are within the permissible levels of BIS guidelines except Al and Pb. The aluminum concentration exceeds the BIS limits at 2 locations including a location situated at more than 8 km from ash mound and lead at all the five locations. This could be due to the geogenic factors.

The following suggestions are made for better management of ash in the plant.

- The industry shall make lucrative policy for fly ash users for large scale utilization of fly ash before exploring the option like quarry and mine void filling.
- The Thermal Power Plants must monitor the ground water quality (pre & post-monsoon every year) around the ash disposal sites by installing bore wells at strategic location to predict future trend.
- The industry must install permanent sprinkler system in the ash mound to control fugitive ash.

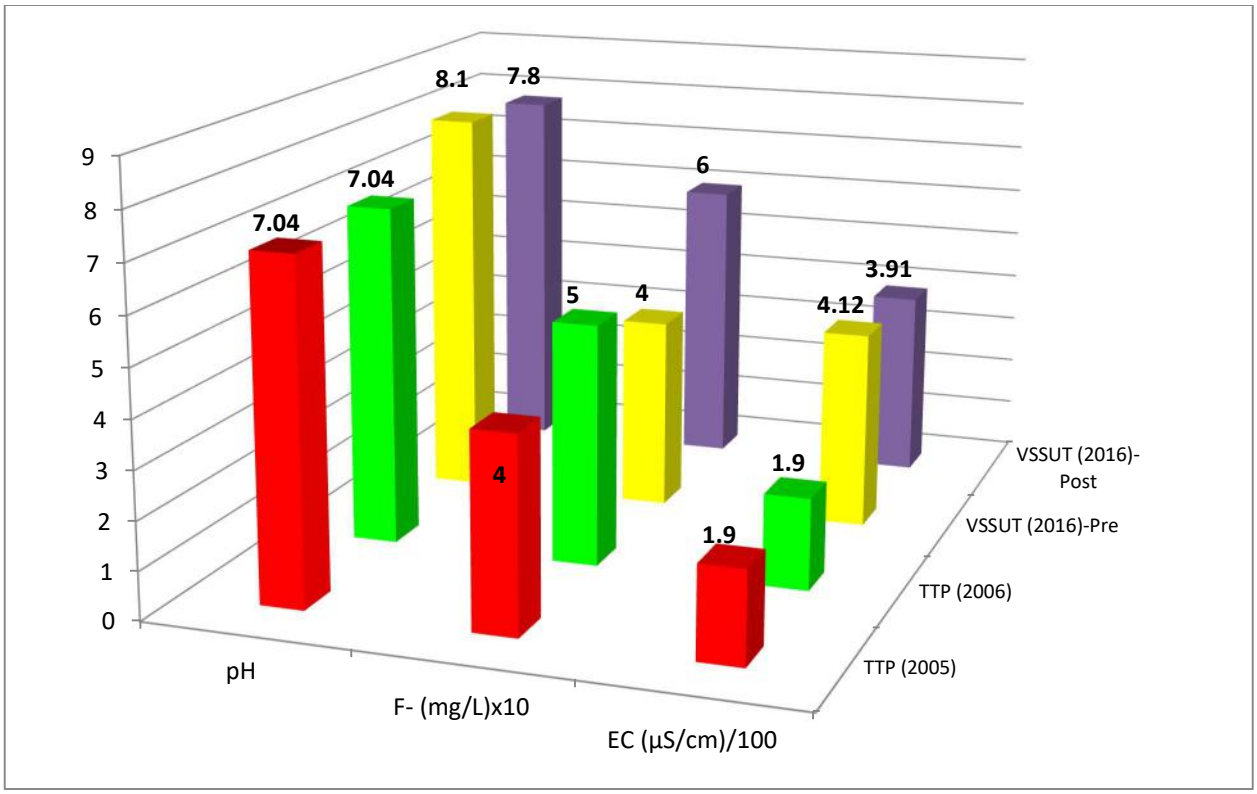


(a)

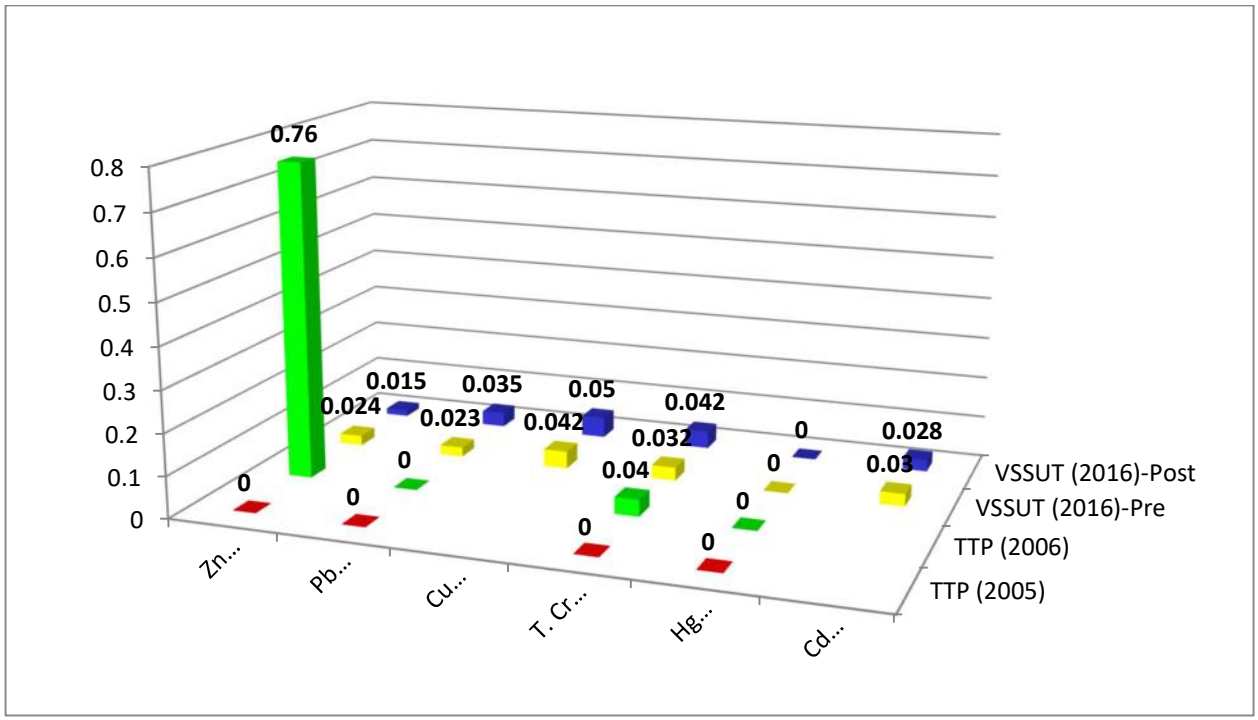


(b)

Fig. 6.5 Comparison of Ground Water Quality at Location HW 01-Budhakanta Village



(a)



(b)

Fig. 6.6 Comparison of Ground Water Quality at Location HW 02-Larbhanga Village

Table 6.9 Analysis Result of Water Sample

Sl No	Sample ID	Season	pH	EC	Ca	Al	Cr^{+6}	T. Cr.	Cd	Pb	Cu	Zn	Hg	F^-
1	HW01	Premonsoon	7.4	492	32	0.024	BDL	0.025	0.0022	0.01	0.05	0.023	BDL	0.6
		Postmonsoon	7.8	421	24	0.03	BDL	0.021	0.0027	0.01	0.042	0.035	BDL	0.4
2	HW02	Premonsoon	8.1	412	42	0.045	BDL	0.032	0.003	0.023	0.042	0.024	BDL	0.4
		Postmonsoon	7.8	391	26	0.056	BDL	0.042	0.0028	0.035	0.05	0.015	BDL	0.6
3	HW03*	Premonsoon	7.5	195	18	0.022	BDL	0.041	0.003	0.034	BDL	0.025	BDL	1.2
		Postmonsoon	7.9	182	20	0.026	BDL	0.034	0.0025	0.028	BDL	0.03	BDL	1.5
4	HW04	Premonsoon	7.6	698	70	0.016	BDL	0.022	0.0022	0.041	0.032	0.042	BDL	0.6
		Postmonsoon	7.8	724	72	0.024	BDL	0.018	0.0026	0.045	0.033	0.027	BDL	0.8
5	HW05	Premonsoon	7.2	428	38	0.036	BDL	0.02	0.0015	0.008	0.042	0.096	BDL	0.5
		Postmonsoon	7.6	467	42	0.045	BDL	0.015	0.0024	0.022	0.035	0.067	BDL	0.6
6	HW06	Premonsoon	7.6	326	30	0.022	BDL	0.022	0.0029	0.02	0.045	0.031	BDL	0.9
		Postmonsoon	7.8	342	36	BDL	BDL	0.016	0.0026	0.026	0.032	0.033	BDL	0.8
		AL	**6.5-8.5**	**-**	**75**	**0.03**	**-**	**0.05**	**0.003**	**0.01**	**0.05**	**5.0**	**0.001**	**1.0**
		DL	**-**	**-**	**-**	**0.002**	**-**	**0.01**	**0.0001**	**0.002**	**0.004**	**0.002**	**0.00007**	**-**

*Surface Water; Unit of all parameters is mg/l except pH and EC; Unit of EC is µS/cm; pH has no unit; AL: Acceptable Limit as per IS 10500:2012; DL: Detectable limit

Table 6.10 Analysis Result of Ash and Soil Sample (SADT and TCLP)

Sl No	Sample ID	Testing Procedure	Ca	Al	Cr^{+6}	T. Cr.	Cd	Pb	Cu	Zn	Hg	F^-
1	HS01	SADT	2445	2100	2.64	15.6	3.96	BDL	BDL	87.6	BDL	--
		TCLP	1989	19	BDL	BDL	1.24	BDL	BDL	2.46	BDL	6.6
2	HS02	SADT	2330	2240	BDL	12.6	3.28	5.22	BDL	77.8	BDL	--
		TCLP	1972	19.2	BDL	BDL	1.14	BDL	BDL	3.56	BDL	7.2
3	HF01	SADT	4005	6541	3.72	25.2	4.22	44.6	34.8	268.8	BDL	--
		TCLP	1950	37.4	BDL	0.4	1.22	0.14	0.24	41.6	BDL	96
4	HF02	SADT	3740	6256	3.46	26.4	4.6	41.2	44.2	283.4	BDL	--
		TCLP	1475	36.6	BDL	0.5	1.34	0.18	0.34	41.4	BDL	88

Unit of all parameters is mg/kg

Chapter 7

Bhusan Power & Steel Ltd., Rengali, Sambalpur

7.1 Introduction

M/s Bhusan Power & Steel Ltd. is located at Rengali, Sambalpur. The power generation capacity of the plant is 506 MW. The total ash generation from this plant was about 635081tons during the financial year 2016-17 with fly ash utilization rate of 90% mostly used for land development, quarry filling and road making.

7.2 Ash management

The two ash mounds of the industry are situated at Derba and Laripalli and one stone quarry filling is located at Babuchakuli. Location of Ash Disposal Sites are given in **Table 7.1**. Details of the ash disposal site along with ash collection system and disposal are summarized in **Table 7.2** respectively.

Table 7.1 Location of Ash Disposal Site at Bhushan Power &Steel Limited

1. Name of the site	Laripali site(Ash Mound)	Derba(Ash Mound)	Abandoned Stone Quarry site (Babuchakuli)
2. Location of the site	Near Laripali village	Near Derba village	Near Babuchakuli village
3. Distance from human habitation	2.0 Km from Village Laripali	2.0 Km from Village Derba	3.0 Km from Village Babuchakuli
4. Distance from water bodies	No water body	No water body	No water body
5. Distance from education al institutions/commercial infrastructure	2.0 Km ,Laripali village UP School	3.0 Km ,Derba village UP School & 2.5 Km from Gumkarma village School	3.5.0 Km,Babuchakuli village UP School
6. Distance from roads & railway line(if any)	4.5 KM from SH-10 & 6.0 KM from SBP-JSG Railway line	12 KM from SH-10 & 9 KM from SBP-JSG Railway line	5 KM from SH-10 4 KM from SBP-JSG Railway line

Table 7.2 Features of Ash Disposal Site at Bhushan Power &Steel Limited

1.Details of the ash disposal site				
a	Name of the ash disposal site	Laripali Site (Ash Mound)	Derba Site(Ash Mound)	Babuchakuli stone quarry filling site
b	Area in acre	Total area - 45 acres	Total available area-110 Acres	1.44 acres
c	Volume in M^3	6151174.15 M^3Aprox	14377935 M^3Aprox	524468.52 M^3
2.Ash collection system		Pneumatic ash conveying system	-	-
a	Collection device used	Ash Silo	Pneumatic ash conveying system	Pneumatic ash conveying system
b	Capacity	Ash Silo capacity 2000 MT	Ash Silo capacity 2000 MT	Ash Silo capacity 2000 MT
c	Frequency of collection	Continuous	Continuous	Continuous
3.Mode of transportation		Through covered Hyva	Through covered Hyva	Through covered Hyva
4. Disposal		Ash Mound		
a	Disposal mode	Dry disposal	Dry disposal	Dry disposal
b	Frequency of disposal	Continuous	Continuous	Continuous

7.3 Studies carried out by the TPP on impact of ash on environment

The plant has carried out some environmental studies (provided by the plant), which are given below in **Table 7.3**.

Table 7.3 Studies Carried Out by TPP on Impact of Ash on Environment

S.N.	Name of the study	Agency (Year)
1	Fly ash characterization	Bhagavathi Ana Labs Pvt. Ltd., Hyderabad (2013)
2	Soil Quality Analysis	Visiontek Consultancy Services Pvt. Ltd., Bhubaneswar*
3	Ground Water Quality Monitoring	Visiontek Consultancy Services Pvt. Ltd., Bhubaneswar*
4	Ambient Air Quality Report	Visiontek Consultancy Services Pvt. Ltd., Bhubaneswar*

** Regularly monitored by the TPP*

The above reports have been reviewed and the salient features of Fly ash characterization, Soil characterization, ground water monitoring and ambient air monitoring are given in **Table 7.4, 7.5, 7.6 and 7.7** respectively.

Table 7.4 Fly Ash Characterization (Studies Carried out by TPP)

Parameters	Units	Bottom ash	Fly ash
Specific Gravity	--	2.59 – 2.68	2.05 – 2.11
Plasticity	--	Non Plastic	Non-plastic
Max Dry Density	g/cc	Sand Size Material	1.07 - 1.18
Optimum Moisture Content	%	Sand Size Material	29 - 33
Cohesion	KN/m^2	Negligible	Negligible
Angle of Internal Friction	Ø deg	38 - 39	33 - 37
Coefficient Index	Cc	--	0.17 - 0.21
Coefficient of consolidation Cv	cm^2/sec	--	$1.7x10^{-3}$
Permeability	cm/sec	$4.5x10^{-3}$	$0.8x10^{-6}$
Particle size Distribution			
Clay	%	0	8
Silt	%	0.47	43
Sand	%	94.47	45
Gravel	%	5.06	4
Coefficient of uniformity	--	16	6.8
$SiO_2 + Al_2O_3 + Fe_2O_3$	%	90.9 – 91.7	89.6 – 90.3
SO_3	%	0.22 - 0.25	0.25 - 0.3
Moisture	%	0.09 - 0.10	0.15 – 0.19
Loss on ignition	%	0.62 - 0.72	2.4 - 2.6
CaO	%	0.98 – 1.12	3.6 - 4.2
Soluble sulphate content	%	0.054 - 0.062	0.12 – 0.14

Table 7.5 Soil Characterization (Studies Carried out by TPP)

Parameters	Units	Laripali Village*	Hirma Village	Derba Village**	Gumkarma Village
pH	-	5.88 – 6.55	5.18 – 6.24	5.35 – 5.64	5.2 – 5.84
Bulk Density	gm/cc	1.26 – 1.34	1.18 – 1.22	1.18 – 1.25	1.22 – 1.3
Porosity	%	20 - 25	22 - 26	20 - 28	24 - 27
Silica as SiO_2	%	6.2 – 14.3	4.8 – 5.8	5.6 – 5.9	5.8 – 6.2
Chloride as Cl^-	%	0.12 – 0.18	0.12 – 0.14	0.13 – 0.15	0.12 – 0.15
Sulphate as SO_4^{2-}	%	0.18 – 1.32	0.2 – 0.78	0.18 – 0.76	0.2 – 0.7
Potassium as K	%	0.058 - 1.08	0.05 - 1.32	0.058 - 1.28	0.064 – 0.7
Magnesium as Mg	%	0.58 – 0.98	0.44 – 0.48	0.42 – 0.46	0.38 – 0.5
Calcium as Ca	%	0.88 – 1.8	0.62 - 0.88	0.58 - 0.88	0.72 – 0.82
Iron as Fe	%	0.078 – 0.428	0.024 – 0.12	0.022 – 0.11	0.018 – 0.084

Nickel as Ni	%	<0.001	<0.001	<0.001	<0.001
Lead as Pb	%	<0.001	<0.001	<0.001	<0.001
Cadmium as Cd	%	<0.001	<0.001	<0.001	<0.001
Chromium as Cr	%	<0.002	<0.002	<0.002	<0.002
Mercury as Hg	%	<0.001	<0.001	<0.001	<0.001
Zinc as Zn	%	0.002 – 0.006	0.004 – 0.008	0.004 – 0.005	0.006 – 0.01

** Similar location as BS14 and ** similar location as BS12 as described in* ***Table 7.7***

Table 7.6 Ground Water Quality Analysis (Studies Carried out by TPP)

Water Quality Parameters	Waste Dumping Site (Ash Pond)*	Derba village tubewell**	Dubenchhapar village tubewell
pH	7.1 – 7.2	6.9 – 7.1	7.1 – 7.3
Turbidity (NTU)	<2	<2	<2
Total Hardness (mg/l $CaCO_3$)	88 - 95	78 - 102	92 - 100
Total dissolved solids(mg/l)	148 - 161	132 -174	155 - 173
Fluoride (as F) (mg/l)	0.06 – 0.08	0.05 – 0.09	0.07 – 0.09
Chloride (as Cl) (mg/l)	32 - 37	30 -37	34 -38
Sulphate(as SO_4^{2-}) (mg/l)	4 – 4.4	2.6 – 3.9	3.6 - 4.2
Calcium (as Ca) (mg/l)	23.6 - 25.6	20.8 - 28.1	24.8 - 27.2
Arsenic(as As)(mg/l)	<0.001	<0.001	<0.001
Selenium (as Se) (mg/l)	<0.001	<0.001	<0.001
Cadmium(as Cd) (mg/l)	<0.001	<0.001	<0.001
Cyanide (as CN) (mg/l)	ND	ND	ND
Lead(as Pb) (mg/l)	<0.001	<0.001	<0.001
Copper(as Cu) (mg/l)	<0.05	<0.05	<0.05
Chromium(as Cr^{+6}) (mg/l)	<0.002	<0.002	<0.002
Mercury(as Hg) (mg/l)	<0.001	<0.001	<0.001
Zinc(as Zn)(mg/l)	<0.05	<0.05	<0.05
Manganese (as Mn)(mg/l)	<0.005	<0.005	<0.005
Phenolic Compounds (mg/l)	<0.001	<0.001	<0.001
Iron as Fe (mg/l)	0.15 – 0.2	0.17 – 0.22	0.16 – 0.25

** Same location as BW11 and ** same location as BW12 as described in* ***Table 7.7***

Table 7.7 Ambient Air Quality Monitoring (Studies Carried out by TPP)

Ambient Air Quality Parameters	Sripura Village	Gumkarma Village
PM_{10} (µg/m^3)	25.8 - 55.1	26.8 – 62.6
$PM_{2.5}$ (µg/m^3)	12.7 - 29.7	13.4 – 62.2
SO_2 (µg/m^3)	<4.0 – 6.8	<4.0 – 11.8
NO_2 (µg/m^3)	<9.0 – 13.1	<9.0 – 17.2

7.4 Sampling locations

Ground Water (BW) samples, soil sample (BS), air sample (BA) were collected around the Thermal Power Plants ash disposal sites and Fly ash (BF) sample is collected from the ash mounds. Ground water (blank sample) is also collected from an area which is at a distance of more than 12 km from ash mound. The description of sampling site and its distance from the ash disposal site are presented in **Table 7.8**. Photographs taken during sampling are given at **Fig. 7.1**. Details of sampling locations are shown in **Fig. 7.2**.

Table 7.8 Location of Sampling Stations

Sl. No.	Sampling Locations	Description of Sampling Locations	Distance from Ash Pond (km)	Direction w.r.t. Ash Pond
1	BW11	Bore well at derba ash mound	0.1	W
2	BW12	Bore well at derba village	1.5	NE
3	BW13	Bore well at Babuchakuli stone quarry filling	0.5	S
4	BW14	Bore well at laripalli ash mound	0.2	W
5	BW15	Bore well at laripalli ash mound	1	S
6	BW16	Borewell at Jharmundaat	12	S
7	BS11	Soil sample near derba ash mound	0.2	NW
8	BS12	Soil sample from derba village	1.5	NE
9	BS13	Soil sample near Babuchakuli stone quarry	0.6	S
10	BS14	Soil sample near laripalli ash mound	0.2	W
11	BF11	Fly ash sample from derba ash mound	0	-
12	BF12	Fly ash sample from Babuchakuli stone quarry filling	0	-
13	BA11	Ambient air quality monitoring at derba village	1.5	NE

Derba ash mound

Ground water sample collection at Derba

Babuchakuli stone quarry filling

Ground water sample collection at Babuchakuli

Laripalli ash mound

Ground water sample collection at laripalli

Fig. 7.1 Photographs of Ash Disposal Sites taken during Sampling

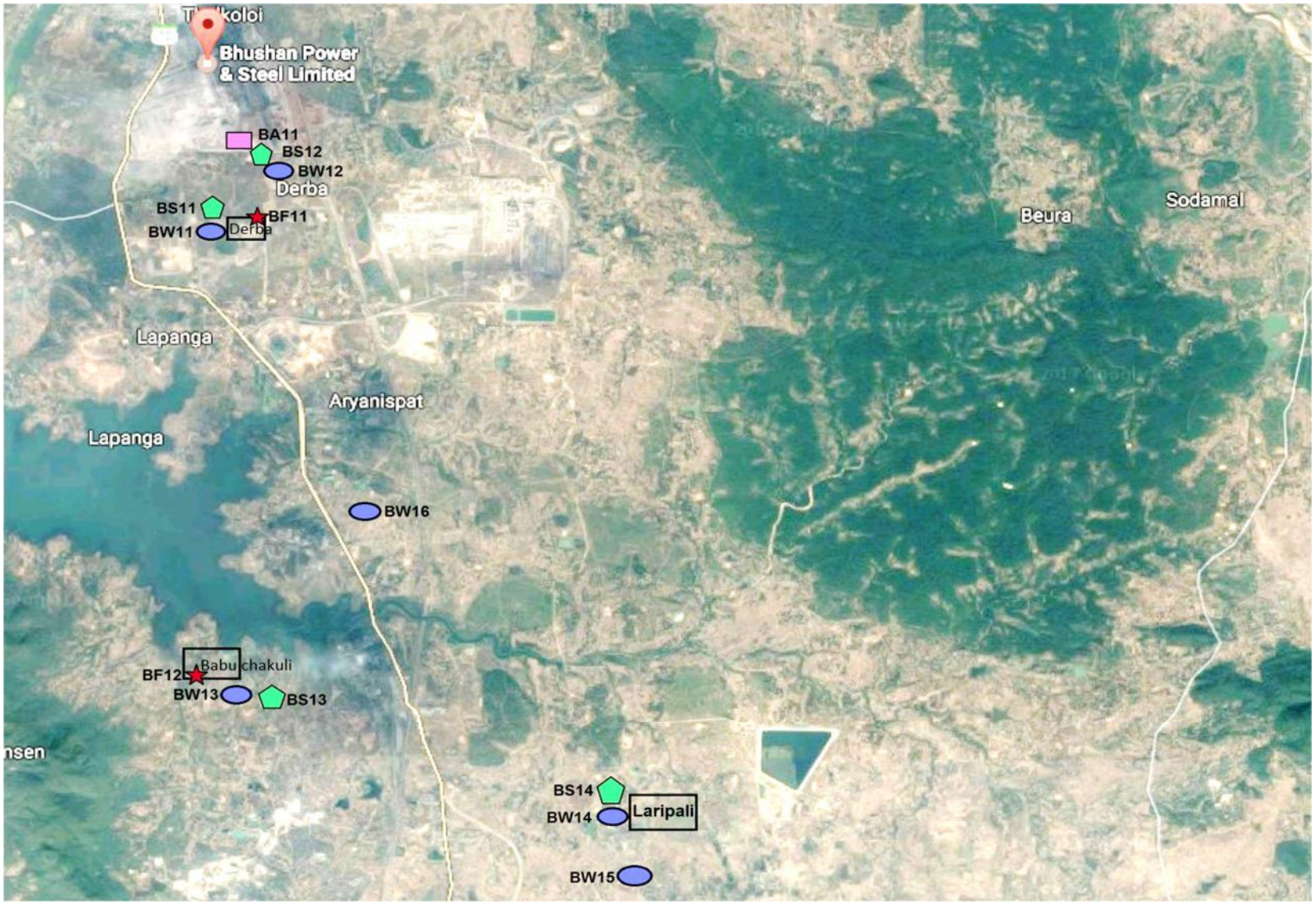


Fig. 7.2 Location of Sampling Points at Bhushan Ash Disposal Sites

7.5 Results and discussion

The results of the physico-chemical and mineralogical characterization of fly ash samples as well as water quality analysis for ground water are given as follows:

7.5.1 Physical properties

It is found that fly ash possesses a mean particle diameter i.e. D_{50} having 46.2 µm and Coefficient of uniformity i.e. C_u having 9. **Table 7.9** shows physical properties of the fly ash. The results of the permeability test of ash samples show that the coefficient of permeability is very low.

Table 7.9 Physical Properties of the Fly Ash Sample

Parameters	Color	Specific Gravity	Maximum dry density, g/cc	Porosity, %	Coefficient of permeability, k x 10^{-5} cm/s
Fly ash	Grey	2.03 - 2.21	1.14 - 1.24	48 - 55	4 - 8

7.5.2 Chemical and mineralogical compositions

The element oxides of ash samples are presented in **Fig. 7.3 (a & b)**. The results show that the ash samples are enriched predominantly with silica (SiO_2) and alumina (Al_2O_3). In addition, they also contain small amounts of iron oxide (Fe_2O_3), TiO_2, K_2O, CaO and MgO. The rest of the compounds present in the ash samples are in minor concentrations. The sum of SiO_2, Al_2O_3 and Fe_2O_3 accounts for more than 90% of the total composition in all fly ash and pond ash samples. Since the sum total of SiO_2, Al_2O_3 and Fe_2O_3 is more than 70% in all fly ash and pond ash samples, they are classified as Class F fly ash according to the ASTM C-618 specifications. The reactive silica content in fly ash is found to be in the range 12 -15 %.

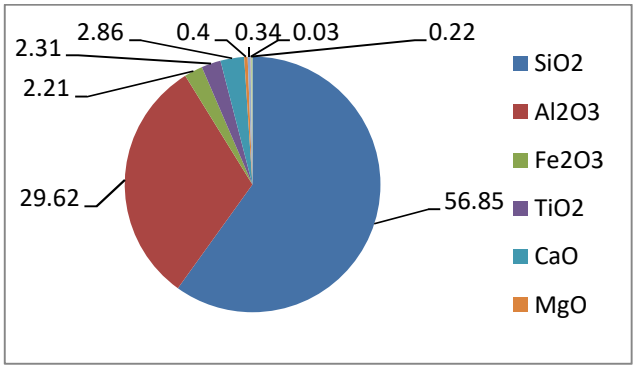


Fig. 7.3 (a) Element Oxides of Fly Ash (BF11)

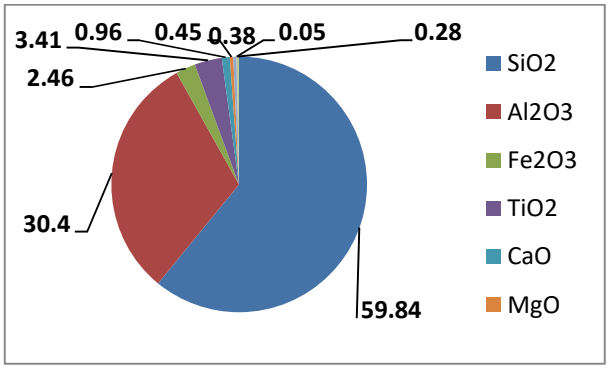


Fig. 7.3 (b) Element Oxides of Fly Ash (BF12)

7.5.3 Ground Water Quality Analysis

The water quality analysis was performed on the water samples collected from the bore well from different locations in the area around fly ash dumpsite. Details of concentration of heavy metals and other water quality parameters in the groundwater samples near the ash disposal sites and at the surrounding villages are given in **Table 7.10**. Water quality analysis for the present study (**Table 7.10**) is compared with the water quality study done by TPP in 2015-16 (**Table 7.6**) and the findings are discussed below:

- pH of the water sample ranged from 7.2 to 8.4, indicating alkaline nature of the water (present study). A neutral range of pH value (pH = 6.9 – 7.3) was found by the studies carried out by TPP. The difference in the results is due to seasonal variations.
- Maximum value for electrical conductivity is 404 µS/cm and minimum value is 287 µS/cm for ground water sample (present study). Lower concentration of TDS i.e. 132 - 174 mg/l (EC = 190 - 250 µS/cm; TDS = 0.7 EC) was found by the studies carried out by TPP. The difference is due to seasonal variation in ground water and recharge of ground water by nearby surface water source.
- Calcium (Ca in mg/l) of the ground water sample ranged from 25 to 80 mg/l for all the ground water samples (present study). Lower concentration of Calcium (20.8 - 28.1 mg/l) was found by the studies carried out by TPP. The difference is due to seasonal variation in ground water and recharge of ground water by nearby surface water source.
- Presence of Aluminum is found in all the six pre-monsoon samples and three out of the six post-monsoon samples.
- Presence of hexavalent chromium is found in three pre-monsoon samples and two post-monsoon samples. Presence of total chromium is found in all ground water samples collected during pre and post monsoon period in a range of 0.035 – 0.083 (present study). Concentration of hexavalent chromium in all the samples tested by the TPP are below detectable limit (<0.002).
- Concentration of Cadmium (Cd in mg/l) is found in all samples with a minimum and maximum concentration of 0.0015 mg/l and 0.0026 mg/l respectively, which are within the acceptable limit (present study). Studies carried out by TPP indicate the presence of cadmium below detectable limit (<0.001 mg/l) in all ground water samples.
- Concentration of Lead (Pb in mg/l) is found in all samples with a minimum and maximum concentration of 0.008 mg/l and 0.059 mg/l respectively (present study). Studies carried out by TPP indicate the presence of lead below detectable limit (<0.001 mg/l) in all ground water samples.

Table 7.10 Analysis Result of Water Sample

Sl No	Sample ID	Season	pH	EC	Ca	Al	Cr^{+6}	T. Cr.	Cd	Pb	Cu	Zn	Hg	F^-
1	BW-11	Premonsoon	7.5	478	86	0.023	0.012	0.062	0.0024	0.051	0.013	0.077	BDL	0.59
		Postmonsoon	7.2	377	62	0.044	BDL	0.035	0.0015	0.042	BDL	0.061	BDL	0.55
2	BW-12	Premonsoon	7.9	344	56	0.012	BDL	0.033	0.0022	0.041	BDL	0.026	BDL	0.49
		Postmonsoon	7.2	332	52	BDL	BDL	0.041	0.0025	0.045	BDL	0.032	BDL	0.52
3	BW-13	Premonsoon	8.3	404	80	0.034	BDL	0.045	0.0021	0.059	0.012	0.132	BDL	0.95
		Postmonsoon	7.8	356	62	0.046	BDL	0.035	0.0022	0.05	BDL	0.022	BDL	0.86
4	BW-14	Premonsoon	8	357	48	0.012	BDL	0.042	0.0023	0.057	BDL	0.341	BDL	0.51
		Postmonsoon	7.6	364	50	BDL	BDL	0.035	0.0016	0.054	BDL	0.024	BDL	0.56
5	BW-15	Premonsoon	8.4	324	25	0.024	0.022	0.081	0.0024	0.01	0.022	0.912	BDL	0.42
		Postmonsoon	7.6	345	28	0.03	0.011	0.062	0.0022	0.044	0.018	0.464	BDL	0.48
6	BW-16	Premonsoon	8.3	296	26	0.028	0.021	0.083	0.0024	0.043	BDL	0.692	BDL	0.22
		Postmonsoon	7.7	287	26	BDL	0.011	0.061	0.0026	0.008	BDL	0.481	BDL	0.3
		AL	**6.5-8.5**	**-**	**75**	**0.03**	**-**	**0.05**	**0.003**	**0.01**	**0.05**	**5.0**	**0.001**	**1.0**
		DL	**-**	**-**	**-**	**0.002**	**-**	**0.01**	**0.0001**	**0.002**	**0.004**	**0.002**	**0.00007**	**-**

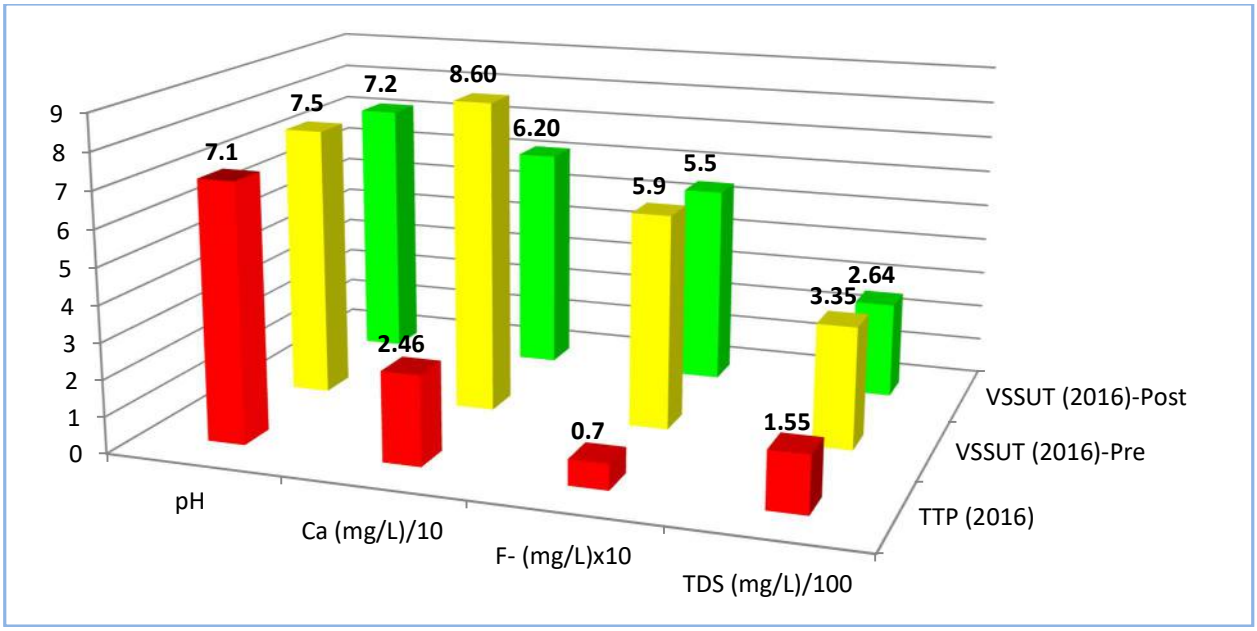
Unit of all parameters is mg/l except pH and EC; Unit of EC is µS/cm; pH has no unit; AL: Acceptable Limit as per IS 10500:2012; DL: Detectable limit

- Concentration of Mercury (Hg in mg/l) in all the water samples (present study) as well as in the sample tested by the TPP are below detectable limit.
- Presence of Copper (Cu in mg/l) is found in three pre-monsoon samples and one post-monsoon sample (present study). However, the concentration of Copper is below the detectable limit. Studies carried out by TPP indicate the presence of copper below detectable limit in all ground water samples (<0.005).
- Maximum value for Zinc concentration is 0.91 mg/l and minimum value is 0.022 mg/l (present study). Studies carried out by TPP indicate the presence of Zinc below detectable limit in all ground water samples (<0.05).
- Fluoride (F^- in mg/l) of the water sample ranged from 0.22 to 0.95 mg/l for all the samples collected from six locations and the concentrations are within the acceptable limit (present study). However, very less concentration (<0.1) was found by the studies carried out by TPP.

The groundwater analysis results reveal that pH, Cr^{+6}, Cd, Cu, Zn, Hg and F^- meet the drinking water standard prescribed in IS10500:2012. The concentrations of heavy metals in post monsoon samples are less compared to pre monsoon samples, probably due to dilution of ground water. No significance change was found in the ground water sample at a distance of 12 km (BW 16-Jharmundaat) from ash disposal site in comparison to other ground water sample collected (BW 11- Derba Ash Mound to BW 15- Laripalli Ash Mound) nearer to ash disposal site. Comparison of ground water quality between present study by VSSUT 2016 and study done by TPP at location BW 11-Derba Ash Mound and at location BW 12-Derba Village is shown in Fig. **7.4-a, b** and **Fig. 7.5-a, b** respectively. Comparison of soil leachability between present study by VSSUT in 2016 and study done by TPP at location BS 11-Derba Ash Mound and at location BS 12-Derba Village is shown in **Fig. 7.6**.

7.5.4 Heavy Metal Analysis in ash and soil samples

Acid digestion data of fly ash and surrounding soils provide the total available concentration levels of trace elements in fly ash & soils which is shown in **Table 7.11**. The results obtained from TCLP were found significantly lower in composition compared to acid digestion test. This is because; metal solubility generally decreases with increasing pH. Concentrations of Ca and Al was found significantly high as compared to other elements. The leaching of metals which were found low in the TCLP test, but found high in the acid digestion test, indicating a strong bonding of metals with the other compounds of ashes.



(a)

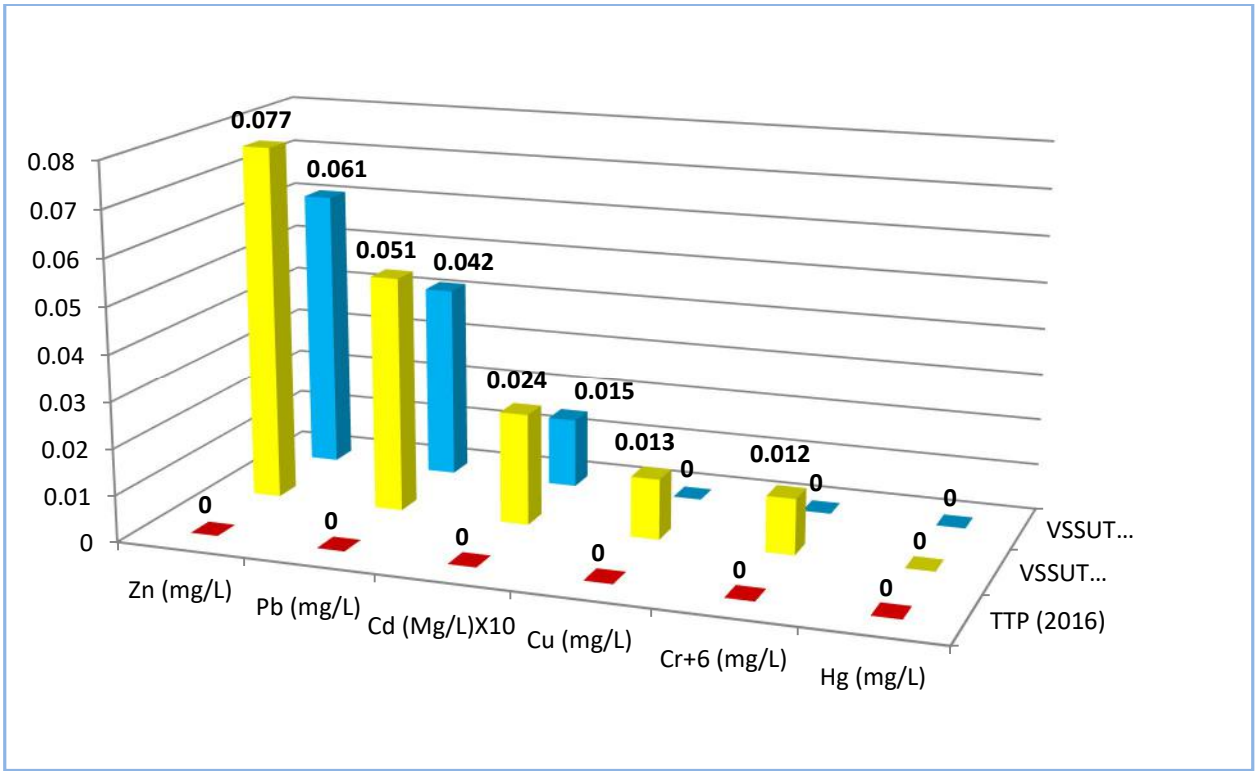


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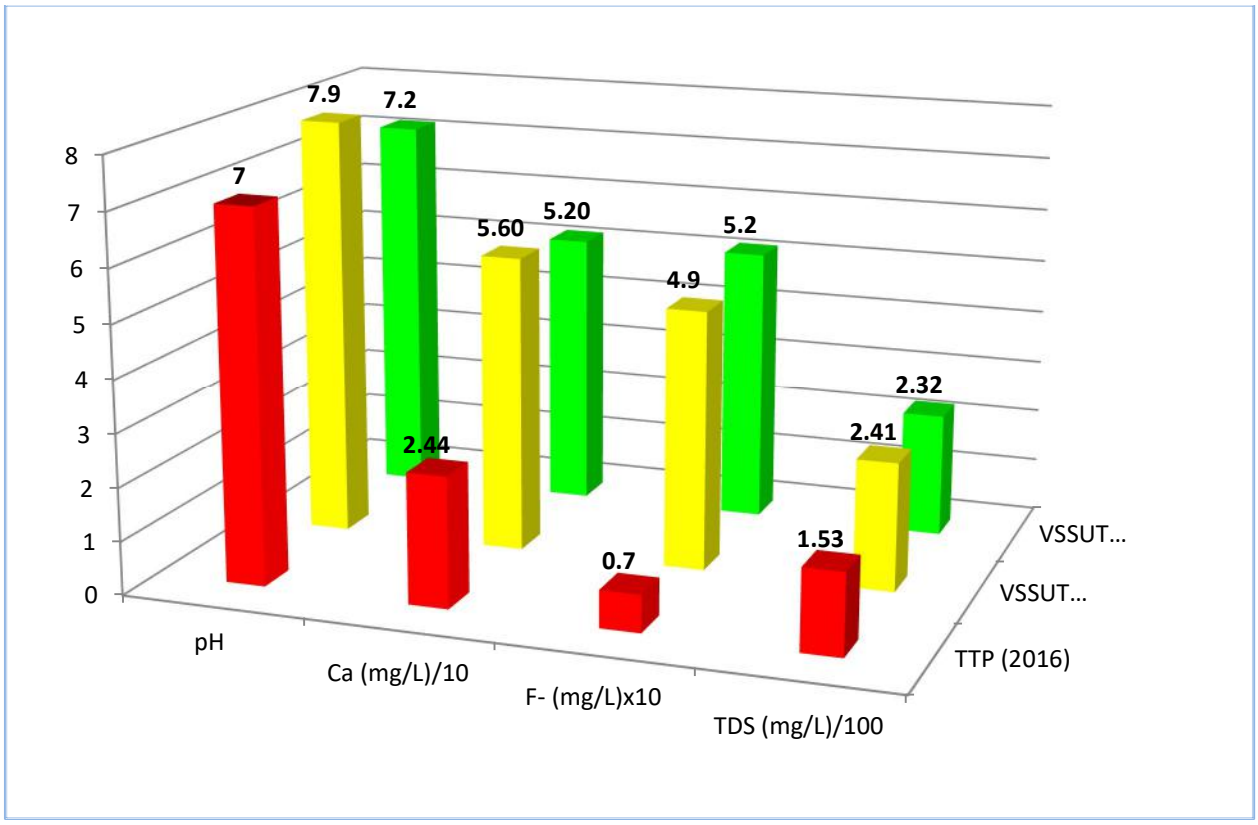
Fig. 7.4 Comparison of Ground Water Quality at BW 11-Derba Ash Mound



(a)

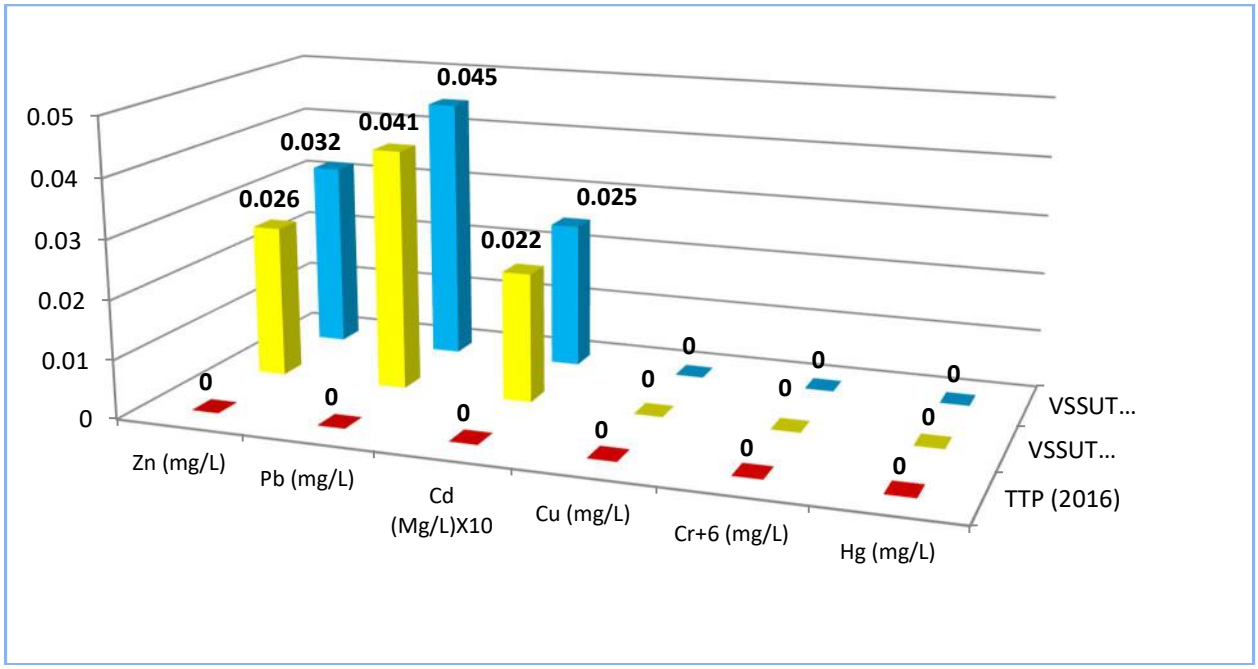


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Fig. 7.5 Comparison of Ground Water Quality at BW 12-Derba Village

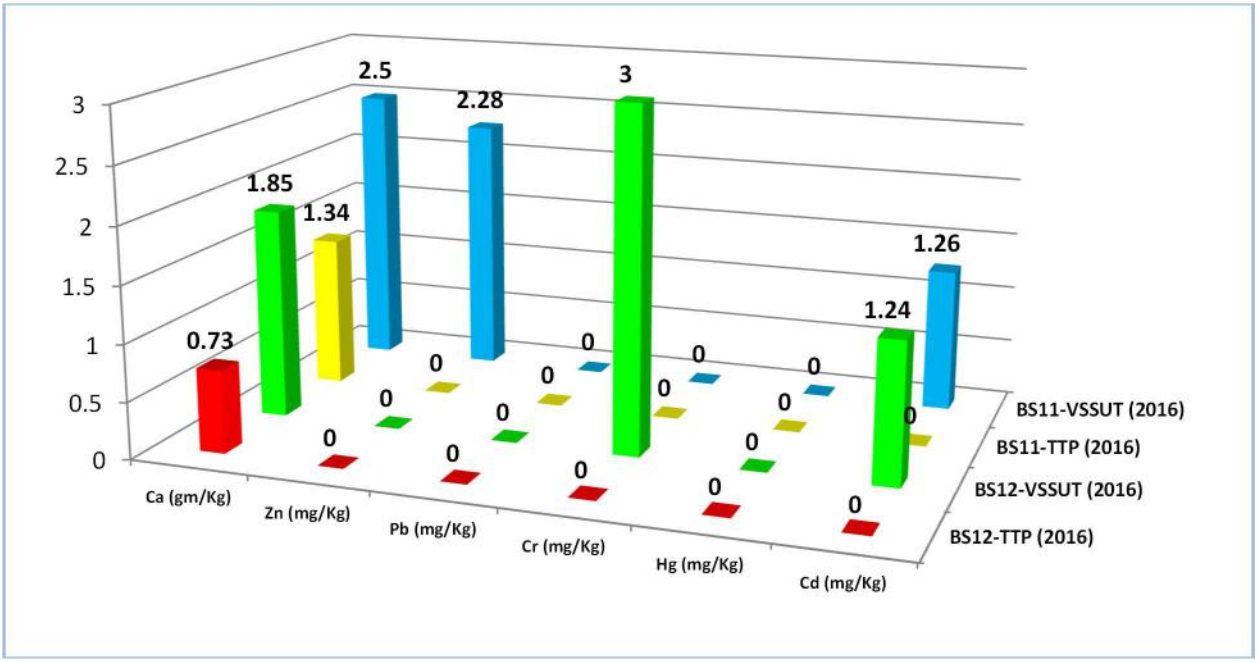


Fig. 7.6 Comparison of Soil Leachability at BS11-Derba Ash Mound and BS12-Derba Village

7.5.5 Air Quality Survey

Ambient air quality monitoring done at Derba village for particulate matter (24 hr sampling period) gives the maximum value as 94.2 µg/m^3 and minimum value as 31.4 µg/$m^3$for PM_{10} and maximum value as 42.4 µg/m^3 and minimum value as 12.4 µg/$m^3$for $PM_{2.5}$.

7.6 Conclusions

On the basis of the study, following conclusions were drawn:

- Analytical results of ground water collected from 6 locations show that the values are within the permissible levels of BIS guidelines except for Ca, Al and Pb. The aluminum and calcium concentration exceeds the BIS limits at 2 locations and lead at all the six locations. This could be due to the geogenic factors.

The following suggestions are made for better management of ash in the plant.

- The industry shall make lucrative policy for fly ash users for large scale utilization of fly ash before exploring the option like quarry and mine void filling.
- The Thermal Power Plants must monitor the ground water quality (pre & post-monsoon every year) around the ash disposal sites by installing bore wells at strategic location to predict future trend.
- The industry must install permanent sprinkler system in the ash mound to control fugitive ash.

Table 7.11 Analysis Result of Ash and Soil Sample (SADT & TCLP)

Sl No	Sample ID	Testing Procedure	Ca	Al	Cr^{+6}	T. Cr.	Cd	Pb	Cu	Zn	Hg	F^-
1	BS11	SADT	2659	7841	1.32	7.2	5.4	BDL	BDL	117.6	BDL	--
		TCLP	2505	21.1	BDL	BDL	1.26	BDL	BDL	2.28	BDL	6.4
2	BS12	SADT	2125	2071	1.28	13.8	6.6	BDL	BDL	48.4	BDL	--
		TCLP	1848	66.8	0.4	3	1.24	BDL	BDL	BDL	BDL	4.4
3	BS13	SADT	4512	2808	BDL	16.4	29.6	BDL	BDL	132.8	BDL	--
		TCLP	2235	27.8	BDL	BDL	4.8	BDL	BDL	BDL	BDL	6.2
4	BS14	SADT	2620	6999	2.88	15.9	30.8	BDL	BDL	21.6	BDL	--
		TCLP	2310	17.6	BDL	BDL	6.8	BDL	BDL	1.62	BDL	5.4
5	BF11	SADT	6846	9277	4.88	26.4	40.8	9.2	18.4	252.4	BDL	--
		TCLP	2805	77.4	BDL	0.34	9.2	BDL	0.22	8.22	BDL	72
6	BF12	SADT	5766	9456	3.92	24.6	42.4	6.2	14.8	186.4	BDL	--
		TCLP	2768	79.6	BDL	0.64	8.8	BDL	BDL	6.84	BDL	62

Unit of all parameters is mg/kg

Chapter 8

Ib Thermal Power Station (OPGC), Banaharpali, Jharsuguda

8.1 Introduction

IB Thermal Power Station (ITPS), is a coal based Thermal Power Plant operating two units of 210 MW each. About 8000 MT of coal is burnt daily for power generation of Unit #1 & 2 (2x210 MW) and approx. 3200 MT of ash is generated daily. Coal ash including bottom ash and fly ash produced in the plant, is disposed off in slurry form for deposition in the ash ponds constructed for the purpose.

The total ash generation from this plant was about 1237357tons during the financial year 2016-17 with fly ash utilization rate of 35% is used for land development and dyke raising.

8.2 Ash Management

ITPS has both wet ash disposal system as well as dry ash disposal system for handling fly ash & bottom ash. For wet disposal of ash, OPGC have 02 Ash Ponds named Ash Pond A & Ash Pond B, located about 3-4 km away from the power plant, again another new Ash Pond, named Ash Pond C is under construction (**Fig. 8.1**). Location of Ash Disposal Sites are given in **Table 8.1**. Details of the ash disposal site along with ash collection system and disposal are summarized in **Table 8.2** respectively.

At ITPS fly ash collection system adopted is of hydro sluicing type system, which employs continuous removal of fly ash from various hoppers through hydro sluicing in the form of slurry. In this system each hopper is provided with manually operated isolating plate valve, expansion joints, flushing apparatus & necessary water connections to flushing apparatus. For evacuation of fly ash, water is to be pumped to the flushing apparatus for mixing with ash, which flows to the open trenches in the form of slurry & collected in the common ash slurry sump. There are four streams for disposal of slurry from the slurry sump to Ash Pond (disposal area) having common facility for both units. There are 3nos of pumps in series in each stream to dispose slurry to ash pond, which is about 6.0 km from pumping station. In normal plant operation two streams of slurry pumps are to be kept in continuous operation, another stream is taken intermittently operation during bottom ash evacuation time. 100 % ash water is being recycled through Collector well, Primary settling tank & secondary settling tank. There are 3 nos

of vertical turbine transfer water pumps (2 working and 1 stand-by) installed at ash water recycling plant for this purpose.

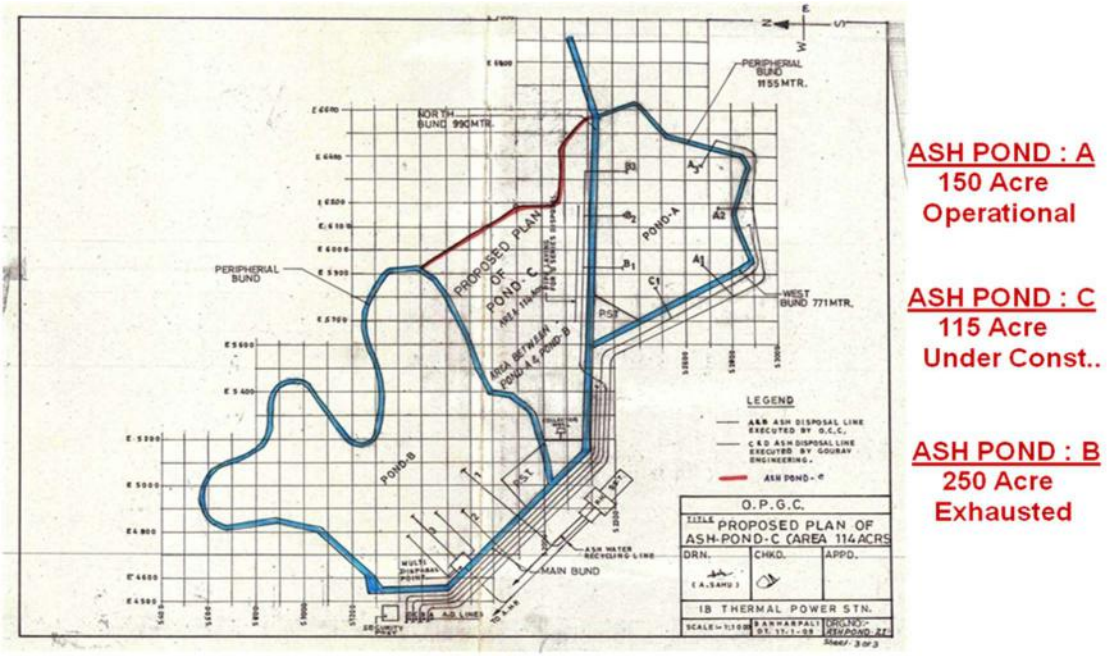


Fig. 8.1 (a) Ash Ponds at OPGC

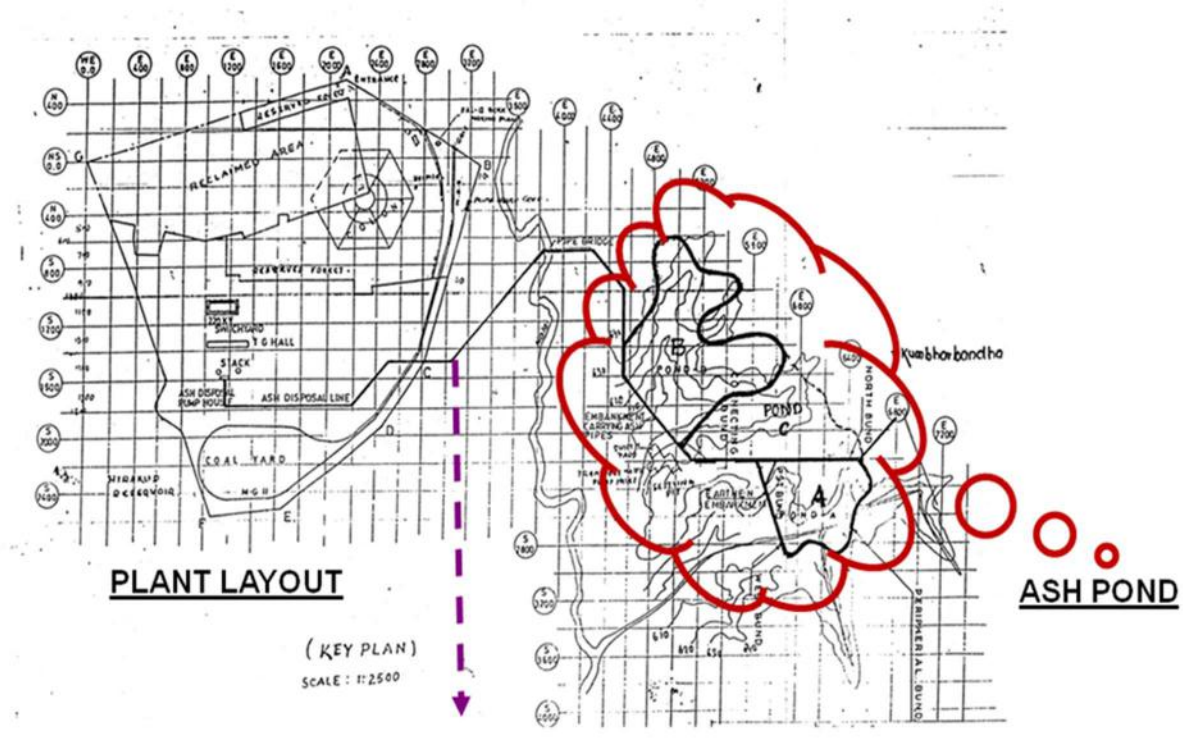


Fig. 8.1 (b) Ash Disposal Pipe Lines at OPGC

Table 8.1 Location of Ash Disposal Site at OPGC

1. Name of the Site	**ITPS, Banharpali**
2. Location of the site	Ash Pond, ITPS, Banharpali
3. Details of land marks	-
4. Distance from human habitation	More than 1.5 Km
5. Distance from water bodies	Adjacent to Hirakud Reservoir
6. Distance from educational institutions / commercial infrastructures	More than 1.5 Km
7. Distance from forest cover	5km (approx)
8. Distance from roads & railway line (if any)	15 KM

Table 8.2 Features of Ash Disposal Site at OPGC

1. Details of Ash Disposal Sites		
a)	Name of Ash Disposal Sites	Ash Pond # A
b)	Area in Acre	150 Acres
c)	Volume in Cum	67,14,500 cum
d)	Over Flow Lagoon (OFL) for recycling of over flow water from ash pond	Water is recycled through Collector well, PST & SST
e)	Other facilities	Collector well, PST, SST
f)	Design height of each raising	3 Mtr
g)	No of raising designed for	4 Nos
h)	Present stage of raising	From RL 205.00 M to RL. 208 M
i)	No of Pipeline	4 Ash Discharge Pipeline discharging Ash in Ring method at 14 Disposal Location
j)	Distance from Plant	6 Km
k)	Operating since	Sep-07
l)	Ash deposited as on	Sep-07
2. Disposal		
a)	Discharge in cubic meter	No ash water or slurry discharge
3. Details of complaint received from local people/ villagers or farmers		Occasional ash blowing during heavy cyclonic wind flow which has been controlled immediately. Further preventive ash blowing measures is being put in place

8.3 Studies carried out by the TPP on Impact of Ash on Environment

The plant has carried out some environmental studies, which are given below in **Table 8.3**.

Table 8.3 Studies Carried out by TPP on Impact of Ash on Environment

S.N.	Name of the study	Agency (Year)
1	Fly ash characterization	Visiontek Consultancy Services Pvt. Ltd., Bhubaneswar (2015)
2	Fly ash leachability Analysis	SGS India Pvt. Ltd.(2010)
3	Heavy metal analysis of surface soil	SGS India Pvt. Ltd.
4	Ground Water Quality Monitoring*	SGS India Pvt. Ltd.

** Regularly monitored by the TPP*

The above reports have been reviewed and the salient features of Fly ash characterization, fly ash leachability analysis, Soil characterization and ground water monitoring are given in **Table 8.4, 8.5, 8.6** and **8.7** respectively.

Table 8.4 Fly Ash Characterization (Studies Carried out by TPP)

Parameters	Units	Fly ash	Parameters	Units	Fly ash
Chromium	mg/Kg	2.76	Cyanide	mg/Kg	<1
Copper as Cu,	mg/Kg	10.69	Fluoride	mg/Kg	34.5
Nickel as Ni,	mg/Kg	4.98	Iron Oxide	%	5.4
Cobalt as Co,	mg/Kg	1.47	Loss on Ignition	%	0.25
Lead as Pb,	mg/Kg	7.42	Magnesium Oxide	%	0.37
Cadmium as Cd,	mg/Kg	<1	Phosphates	%	0.31
Arsenic as As,	mg/Kg	7.32	Potassium	mg/Kg	142.52
Mercury as Hg,	mg/Kg	1.17	Silicon Dioxide	%	62.46
Selenium as Se,	mg/Kg	2.41	Sodium as Na	mg/Kg	82.4
Molybdenum as Mo,	mg/Kg	8.08	Sodium as Na_2O	mg/Kg	111.06
Antimony as Sb,	mg/Kg	11.77	TIN	mg/Kg	<10
Aluminium Oxide	%	29.61	Titanium	mg/Kg	423.84
Boron	mg/Kg	<5	Total sulphur		0.24

Table 8.5 Fly Ash Leachability Analysis – TCLP (Studies Carried out by TPP)

Parameters	Units	Fly ash	Parameters	Units	Fly ash
Copper as Cu	mg/Kg	0.0171	Hexavalent Chromium	mg/Kg	BDL
Cobalt as Co	mg/Kg	BDL	Total Chromium	mg/Kg	BDL
Lead as Pb	mg/Kg	0.00021	Nickel as Ni	mg/Kg	0.0084
Cadmium as Cd	mg/Kg	0.00168	Zinc as Zn	mg/Kg	BDL
Arsenic as As	mg/Kg	BDL	Vandium	mg/Kg	0.00672
Mercury as Hg	mg/Kg	BDL	Iron as Fe	mg/Kg	0.0012

Table 8.6 Soil Characterization (Studies Carried out by TPP)

Parameters (mg/Kg)	Bhalupali	Ash pond C	Ash pond B
Copper as Cu	<0.01	<0.01	<0.01
Lead as Pb,	<0.01	<0.01	<0.01
Cadmium as Cd	<0.01	<0.01	<0.01
Arsenic as As,	<0.01	<0.01	<0.01
Manganese as Mn	2.9	5.42	<0.01
Hexavalent Chromium	<0.01	<0.01	<0.01
Trivalent Chromium	<0.01	<0.01	<0.01

Table 8.7 Ground Water Quality Analysis (Studies Carried out by TPP)

Parameters	Bhalupali Village*	Rengali Village**	Kantatikra Village
pH	7.1	7.2	6.9
Fluoride (as F) (mg/l)	0.08	<0.1	<0.1
Arsenic(as As)(mg/l)	<0.01	<0.01	<0.01
Cadmium(as Cd) (mg/l)	<0.01	<0.01	<0.01
Lead(As Pb) (mg/l)	0.01	0.01	<0.01
Copper(as Cu) (mg/l)	0.04	<0.01	<0.01
Chromium(as Cr^{+6}) (mg/l)	<0.05	<0.05	<0.05
Mercury(as Hg) (mg/l)	<0.005	<0.005	<0.005
Manganese (as Mn)(mg/l)	0.05	0.06	0.15

** Location same as OW 24 and ** location same as OW 21as described in* ***Table 8.8***

It can be observed that all the measured water quality parameters are within the permissible limits.

8.4 Sampling Locations:

Ground Water (OW) samples, soil sample (OS), air sample (OA) were collected around the Thermal Power Plants ash disposal sites and Fly ash (HF) sample is collected from the ash mound and pond. Ground water (blank sample) is also collected from an area which is at a distance of more than 10 km from ash mound. The description of sampling site and its distance from the ash disposal site are presented in **Table 8.8**. Photographs taken during sampling are given at **Fig. 8.2**. Details of sampling locations are shown in **Fig. 8.3**.

Table 8.8 Location of Sampling Stations

Sl. No.	Sampling Locations	Description of Sampling Locations	Distance from Ash Pond (km)	Direction w.r.t. Ash Pond
1	OW21	Bore well at Rengali village	2	NE
2	OW22	Open pond	0.5	NW
3	OW23	Borewell at Belpahar	10	NE
4	OW24	Borewell at Bhalupali	3	SE
5	OS21	Soil sample from a pit at ash disposal site	0.5	NW
6	OS22	Soil sample near Rengali village	2	E
7	OF21	Fly ash sample from ash disposal site	0	-
8	OF22	Pond ash sample from ash disposal site	0	-
9	OA21	Ambient air quality monitoring at Rengali village	2	NE

8.5 Results and discussion

The results of the physico-chemical and mineralogical characterization of fly ash and pond ash samples as well as water quality analysis for ground water are given as follows:

8.5.1 Physical Properties

It is found that fly ash possesses a mean particle diameter i.e. D_{50} having 41.4 µm and Coefficient of uniformity i.e. C_u having 11 and pond ash possesses a mean particle diameter i.e. D_{50} having 44.7 µm and Coefficient of uniformity i.e. C_u having 7. **Table 8.9** shows physical

properties of the fly ash and pond ash. The results of the permeability test of ash samples show that the coefficient of permeability is very low.

Dyke Raising | Ash Pond-A

Ash Pond-C | Fly ash sample collection

Fig. 8.2 Photographs of Ash Disposal Site taken during Sampling

8.5.2 Chemical and Mineralogical Compositions

The element oxides of ash samples are presented in **Fig. 8.4 (a & b)**. The results show that the ash samples are enriched predominantly with silica (SiO_2) and alumina (Al_2O_3). In addition, they also contain small amounts of iron oxide (Fe_2O_3), TiO_2, K_2O, CaO, SO_3 and MgO. The rest of the compounds present in the ash samples are in minor concentrations. The sum of SiO_2, Al_2O_3 and Fe_2O_3 accounts for more than 90% of the total composition in all fly ash and pond ash samples. Since the sum total of SiO_2, Al_2O_3 and Fe_2O_3 is more than 70% in all fly ash and pond ash samples, they are classified as Class F fly ash according to the ASTM C-618 specifications. The fly ash and pond ash samples possess more or less similar physico-chemical and mineralogical properties. The reactive silica content in fly ash is found to be in the range 13 – 14.5 %.

Fig. 8.3 Location of Sampling Points at OPGC Ash Disposal Site

Table 8.9 Physical Properties of the Fly Ash and Pond Ash Samples

Parameters	Color	Specific Gravity	Maximum dry density, g/cc	Porosity, %	Coefficient of permeability, k x 10^{-5} cm/s
Fly ash	Grey	2.03 - 2.21	1.16 - 1.22	46 - 52	3-4
Pond ash	Dark Gray	2.11 - 2.25	1.13 -1.17	44 - 48	6 - 8

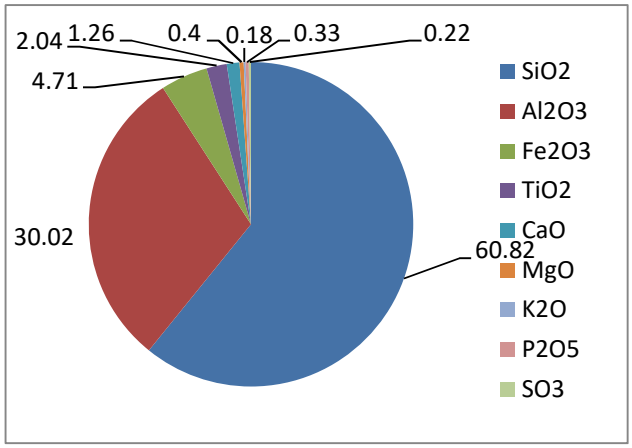


Fig. 8.4 (a) Element Oxides of Fly Ash

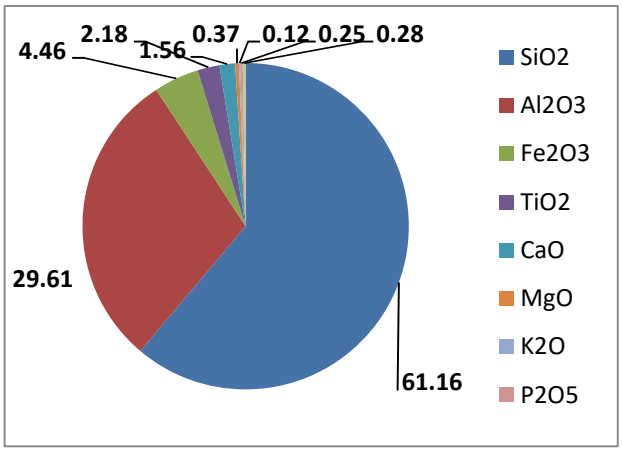


Fig. 8.4 (b) Element Oxides of Pond Ash

8.5.3 Ground Water Quality Analysis

The water quality analysis was performed on the water samples collected from the bore well and open pond from different locations in the area around fly ash dumpsite. Details of concentration of heavy metals and other water quality parameters in the water samples near the ash disposal sites and at the surrounding villages are given in **Table 8.10**. Water quality analysis for the present study (**Table 8.10**) is compared with the water quality study done by TPP in 2016 (**Table 8.7**) and the findings are discussed below:

- pH of the water sample ranged from 7.2 to 8.4, indicating alkaline nature of the water (present study). A neutral range of pH value (pH = 6.9 – 7.2) was found by the studies carried out by TPP. The difference is due to seasonal variations.
- Maximum value for electrical conductivity is 534 µS/cm and minimum value is 435 µS/cm for ground water sample (present study). Surface water sample contain less TDS (TDS = 0.7 EC). The difference is due to seasonal variations.

- Calcium (Ca in mg/l) of the ground water sample ranged from 28 to 53 mg/l for all the samples collected from three locations (present study).
- Presence of Aluminum is found in only at one ground water sampling location as well as in lone surface water sample (present study).
- Concentration of hexavalent chromium in all the three post-monsoon ground water samples and two pre-monsoon ground water samples (present study) as well as in the all samples tested by the TPP are below detectable limit (<0.05 mg/l). Presence of total chromium is found in all ground water and surface water samples with a minimum and maximum concentration of 0.022 mg/l and 0.088 mg/l respectively (present study).
- Concentration of Cadmium (Cd in mg/l) is found in all samples (except one post monsoon sample) with a minimum and maximum concentration of 0.0019 mg/l and 0.0024 mg/l respectively, which are within the acceptable limit (present study). Studies carried out by TPP indicate the presence of cadmium below detectable limit (<0.01 mg/l) in all ground water samples.
- Concentration of Lead (Pb in mg/l) is found in all samples with a minimum and maximum concentration of 0.02 mg/l and 0.056 mg/l respectively (present study). Studies carried out by TPP indicate the presence of lead at two locations (0.01 mg/l).
- Concentration of Mercury (Hg in mg/l) in all the water samples as well as in the sample tested by the TPP are below detectable limit.
- Concentration of Copper (Cu in mg/l) except one sample is below detectable limit (<0.004). Studies carried out by TPP indicate the presence of copper below detectable limit in all ground water samples (<0.005).
- Maximum value for Zinc concentration is 0.46 mg/l and minimum value is 0.15 mg/l. Surface water contains higher concentration of zinc in comparison to ground water.
- Fluoride (F^- in mg/l) of the water sample ranged from 0.22 to 0.84 mg/l for all the samples collected from four locations. However, the concentrations are within the acceptable limit. No significance change was found for surface water in comparison to ground water sample. However, less concentration (<0.1) was found by the studies carried out by TPP.

The groundwater analysis results reveal that pH, Ca, Cr^{+6}, Cd, Cu, Zn, Hg and F^- meet the drinking water standard prescribed in IS10500:2012. The concentrations of heavy metals in post

monsoon samples are less compared to pre monsoon samples, probably due to dilution of ground water. No significance change was found in the ground water sample at a distance of 10 km (OW 23 - Belpahar) from ash disposal site in comparison to other ground water sample collected (OW 21 -Rengali village and OW 24 -Bhalupali) just at the ash disposal site. Comparison of fly ash leachability (TCLP)between present study and study carried out by TPP in 2010is shown in **Fig. 8.5**. Comparison of ground water quality between present study and study done by TPP at location OW 21 -Rengali village and at location OW 24 -Bhalupaliin 2016 is shown in **Fig. 8.6-a, b** and **Fig. 8.7-a, b** respectively.

8.5.4 Heavy Metal Analysis in ash and soil samples

Acid digestion data of fly ash and surrounding soils provide the total available concentration levels of trace elements in fly ash & soils which is shown in **Table 8.11**. The results obtained from TCLP were found significantly lower in composition compared to acid digestion test. This is because; metal solubility generally decreases with increasing pH. Concentrations of Ca and Al was found significantly high as compared to other elements. The leaching of metals which were found low in the TCLP test, but found high in the acid digestion test, indicating a strong bonding of metals with the other compounds of ashes.

8.5.5 Air Quality Survey

Ambient air quality monitoring done at Rengali village for particulate matter (24 hr sampling period) gives the maximum value as 143.2 µg/m^3 and minimum value as 22.4 µg/$m^3$for PM_{10} and maximum value as 48.4 µg/m^3 and minimum value as 16.6 µg/$m^3$for $PM_{2.5}$.

8.6 Conclusions

On the basis of the study, following conclusions were drawn:

- Analytical results of ground water collected from 4 locations show that the values are within the permissible levels of BIS guidelines except Al and Pb. The aluminum concentration exceeds the BIS limits at one locations and lead at all the four locations including a location situated at more than 10 km from ash disposal site. This could be due to the geogenic factors.

Table 8.10 Analysis Result of Water Sample

Sl No	Sample ID	Season	pH	EC	Ca	Al	Cr^{+6}	T. Cr.	Cd	Pb	Cu	Zn	Hg	F^-
1	OW21	Premonsoon	8.2	698	67	BDL	0.035	0.105	0.0022	0.034	BDL	0.29	BDL	0.35
		Postmonsoon	7.9	534	53	BDL	BDL	0.088	0.0022	0.034	BDL	0.15	BDL	0.42
2	OW22*	Premonsoon	7.2	215	11	0.034	0.022	0.082	0.0024	0.056	BDL	1.08	BDL	0.23
		Postmonsoon	7.4	185	18	0.078	0.02	0.068	0.0019	0.046	BDL	0.86	BDL	0.84
3	OW23	Premonsoon	8.2	487	29	0.024	BDL	0.033	0.0024	0.033	0.029	0.46	BDL	0.22
		Postmonsoon	8.4	435	34	0.018	BDL	0.022	0.0019	0.01	BDL	0.44	BDL	0.34
4	OW24	Premonsoon	7.6	523	34	BDL	BDL	0.056	0.0022	0.024	BDL	0.35	BDL	0.4
		Postmonsoon	7.9	486	28	BDL	BDL	0.046	BDL	0.01	BDL	0.35	BDL	0.47
		AL	**6.5-8.5**	**-**	**75**	**0.03**	**-**	**0.05**	**0.003**	**0.01**	**0.05**	**5.0**	**0.001**	**1.0**
		DL	**-**	**-**	**-**	**0.002**	**-**	**0.01**	**0.0001**	**0.002**	**0.004**	**0.002**	**0.00007**	**-**

*Surface Water; Unit of all parameters is mg/l except pH and EC; Unit of EC is µS/cm; pH has no unit; AL: Acceptable Limit as per IS 10500:2012; DL: Detectable limit

Table 8.11 Analysis Result of Ash and Soil Sample (SADT & TCLP)

Sl No	Sample ID	Testing Procedure	Ca	Al	Cr^{+6}	T. Cr.	Cd	Pb	Cu	Zn	Hg	F^-
1	OS21	SADT	2025	2348	1.44	16.7	22.4	BDL	BDL	10.82	BDL	--
		TCLP	1846	19.4	BDL	BDL	8.42	BDL	BDL	BDL	BDL	3.4
2	OS22	SADT	2310	2806	BDL	24.9	18.6	BDL	5.88	8.68	BDL	--
		TCLP	1956	27.6	BDL	BDL	6.44	BDL	BDL	BDL	BDL	6.2
3	OF21	SADT	2511	3302	3.84	63.6	43.2	22.6	34.6	22.82	0.03	--
		TCLP	2355	22	BDL	BDL	9.82	0.22	0.24	3.62	BDL	48
4	OF22	SADT	2905	3612	2.28	47.8	40.8	32.8	34.8	22.61	BDL	--
		TCLP	2436	18.6	BDL	0.86	9.42	0.34	0.42	2.62	BDL	64

Unit of all parameters is mg/kg

The following suggestions are made for better management of ash in the plant.

- The industry shall make lucrative policy for fly ash users for large scale utilization of fly ash before exploring the option like quarry and mine void filling.
- The Thermal Power Plants must monitor the ground water quality (pre & post-monsoon every year) around the ash disposal sites by installing bore wells at strategic location to predict future trend.
- The industry must install permanent sprinkler system in the ash mound to control fugitive ash.

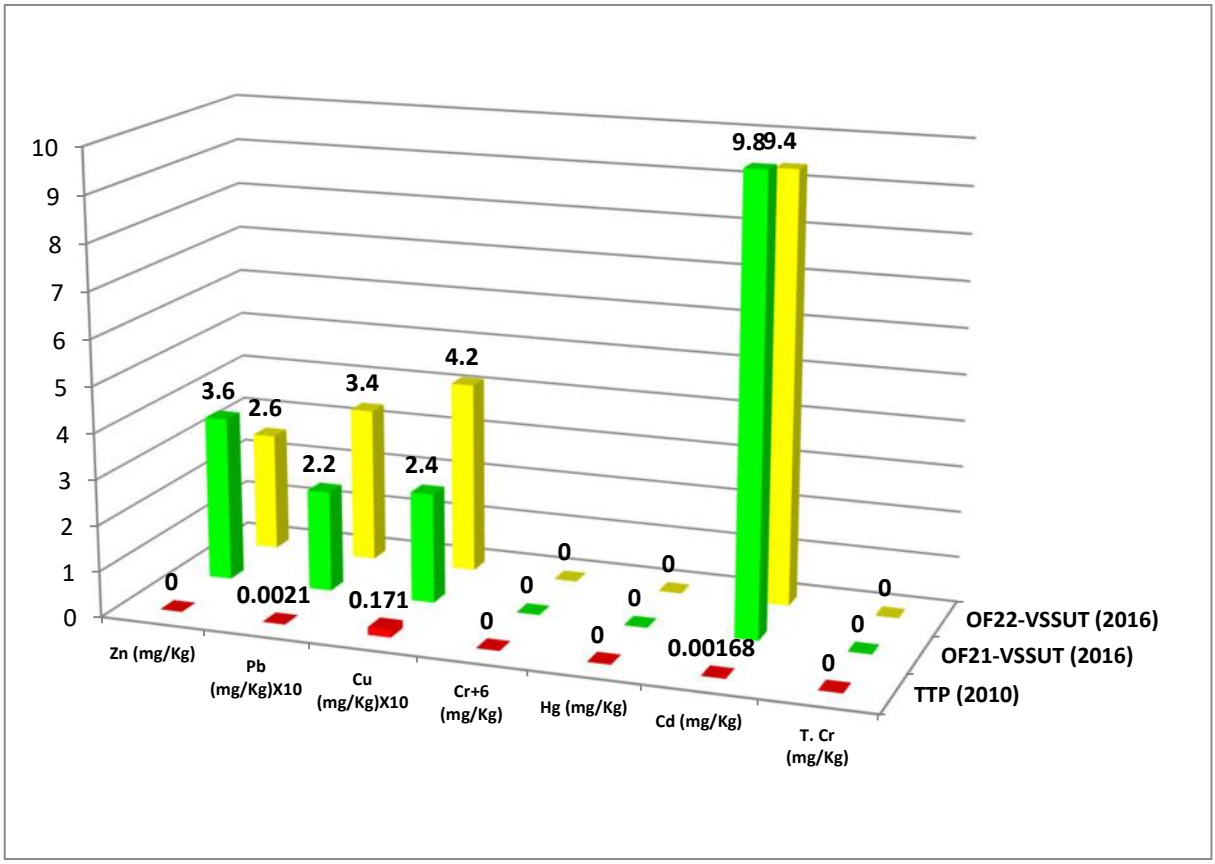
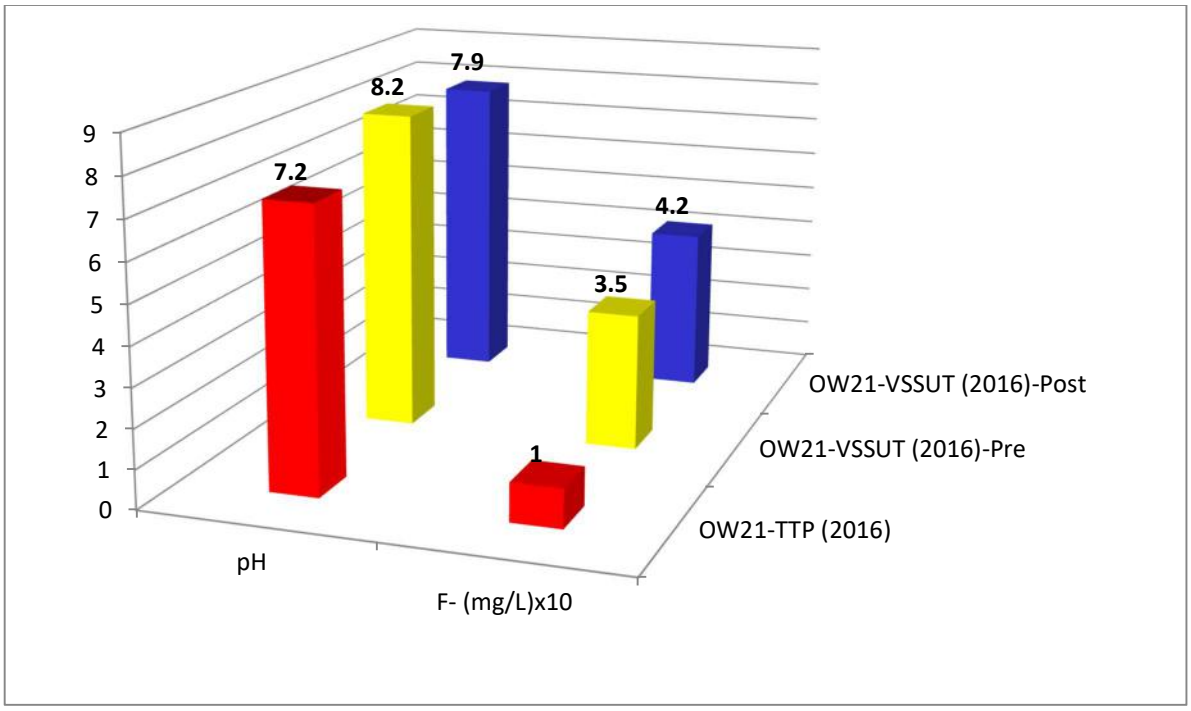
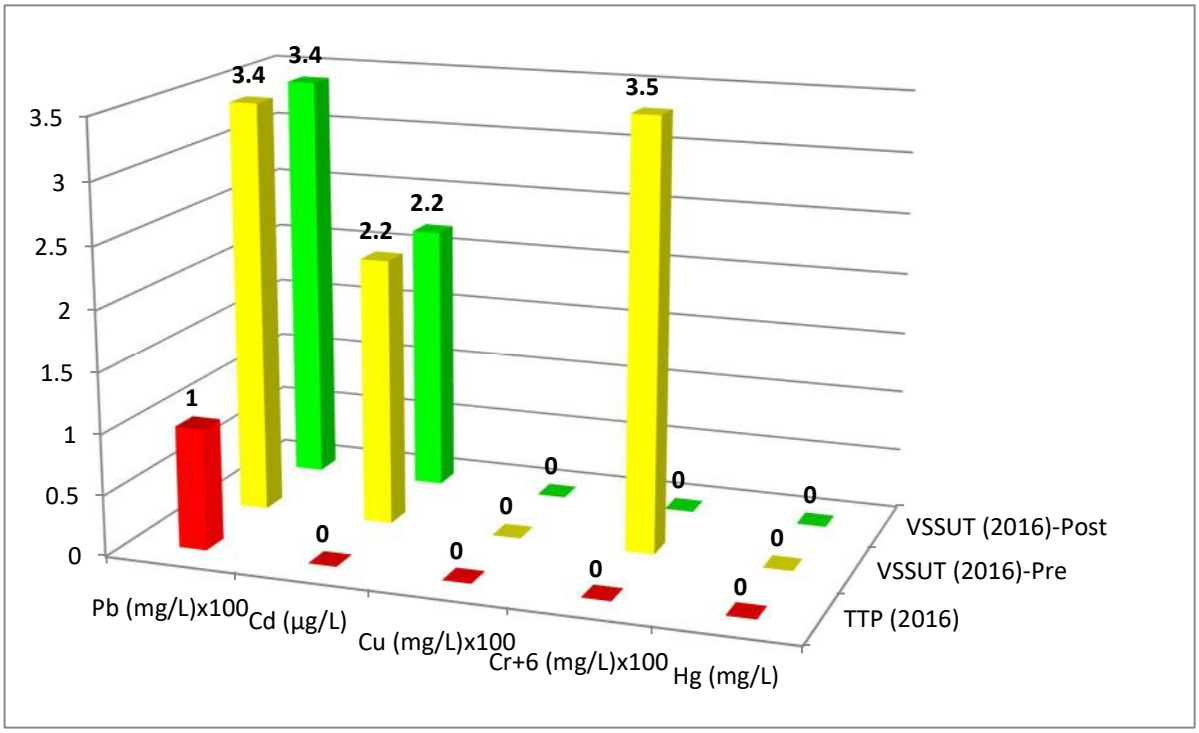


Fig. 8.5 Comparison of Fly Ash Leachability (TCLP)

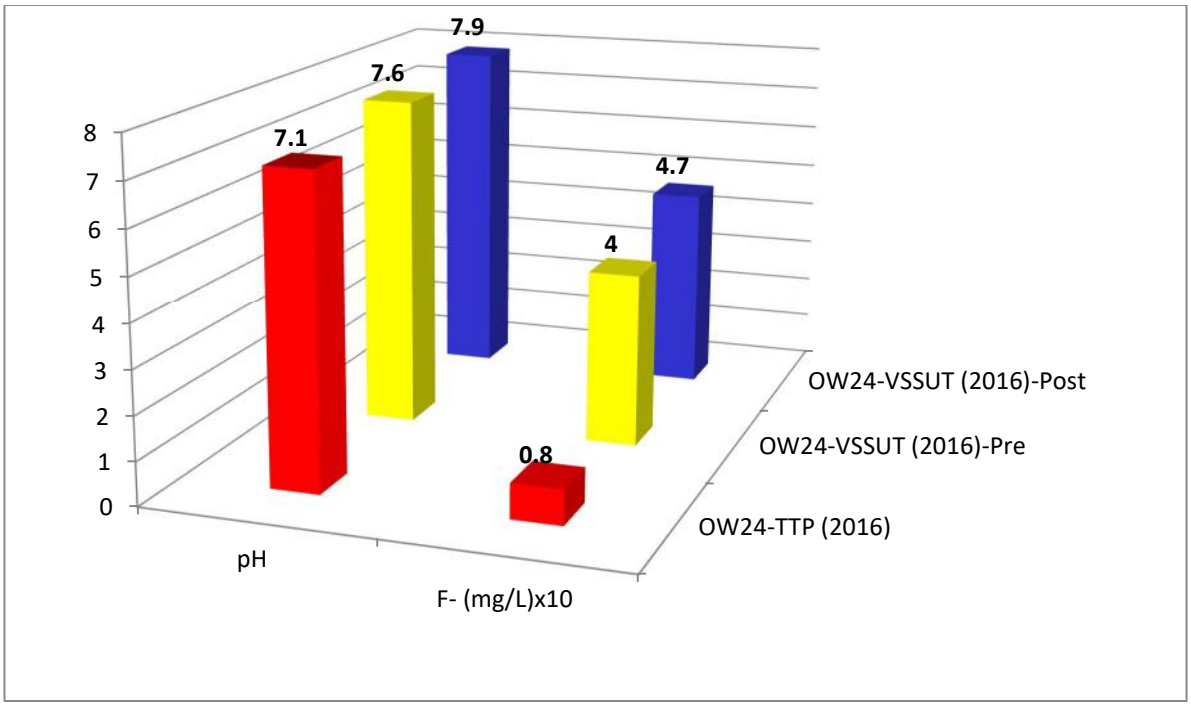


(a)

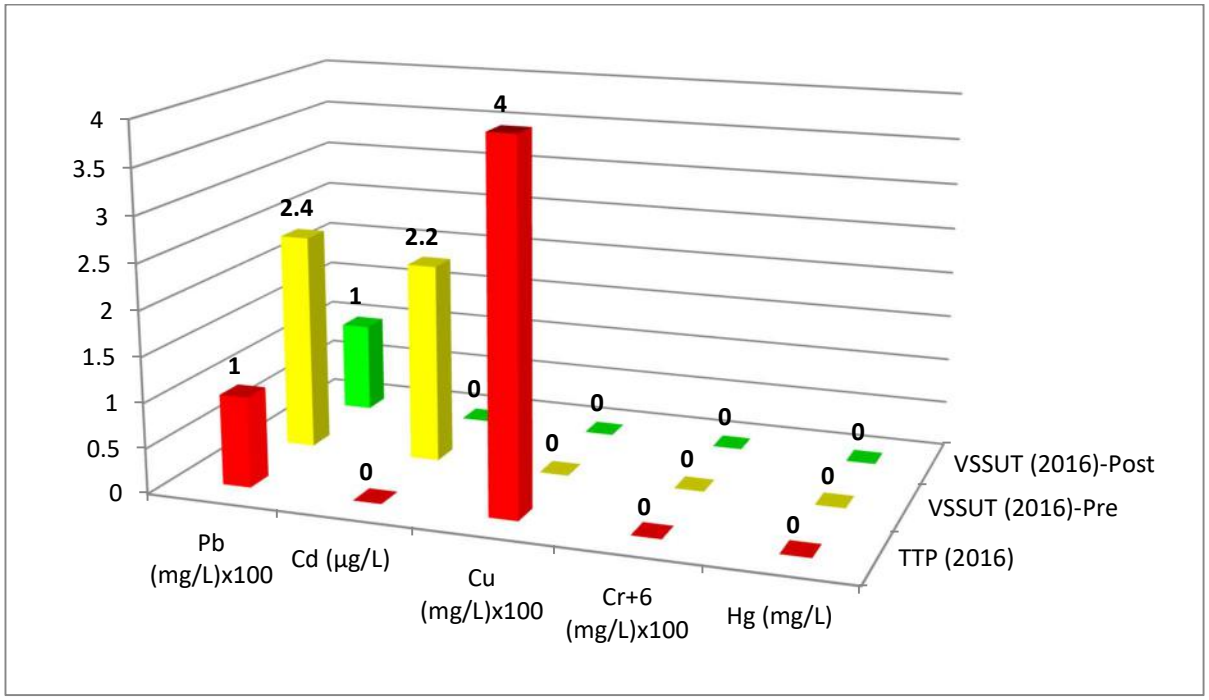


(b)

Fig. 8.6 Comparison of Ground Water Quality at OW 21 -Rengali village



(a)



(b)

Fig. 8.7 Comparison of Ground Water Quality at OW 24 -Bhalupali

Chapter 9

Vedanta Ltd., CPP & IPP, Bhurkahamunda, Jharsuguda

9.1 Introduction

M/s Vedanta Ltd. is located at Bhurkahamunda, Jharsuguda. The power generation capacity of the plant is 3615 MW comprising 9 x 135 MW of CPP and 4 x 600 MW of IPP (1215+2400). The total ash generation from this plant was about 6 million tonnes during the financial year 2016-17 with fly ash utilization rate of 70.3%. The ash is mostly used for land development, road construction and dyke raising.

9.2 Ash Management

M/s Vedanta Ltd. have 02 Ash Ponds named Katikela & Kurebaga. Locations of Ash Disposal Sites are given in **Table 9.1**. Details of the ash disposal site along with ash collection system and disposal are summarized in **Table 9.2** respectively.

Table 9.1 Location of Ash Disposal Site at Vedanta Ltd.

1. Name of the site	Katikela Ash Pond (Lagoon -1 & 2)	Kurebaga Ash Pond (Pond-1,2 & 3)
2. Location of the site	Katikela	Kurebaga
3. Distance from human habitation	Katikela village Direction: NE Distance: 1 km	Kurebaga village Direction: N Distance: 1 km
4. Distance from water bodies	River (Bheden) Direction: S Distance: 0.2Km	KharkhariNallah Direction: S Distance: 0.1Km River (Bheden) Direction: SSW Distance: 2.5 Km
Distance from educational institutions/ commercial infrastructures	Katikela Primary School Direction: NE Distance: 1 km	Kurebaga Primary School Direction: N Distance: 0.8 Km
Distance from forest cover	Katikela Reserve Forest Direction: W Distance: 0.1 km	Kurebaga Reserve Forest Direction: N &NE Distance: 0.2 Km
Distance from roads & railway line (if any)	**1.** Road: Nearest State High Way-SH-10 Direction: W Distance: 5 km	Road- Nearest State High Way-SH-10 Direction: W Distance: 4.6 Km Railway line-

	2. Railway line- Nearest Railway station is Brundamal Direction: NW Distance: 5.5 km	Nearest Railway station is Brundamal Direction: W Distance: 4 km
Distance from heritage site	No heritage site within 10 Km	No heritage site within 10 Km
Any other information	-	-

Table 9.2 Features of Ash Disposal Site at Vedanta Ltd.

1. Details of ash disposal sites			
a	Name of the ash disposal site	Kurebaga Ash Pond	Katikela Ash Pond
b	Area in Acre	143	192
c	Volume in m3	Pond-1 : 54.0 Lakh m3 (Closed)	Lagoon-1 : 55 Lakh m3 (excluding raising in progress)
		Pond-2 : 24.5 Lakh m3 (Closed)	Lagoon-2 : 50 Lakh m3 (excluding raising in progress)
		Pond-3 : 35 Lakh m3 (at present height)	
d	Over Flow Lagoon(OFL) for recycling of overflow water from ash pond	Exists	Exists
e	Other facilities	Recycling facilities with pumps and pipe line	Recycling facilities with pumps and pipe line
f	Design Height of each raising	4 to 6 m	4 to 6 m
g	No.of raising designed for	Upto height 40 m	Upto height 40 m
h	Present stage of raising	Pond-1 Starter Dyke-8m First Raising-4m Second Raising-4m Third Raising-4m Fourth Raising-4m Fifth Raising-4m Sixth Raising-4m	Lagoon-1 Starter Dyke-9 First Raising-6 Second Raising-6 Third Raising-5 (In Progress)
		Pond-2 Starter Dyke-8m First Raising-4m Second Raising-4m Third Raising-4m Fourth Raising-4m Fifth Raising-6m	Lagoon-2 Starter Dyke-10 First Raising-5 Second Raising-5 (In Progress)

		Pond-3 Starter Dyke-10m First Raising-4m Second Raising-4m Third Raising-4m	
h	No.of Pipelines	8	6
i	Distance from Plant	CPP- 7.5 Km, IPP-3 Km	CPP- 4 Km, IPP-10 Km
j	Operating since	Pond-1 : 2008	Lagoon-1: 2011
		Pond-2: 2009	Lagoon-2: 2013
		Pond-3: 2010	
2. Ash collection system			
a	Collection device used	1. Fly Ash collected in Hoppers &pneumatically conveyed to silos.From silo it goes to mixing tank where it get mixed with bottom ash and pumped through Geho pump to ash pond (HCSD system). 2. Bottom Ash collected from the boilers is pumped in form of slurry to dewatering bin and goes to mixing tank.	
b	Capacity	1. CPP-490 MT /hr 2. IPP- 1020 MT /hr	
c	Frequency of collection	Continuous	
3.	Ash slurry preparation	High Concentration Slurry (Ash: Water= 70:30)	
4. Transportation/ Pumping			
a	Modes of transportation	High Concentration Slurry Disposal(HCSD) Pumped by GEHO pumps & conveyed to ash ponds through pipe lines)	
b	Pumping details (No of pumping shift per day, discharge per shift etc)	Pumping done in all the three shifts (A B & C)	
5. Disposal			
a	Disposal Modes	HCSD	
b	Frequency of disposal	Continuous	
c	Discharge in cubic meter	CPP-1100 m3/Hr IPP-1578 m3/Hr	

9.3 Studies carried out by the TPP on Impact of Ash on Environment

It was observed that the TPP has conducted some studies i.e. Fly ash characterization for finding geotechnical properties by NIT Rourkela during (2013) and regular Ground Water Quality monitoring. The results of some of ground water quality monitoring values carried out during (2016) are given below in **Table 9.3**.

Table 9.3 Ground Water Quality Analysis (Studies Carried out by TPP in 2016)

Water Quality Parameters	Katikela ash disposal site*		Kurebaga ash disposal site*	
	North Bore well	South Bore well	East Bore well	West Bore well
pH	7.2 – 7.4	6.9 – 7.4	6.9 – 7.5	5.9 – 7.2
Turbidity (NTU)	2.6 - 2.9	2.2 – 3.6	1.2 – 1.5	0.7 – 0.8
Total alkalinity (mg/l $CaCO_3$)	52.5 – 87.5	45 - 80	63 - 152	67 - 105
Total Hardness (mg/l $CaCO_3$)	142 - 152	118 -138	92 - 120	54 - 122
Total dissolved solids(mg/l)	235 - 259	248 - 273	177 - 293	175 -294
Fluoride (as F) (mg/l)	0.31 – 0.35	0.33 – 0.37	0.32 – 0.39	0.34 – 0.37
Chloride (as Cl) (mg/l)	34 – 36.5	33 – 39.5	27.5 – 36.5	11.5 – 29.8
Sulphate(as SO_4^{2-}) (mg/l)	26.9 -29.7	24.7 – 26.8	14 - 30	8 - 29
Calcium (as Ca) (mg/l)	34.6 – 73.8	43.2 – 53.5	32.8 – 48.5	12.4 – 46.8
Aluminium (as Al) (mg/l)	BDL	BDL	BDL	BDL
Boron (as B)(mg/l)	0.086 – 0.096	0.073 – 0.322	0.01 – 0.041	BDL – 0.01
Arsenic(as As)(mg/l)	BDL	BDL	BDL	BDL
Selenium (as Se) (mg/l)	BDL	BDL	BDL	BDL
Cadmium(as Cd) (mg/l)	BDL	BDL	BDL	BDL
Cyanide (as CN) (mg/l)	BDL	BDL	BDL	BDL
Lead(As Pb) (mg/l)	BDL – 0.059	BDL – 0.071	BDL – 0.01	BDL – 0.01
Copper(as Cu) (mg/l)	0.035 – 0.042	0.038 – 0.046	0.01 – 0.02	0.01
Chromium(as Cr^{+6}) (mg/l)	BDL	BDL	BDL	BDL
Mercury(as Hg) (mg/l)	BDL	BDL	BDL	BDL
Mineral Oil (mg/l)	BDL	BDL	BDL	BDL
Zinc(as Zn)(mg/l)	0.30 – 0.47	0.38 – 0.55	0.23 – 0.35	0.24 – 0.25
Iron(as Fe)(mg/l)	0.21 -0.27	0.23 – 0.25	0.19 – 0.20	0.16 – 0.22
Manganese (as Mn)(mg/l)	0.036 – 0.044	0.040 – 0.046	0.01 – 0.09	0.01 – 0.03
Phenolic Compounds (mg/l)	BDL	BDL	BDL	BDL

** Same location same as VW 31, VW 32, VW 33 and VW 34 as described in **Table 9.4***

From **Table 9.3** it can be observed that all the measured water quality parameters are within the permissible limits except lead for some of the bore wells.

9.4 Sampling Locations

Ground Water (VW) samples, soil sample (VS), air sample (VA) were collected around the Thermal Power Plants ash disposal sites and Fly ash (VF) sample is collected from the ash pond. Photographs taken during sampling are given at the description of sampling site and its

distance from the ash disposal site are presented in **Table 9.4.and Fig. 9.1**. Details of sampling locations are shown in **Fig. 9.2**.

Table 9.4 Location of Sampling Stations

Sl. No.	Sampling Locations	Description of Sampling Locations	Distance from Ash Pond (km)	Direction w.r.t. Ash Pond
1	VW31	South bore well adjacent to Katikela ash disposal site	0.1	S
2	VW32	North bore well adjacent to Katikela ash disposal site	0.1	N
3	VW33	East bore well adjacent to Kurebaga ash disposal site	0.1	E
4	VW34	West bore well adjacent to Kurebaga ash disposal site	0.1	W
5	VW35	Borewell at Sripura	8	W
6	VS31	Soil sample from Katikela	0.3	N
7	VS32	Soil sample from Kurebaga	0.3	E
8	VS33	Soil sample from Sripura	3	W
9	VF31	Pond ash sample from Katikela ash disposal site	0	-
10	VF32	Fly ash sample from Kurebaga ash disposal site	0	-
11	VA31	Ambient air quality monitoring at Sripura	3	W

9.5 Results and discussion

The results of the physico-chemical and mineralogical characterization of fly ash and pond ash samples as well as water quality analysis for ground water are given as follows:

9.5.1 Physical Properties

It is found that fly ash possesses a mean particle diameter i.e. D_{50} having 42.6 µm and Coefficient of uniformity i.e. C_u having 12 and pond ash possesses a mean particle diameter i.e. D_{50} having 43.9 µm and Coefficient of uniformity i.e. C_u having 8. **Table 9.5** shows physical properties of the fly ash and pond ash. The results of the permeability test of ash samples show that the coefficient of permeability is very low.

Katikela ash disposal site

Soil sample collection at Katikela

Katikela ash disposal site

Ground water sample collection at Katikela

Fig. 9.1 Photographs of Ash Disposal Site taken during Sampling

9.5.2 Chemical and Mineralogical Compositions

The element oxides of ash samples are presented in **Fig. 9.3 (a & b)**. The results show that the ash samples are enriched predominantly with silica (SiO_2) and alumina (Al_2O_3). In addition, they also contain small amounts of iron oxide (Fe_2O_3), TiO_2, K_2O, CaO, SO_3 and MgO. The rest of the compounds present in the ash samples are in minor concentrations. The sum of SiO_2, Al_2O_3 and Fe_2O_3 accounts for more than 90% of the total composition in all fly ash and pond ash samples. Since the sum total of SiO_2, Al_2O_3 and Fe_2O_3 is more than 70% in all fly ash and pond ash samples, they are classified as Class F fly ash according to the ASTM C-618 specifications. The fly ash and pond ash samples possess more or less similar physico-chemical and mineralogical properties. The reactive silica content in fly ash is found to be in the range13 -16 %.

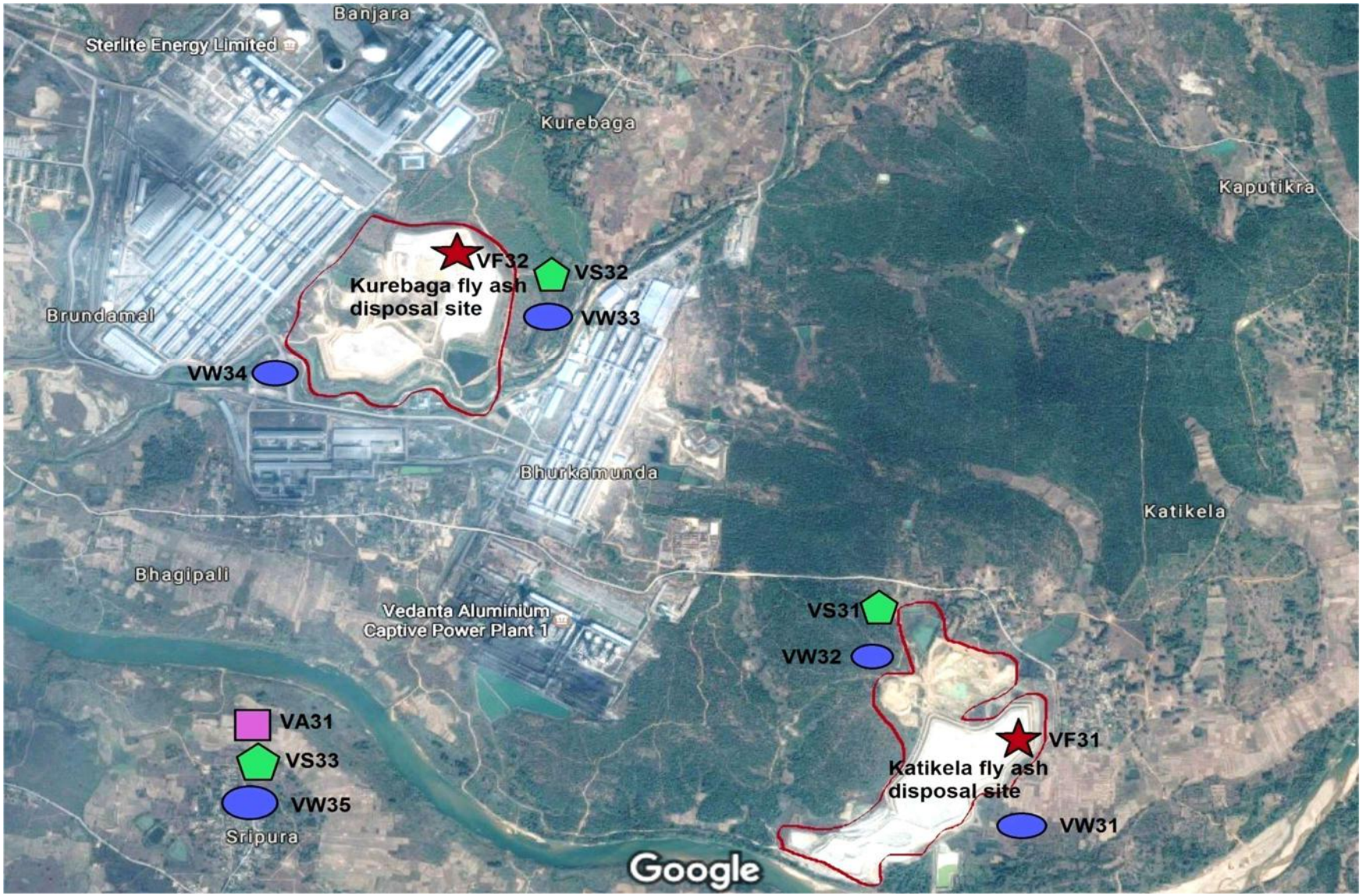


Fig. 9.2 Location of Sampling Points at Vedanta Ash Disposal Site

Table 9.5 Physical Properties of the Fly Ash and Pond Ash Samples

Parameters	Color	Specific Gravity	Maximum dry density, g/cc	Porosity, %	Coefficient of permeability, k x 10^{-5} cm/s
Fly ash	Grey	1.93 - 2.01	1.15 - 1.27	47 - 51	4–4.5
Pond ash	Dark Grey	1.96 - 2.15	1.18 -1.24	46 - 48	7 - 8

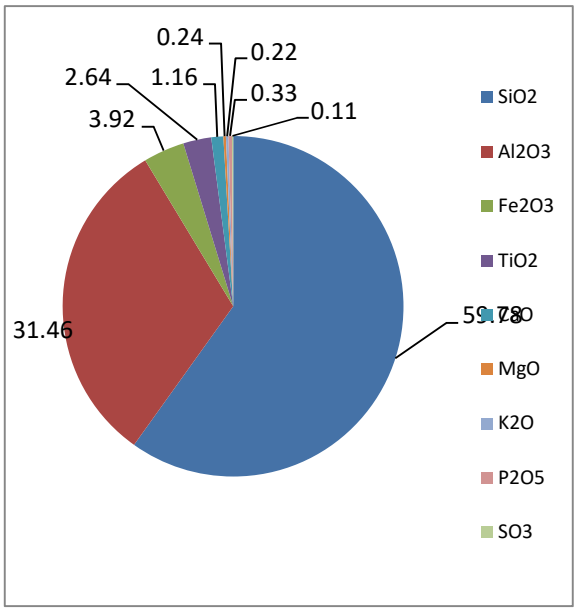


Fig. 9.3 (a) Element Oxides of Pond Ash

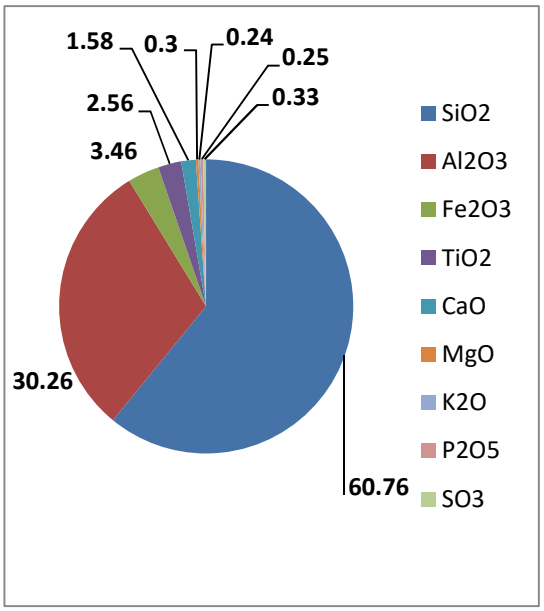


Fig. 9.3 (b) Element Oxides of Fly Ash

9.5.3 Ground Water Quality Analysis

The water quality analysis was performed on the water samples collected from the bore well from different locations in the area around fly ash dumpsite. Details of concentration of heavy metals and other water quality parameters in the groundwater samples near the ash disposal sites and at the surrounding villages are given in **Table 9.6**. Water quality analysis for the present study (**Table 9.6**) is compared with the water quality study done by TPP in 2016 (Table 9.3) and the findings are discussed below:

- pH of the water sample ranged from 7.8 to 8.5 for all the samples collected from five locations, indicating alkaline nature of the water (present study). A broader range of pH value (pH = 5.9 – 7.5) was found by the studies carried out by TPP due to seasonal variations.

Table 9.6 Analysis Result of Water Sample

Sl No	Sample ID	Season	pH	EC	Ca	Al	Cr^{+6}	T. Cr.	Cd	Pb	Cu	Zn	Hg	F^-
1	VW-31	Premonsoon	8.2	449	80	0.022	BDL	0.021	0.0025	0.054	BDL	0.14	BDL	0.4
		Postmonsoon	7.8	411	68	0.034	BDL	0.022	0.0016	0.01	BDL	0.26	BDL	0.5
2	VW-32	Premonsoon	7.8	431	19	0.036	0.011	0.057	0.0023	0.053	BDL	0.27	BDL	1.4
		Postmonsoon	7.9	388	32	0.045	BDL	0.044	0.0018	0.044	BDL	0.24	BDL	1.2
3	VW-33	Premonsoon	8.5	322	40	0.022	BDL	0.037	0.0023	0.052	BDL	0.59	BDL	1.2
		Postmonsoon	7.8	387	28	0.012	BDL	0.024	0.0026	0.036	BDL	0.68	BDL	0.9
4	VW-34	Premonsoon	8.5	412	39	0.024	0.025	0.089	0.0023	0.045	0.02	0.11	BDL	1.3
		Postmonsoon	7.9	434	25	0.034	BDL	0.054	0.0023	0.046	BDL	0.29	BDL	0.9
5	VW-35	Premonsoon	8.4	465	65	0.036	BDL	0.044	0.0021	0.035	BDL	0.34	BDL	0.8
		Postmonsoon	8.2	397	61	0.03	BDL	0.034	0.0016	0.009	BDL	0.64	BDL	0.6
		AL	**6.5-8.5**	**-**	**75**	**0.03**	**-**	**0.05**	**0.003**	**0.01**	**0.05**	**5.0**	**0.001**	**1.0**
		DL	**-**	**-**	**-**	**0.002**	**-**	**0.01**	**0.0001**	**0.002**	**0.004**	**0.002**	**0.00007**	**-**

Unit of all parameters is mg/l except pH and EC; Unit of EC is µS/cm; pH has no unit; AL: Acceptable Limit as per IS 10500:2012; DL: Detectable limit

Table 9.7 Analysis Result of Ash and Soil Sample (SADT & TCLP)

Sl No	Sample ID	Testing Procedure	Ca	Al	Cr^{+6}	T. Cr.	Cd	Pb	Cu	Zn	Hg	F^-
1	VS31	SADT	2127	2411	BDL	0.84	36.8	BDL	4.26	42	BDL	--
		TCLP	1620	26.6	BDL	BDL	8.2	BDL	BDL	BDL	BDL	5.8
2	VS32	SADT	2044	2234	1.52	5.2	47.2	4.2	3.44	22.8	BDL	--
		TCLP	1658	22.6	BDL	BDL	10.4	0.24	BDL	2.6	BDL	8.6
3	VS33	SADT	2512	2828	BDL	10.4	28.4	BDL	BDL	39.6	BDL	--
		TCLP	2234	27.4	BDL	BDL	3.6	BDL	BDL	BDL	BDL	6.2
4	VF31	SADT	2852	5237	1.54	7.2	48.2	BDL	46.8	45.6	0.0228	--
		TCLP	2085	25.2	BDL	BDL	10	BDL	0.62	BDL	BDL	34
5	VF32	SADT	3846	11815	3.36	26.4	46.8	BDL	78.9	139.2	0.0264	--
		TCLP	2790	45.4	BDL	BDL	10.2	BDL	0.66	BDL	BDL	30

Unit of all parameters is mg/kg

- Maximum value for electrical conductivity is 465 µS/cm and minimum value is 322 µS/cm (present study). Similar result i.e. TDS of 175 - 294 mg/l (EC = 250 - 420 µS/cm; TDS = 0.7 EC) was found by the studies carried out by TPP. This indicates the presence of lesser concentration of common anions and cations in ground water.
- Calcium (Ca in mg/l) of the water sample ranged from 19 to 68 mg/l for all the samples collected from five locations (present study). Similar result (12.4 – 73.8 mg/l) was found by the studies carried out by TPP.
- Presence of Aluminum is found in all pre-monsoon and post-monsoon samples (present study). Studies carried out by TPP indicate the presence of aluminum below detectable limit in all ground water samples.
- Concentration of hexavalent chromium in all the five post-monsoon samples and three pre-monsoon samples (present study) as well as in the all samples tested by the TPP (**Table 9.3**) are below detectable limit (<0.01 mg/l). Presence of total chromium is found in all samples with a minimum and maximum concentration of 0.021 mg/l and 0.089 mg/l respectively (present study).
- Concentration of Cadmium (Cd in mg/l) is found in all samples with a minimum and maximum concentration of 0.0016 mg/l and 0.0026 mg/l respectively, which are within the acceptable limit (present study). Studies carried out by TPP indicate the presence of cadmium below detectable limit in all ground water samples.
- Concentration of Lead (Pb in mg/l) is found in all samples with a minimum and maximum concentration of 0.01 mg/l and 0.053 mg/l respectively. Studies carried out by TPP indicate the presence of lead below detectable limit in all ground water samples.
- Concentration of Mercury (Hg in mg/l) in all the ground water samples (present study) as well as in the sample tested by the TPP are below detectable limit.
- Concentration of Copper (Cu in mg/l) except one sample are below detectable limit in other ground water samples. Studies carried out by TPP indicate the presence of copper below detectable limit in all ground water samples.
- Maximum value for Zinc concentration is 0.68 mg/l and minimum value is 0.11 mg/l (present study). Similar result i.e. Zn of 0.23 – 0.55 mg/l was found by the studies carried out by TPP. However, the concentration of Zn in ground water samples is within the acceptable limit.

- Fluoride (F^- in mg/l) of the water sample ranged from 0.4 to 1.4 mg/l for all the samples collected from five locations (present study). Less concentration of fluoride (0.31- 0.39 mg/l) was found by the studies carried out by TPP.

The groundwater analysis results reveal that pH, Cr^{+6}, Cd, Cu, Zn, Hg meet the drinking water standard prescribed in IS10500:2012. The concentrations of heavy metals in post monsoon samples are less compared to pre monsoon samples, probably due to dilution of ground water. No significance change was found in the ground water sample at a distance of 8 km (VW 35) from ash disposal site in comparison to other ground water sample collected (VW 31 to VW 34) just at the ash disposal site. Comparison of ground water quality between present study by VSSUT 2016 and study done by TPP at location VW 31-South bore well Katikela ash disposal site, VW 32-North bore well Katikela ash disposal site, VW 33- East bore well Kurebaga ash disposal site and VW 34- West bore well Kurebaga ash disposal site are shown in **Fig. 9.4 (a, b)**, **Fig. 9.5 (a, b)**, **Fig. 9.6 (a, b)** and **Fig. 9.7 (a, b)** respectively.

9.5.4 Heavy Metal Analysis in ash and soil samples

Acid digestion data of fly ash and surrounding soils provide the total available concentration levels of trace elements in fly ash & soils which is shown in **Table 9.7**. The results obtained from TCLP were found significantly lower in composition compared to acid digestion test. This is because; metal solubility generally decreases with increasing pH. Concentrations of Ca and Al was found significantly high as compared to other elements. The leaching of metals which were found low in the TCLP test, but found high in the acid digestion test, indicating a strong bonding of metals with the other compounds of ashes.

9.5.5 Air Quality Survey

Ambient air quality monitoring done at Sripura village for particulate matter (24 hr sampling period) gives the maximum value as 39.2 μg/m^3 and minimum value as 24.6 μg/$m^3$for PM_{10} and maximum value as 30.4 μg/m^3 and minimum value as 16.2 μg/$m^3$for $PM_{2.5}$.

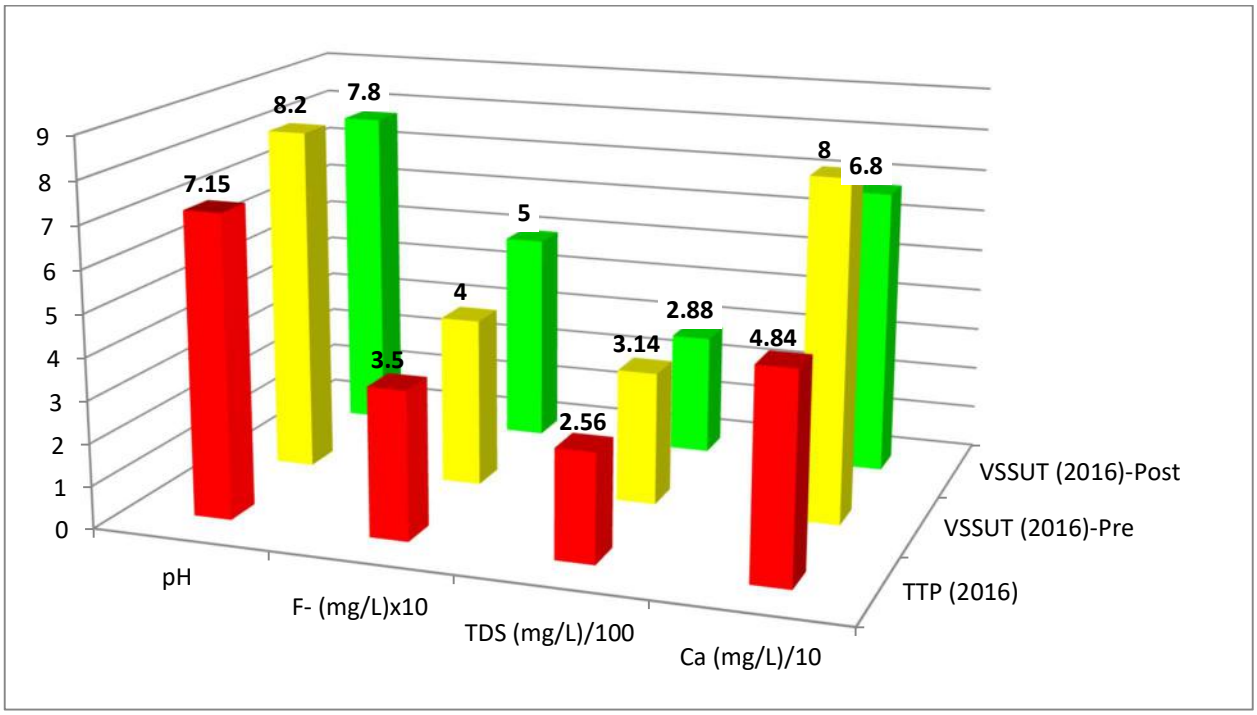
9.6 Conclusions

On the basis of the study, following conclusions were drawn:

- Analytical results of ground water collected from 5 locations show that the values are within the permissible levels of BIS guidelines except Al and Pb. The aluminum concentration exceeds the BIS limits at 4 locations and leads at all the 5 locations. This could be due to the geogenic factors.

The following suggestions are made for better management of ash in the plant.

- The industry shall make lucrative policy for fly ash users for large scale utilization of fly ash other than the option like quarry and mine void filling.



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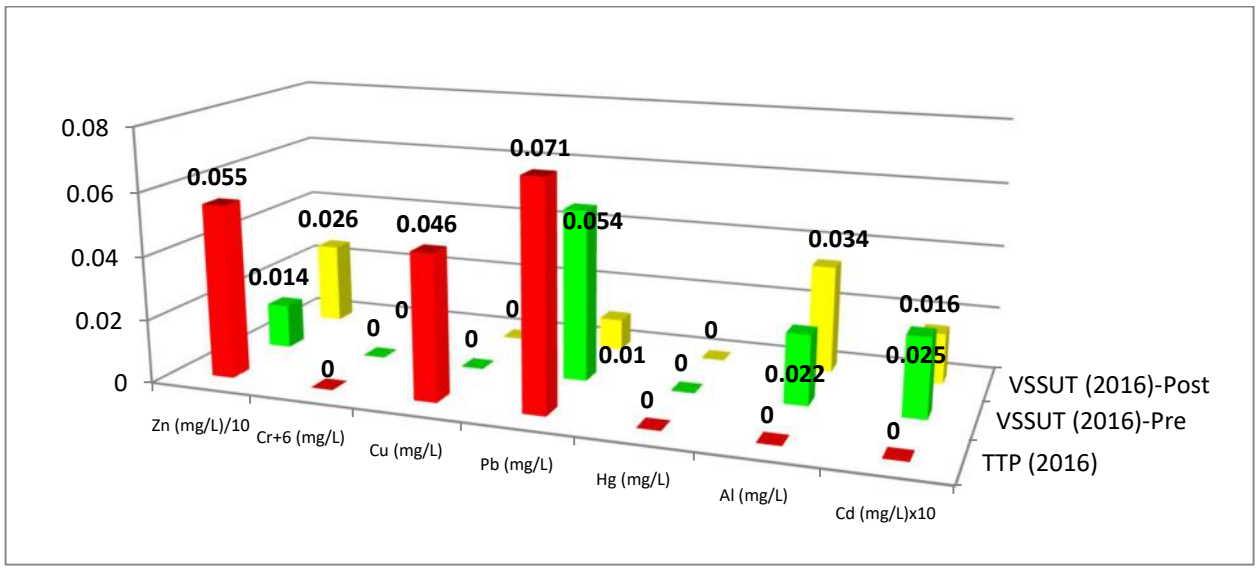

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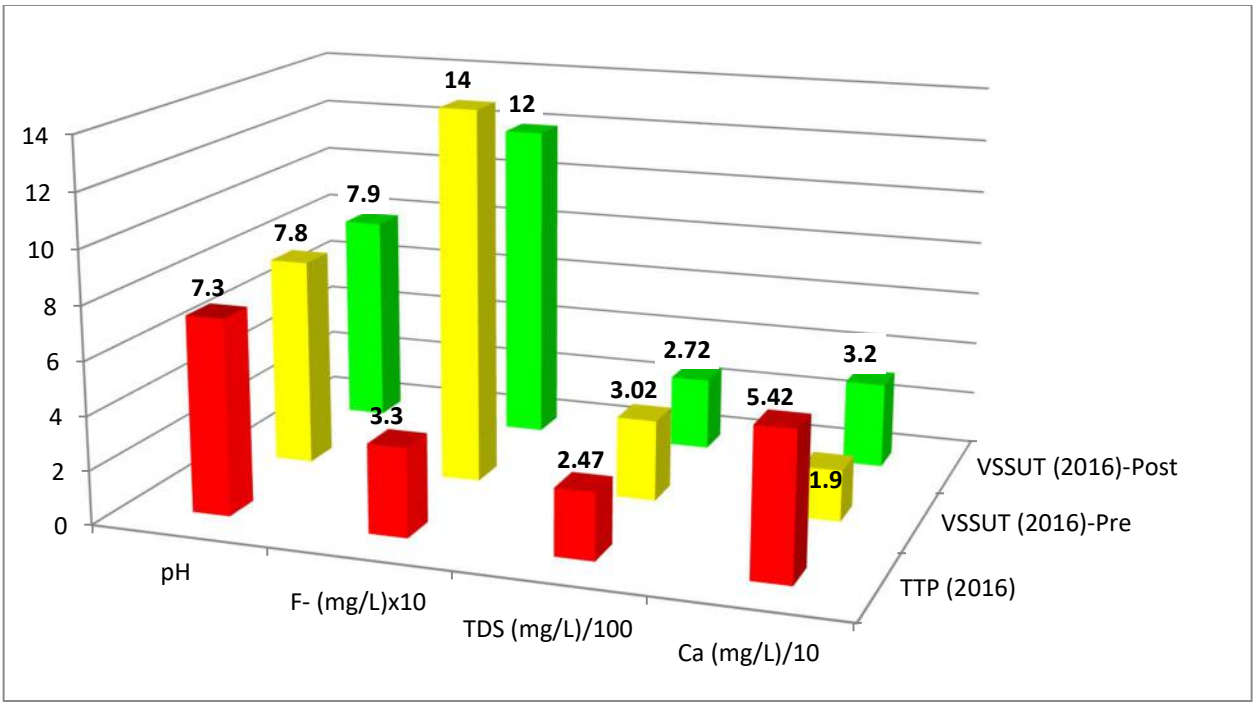
Fig. 9.4 Comparison of Ground Water Quality at VW 31-South Bore Well Katikela



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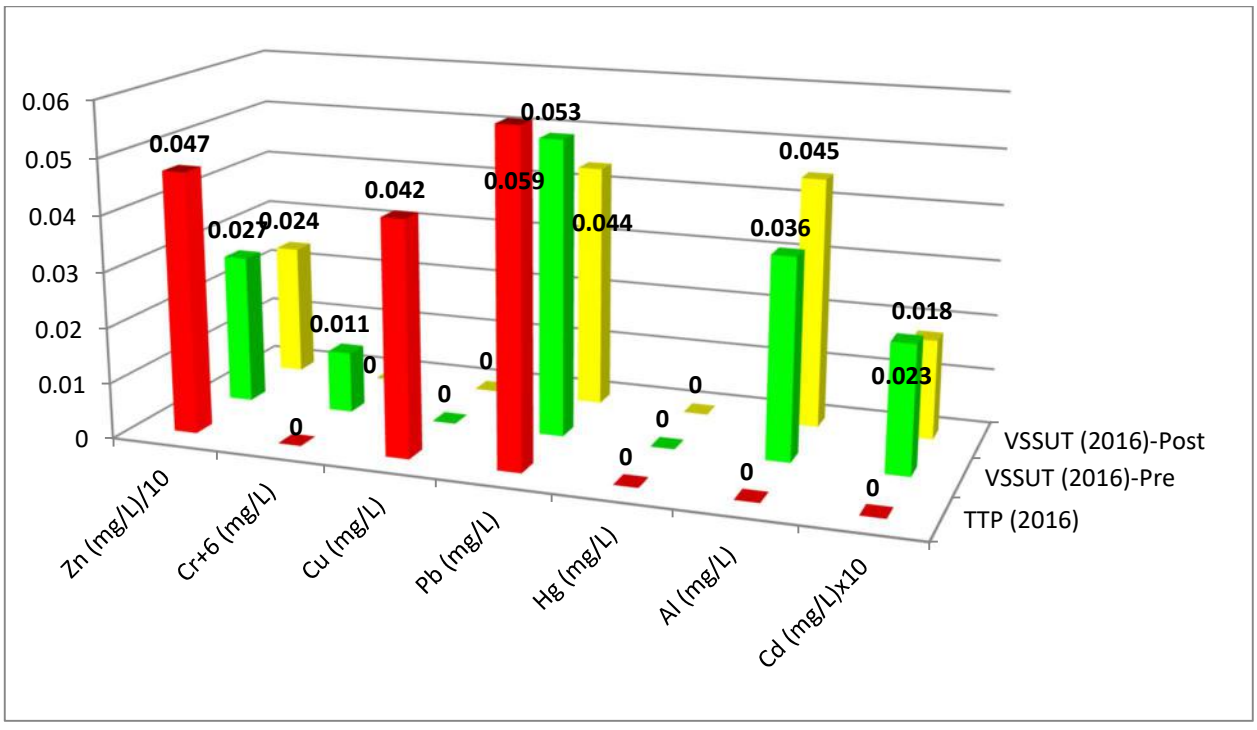

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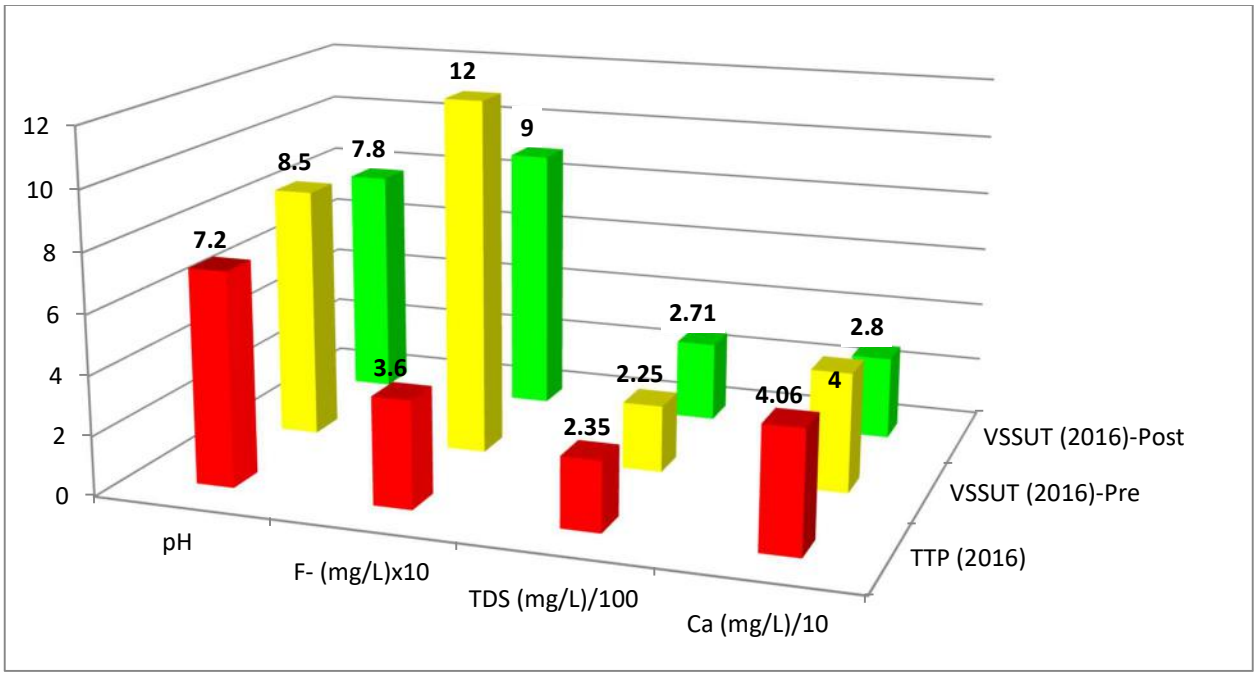
Fig. 9.5 Comparison of Ground Water Quality at VW 32- North Bore Well Katikela



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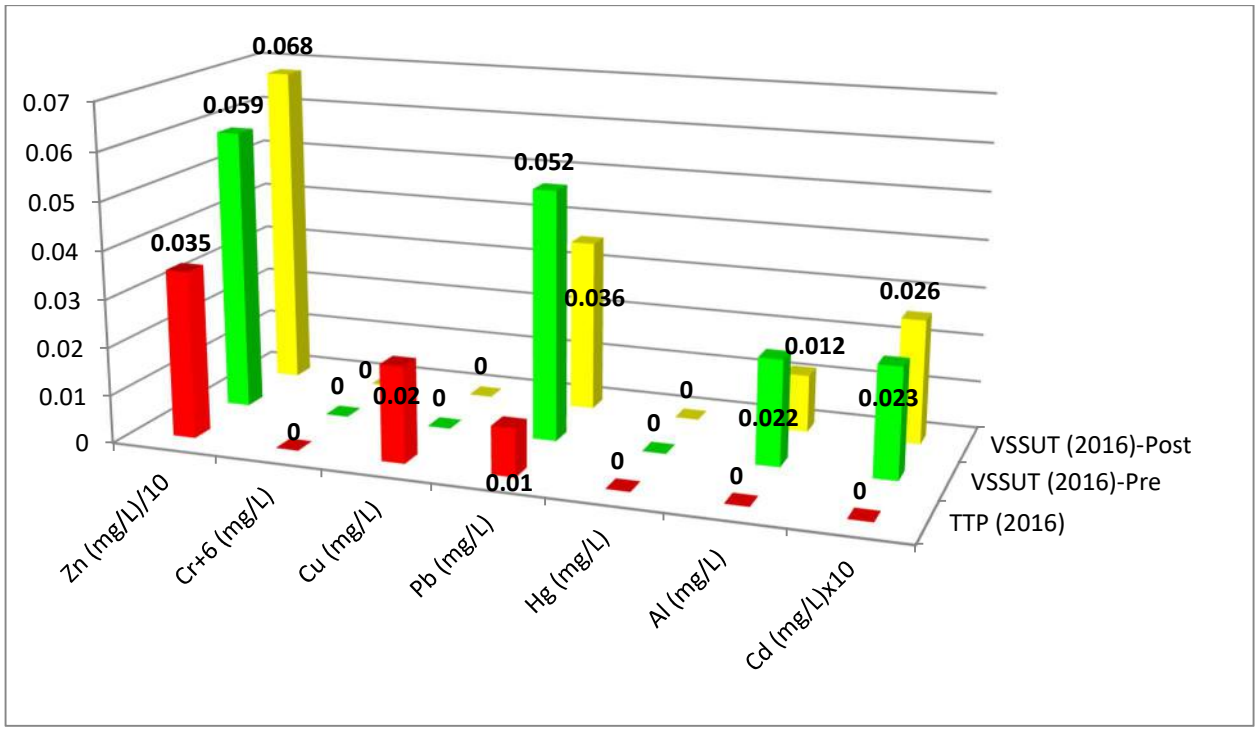

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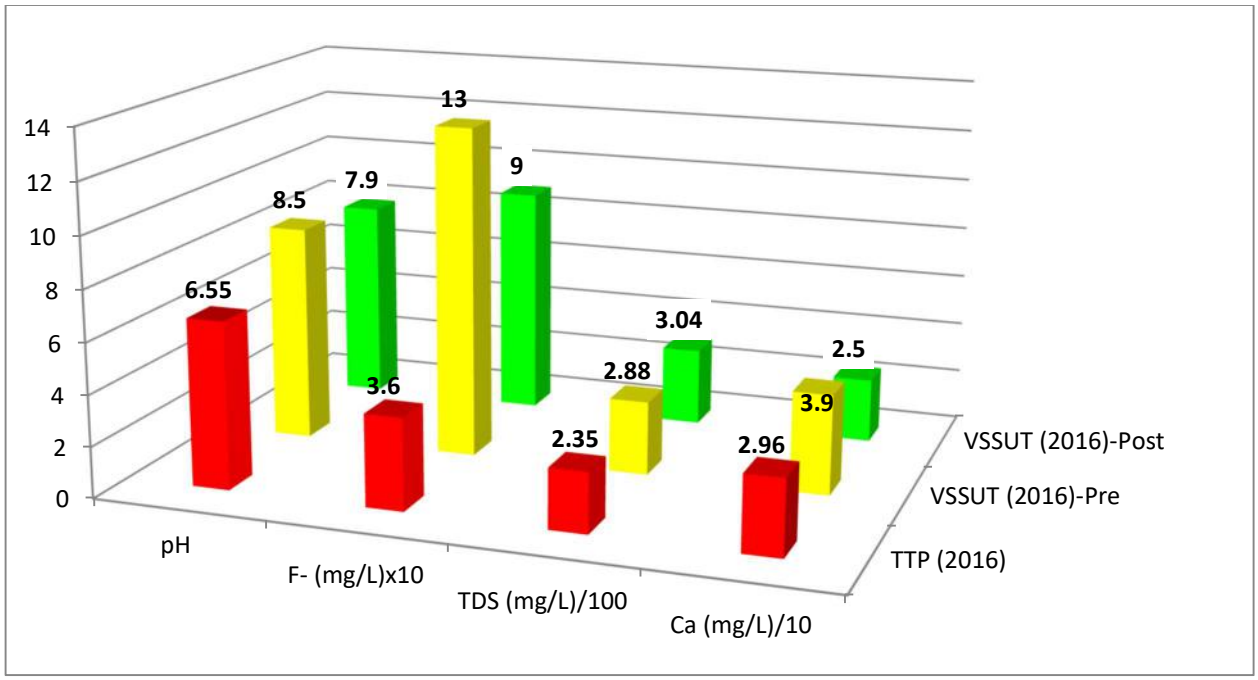
Fig. 9.6 Comparison of Ground Water Quality at VW 33- East Bore Well Kurebaga



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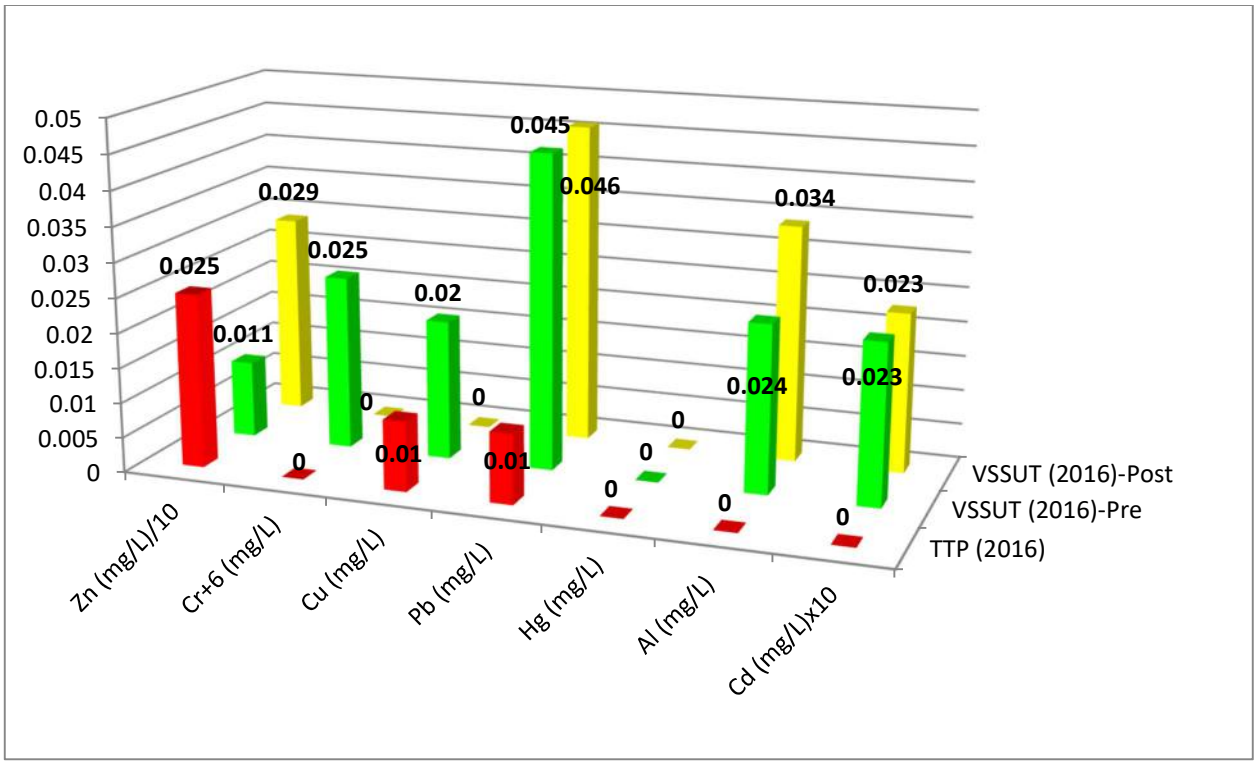


(b)

Fig. 9.7 Comparison of Ground Water Quality at VW 34- West Bore Well Kurebaga

Chapter 10

NTPC-SAIL Power Co. Ltd. CPP-II, Rourkela

10.1 Introduction

M/s NTPC-SAIL Power Co. Ltd. is located at Rourkela. The power generation capacity of the plant is 120 MW (2 x 60 MW). The total ash generation from this plant was about 462372ton during the financial year 2016-17 with fly ash utilization rate of 100 % of which major portion utilized in land development, brick manufacturing and dyke raising.

10.2 Ash Management

M/s NTPC-SAIL Power Co. Ltd. have 03 Ash Ponds named A, B & C Location of Ash Disposal Sites are given in **Table 10.1**. Details of the ash disposal site along with ash collection system and disposal are summarized in **Table 10.2** respectively.

10.3 Studies carried out by the TPP on Impact of Ash on Environment

The plant has carried out some environmental studies (provided by the plant), which are given below in **Table 10.3**.

Table 10.1 Location of Ash Disposal Site at NTPC-SAIL Power Co. Ltd.

1	Name of the Industry	NTPC-SAIL Power Company (P) Limited
2	Name of the Site	NSPCL, Rourkela
3	Location of the site	CPP-II,RSP complex
4	Details of land marks	RSP complex
5	Distance from human habitation	2 km
6	Distance from water bodies	5 km
7	Distance from educational institutions / commercial infrastructures	3 km/1 km
8	Distance from forest cover	10 km
9	Distance from roads & railway line	300m;500m
10	Distance from heritage site	14km
11	Any other information	None

Table 10.2 Features of Ash Disposal Site at NTPC-SAIL Power Co. Ltd.

Sl. No	Details	
1	Name of the Industry	CPP-II NSPCL Rourkela, Sundergarh, Odisha
2	Details of Ash Disposal Sites	
a)	Name of Ash Disposal Sites	Ash Pond(Lagoons)-A,B AND C
b)	Area in Acre	A-23.5 acre, B-19.5 acre and C-28.5 acre
c)	Volume in Cum	10.25 lakhs cum
d)	Lagoon - 1-A	3.50 lakh cum,
e)	Lagoon-2-B	2.75 lakh cum
	Lagoon-3-C	4.00lakh cum
f)	Over Flow Lagoon (OFL) for recycling of over flow water from ash pond	100% water under recirculation from pond-B and C, pond a is under buttressing
g)	Other facilities	
h)	Design height of each raising	4 to 4.5 mtrs
i)	No of raising designed for	A-3rd raising, B-3rd raising and C-1st raising
j)	Present stage of raising	A-RL-235 m, B-235m and C-232.5
k)	No of Pipeline	CPP-I 3 pipe lines and CPP-II 4 pipe lines
l)	Distance from Plant (APPROX.)	A-1.00 km, B-0.8km and C-3 km
m)	Operating since	A-2001, B-2001 and C-2007
n)	Ash deposited as on	A-1.70 lakhs cum (3rd raising), B-2.40 lakhs cum(3rd raising),and C-2.00 lakh cum(1st raising)
3	Volume of the allotted quarry voids for ash disposal	2.45 lakh cum
a)	% used	33%
4	Improvement in present practices planned by TPP	Reduction in ash water ratio for ash disposal, recirculation of water from ash dykes
5	Details of complaint received from local people/ villagers or farmers	None
6	Lacuna in the system of disposal	-----
7	Improvements needed	Ash utilisation in road construction sector to be explored.

Table 10.3 Studies Carried out by TPP on Impact of Ash on Environment

S.N.	Name of the study	Agency (Year)
1	Leaching Test of ash	NIT Rourkela Pvt.Ltd. (2015)
2	Ground Water Quality Report	Mitra S. K. Pvt. Ltd. (2016)*
3	Ambient Air Quality Report	Mitra S. K. Pvt. Ltd. (2016)*

** Regularly monitored*

The above reports have been reviewed and the salient features of leaching test of ash, ground water monitoring and ambient air quality monitoring are given in **Table- 10.4, 10.5** and **10.6** respectively.

Table 10.4 Leaching Test of Ash (Studies Carried out by TPP)

Parameters	Units	Fly ash	Bottom ash
pH	--	8.19	8.23
TSS	mg/l	98	78
TDS	mg/l	221	209
Ca	%	66.2	54.1
Mg	%	19.1	15.0
Na	%	0.83	0.53
K	%	0.21	0.19
NO_3^-	%	5.9	4.7
F^-	%	1.4	1.4
I^-	%	0.003	0.002
SO_4^{2-}	%	0.29	0.32
Fe	%	0.32	0.45
Pb	%	0.02	0.01
Cd	%	0.001	0.002
Ni	%	BDL	BDL
Total Cr	%	BDL	BDL
Co	%	BDL	BDL
As	%	BDL	BDL
Hg	%	BDL	BDL

Table 10.5 Groundwater Quality Analysis (Studies Carried out by TPP)

Water Quality Parameters	Koila gate tube well*	Water Quality Parameters	Koila gate tube well*
pH	6.7	Selenium (as Se) (mg/l)	<0.002
Turbidity (NTU)	5	Cadmium(as Cd) (mg/l)	<0.002
Total alkalinity (mg/l $CaCO_3$)	173.4	Cyanide (as CN) (mg/l)	<0.01
Total Hardness (mg/l $CaCO_3$)	320.1	Lead(As Pb) (mg/l)	<0.005
Total dissolved solids(mg/l)	433	Copper(as Cu) (mg/l)	<0.02
Magnesium (as Mg) (mg/l)	18.62	Chromium(as Cr^{+6}) (mg/l)	<0.01
Fluoride (as F) (mg/l)	0.25	Mercury(as Hg) (mg/l)	<0.002
Chloride (as Cl) (mg/l)	87.7	Mineral Oil (mg/l)	<0.01
Sulphate(as SO_4^{2-}) (mg/l)	84.4	Zinc(as Zn)(mg/l)	0.72
Calcium (as Ca) (mg/l)	97.0	Iron(as Fe)(mg/l)	0.98
Aluminium (as Al) (mg/l)	<0.01	Manganese (as Mn)(mg/l)	0.03
Boron (as B)(mg/l)	<0.5	Phenolic Compounds (mg/l)	<0.001
Arsenic(as As)(mg/l)	<0.01		

** Same location same as NW 42 as described in **Table 10.7***

Table 10.6 Ambient Air Quality Monitoring (Studies Carried out by TPP)

Ambient Air Quality Parameters	Raw water sump	Switch Yard	Coal handling plant	Sector-IX guest house
PM_{10} (µg/m^3)	70.0	64.0	74.7	57.0
$PM_{2.5}$ (µg/m^3)	39.7	35.7	41.7	32.7
SO_2 (µg/m^3)	6.7	6.3	7.1	5.6
NO_2 (µg/m^3)	27.9	27.3	29.3	21.8

From **Table 10.4** it can be observed that leached water from the fly ash and bottom ash is alkaline in nature and most of heavy metals are absent in it. Ground water monitoring indicates that all the measured water quality parameters are within the permissible limits except Iron. All the measured ambient air quality parameters are within the permissible limits.

10.4 Sampling locations:

Ground Water (NW) samples, soil sample (NS), air sample (NA) were collected around the Thermal Power Plants ash disposal sites and Fly ash (NF) sample is collected from the ash

disposal site. The description of sampling site and its distance from the ash disposal site are presented in **Table 10.7**. Details of sampling locations are shown in **Fig. 10.1**.

Table 10.7 Location of Sampling Stations

Sl. No.	Sampling Locations	Description of Sampling Locations	Distance from Ash Pond (km)	Direction w.r.t. Ash Pond
1	NW41	Bore well	2	N
2	NW42	Bore well located at koila gate	1.5	N
3	NW43	Bore well	1.2	NE
4	NW44	Bore well	1.7	S
5	NS41	Soil sample at koila gate	1.0	N
6	NS42	Soil sample from a pit	1.5	S
7	NF41	Fly ash sample from ash disposal site	0	-
8	NF42	Pond ash sample from ash disposal site	0	-
9	NA41	Ambient air quality monitoring at koila gate	1.5	N

10.5 Results and discussion

The results of the physico-chemical and mineralogical characterization of fly ash and pond ash samples as well as water quality analysis for ground water are given as follows:

10.5.1 Physical Properties

It is found that fly ash possesses a mean particle diameter i.e. D_{50} having 40.6 µm and Coefficient of uniformity i.e. C_u having 11 and pond ash possesses a mean particle diameter i.e. D_{50} having 42.7 µm and Coefficient of uniformity i.e. C_u having 6. **Table 10.8** shows physical properties of the fly ash and pond ash. The results of the permeability test of ash samples show that the coefficient of permeability is very low.

Table 10.8 Physical Properties of the Fly Ash and Pond Ash Samples

Parameters	Color	Specific Gravity	Maximum dry density, g/cc	Porosity, %	Coefficient of permeability, k x 10^{-5} cm/s
Fly ash	Gray	1.98 - 2.14	1.17 - 1.24	47 - 49	2–2.5
Pond ash	Dark Gray	2.02 - 2.18	1.18 -1.28	48 - 51	5 – 7.5

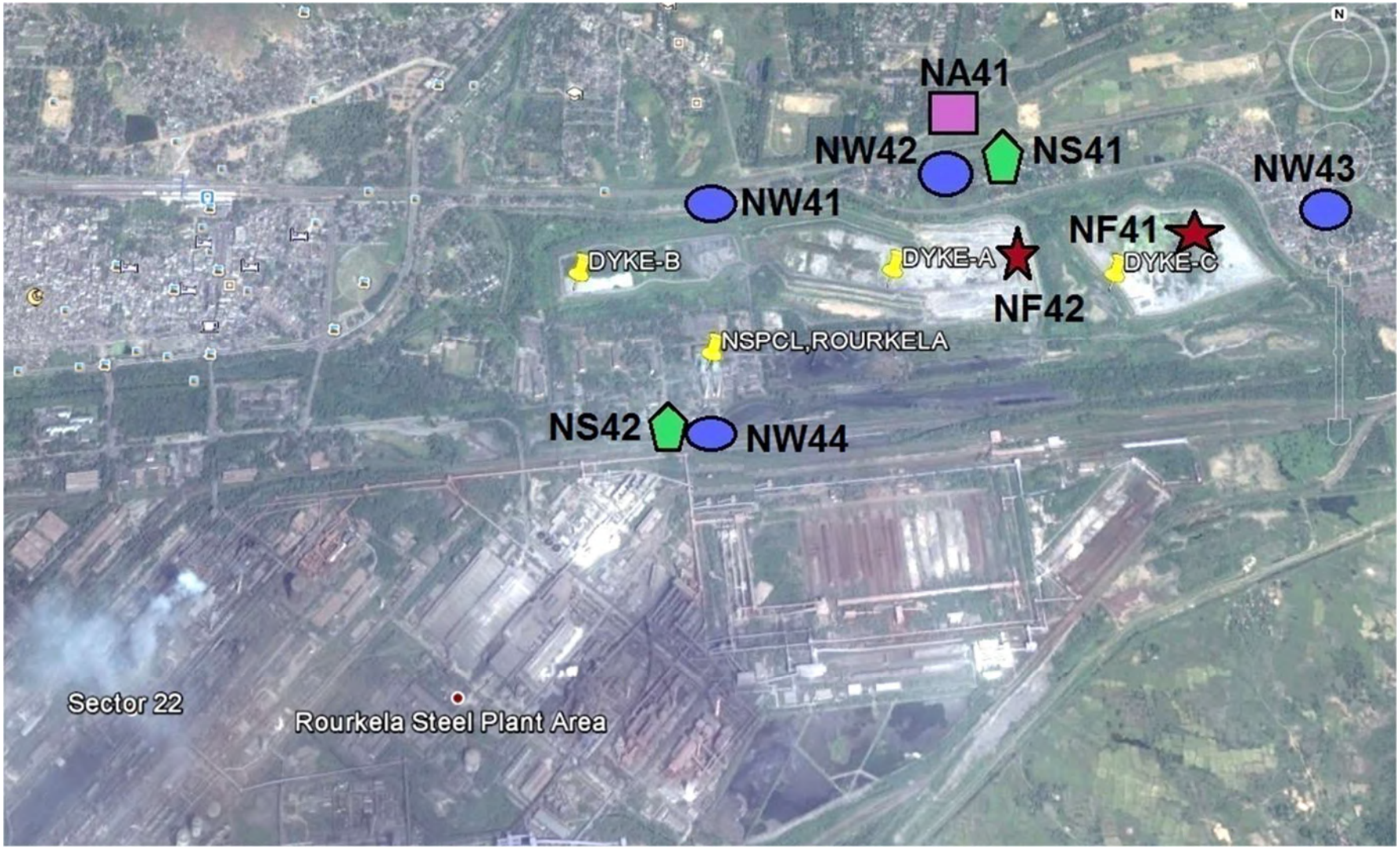


Fig. 10.1 Location of Sampling Points at NSPCL Ash Disposal Site

10.5.2 Chemical and Mineralogical Compositions

The element oxides of ash samples are presented in **Fig. 10.2 (a & b)**. The results show that the ash samples are enriched predominantly with silica (SiO_2) and alumina (Al_2O_3). In addition, they also contain small amounts of iron oxide (Fe_2O_3), TiO_2, K_2O, CaO, SO_3 and MgO. The rest of the compounds present in the ash samples are in minor concentrations. The sum of SiO_2, Al_2O_3 and Fe_2O_3 accounts for more than 90% of the total composition in all fly ash and pond ash samples. Since the sum total of SiO_2, Al_2O_3 and Fe_2O_3 is more than 70% in all fly ash and pond ash samples, they are classified as Class F fly ash according to the ASTM C-618 specifications. The fly ash and pond ash samples possess more or less similar physico-chemical and mineralogical properties. The reactive silica content in fly ash is found to be in the range15 – 16.5 %.

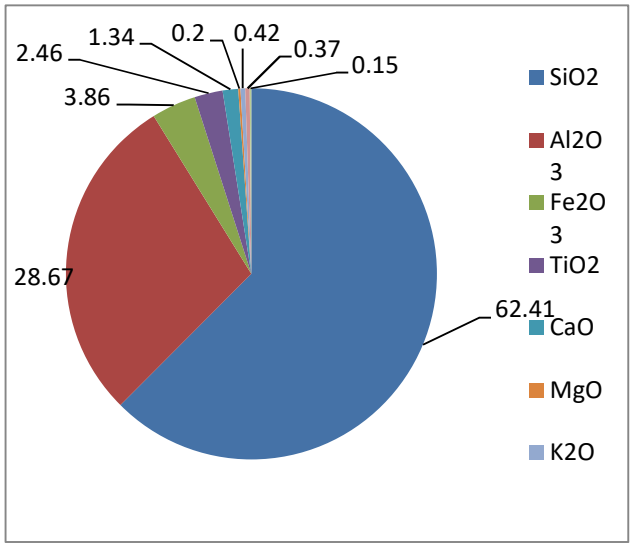


Fig. 10.2 (a) Element Oxides of Fly Ash

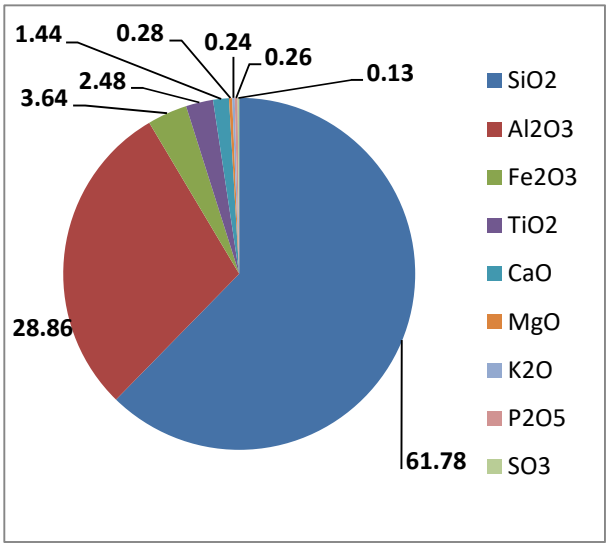


Fig. 10.2 (b) Element Oxides of Fly Ash

10.5.3 Ground Water Quality Analysis

The water quality analysis was performed on the water samples collected from the bore well from different locations in the area around fly ash dumpsite. Details of concentration of heavy metals and other water quality parameters in the groundwater samples near the ash disposal sites and at the surrounding villages are given in **Table 10.9**. Water quality analysis for the present study (**Table 10.9**) is compared with the water quality study done by TPP in 2016 (**Table 10.5**) and the findings are discussed below:

- pH of the water sample ranged from 6.7 to 7.1 for all the samples collected from four locations, indicating neutral nature of the water (present study). Similar result (pH = 6.7) was found by the studies carried out by TPP.
- Maximum value for electrical conductivity is 645 µS/cm and minimum value is 523 µS/cm (present study). Similar result i.e. TDS of 433 mg/l (EC = 618 µS/cm; TDS = 0.7 EC) was found by the studies carried out by TPP. This indicates the presence of common anions and cations in ground water.
- Calcium (Ca in mg/l) of the water sample ranged from 44 to 97 mg/l for all the samples collected from four locations (present study). Similar result (97 mg/l) was found by the studies carried out by TPP.
- Presence of Aluminum is found in three of the four pre-monsoon samples and two of the four post-monsoon samples. However, the concentrations are within the acceptable limit (present study). Studies carried out by TPP at one location indicates the presence of aluminum below detectable limit (<0.01 mg/l).
- Concentration of hexavalent chromium in all the four samples as well as in the sample tested by the TPP are below detectable limit (<0.01 mg/l). However, presence of total chromium is found in all samples with a minimum and maximum concentration of 0.012 mg/l and 0.034 mg/l respectively and are below acceptable limit (present study).
- Concentration of Cadmium (Cd in mg/l) and Mercury (Hg in mg/l) in all the four samples as well as in the sample tested by the TPP are below detectable limit (present study).
- Presence of Lead is found in three of the four pre-monsoon samples but none in the post-monsoon samples. Similar observations are made for Copper, where it is found in two of the pre-monsoon samples but not in the post-monsoon sample. Concentrations are within the acceptable limit for copper (present study). Above trace metals are below detectable limit in the studies carried out by TPP.
- Maximum value for Zinc concentration is 0.92 mg/l and minimum value is 0.41 mg/l(present study). Similar result i.e. Zn of 0.72 mg/l was found by the studies carried out by TPP. However, the concentrations are within the acceptable limit.
- Fluoride (F^- in mg/l) of the water sample ranged from 0.25 to 0.42 mg/l for all the samples collected from four locations (present study). However, the concentrations are within the acceptable limit. Similar result (0.25 mg/l) was found by the studies carried out by TPP.

The groundwater analysis results reveal that pH, Al, Cr^{+6}, Cd, Cu, Zn, Hg and F^- meet the drinking water standard prescribed in IS10500: 2012.The concentrations of heavy metals in post monsoon samples are less compared to pre monsoon samples, probably due to dilution of ground water. Comparison of ground water quality between present study by VSSUT in 2016 and TPP in the same year at location NW 42-Koila gate is shown in **Fig. 10.3 (a, b)**.

10.5.4 Heavy Metal Analysis in ash and soil samples

Acid digestion data of fly ash and surrounding soils provide the total available concentration levels of trace elements in fly ash & soils is shown in **Table 10.10**. The results obtained from TCLP were found significantly lower in composition compared to acid digestion test. This is because; metal solubility generally decreases with increasing pH. Concentrations of Ca and Al was found significantly high as compared to other elements. The leaching of metals which were found low in the TCLP test, but found high in the acid digestion test, indicating a strong bonding of metals with the other compounds of ashes.

10.5.5 Air Quality Survey

Ambient air quality monitoring done at koila gate for particulate matter (24 hr sampling period) gives the maximum value as 74.5 μg/m^3 and minimum value as 22.4 μg/$m^3$for PM_{10} and maximum value as 42.4 μg/m^3 and minimum value as 19.8 μg/$m^3$for $PM_{2.5}$.

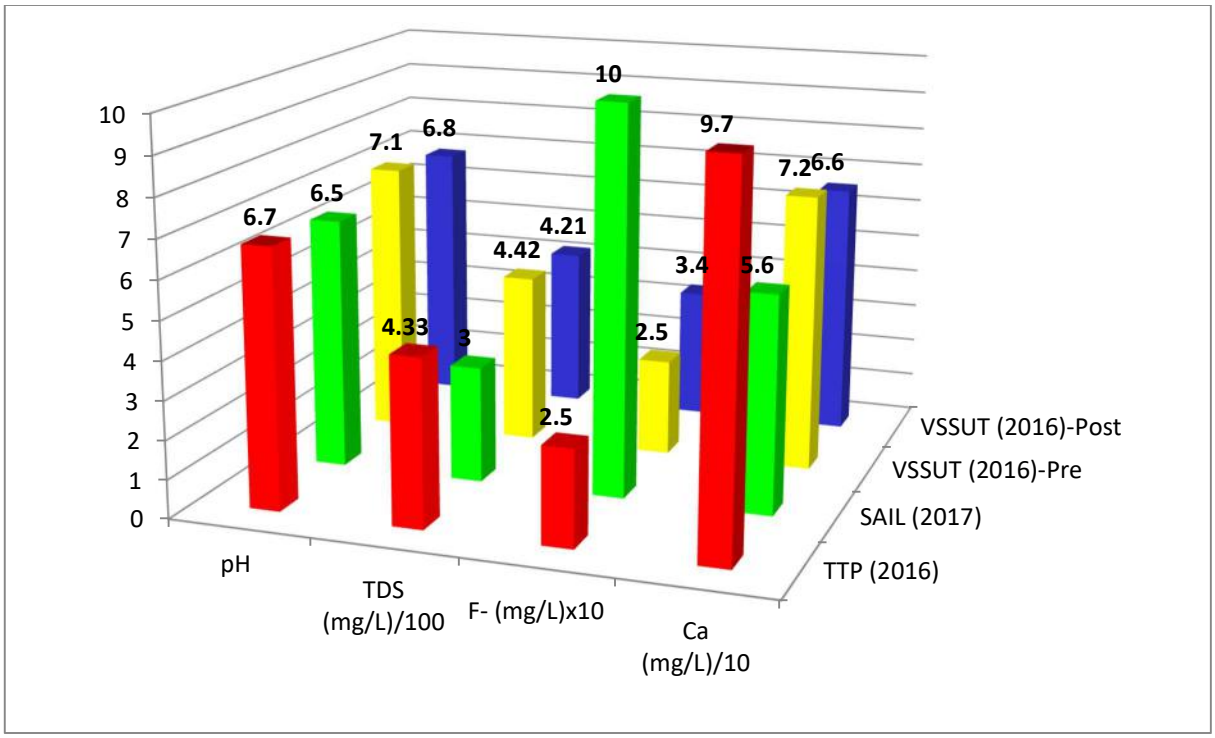
10.6 Conclusions

On the basis of the study, following conclusions were drawn:

- Analytical results of ground water collected from 4 locations show that the values are within the permissible levels of BIS guidelines except Ca and Pb. The calcium concentration exceeds the BIS limits at one location and lead at 3 locations. This could be due to the geogenic factors.

The following suggestions are made for better management of ash in the plant.

- The industry shall make lucrative policy for fly ash users for large scale utilization of fly ash before exploring the option like quarry and mine void filling.
- The Thermal Power Plants must monitor the ground water quality (pre & post-monsoon every year) around the ash disposal sites by installing bore wells at strategic location to predict future trend.
- The industry must install permanent sprinkler system in the ash mound to control fugitive ash.



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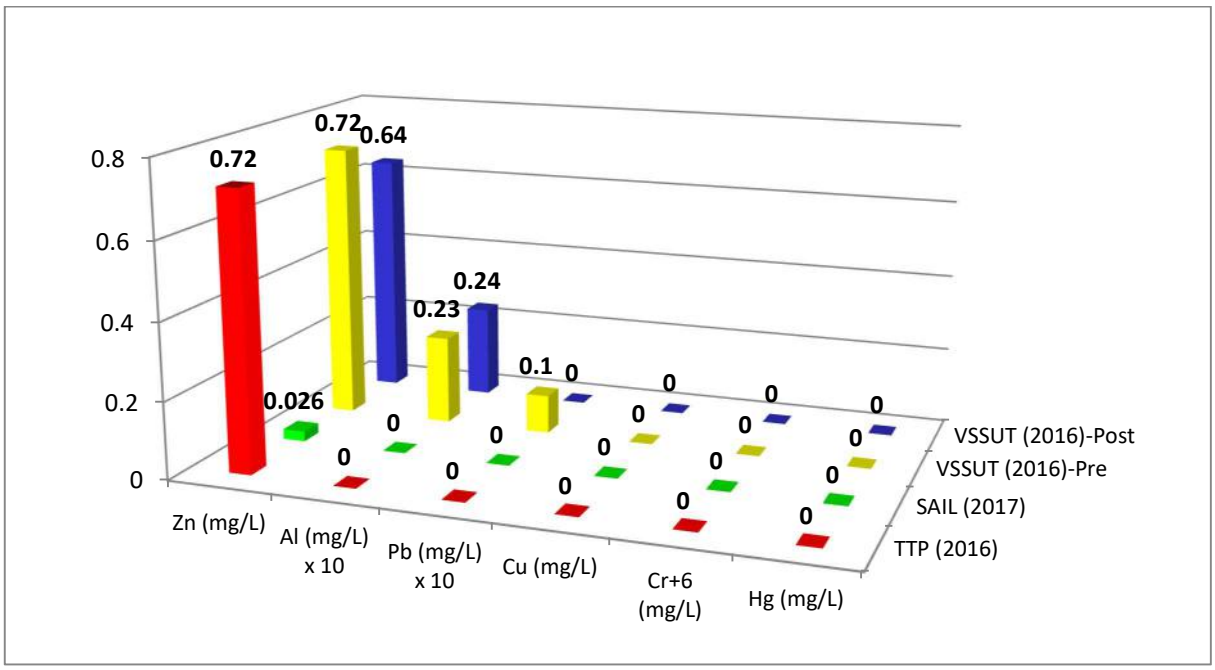

(b)

Fig. 10.3 Comparison of Ground Water Quality at NW 42-Koila Gate

Table 10.9 Analysis Result of Water Sample

Sl No	Sample ID	Season	pH	EC	Ca	Al	Cr^{+6}	T. Cr.	Cd	Pb	Cu	Zn	Hg	F^-
1	NW-41	Premonsoon	6.9	524	61	0.03	BDL	0.022	BDL	0.015	0.021	0.42	BDL	0.3
		Postmonsoon	6.7	578	72	BDL	BDL	0.012	BDL	BDL	BDL	0.64	BDL	0.42
2	NW-42	Premonsoon	7.1	632	72	0.023	BDL	0.025	BDL	0.009	BDL	0.72	BDL	0.25
		Postmonsoon	6.8	602	66	0.024	BDL	0.022	BDL	BDL	BDL	0.64	BDL	0.34
3	NW-43	Premonsoon	7.4	645	88	BDL	BDL	0.034	BDL	BDL	BDL	0.53	BDL	0.25
		Postmonsoon	7.1	616	97	BDL	BDL	0.014	BDL	BDL	BDL	0.74	BDL	0.42
4	NW-44	Premonsoon	6.9	523	53	0.028	BDL	0.028	BDL	0.01	0.022	0.41	BDL	0.37
		Postmonsoon	7.1	528	44	0.018	BDL	0.024	BDL	BDL	BDL	0.92	BDL	0.33
		AL	**6.5-8.5**	**-**	**75**	**0.03**	**-**	**0.05**	**0.003**	**0.01**	**0.05**	**5.0**	**0.001**	**1.0**
		DL	**-**	**-**	**-**	**0.002**	**-**	**0.01**	**0.0001**	**0.002**	**0.004**	**0.002**	**0.00007**	**-**

Unit of all parameters is mg/l except pH and EC; Unit of EC is µS/cm; pH has no unit; AL: Acceptable Limit as per IS 10500:2012; DL: Detectable limit

Table 10.10 Analysis Result of Ash and Soil Sample (SADT & TCLP)

Sl No	Sample ID	Testing Procedure	Ca	Al	Cr^{+6}	T. Cr.	Cd	Pb	Cu	Zn	Hg	F^-
1	NS41	SADT	1954	2240	1.88	9.6	12.4	BDL	BDL	48.4	BDL	--
		TCLP	1482	19.2	BDL	BDL	4.6	BDL	BDL	BDL	BDL	4
2	NS42	SADT	1836	2454	BDL	6.7	8.6	BDL	BDL	32.4	BDL	--
		TCLP	1372	18.6	BDL	BDL	4.4	BDL	BDL	1.44	BDL	5.2
3	NF41	SADT	2133	4345.2	2.64	51.6	38.4	16.8	22.6	74.4	BDL	--
		TCLP	1620	56.4	BDL	BDL	7	BDL	BDL	BDL	BDL	42
4	NF42	SADT	1881	5476.8	2.4	44.4	49.2	22.4	28.4	39.6	BDL	--
		TCLP	1470	26.6	BDL	0.64	10.2	BDL	BDL	BDL	BDL	38

Unit of all parameters is mg/kg

Chapter 11

Conclusions

Study of the environmental impact of fly ash disposal sites of nine major Thermal Power Plants located at Angul-Talcher Area and Sambalpur-Jharsuguda Area, Odisha i.e (i) CPP, National Aluminum Company Ltd (NALCO), Angul (ii) Talcher Thermal Power Station (TTPS), Talcher(iii) Talcher Super Thermal Power Station(TSTPS), Kaniha (iv) Bhushan Energy Ltd, Dhenkanal (v) Hindalco Industries Ltd. Hirakud (vi) Bhushan Steel & Power Ltd, Rengali (vii) OPGC, Bnaharpali (viii) Vedanta Ltd., Jharsuguda (ix) NTPC-SAIL Power Co. Ltd., Rourkela was conducted.

The study mainly includes the inventory and assessment of ash disposal sites; characterization of fly ash with its leaching potential; analysis of air, surface & ground water & soil samples within 2 km of ash disposal sites and comparison with past data.

Fly ash samples were analysed for physical properties (particle size distribution, specific gravity, and bulk density); chemical and mineralogical composition; and trace elements such as Ca, Al, Cr^{+6}, T. Cr, Cd, Pb, Cu, Zn, Hg, F^- by both Strong Acid Digest Test (SADT) and Toxicity Characteristics Leachate Procedure (TCLP). Analysis for trace elements were done for soil samples collected near the ash disposal sites. Ground water samples and some surface water samples, collected near ash disposal sites were analysed for important water quality parameters such as pH, EC, Ca, Al, Cr^{+6}, T. Cr., Cd, Pb, Cu, Zn, Hg and F^-. Ambient air from locations nearer to ash disposal sites were collected and analysed for particulate matter.

11.1 Findings of the study

On the basis of the study, the following conclusions for Angul-Talcher and Sambalpur-Jharsuguda area has been drawn:

(a) Ash management system

- All the plants have proper ash disposal system. Plants have either ash ponds (wet disposal system) or ash mound (dry disposal system) for disposal of ash. Few plants are exploring the use of abandoned coal mine void for ash filling by lean slurry mode. Filling of mine voids by ash is the major source of utilization of fly ash. Presently some TPPS (Talcher Thermal Power Station (NTPC), Bhushan Energy Ltd, Dhenkanal and Bhushan Steel Ltd., Meramundali) are disposing their ash in allotted mine voids.

- All the plants have installed silos for supply of dry ash to outside parties. Few need to install more silos for storage of ash for smooth supply of the same.

(b) Physical properties, chemical and mineralogical composition of fly ash and bottom ash

- The ash analysis results of all TPPs indicates that the fly ash comes under class F. The sum of SiO_2(Min. - 56.85%, Max. – 62.85%), Al_2O_3(Min. –28.67%, Max. – 31.69%)and Fe_2O_3 (Min. –2.01%, Max. – 4.71%)account for more than 90% of the total composition in fly ash and pond ash samples.
- The fly ash and pond ash samples possess more or less similar physico-chemical and mineralogical properties. Mean particle diameter (D_{50}) of fly ash is in the range of having 14.46 – 46.2 µm. Color of the fly ash is grey whereas for bottom ash, it is dark grey. Specific gravity and bulk density of the ash are in the range of 1.93 – 2.26 and 1.03 – 1.28 respectively. Porosity and Coefficient of permeability of the ash are in the range of 44 – 58% and 2.5 $x10^{-6}$- 4.42 x 10^{-4}cm/s respectively.
- The reactive silica content in fly ash was found to be in the range of 12 -22%.

(c) Ground Water Quality Analysis

- The groundwater analysis results obtained, during pre and post monsoon periods, reveal that pH (range 6.51 – 8.5), Cd (range BDL – 0.003 mg/l), Cu (range BDL – 0.003 mg/l), Zn (range BDL – 2.66 mg/l) and Hg (range BDL – 0.00048 mg/l) meet the drinking water standard prescribed in IS10500:2012.
- Calcium concentration exceeds the drinking water standard limit in 29 samples (out of 122 samples) and having maximum value of 124 mg/l. The aluminium concentration exceeds the drinking water standard limit in 39 samples and has maximum value of 0.087 mg/l. The fluoride concentration exceeds the drinking water standard limit in 21 samples and has maximum value of 1.87 mg/l. It has been established that the excess of fluoride and aluminum concentration in ground water in few locations is mainly due to fluoride and aluminium bearing materials.
- The total chromium concentration exceeds the drinking water standard limit in more than 55% of the samples and found to be in the range of 0.012 – 1.132 mg/l. Similarly, the lead concentration exceeds the drinking water standard limit in more than 47% of the samples and has maximum value of 0.068 mg/l. Although some groundwater contamination i.e. total Cr in

some areas or Pb in some other areas or both, at disposal sites is occurring, it appears to be localized in the vicinity of the disposal site. The excess of chromium and lead concentration in ground water may be due to local hydro-geologic characteristics and climate of the area.

- The concentrations of heavy metals in most of the post monsoon samples were less compared to pre monsoon samples, probably due to dilution of ground water.

(d) Trace elements in ash and soil

- The results obtained from TCLP (Toxicity Characteristics Leachate Procedure) of fly ash and surrounding soil to find the total available concentration levels of trace elements in fly ash & soils were found significantly lower in composition compared to strong acid digestion test for the same. This is due to the fact that metal solubility generally decreases with increasing pH.
- The leaching of metals which were found low in the TCLP test, but found high in the acid digestion test, indicating a strong bonding of metals with the other compounds of ashes.
- Concentrations of Ca and Al was found significantly high as compared to other elements.
- Concentrations of Ca in ash was found to be in the range of 1470– 5945 mg/kg and 1881 - 6846 mg/kg when analyzed by TCLP and SADT respectively. Similarly, concentrations of Ca in surrounding soils was found to be in the range of 1372– 2929 mg/kg and 1836 - 7400 mg/kg when analyzed by TCLP and SADT respectively. This may be due to the geological formation.
- Concentration of Al in ash was found to be in the range of 18.6– 79.6 mg/kg and 3302 - 11815 mg/kg when analyzed by TCLP and SADT respectively. Similarly, concentration of Al in surrounding soils was found to be in the range of 10.5– 66.8 mg/kg and 2071 - 7841 mg/kg when analyzed by TCLP and SADT respectively.
- Concentration of Cr^{+6} in ash and soil samples was below detectable limit (TCLP) for all the samples (except one soil sample) and have a maximum value of 4.58 mg/kg for ash and 2.88 mg/kg for soil (SADT). Concentration of Total Cr in some ash and soil samples was below detectable limit and having maximum value of 0.86 mg/kg and 3.0 mg/kg for ash and soil sample respectively(TCLP). Concentration of Total Cr in ash and soil samples was found to be in the range of 7.2 – 319 mg/kg and BDL – 60.3 mg/kg respectively (SADT).
- Concentration of Cd in ash was found to be in the range of 0.001– 10.2 mg/kg and 3.8 – 49.2 mg/kg when analyzed by TCLP and SADT respectively. Similarly, concentration of Cd in

surrounding soils was found to be in the range of BDL– 10.4 mg/kg and BDL – 47.2 mg/kg when analyzed by TCLP and SADT respectively. Similar results were found for Pb, Cu and Zn. Concentration of Hg in all ash (TCLP) and soil samples (TCLP as well as SADT) was below detectable limit except one soil sample where it is 0.21 mg/kg (SADT).

(e) Air quality

Ambient air quality in respect of PM_{10}at locations nearer to ash disposal site was found to be in the range of 39 – 144 µg/m^3.

From the above, it may be concluded that the fly ash disposal sites do not have significant adverse impact on the ground water, soil, air and surface water. Most of the metal content may be due to geological formation in the area.

11.2 Recommendations

- The industry shall install adequate number of silos for storage of ash.
- The industry shall make lucrative policy for fly ash users for large scale utilization of fly ash before exploring the option like quarry and mine void filling.
- The industry must install permanent sprinkler system in the ash dyke to control fugitive ash during ash pond dyke raising.
- Water sprinkling in ash ponds and mounds should be provided. Regular sprinkling of water should be more during summer and winter.
- Thermal Power Plants should monitor the ground water quality around the ash disposal sites and at other strategic location to keep track on the trend, if any, on annual basis by a suitable organization identified CPCB/SPCB.
- Planting of saplings having tolerance to slurry water and heavy metals may be considered to be the most ideal mitigation measure, since the biomass can also adsorb toxic metals as nutrients and provide obstruction for windblown particulates.
- It is emphasized that proper design and location of ash disposal sites, whether landfills /settling basins/mine voids, is essential to prevent, or at least limit, groundwater contamination.
- The fly ash ponds and mounds should be reclaimed in a planned manner by suitable biological methods.

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APPENDIX-A

Design and Maintenance of Ash Pond for Fly Ash Disposal

A.1 Ash Pond Layout

Following points shall be looked into while selecting the location and layout of the ash pond:

1. The ash disposal area shall be located in close proximity to the power plant to reduce the pumping cost.

2. Scope for vertical and horizontal expansion of the ash pond depending on estimated life span of the power plant shall be reserved.

3. The area shall be away from water bodies such as river, lake, etc. to prevent pollution of the water body due to the seepage of water from ash slurry.

4. An impervious stratum (preferably plastic liner) shall be provided to prevent the migration of ash water into the ground water. However, due to the presence of plastic liner, provision of the drainage becomes difficult and as result, the deposited sediments could not get consolidated to the same extent as that anticipated in the pond without plastic liner. Whenever plastic liner is provided, it is important to check the adequacy of strength parameters for the deposited ash for supporting the next section of the dyke if upstream method of construction is adopted.

5. The total ash pond area is usually divided into two or more compartments. Each compartment is required to have certain minimum area to ensure that there is adequate time available for settlement of ash particles while this slurry travels from the discharge point to the outlet point. This distance should be minimum 200m to ensure that only clear water accumulates near the outlet. The water, after decantation is not allowed to accumulate in the pond but it is removed from the pond to ensure that the phreatic line is maintained at lower level.

A.2 Design of Dyke

The ash pond is normally constructed in stages having an incremental height of each stage about 3 to 5m. However, the following features must be taken into account while designing the bund (upstream method).

- The entire weight of new construction for raising the dyke is supported on deposited ash. Unless ash deposition is carefully done, there can be finer ash particles deposited along the bund and may not have adequate baring capacity to support the new dyke. If the deposit is not safe against liquefaction, suitable remedial measures needs to be adopted before raising dyke.
- The drain provided on the upstream face needs to be suitably connected to the drain of the earlier segment. If this is not carried out properly, the drainage can be ineffective resulting in rising of phreatic line and reducing the stability of slope.
- The entire upstream face of the dyke shall be provided with stone pitching or brick lining or precast tile lining to prevent erosion of the slope by wave action during heavy wind.
- The entire downstream slope shall be provided with grass turfing to prevent erosion of the downstream side during rains.

- A rock toe and toe drain shall be provided for safe exit of seepage water into a natural drain without any inundation of the downstream area and thereby softening of the natural strata.
- Adequate transverse and longitudinal drains shall be provided on the downstream face. Wherever the height of the dyke is exceeding 5m, berms shall be provided at ever 3m vertical intervals with a longitudinal drain to prevent erosion.
- Decanting system shall be provided to ensure that free water inside the ash pond does not pile up to a large head. After decantation, the clear water shall be drained off ensuring minimum height of water above the ash deposition at the outlet such that the suspended particles are within the permissible limit of 100ppm.
- A spillway shall be provided for the unforeseen circumstance of very heavy rain and blocking of the decanting system.

A.3 Maintenance of Ash Dyke

The following points are to be observed during operation of the dyke.

(a) *Method of Slurry Discharge*: The discharge of slurry shall be distributed uniformly over the entire perimeter of the ash dyke, except at location close to the water exit point. This will provide adequate bearing capacity and resistance against slip circle failure for the construction of ash dyke over the deposited ash along the perimeter.

(b) *Raising of Ash Dyke*: The pond which has already been filled-up shall be allowed to dry without any further discharge of slurry for a minimum period of 1 month before the construction for raising the height is taken up. The pond which is not being used or during raising shall be provided with water sprinklers at regular intervals to ensure that the surface of the pond is maintained moist to prevent dust pollution.

(c) *Maintenance of Ash Dyke*: It is very important to constantly supervise the ash dyke and carryout necessary remedial measures. Following aspects have to be considered during inspection of the dyke:

i. Wet patches on downstream slope: If the wet patches appear on downstream slope, the area shall be protected by placing a sand filter layer followed by a layer of stones to prevent piping failure.

ii. Gulley formation: The downstream face can have gulley formation due to surface water flow during rain. This can be prevented by maintaining grass turfing and by selecting non erodible earth cover during the dyke construction.

iii. Rat holes / animal burrows: During inspection if any rat holes or animal burrows are noticed, the same shall be plugged using cohesive soil and covered with grass turfing.

(d) Monitoring the Dyke: It is preferable to monitor the performance of the dyke throughout its operation. Instruments commonly provided for such monitoring are listed below: (i) Settlement gauges along the top of the bund. (ii) Piezometers, minimum 3 to 4 nos. at critical sections to check the phreatic line during various stages of operation to verify the efficiency of internal drains. (iii) Inclinometers to check for any instability in the slope and lateral movement of the dyke. The measurements on these instruments shall be regularly carried out in every month and the results shall be maintained in a register for review.

APPENDIX-B

IS 10500: 2012: Indian Standard: Drinking Water – Specification

Parameters	Requirement (Acceptable Limit)	Permissible Limit in the Absence of Alternate Source
Colour, Hazen units	5	15
Odour & Taste	Agreeable	Agreeable
pH value	6.5 to 8.5	No relaxation
Turbidity, NTU	1	5
Total dissolved solids, mg/l	500	2000
Total hardness as $CaCO_3$, mg/l	300	600
Total alkalinity as calcium carbonate, mg/l	200	600
Chloride as Cl, mg/l	250	1000
Sulphates as SO_4, mg/l	200	400
Nitrate as NO_3, mg/l	45	No relaxation
Fluoride as F, mg/l	1	1.5
Calcium as Ca , mg/l	75	200
Magnesium as Mg, mg/l	30	100
Iron as Fe, mg/l	0.3	1
Total arsenic (as As), mg/l	0.01	0.05
Manganese as Mn, mg/l	0.1	0.3
Zinc as Zn, mg/l	5	15
Copper as Cu, mg/l	0.05	1.5
Total chromium (as Cr), mg/l	0.05	No relaxation
Lead as Pb, mg/l	0.01	No relaxation
Mercury as Hg, mg/l	0.001	No relaxation
Cadmium as Cd, mg/l	0.003	No relaxation
Cyanide as CN, mg/l	0.05	No relaxation
Aluminium (as Al), mg/l	0.03	0.2
Boron as B, mg/l	0.5	1.0

Parameters	Requirement (Acceptable Limit)	Permissible Limit in the Absence of Alternate Source
Selenium as Se, mg/l	0.01	No relaxation
Barium (as Ba), mg/l	0.7	No relaxation
Silver (as Ag), mg/l	0.1	No relaxation
Molybdenum (as Mo), mg/l	0.07	No relaxation
Nickel (as Ni), mg/l	0.02	No relaxation
Anionic detergents (as MBAS), mg/l	0.2	1.0
Minerals Oil, mg/l	0.5	No relaxation
Phenolic compounds, mg/l	0.001	0.002
Ammonia (as total ammonia-N), mg/l	0.5	No relaxation

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