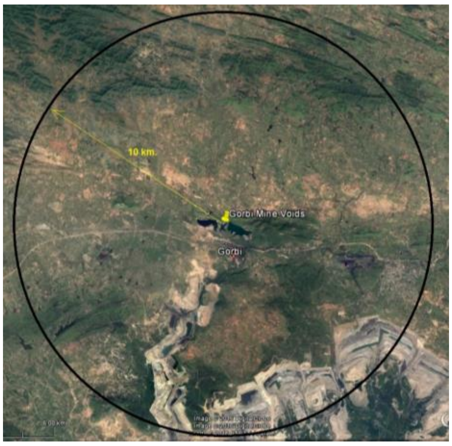
Final Report

Study of Flora - Fauna and Ash Characterization for Backfilling of Ash from NTPC Vindhyachal STPS in Mine Voids of Gorbi Mines of Northern Coalfields Ltd.



For

NTPC, Vindhyachal STPS

District Singrauli, Madhya Pradesh

CSIR-National Environmental Engineering Research Institute (NEERI), Delhi Zonal Centre, Naraina, New Delhi 110028

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Chapter 1

Introduction

1.1 Preamble

NTPC is operating Vindhyachal Super Thermal Power Station (VSTPS) in Singrauli district of Madhya Pradesh located on the North West Bank of Rihand Reservoir (Gobind Ballabh Pant Sagar). The present capacity of VSTPS is 4760 MW, which has been implemented in five stages. Stage-I (6x210 MW), Stage-II (2x500 MW) and Stage-III (2x500 MW), Stage-IV (2x500 MW) and Stage-V (1x500 MW). All the units are under commercial operation.

At present, the unused ash from the station is disposed of in the ash dykes located in the peninsular region of Rihand reservoir at about 2.5 km in the South East direction. However, in order to supplement the storage capacity of the ash dykes as well as to reclaim the abandoned mine voids of the de-coaled mines, NTPC proposes to dispose ash from Vindhyachal STPS into abandoned voids of Gorbi mines located at about 35 km in North West direction.

Accordingly, permission from MP Pollution Control Board shall be required for disposal of ash into Gorbi mine voids.

In order to establish environmental sustainability of the proposed ash filling in the Gorbi Mine Voids, environmental protection plan needs to be prepared. Further, this will help to obtain the permissions from MPPCB. Detailed terms of reference (ToR) have been prepared for EIA study incorporating baseline data collection, prediction of impacts and suggest appropriate environmental management plan to mitigate the adverse impacts of backfilling of ash into void mines, if any.

NTPC approached CSIR-NEERI to undertake part of the EIA study relating to assessment of flora and fauna, and fly ash characterization, as per the following scope of work.

1.2 Scope of Work

1.2.1 Study of Flora & Fauna

The studies on Flora and Fauna will cover an area of 10 km radius around mine voids and shall cover the following:

- Study on biota (herbs, shrubs and trees of plants and soil invertebrates and other animals) inhabiting in the areas located at 500 m, 1000 m, 5000 m, and 10,000 m from the mine void.

- Study on bio-accumulation and bio-magnification of trace elements in plants (herbs, shrubs and trees) and the invertebrates inhabiting in the areas located at 500 m, 1000 m, 5000 m, and 10,000 m from the mine void and also aquatic fauna in the mine void.

- The study shall be based on primary survey undertaken at representative sites for flora-fauna and the analysis of their tissues for bio-accumulation and bio-magnification of trace elements. No. of sampling locations proposed and the parameters to be analysed shall be as per **Table 1.2.1**.

Table 1.2.1: Details of Sampling Locations/ Villages in the 10 km Radial Area

Sr. No.	Sampling Locations wrt Mine Voids	No. of Sampling Locations / Villages	Parameters to be Analyzed at each Sampling Location
1.	Within 500 m	1	• Listing of Flora (herbs, shrubs and trees) and Fauna (soil invertebrates and other animals) based on field observations and review of information available • Analysis of trace elements in plants (herbs, shrubs and trees), the invertebrates (10 samples at each location) • Analysis of trace elements in aquatic fauna from the mine void filled with fly ash (5 samples at each of the 2 locations) • Analysis of trace elements in mine water and ground water samples (15 samples). • Trace elements in the above shall include As, Ba, Cd, Co, Cr, Cu, Fe, Hg, Mn, Ni, Pb, Zn
2.	Between 500 m-1000 m	3	
3.	Between 1000 m-5000 m	3	
4.	Between 5000 m-10000 m	6	
5.	Total	13	

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

- Presence of wetlands and other ecologically sensitive areas such as National Parks/Sanctuaries, if any, is to be identified and indicated on a map.

- The study will also indicate possible impact and severity of any disturbance in the ecosystem through external factors such as ash filling, truck movement, construction activities etc.

1.2.2 Ash Characterization and Leachate Study

The representative ash samples to be collected as per standard sampling techniques from the electrostatic precipitator (ESP) hopper as well as boiler furnace bottom, and standard tests shall be carried out like physical, chemical, mineralogical tests etc. in accordance with the requirement of regulatory agencies and duly labeled and sealed representative samples of bottom and fly ash collected for reference purpose.

In each season 5 samples each of fly ash, bottom ash and pond ash (collected at a 5-10 m depth from surface) shall be collected and analysed for the following parameters for characterization.

Samples	Parameters to be Analysed
Ash Samples (Tentative Numbers = 30) {FA(5) + BA (5) + PA (5) } x Two Seasons	Chemical Parameters (%): SiO_2, Al_2O_3, Fe_2O_3, K_2O, TiO_2, CaO, MgO, Na_2O, P_2O_5, SO_3 Trace Elements (mg/kg, using TCLP Test): As, Ba, Cd, Co, Cr, Cu, Fe, Hg, Mn, Ni, Pb, Zn

Keeping in view the scope of work, preliminary survey of the study area was conducted by NEERI study team during July 18-20, 2018, and discussions were held with the representatives of NTPC to identify the villages/sampling locations as per the study requirement.

The studies were conducted during winter (December 2018) and summer (May 2019) seasons as per the scope of work. The study findings along with sampling methodology and analysis results are presented in the following Chapters.

Chapter 1: *Introduction*

Chapter 2: *Study of Flora (with focus on assessment of metals content and bio-accumulation in different species)*

Chapter 3: *Study of Fauna (with focus on assessment of metals content and bio-accumulation in different species)*

Chapter 4: *Ash Characterization and Leachate Study*

Chapter 5: *Ash Transport Impact Study*

Chapter 6: *Overalll Summary and Recommendations*

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Chapter 2

Study of Flora with Water & Soil Quality Status and Bio-accumulation

The chapter deals with the study of floral species in terms of trees, shrubs, herbs, crops which produce different types of vegetables, fruits, cereals etc. The edible portion is consumed by human beings whereas non-edible portion (biomass) is used as fodder by animals and other living beings. The chapter covers the following aspects:

- Details of sampling locations
- Water quality status of mine voids and in nearby villages
- Soil quality status
- Status of flora in the study region
- Metals content in the floral species
- Bio-accumulation of metals in different floral species.

2.1 Details of Sampling Locations

A pre-sampling survey was conducted by NEERI study team along with the officials of VSTPS for identification of sampling locations/villages in the entire 10 km radial area from the mine voids. Besides the mine void area, a total 13 villages were identified for collection of samples for water, soil and different floral species (trees, herbs, shrubs which are primarily consumed by human beings and animals as fodder). The samples were collected during winter and summer seasons, wherein floral samples of seasonal fruits, vegetables and crops were collected. Location of the mine voids and identified villages are shown in **Fig. 2.1**.1.

Details of sampling locations/villages, their distance & direction with respect to mine voids, number of samples collected for water, soil and floral species (edible/non-edible) and general features of the village within 1 km of the sampling location were recorded, as summarized in **Table 2.1.1.**

Photographs showing collection of water and soil samples are shown in Plates 2.1.1

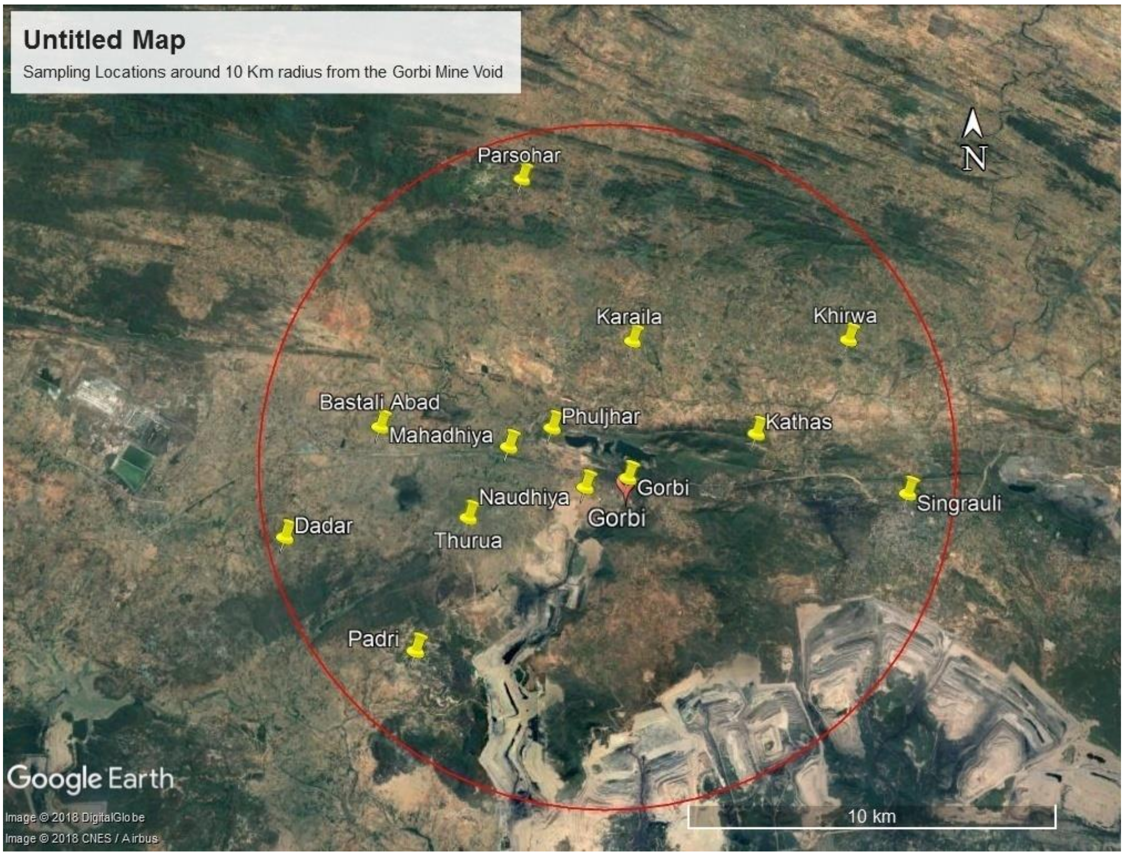


Fig. 2.1.1: Sampling Locations for Water, Soil and Plant Species in the Study Area

Table 2.1.1: Village-wise Details of Sampling Locations and Samples Collected

Sr. No.	Village	Distance & Direction wrt Mine Void	Number of Samples per Season (Winter/Summer)			Remarks (within 1 Km Buffer area)
			Water	Soil	Floral Species	
1.	Mine Void	0 Km	3/3 Lakes	2 /3	6/4	• Forest patch • Dispersed Settlement • Drainage • Agricultural Land
2.	Phuljhar	0.75 Km North	1HP/ 1HP	3/3	15/7	• Scattered settlement • Agricultural land • Drainage • Forest Patch
3.	Naudhiya	2 Km South West	1 HP,1 DW/ 1 HP,1 DW	2/4	10/15	• Road and Rail (Bargawa-Singrauli Road) • Mine present in South East • Linear type of settlement • Agricultural Land

4.	Mahadhiya	2.5 Km South West	1 DW/ 1 HP,1DW	2/1	12/6	• Road and Rail (Bargawa-Singrauli Road) • Mine present in South East • Linear type of settlement • Agricultural Land • Drainage
5.	Gorbi	3.5 Km East	1 BW/ 1 DW,1 BW	3/4	11/12	• Scattered settlement • Agricultural land • Forest Patch • Railway and Road (Bargawa- Singrauli Road)
6.	Thurua	4 Km South West	1 HP/ 1HP	2/1	11/3	• Road Network • Mine present in East • Agricultural Land • Nucleated and Linear Settlement
7.	Karaila	4.5 Km North East	1 HP/ 1HP	2/3	11/7	• Road Network (Singrauli - Chitrangi Road) • Agricultural Land • Forest Patch • Nucleated /Dispersed /Linear Settlement
8.	Padri	5 Km South West	1 HP/ 1HP	3/2	11/5	• Road Network • Forest Patch • Agricultural Land • Linear Settlement
9.	Bastali Abad	5 Km West	1 HP/ 1HP	2/1	9/8	• Rail and Road Network (Bargawa- Singrauli Road) • Agricultural Land • Nucleated and Linear Settlement
10.	Kathas	6 Km East	1 DW/1DW	2 /2	13/3	• Rail and Road (Bargawa-Singrauli Road) • Drainage • Forest Patch (Singrauli - Chitrangi Road) • Nucleated/Dispersed Settlement
11.	Parsohar	7 Km North	1 HP/1HP	2/2	12/7	• Road Network (Singrauli - Chitrangi Road) • Forest Patch • Drainage • Agricultural Land • Linear / Dispersed Settlement
12.	Khirwa	7 Km East	1 DW/1DW	2/2	11/7	• Road Network (Singrauli - Chitrangi Road) • Drainage • Dispersed Settlement • Forest Patch (Singrauli - Chitrangi Road) • Agricultural Land

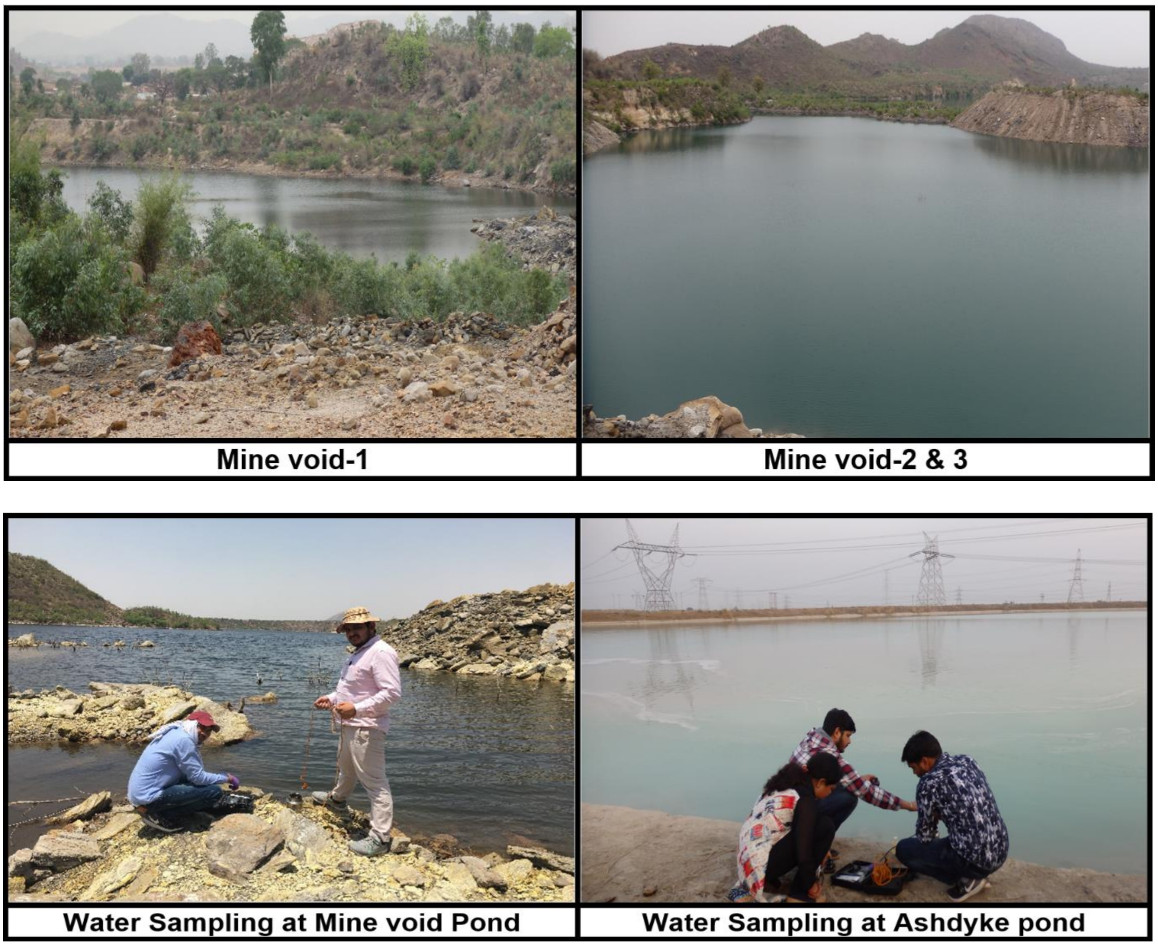
13.	Dadar	7.25 Km West	1 DW/ 1 DW,1 HP	3/3	10/7	• Road Network • Agricultural Land • Dispersed/Linear/Nucleated Settlement
14.	Singrauli	8 Km East	1 HP/1HP	3/2	10/5	• Rail and Road (Jayant-Singrauli main Road) • Drainage • Nucleated Settlement • Forest Patch • Agricultural Land
15.	Ash Dyke	19 Km South	1/1Lake	1/1	2/2	• Rail • Agricultural Land • Nucleated/ Linear Settlement • Drainage
16.	Baliyari (Near Ash Dyke)	18 Km South	1 HP/1HP	2/2	6/5	

HP: Hand Pump, DW: Dug Well, BW: Bore Well.

Photographs showing water sampling from mine voids and ash dyke pond are shown in **Plate 2.1.1.** Photographs showing water sample collection from different water sources (bore well, dug well and handpumps) in different villages of the study area are shown in **Plate 2.1.2.**

Photographs showing soil sample collection from different villages is shown in **Plate 2.1.3.**

Photographs showing collection of different floral species/plants from different villages in the study area are shown in **Plate 2.1.4.** Air drying of different plant species is shown in Plate **2.1.5.**



Mine void-1 | Mine void-2 & 3
Water Sampling at Mine void Pond | Water Sampling at Ashdyke pond

Plate 2.1.1: Water Sampling from Mine Voids and Ash Dyke Pond

Plate 2.1.2: Water Sampling from Different Sources of Water in the Study Area


Soil Sampling Near Grown Vegetables


Soil Sampling in harvested wheat field

Plate 2.1.3: Soil Sampling from Different Villages within the Study Area


Lady Finger (Bhindi)


Brinjal(Baigan)


Karonda


Lakra


Arhar


Lauki

Plate 2.1.4: Collection of Plant Samples from different Villages in the Study Area

Non-edible Portion

Edible Portion

Plate 2.1.5: Air Drying of Different Plant Species for Analysis

Status of water quality, soil quality and plant species, specifically with respect to metal content is presented in the subsequent sections.

2.2 Water Quality Status

2.2.1 Sample Collection and Analysis

In all 19 samples were collected, which included 3 samples from mine voids pond, one sample fom ash dyke pond and 15 samples from hand pumps/dug wells/bore well in different villages as detailed in earlier Section 2.1.

The collected samples were analysed for physico-chemical parameters (temperature, pH, EC and TDS) and heavy metals (As, Ba, Cd, Co, Cr, Cu, Fe, Hg, Mn, Ni, Pb and Zn) following the standard procedures (APHA, 2012). Water samples were collected in 500 ml and 250 ml polyethylene bottles for physico-chemical parameters and heavy metal analysis respectively. Concentrated HNO_3 was added to the heavy metal samples for preservation. Ion selective electrode method was used for determination of Fluoride in water samples.

Sample digestion and analysis for heavy metals content

The water samples were digested using microwave digester(Model: MARS ONE, 240/50), wherein 45ml water sample was added to each digester vessel along with 5ml of HNO_3. The method followed for digestion was as per standard protocol of the instrument. The digested samples were filtered twice using Whatmann filter paper No. 42 and syringe filter (0.45 microns). Filtered sample volume was made up to 50 ml and was stored for further analysis for heavy metals using ICP-OES(Model: Prodigy High Dispersion ICP, M/S Teledyne Leeman Labs).

2.2.2 Water Quality Characteristics and Heavy Metal Content

The source of water in the villages falling in the study area is ground water (Handpumps, Borewells and Dug wells) which is mainly used for drinking and irrigation purposes. Water samples were collected from each village and were tested in the field for basic parameters and for metals content in the laboratory. Water quality parameters are compared with respect to drinking water quality standards (BIS 10500-2012) and Irrigation water quailty standard (Ayers& Westcot, 1994).

Status of physico-chemical characteristics (in terms of temperature, pH, EC & TDS) of all the water samples collected during Winter and Summer season are given in **Tables 2.2.1 and 2.2.2,** respectively. Metals content in water samples collected during Winter and Summer are given in **Tables 2.2.3 and 2.2.4** respectively. Further, village-wise status of samples exceeding different parameters with respect to drinking water quality and irrigation standards is summarized in **Table 2.2.5.**

2.2.3 Observations

a. Characterisation of Mine Voids Water

Water samples were collected from three Mine Voids which were adjacent to each other in Gorbi mines area. Water present in the Mine Voids was found highly acidic in nature (pH range 2.5-3.0) in both the seasons. TDS varied in the range of 750-1580 mg/l during winter and 790-1750 mg/l during summer. Trace metal concentration was found considerably higher with respect to Co, Cr, Fe, Mn, Ni and Zn in both the seasons.In general, trace metal concentration was higher in Mine Void 1 as compared to Mine Voids 2 & 3. At present, the water present in the Mine Voids is not used for any purpose.

b. Characterisation of Ash Dyke Pond Water

Water sample was collected from Ash dyke after treatment. Water was neutral in pH with EC 460 μS/cm (TDS - 240 mg/l) in winter and 550 μS/cm (TDS - 280 mg/l) in summer season. All the trace metals were also found within the standard limits of irrigation water quality.

c. Status of Drinking Water Quality in Villages

The water samples in both the seasons were within the acceptable limits with respect to pH and TDS. However, TDS in few villages (Phuljhar, Naudhaiya, Mahadhiya, Padri and Thurua) was found to be more than the acceptable limit of 500 mg/l, but was very much within the permissible limit of 2000 mg/l, as there is no other alternate source of water.

Among the trace metals, the concentration of Cr and Fe was found above the acceptable limits in case of handpump samples of most of the villages in the winter season. Hg concentration was found slightly above the standard limit of 0.001 mg/l in almost all the villages. During summer season, the concentration of Cr and Fe was higher than the acceptable limits in Handpump of Mahadhaiya, Thurua, Padri, Parsohar, Dadar and Singrauli. However, unlike winter season, Hg was found within the standard limit in all the villages, except in Phuljhar, Mahadhaiya and Bastali Abad marginally.

d. Status of Irrigation Water Quality in Villages

The water samples of both the seasons were assessed on the basis of pH, EC and TDS and it has been observed that pH of the samples in the villages were within limits (6.5-8.5), except for Parsohar (6.2) and Singraulii (6.4) during winter, and Parsohar (6.2), Singrauli (6.3) and Phuljhar (6.4). On the basis of TDS, except for few villages where it was catergorised under“ no restriction in use (TDS < 450 mg/l)” viz, Parsohar, Kathas, Bastali Abad, Kairala, Khirwa, Singrauli and Baliyari, rest of all the villages showed water under the category of “slight to moderate restriction in use (TDS in the range of 450-2000 mg/l).”

Among the trace metals, except for Cr (which was found above the standard limit of 0.1mg/l), all the other trace metals were within the irrigation water standard limits. Although Cr is not recognized as an essential growth element, standard limit is recommended due to lack of knowledge on its toxicity to plants. Zn was found above limits in village Padri during both the seasons, whereas Cu was marginally above the limits in Kathas during winter and Mn was marginally above in Gorbi and Kathas during summer.

Fluoride concentration was found to be above the acceptable limit of 1.0 mg/L at the Dadar Village dug well and in the ash dyke pond, whereas it was within limit in rest of the villages including the Mine Voids. The pattern was found similar in both the seasons.

Table 2.2.1:Characteristics of Water Samples Collected during Winter Season

Sr. No.	Sampling Location / Village	Source	Temp (˚C)	pH	EC (µS/cm)	TDS (mg/L)	Fluoride (mg/L)
1.	Mine void-1	Pond 1	24.5	2.5	3110	1580	0.02
2.	Mine void-2	Pond 2	22.6	2.7	2400	1220	0.59
3.	Mine void-3	Pond 3	23.8	3.0	1480	750	0.55
4.	Ash Dyke Pond	Pond	22.2	7.3	460	240	1.72
5.	Phuljhar	HP	28.3	6.5	1220	630	0.43
6.	Naudhiya	HP	28.0	6.6	1990	1010	0.44
7.	Naudhiya	DW	24.0	7.0	1480	750	0.42
8.	Mahadhiya	DW	23.2	7.0	1100	560	0.29
9.	Gorbi	BW	26.5	6.8	880	450	0.91
10.	Thurua	HP	24.6	6.9	1340	690	0.24
11.	Karaila	HP	26.8	6.6	490	250	0.34
12.	Padri	HP	26.2	6.6	1170	600	0.14
13.	Bastali Abad	HP	22.4	7.1	660	340	0.23
14.	Kathas	DW	22.1	6.9	420	210	0.28
15.	Parsohar	HP	26.2	6.2	320	170	0.22
16.	Khirwa	DW	21.0	7.2	830	410	0.28
17.	Dadar	DW	23.3	6.9	930	470	1.44
18.	Singrauli	HP	25.1	6.4	520	270	0.05
19.	Baliyari (Near Ash Dyke)	HP	26.6	7.4	850	440	0.32
Drinking Water Quality Sandards (BIS 10500: 2012) Acceptable Limit/ Permissible Limit			-	6.5-8.5	-	500 / 2000	1.0 / 1.5
Irrigation Water Standards (FAO) (Ayers & Westcot 1994)			-	6.5-8.5	-	<450* 450-2000** >2000***	1.0

* No restriction in use, ** Slight to moderate restriction in use,*** Severe restriction in use

HP: Hand Pump, DW: Dug Well,BW: Bore Well

Table 2.2.2: Characteristics of Water Samples Collected during Summer Season

Sr. No.	Sampling Location / Village	Source	Temp (˚C)	pH	EC (µS/cm)	TDS (mg/L)	Fluoride (mg/L)
1.	Mine void-1	Pond 1	30.3	2.5	3420	1750	0.02
2.	Mine void-2	Pond 2	32.1	2.7	2420	1230	0.60
3.	Mine void-3	Pond3	31.9	2.9	1540	790	0.55
4.	Ash Dyke Pond	Pond	30.1	7.7	550	280	2.33
5.	Phuljhar	HP	30.9	6.4	1230	630	0.43
6.	Naudhiya	HP	29.6	6.6	1920	980	0.44
7.	Naudhiya	DW	28.5	7.2	1470	750	0.43
8.	Mahadhiya	HP	29.1	7.0	670	340	0.37
9.	Mahadhiya	DW	30.3	7.1	950	490	0.30
10.	Gorbi	DW	27.1	7.4	1020	530	0.81
11.	Gorbi	BW	29	6.8	880	450	1.00
12.	Thurua	HP	30	7.0	1180	600	0.25
13.	Karaila	HP	29.3	6.5	660	340	0.43
14.	Padri	HP	30.4	6.8	1080	560	0.14
15.	Bastali Abad	HP	27.8	6.9	500	260	0.29
16.	Kathas	DW	26.2	6.8	390	200	0.30
17.	Parsohar	HP	27.7	6.2	320	160	0.21
18.	Khirwa	DW	30.3	6.6	490	250	0.27
19.	Dadar	HP	29.4	6.9	940	480	1.46
20.	Dadar	DW	28.3	7.0	730	370	1.43
21.	Singrauli	HP	27.9	6.3	430	220	0.05
22.	Baliyari (Near Ash Dyke)	HP	29.5	7.5	900	460	0.42
Drinking Water Quality Sandards (BIS 10500: 2012) Acceptable Limits / Permissible Limits			-	6.5-8.5	-	500 / 2000	1.0 / 1.5
Irrigation Water Standards (FAO) (Ayers & Westcot 1994)			-	6.5-8.5	-	<450* 450-2000** >2000***	1.0

*No restriction in use,** Slight to moderate restriction in use,***Severe restriction in use

HP: Hand Pump,DW: Dug Well,BW: Bore Well

Table 2.2.3: Heavy Metals Concentration in Water Samples Collected from the Study Area during Winter Season

Sr. No.	Sampling Site / Villages & Source	Metal Concentration (mg/L)											
		As	Ba	Cd	Co	Cr	Cu	Fe	Hg	Mn	Ni	Pb	Zn
1.	Mine Void-1	0.0019	0.03	0.003	1.36	6.80	0.058	34.6	0.0026	7.08	2.385	0.033	5.57
2.	Mine Void-2	0.0007	0.05	0.002	0.71	5.28	0.028	7.36	0.0014	3.54	1.595	0.014	2.98
3.	Mine Void-3	0.0005	0.06	BDL	0.36	2.56	0.011	4.30	BDL	1.74	0.755	0.002	1.56
4.	Ash Dyke Pond	0.0015	0.10	BDL	BDL	0.10	0.008	0.18	0.0012	0.05	0.006	BDL	0.08
	Villages												
1.	Phuljhar (HP)	0.0013	0.03	BDL	0.01	0.26	0.002	1.97	0.0031	0.07	0.029	BDL	0.22
2.	Naudhiya (HP)	0.0048	0.18	BDL	BDL	0.11	BDL	4.04	0.0049	0.02	0.002	BDL	0.11
3.	Naudhiya (DW)	0.0032	0.2	BDL	BDL	0.02	BDL	0.17	0.0038	BDL	0.001	BDL	0.02
4.	Mahadhiya (DW)	0.0011	0.21	BDL	BDL	0.02	BDL	0.02	0.0013	BDL	0.001	BDL	0.01
5.	Gorbi (BW)	0.0006	0.15	BDL	BDL	0.02	BDL	0.06	0.0025	BDL	BDL	BDL	0.03
6.	Thurua (HP)	0.0014	0.06	BDL	BDL	1.64	BDL	2.20	0.0035	BDL	BDL	BDL	1.24
7.	Karaila (HP)	0.0010	0.02	BDL	BDL	0.13	0.039	2.61	0.0015	0.01	BDL	0.029	0.11
8.	Padri (HP)	0.0008	0.1	BDL	BDL	5.89	0.001	2.79	0.0005	0.03	0.002	BDL	4.12
9.	Bastali Abad (HP)	BDL	0.03	BDL	BDL	0.40	0.013	0.53	0.0018	BDL	0.003	0.005	0.32
10.	Kathas (DW)	0.0004	0.08	BDL	BDL	0.11	0.249	0.23	0.0010	BDL	BDL	0.22	0.01
11.	Parsohar (HP)	0.0000	0.08	BDL	BDL	0.93	0.006	1.78	0.0026	0.001	0.001	0.003	0.84
12.	Khirwa (DW)	0.0004	0.02	BDL	BDL	0.02	BDL	0.03	0.0025	BDL	BDL	BDL	0.02
13.	Dadar (DW)	BDL	0.16	BDL	BDL	0.10	BDL	0.06	0.0082	BDL	0.001	BDL	0.04
14.	Singrauli (HP)	0.0005	0.25	BDL	BDL	1.18	0.001	4.64	0.0014	0.03	0.009	BDL	0.71
15.	Baliyari (HP)	0.0019	0.04	BDL	BDL	0.71	0.003	0.05	0.0017	0.05	BDL	BDL	0.60
Drinking Water Quality Sandards (BIS 10500: 2012) Acceptable limits		**0.01**	**0.7**	**0.003**	–	**0.05**	**0.05**	**0.3**	**0.001**	**0.1**	**0.02**	**0.01**	**5**
Irrigation Water Standards (FAO) (Ayers & Westcot 1994)		**0.1**	–	**0.01**	**0.05**	**0.1**	**0.2**	**5**	–	**0.2**	**0.2**	**5**	**2**

BDL - Below Detection Limit; HP: Hand Pump, DW: Dug Well, BW: Bore Well

Table 2.2.4: Heavy Metals Concentration in Water Samples Collected from the Study Area during Summer Season

Sr. No.	Sampling Site / Villages & Source	Metal Concentration (mg/L)											
		As	Ba	Cd	Co	Cr	Cu	Fe	Hg	Mn	Ni	Pb	Zn
1.	Mine Void-1	0.0032	0.02	0.001	1.35	5.91	0.06	26.05	0.0006	6.25	2.253	0.039	7.34
2.	Mine Void-2	0.0011	0.03	BDL	0.81	3.13	0.029	6.1	0.0008	4.16	1.251	0.023	0.004
3.	Mine Void-3	0.0004	0.04	BDL	0.44	1.58	0.008	5.18	0.0014	2.13	0.001	0.002	0.002
4.	Ash Dyke Pond	0.0023	0.14	BDL	BDL	BDL	0.006	0.59	0.0009	0.06	0.009	0.005	1.430
	Villages												
1.	Phuljhar (HP)	0.0006	0.02	BDL	BDL	0.02	BDL	1.15	0.0012	0.044	0.004	BDL	0.03
2.	Naudhiya (HP)	0.0044	0.10	BDL	BDL	BDL	0.006	0.534	0.0005	0.008	BDL	0.001	BDL
3.	Naudhiya (DW)	0.0030	0.13	BDL	BDL	BDL	0.006	0.09	0.0004	0.003	BDL	BDL	BDL
4.	Mahadhiya (HP)	0.0006	0.09	BDL	BDL	0.16	0.004	0.32	0.0026	0.005	BDL	BDL	0.156
5.	Mahadhiya (DW)	0.0015	0.13	BDL	BDL	BDL	0.006	0.08	0.0012	0.006	BDL	BDL	BDL
6.	Gorbi (DW)	0.0003	0.17	BDL	BDL	BDL	0.023	0.22	0.0008	0.251	BDL	0.013	BDL
7.	Gorbi (BW)	0.000	0.13	BDL	BDL	BDL	0.005	0.03	0.0005	BDL	BDL	BDL	BDL
8.	Thurua (HP)	0.0014	0.04	BDL	BDL	1.12	0.015	4.28	0.0006	0.051	BDL	0.006	1.15
9.	Karaila (HP)	0.0004	0.02	BDL	BDL	BDL	0.004	0.009	0.0004	BDL	0.001	BDL	BDL
10.	Padri (HP)	0.0006	0.05	BDL	BDL	2.67	0.013	4.99	0.0004	0.021	BDL	BDL	3.43
11.	Bastali Abad (HP)	BDL	0.02	BDL	BDL	BDL	BDL	0.02	0.0011	BDL	BDL	BDL	BDL
12.	Kathas (DW)	0.0002	0.07	BDL	BDL	BDL	0.005	0.32	0.0010	0.259	0.004	BDL	BDL
13.	Parsohar (HP)	BDL	0.00	BDL	BDL	0.28	0.003	3.37	0.0004	0.024	BDL	BDL	BDL
14.	Khirwa (DW)	BDL	0.02	BDL	BDL	BDL	0.002	0.03	0.0003	0.016	BDL	BDL	0.28
15.	Dadar (HP)	0.0004	0.07	BDL	BDL	1.20	0.022	3.93	0.0010	0.032	0.001	0.013	BDL
16.	Dadar (DW)	0.0001	0.07	BDL	BDL	BDL	0.002	0.08	0.0003	0.02	BDL	BDL	BDL
17.	Singrauli (HP)	0.0003	0.19	BDL	BDL	1.14	0.008	3.99	0.0008	0.041	0.009	0.001	0.24
18.	Baliyari (HP)	0.0014	0.867	BDL	BDL	0.24	0.016	0.23	0.0006	0.054	0.004	0.006	BDL
Drinking Water Quality Sandards (BIS 10500: 2012) Acceptable limits		**0.01**	**0.7**	**0.003**	**–**	**0.05**	**0.05**	**0.3**	**0.001**	**0.1**	**0.02**	**0.01**	**5**
Irrigation Water Standards (FAO) (Ayers & Westcot 1994)		**0.1**	**–**	**0.01**	**0.05**	**0.1**	**0.2**	**5**	**–**	**0.2**	**0.2**	**5**	**2**

BDL - Below Detection Limit; HP: Hand Pump, DW: Dug Well, BW: Bore Well

Table 2.2.5: Summary of Samples Exceeding Acceptable Limits for Drinking and Irrigation Water Quality in Different Villages

Sr. No.	Village	Source	Drinking Water Quality Standards (BIS 10500- 2012)	Irrigation Water Standards (FAO) (Ayers & Westcot 1994)
A.	**Winter Season**			
1.	Phuljhar	HP	TDS, Cr, Fe, Hg, Ni	Cr
2.	Naudhaiya	HP	TDS, Cr, Fe, Hg	Cr
		DW	TDS, Hg	-
3.	Mahadhaiya	DW	TDS, Hg	-
4.	Gorbi	BW	Hg	-
5.	Thurua	HP	TDS, Cr, Fe, Hg	Cr
6.	Karaila	HP	Cr, Fe, Hg, Pb	Cr
7.	Padri	HP	TDS, Cr, Fe	Cr, Zn
8.	Bastali Abad	HP	Cr, Fe,Hg	Cr
9.	Kathas	DW	Cr, Cu, Pb	Cr, Cu
10.	Parsohar	HP	pH, Cr, Fe, Hg	Cr
11.	Khirwa	DW	Hg	-
12.	Dadar	DW	Cr, Hg, F	F
13.	Singrauli	HP	pH, Cr, Fe, Hg	Cr
14.	Baliyari	HP	Cr, Hg	Cr
B.	**Summer Season**			
1.	Phuljhar	HP	pH, TDS, Fe, Hg	-
2.	Naudhaiya	HP	TDS, Fe	-
		DW	TDS	-
3.	Mahadhaiya	HP	Cr, Fe, Hg	Cr
		DW	Hg	-
4.	Gorbi	DW	TDS, Mn, Pb	Mn
		BW	-	-
5.	Thurua	HP	TDS, Cr, Fe	Cr
6.	Karaila	HP	-	-
7.	Padri	HP	TDS, Cr, Fe	Cr, Zn
8.	Bastali Abad	HP	Hg	-
9.	Kathas	DW	Fe, Mn	Mn
10.	Parsohar	HP	pH, Cr, Fe	Cr
11.	Khirwa	DW	-	-
12.	Dadar	HP	Cr, Fe, Pb, F	Cr, F
		DW	F	F
13.	Singrauli	HP	pH, Cr, Fe	Cr
14.	Baliyari	HP	Ba, Cr	Cr

HP: Hand Pump, DW: Dug Well, BW: Bore Well.

2.3 Soil Quality Status

2.3.1 Sample Collection and Analysis

The soil samples were collected from the respective vegetables fields from where the plant samples were collected. First, all the collected samples were air dried naturally. Then the dried samples were grinded and sieved using 2 mm sieve for further analysis of physical parameters and heavy metal content determination.

The physical parameters, viz. texture, colour, pH & electrical conductivity (EC) of all the soil samples were determined for one season (winter) only, as these are not expected to vary in other season. The texture was estimated by International Pipette Method (Black, 1964) for determination of particle size and the soils were classified on the basis of their textural class. pH and EC were analysed by preparing soil extract in distilled water in ratio 1:2 (as per Jackson procedure, 1967). Soil Colour was compared and identified using Munsell colour chart, 1994. Ion selective electrode method was used for determination of Fluoride in soil samples.

Heavy metal content determination: The soil samples were digested using Microwave digester, wherein 0.5 g of soil sample was taken in each digester vessel along with 10 ml of aqua regia. The digestion method followed was as per standard protocol of the instrument. The digested samples were filtered twice using Whatmann filter paper No. 42 and syringe filter (0.45 microns). Sample volume was made up to 50 ml and heavy metal analysis was done by using ICP-OES.

2.3.2 Soil Quality Status

Physical characteristics of soil samples in terms of color, sand, silt & clay content, texture class, pH and EC are given in **Table 2.3.1.**

The collected soils from the study area were moderate textured with pale brown to brown in color. Texture of soil samples of 12 villages was sandy loam (Sand content: 56-70%, Silt: 22-38%, Clay: 4-16%), whereas 2 samples/villages (Phuljhar & Baliyari) have loamy sand. Soil near the mine voids was mostly sandy (sand content: 88-90%) in nature.

pH of the soil samples was neutral ranging between 6.5 to 7.7, whereas near mine voids, pH of soil was found in the range of 2.8-3.5. The EC of the soils ranged from 263 µS/cm (Khriwa village) to 1949 µS/cm (Bastali Abad village).

Heavy Metal Content in Soil Samples

Soil samples collected from different locations/villages of study area were analyzed for different heavy metals (As, Ba, Cd, Co, Cr, Cu, Fe, Hg, Mn, Ni, Pb and Zn) for both, winter and summer seasons. The results are compared with the available Indian Standards, Awasthi, 2000 (Anwarzeb Khan et.al 2015) as given in **Tables 2.3.2**

and 2.3.3, respectively for winter and summer season. Further, results of metals content in the samples collected from 14 villages during winter and summer are summarised in **Table 2.3.4.**

Perusal of table indicates that all the metals for which Indian Standards are available, were well below the limits in all the villages. Cd content was in the range 0.4-5 mg/kg against the limit of 3-6 mg/kg. Cu content was in the range of 9-32 mg/kg against the limit of 135-270 mg/kg.Ni content was in the range of 5-28 mg/kg against the limit of 75-150 mg/kg.Pb content was in the range of 6-24mg/kg against the limit of 250-500 mg/kg.

All the metals in the soils near mine voids were also found well below the limits in both the seasons.

Fluoride content was found to be in the range of 0.53 mg/kg at Thurua to 2.09 mg/kg at Khirwa. Near the Mine Voids 1 & 2, the fluoride content in soil was found to be 0.98 and 1.11 mg/kg respectively.

Soil fluoride is derived from the parent material and therefore its distribution pattern in soil is related to the process of soil formation. The lowest F content are usually present in sandy soil, while the higher concentrations of F are found in soil from weathered mafic rocks and in heavy clay soil. Further, there is no standard limit for fluoride in soil.

Table 2.3.1: Physical Characteristics of Soil Samples Collected from the Study Area

Sr. No.	Sampling Site/ Village	Colour	Content (%)			Texture Class	pH	EC (µS/cm)	Fluoride (mg/L)
			Sand	Silt	Clay				
1.	Mine Void 1	Grey	90	8	2	Sand	3.5	457	0.98
2.	Mine Void 2	Pale brown	89	9	2	Sand	2.8	444	1.11
3.	Phuljhar	Brown	78	20	2	Loamy Sand	7.7	656	1.52
4.	Naudhiya	Light brownish grey	66	25	9	Sandy loam	6.5	494	1.03
5.	Mahadhiya	Light brownish grey	70	24	6	Sandy loam	7.7	768	0.57
6.	Gorbi	Light brownish grey	68	28	4	Sandy Loam	6.8	683	0.94
7.	Thurua	Light brownish grey	60	32	8	Sandy loam	7.7	485	0.53
8.	Karaila	Brown	58	38	4	Sandy loam	7.6	374	0.98
9.	Padri	Brown	64	26	10	Sandy loam	7.6	904	1.16
10.	Bastali Abad	Pale Brown	60	24	16	Sandy loam	7.6	1949	1.18
11.	Kathas	Light Brown	58	30	12	Sandy loam	7.7	1000	1.81
12.	Parsohar	Brown	56	38	6	Sandy loam	7.4	455	1.98
13.	Khirwa	Light yellowish brown	62	33	5	Sandy loam	7.1	263	2.09
14.	Dadar	Brown	68	26	6	Sandy loam	7.5	453	1.99
15.	Singrauli	Brown	68	22	10	Sandy loam	7.3	1330	1.82
16.	Balyari (Near Ash Dyke)	Light yellowish brown	78	19	3	Loamy sand	7.6	586	1.71

Table 2.3.2: Heavy Metals Concentration in Soil Samples Collected From Study Area during Winter Season

Sr. No.	Sampling Site	Metal Concentration (mg/Kg)											
		As	**Ba**	**Cd**	**Co**	**Cr**	**Cu**	**Fe**	**Hg**	**Mn**	**Ni**	**Pb**	**Zn**
1.	Mine Void-1	BDL	321	2	BDL	32	14	50114	0.01	36	10	34	35
2.	Mine Void-2	BDL	241	2	BDL	45	4	31265	0.02	64	3	19	45
	Villages												
1.	Phuljhar	11.0	110	3.0	2.9	39	12	41033	0.03	162	10	14	32
2.	Naudhiya	3.7	113	2.0	2.6	39	11	40657	0.03	142	10	8	48
3.	Mahadhiya	4.5	156	1.0	2.3	34	10	33104	0.03	152	8	10	42
4.	Gorbi	2.7	119	3.3	3.1	28	16	41944	0.04	142	9	11	27
5.	Thurua	3.9	140	2.0	3.1	44	13	31488	0.03	172	12	18	56
6.	Karaila	1.8	113	3.0	5.4	41	14	36006	0.03	247	12	14	48
7.	Padri	5.1	104	2.0	3.8	46	12	40081	0.06	189	11	11	36
8.	Bastali Abad	7.5	203	2.0	4.5	54	9	26762	0.03	199	13	10	40
9.	Kathas	2.0	258	3.5	7.0	56	18	32649	0.04	283	16	18	50
10.	Parsohar	4.2	132	3.5	5.1	48	29	38553	0.04	235	12	22	36
11.	Khirwa	9.0	118	5.0	6.2	46	17	39252	0.02	214	16	14	41
12.	Dadar	4.5	103	1.7	4.1	39	22	32507	0.04	292	12	10	43
13.	Singrauli	2.5	146	3.3	4.5	50	13	30983	0.05	290	13	16	53
14.	Baliyari	3.0	55	1.1	2.0	30	12	30359	0.05	120	5	9	34
***Indian Standards Awasthi 2000**		**-**	**-**	**3-6**	**-**	**-**	**135-270**	**-**	**-**	**-**	**75-150**	**250-500**	**-**

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Table 2.3.3: Heavy Metals Concentration in Soil Samples Collected From Study Area during Summer Season

Sr. No.	Sampling Site	Metal Concentration (mg/Kg)											
		As	Ba	Cd	Co	Cr	Cu	Fe	Hg	Mn	Ni	Pb	Zn
1.	Mine Void-1	BDL	277	2.3	4.7	40	20	56393	0.44	36	16	41	44
2.	Mine Void-2	BDL	105	2	2.6	48	6	31339	0.14	57	4	26	44
	Villages												
1.	Phuljhar	14.5	85	1.2	7.7	45	19	33270	0.06	338	22	13	34
2.	Naudhiya	2.7	97	0.5	6.2	38	16	25764	0.03	231	16	6	41
3.	Mahadhiya	2.2	113	0.5	6.6	39	16	26672	0.10	301	17	8	40
4.	Gorbi	3.9	88	0.4	5.9	27	17	27707	0.09	226	12	8	26
5.	Thurua	11.6	125	4.1	8.1	51	18	24321	0.12	346	22	11.	57
6.	Karaila	4.0	99	1.4	12.0	51	20	31169	0.11	426	21	12	59
7.	Padri	13.4	104	3.6	9.8	56	1	29357	0.08	430	24	11	48
8.	Bastaliabad	14.2	126	0.9	8.8	59	14	21346	0.06	336	25	10	39
9.	Kathas	6.0	217	1.7	15.9	58	24	34361	0.16	570	28	17	60
10.	Parsohar	3.8	115	2.8	12.7	54	32	37299	0.06	434	21	24	51
11.	Khirwa	7.4	71	1.1	9.8	50	16	29428	0.07	233	19	13	56
12.	Dadar	4.1	135	2.4	18.6	49	28	38437	0.08	570	25	11	57
13.	Singrauli	8.8	138	1.7	11.7	56	13	34223	0.11	382	26	20	64
14.	Baliyari	5.2	54	1.4	5.5	36	10	24139	0.07	207	12	8	39
***Indian Standards Awasthi 2000**		**-**	**-**	**3-6**	**-**	**-**	**135-270**	**-**	**-**	**-**	**75-150**	**250-500**	**-**

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Table 2.3.4: Summary of Metal Contents in the Soil of Different Villages

Metal	Metal Content (mg/kg)				*Indian Standards Awasthi 2000
	Winter		Summer		
	Min	Max	Min	Max	
As	1.8	11	2.2	14.5	-
Ba	55	258	54	217	-
Cd	1	5	0.4	4.1	3-6
Co	2	7	5.5	18.6	-
Cr	28	56	27	59	-
Cu	9	29	10	32	135-270
Fe	26762	41944	21346	38437	-
Hg	0	0.1	0.03	0.12	-
Mn	120	292	207	570	-
Ni	5	16	12	28	75-150
Pb	8	22	6	24	250-500
Zn	27	56	26	64	-

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2.4 Status of Flora in the Study Region

An intensive field survey was conducted in the study area, wherein 92 types of different plant species belonging to 40 families were identified. Of the total families, the dominant families of the flora were found belonging to Fabaceae, Malvaceae, Poaceae, and Asteraceae(Arvind Singh 2011 & 2012). List of tree, shrubs, herbs and other plant species observed in the different identified villages are given in **Table 2.4.1 to 2.4.4** respectively. The details of observed plant species along with their families and economic importance are given in **Annxeure 2.1.**

It has been observed that maximum plants listed were observed in Mahadhiya, Thurua, Karaila, Bastali Abad and Baliyari village (near Ash dyke). The tree species which were commonly found in the villages were *Acacia nilotica, Acacia Catechu, Azadirachta indica, Artocarpus heterophyllus, Butea monosperma, Cassia fistula, Ficus religiosa, Gmelina arborea, Madhuca indica, Mangifera indica, Terminalia bellirica,* and *Ziziphus mauritiana.*

Among the commonly found shrubs were *Ricinus communis, Psidium guajava, Calotropis spp., Lantana camara, Jatrophagossypifolia, Grewia asiatica* and Herbs were *Achyranthes aspera, Alternanthera sessilis, Cassia tora, Desmodium triflorum Euphorbia hirta Scoparia dulcis Sterculia vilosa, Xanthium strumarium.*

Listing and survey of the plant species carried out was a part of natural vegetation found in the study area. Hence only selective Trees/shrubs/herbs were included in the trace metal study which were growing in the vicinity of the inhabited area. They included Bel, Ber (Zizipus), Kathal, Mango, Guvava, Papya, Karonda, Castor (Arand), Neem, Sessile joy weed, Ban-tulsi. A few tree species besides other plants growing in the Mine Void area were also collected viz., Acacia, Babul, Bamboo for metals content analysis.

Table 2.4.1: List of Tree Species Observed in the Study Area during Survey

Sr. No.	Plant Species/ Common Name	Mine Void	Phuljhar	Naudhiya	Mahadhiya	Gorbi	Thurua	Karaila	Padri	Bastali Abad	Kathas	Parsohar	Khirwa	Dadar	Slingrauli	Baliyari
1.	Acacia*	+		+		+	+		+						+	
2.	Babul*	+	+	+	+		+	+	+	+		+		+	+	
3.	Safed Khair			+		+	+		+						+	
4.	Haldu			+		+	+		+						+	
5.	Bel*				+	+	+				+	+				
6.	Lebbek tree	+	+						+							
7.	Jack fruit/ Kathal*		+			+	+				+	+		+	+	
8.	Neem*	+	+	+	+	+	+	+	+		+	+			+	+
9.	Kachnaar	+						+								
10.	Kasai			+		+	+		+						+	
11.	Palash		+	+		+		+	+		+	+		+	+	
12.	Amaltas	+		+		+	+		+						+	
13.	Kassod			+				+								
14.	Jangli Sem			+		+	+		+						+	
15.	Kapok tree	+														
16.	Sheesam	+						+	+			+				
17.	Gulmohar									+	+				+	
18.	Tendu			+		+	+		+						+	
19.	Amla			+		+	+		+						+	
20.	Eucalyptus		+	+		+	+				+					
21.	Banyan Tree								+							+
22.	Peepal		+	+	+	+	+	+	+	+	+			+		+
23.	Gambhar/ Khomer	+		+		+	+		+						+	
24.	Chilbil							+							+	
25.	Mahua		+	+		+		+						+		
26.	Mango*			+	+	+		+	+	+		+	+	+	+	+
27.	MahaNeem/ Babin			+		+	+		+						+	
28.	Drumstick		+		+						+					
29.	Kadamb				+					+				+		
30.	Jelly bean tree			+												
31.	Radhachura										+					
32.	Jungle jalebi	+	+													
33.	Karanj	+		+			+				+					+

34.	Junglee kikar		+	+												
35.	Ashok					+										
36.	Kusum/ Lac Tree			+		+	+		+						+	
37.	Bhela/ Varnish Tree			+		+	+		+						+	
38.	Sal			+		+	+		+						+	
39.	Jamun	+				+				+		+				
40.	Tamarind								+							
41.	Sagaon	+			+	+			+							
42.	Arjuna	+														
43.	Bahera	+		+		+	+		+						+	
44.	Ber/ Zizipus*	+	+	+	+	+	+	+	+	+	+	+	+	+		

**Plant samples collected for heavy metal analysis.*

Table 2.4.2: List of Shrubs Observed in the Study Area during Survey

Sr. No.	Plant Species/ Common Name	Mine Void	Phuljhar	Naudhiya	Mahadhiya	Gorbi	Thurua	Karaila	Padri	Bastali Abad	Kathas	Parsohar	Khirwa	Dadar	Slingrauli	Baliyari
1.	Shareefa													+		
2.	Yellow December								+							
3.	Glory of garden														+	
4.	Aak/ Madaar					+	+		+	+				+		
5.	Papaya*				+											
6.	Karonda*					+										
7.	Falsa			+		+	+		+						+	
8.	Lal bherenda			+		+	+		+						+	
9.	Raimuniya/ Lantana	+	+	+		+								+		
10.	Subabul		+							+					+	
11.	Flax					+										
12.	Maror Phali			+		+	+		+						+	
13.	Banana						+									
14.	Guava/ Amrud*					+	+		+			+			+	
15.	Castor oil/ Arand plant*				+			+	+		+	+	+			+
16.	Bala			+		+	+		+						+	

**Plant sample collected for heavy metal analysis.*

Table 2.4.3: List of Herbs Observed in the Study Area during Survey

Sr. No.	Plant Species/ Common Name	Mine Void	Phuljhar	Naudhiya	Mahadhiya	Gorbi	Thurua	Karaila	Padri	Bastali Abad	Kathas	Parsohar	Khirwa	Dadar	Slingrauli	Baliyari
1.	Aapamar/ Chirchiri			+		+	+		+						+	
2.	Sessile joy Weed*	+					+		+	+	+	+		+		+
3.	Prickly poppy										+			+		
4.	Chekor			+		+	+		+						+	
5.	Sohari					+										
6.	Beggar weed			+		+	+		+						+	
7.	Thorny Ball			+												
8.	Dudhi			+		+	+		+						+	
9.	Shankhpushpa			+		+	+		+						+	
10.	Shoe flower				+											
11.	Morning glory			+	+	+		+						+		
12.	Ban Tulsi*	+	+			+							+			+
13.	Pink Weed			+	+											
14.	Ban Mirach			+		+	+		+						+	
15.	Wire weed					+										
16.	Heart-leaf sida				+											
17.	Thorny night shade/BhatKat taiya			+		+	+		+						+	
18.	Ghost Tree/ Kulu			+		+	+		+						+	
19.	Udal/ Elephant rope tree			+		+	+		+						+	
20.	Tridax daisy			+												
21.	Rough cocklebur			+	+	+	+		+							

**Plant sample collected for heavy metal analysis.*

Scientific names of the species are given in Annexure 2.1.

Table 2.4.4: List of Other Plant Species Observed in the Study Area during Survey

Sr. No.	Plant Species/ Common Name	Mine Void	Phuljhar	Naudhiya	Mahadhiya	Gorbi	Thurua	Karaila	Padri	Bastali Abad	Kathas	Parsohar	Khirwa	Dadar	Slingrauli	Baliyari
1.	Doob Ghass			+		+	+		+						+	
2.	Aparajita				+											
3.	Bamboo*	+	+		+				+	+	+			+	+	
4.	Purple yam			+		+	+		+						+	
5.	Kurchi/ Koraiya			+		+	+		+						+	
6.	Prickly pear				+											
7.	Congress grass			+	+	+		+	+	+	+					
8.	Deenanath Grass					+										
9.	Kansi Ghass			+		+	+		+						+	
10.	Jharu Grass			+		+	+		+						+	
11.	Pili Kaner	+														

**Plant samples collected for heavy metal analysis.*

2.5 Metal Content in the Floral Species

2.5.1 Sample Collection and Analysis

Floral species samples of herbs, shrubs and trees were collected from different villages during winter & summer season, depending upon the availability in that particular season. The plant samples collected from each village were grown by the people living in that area for their consumption. Also few fruit trees and weeds used as fodder were also included in the samples.

The collected samples were categorised as Edible portion of Fruit/ vegetables/ grains and non-Edible Portion (biomass samples - leaf & stem only). The availability of the edible portion in the plants depended on the stage of plant growth (vegetative/ fruiting) and season. Hence edible portion was collected where ever available in order to assess the bioaccumulation of metals in the edible portion which is consumed by the human beings.

Accordingly, total 225 number of samples (65 samples of edible portion and 160 samples of non-edible portion) were collected during winter season. Similarly, 172 number of samples (69 samples of edible portion and 103 samples of non-edible portion) were collected during summer. Village-wise details of samples collected for different edible and non-edible portion of vegetables, fruits, trees, cereal crops and weeds are given in **Tables 2.5.1 & 2.5.2** for winter season and in **Tables 2.5.3 & 2.5.4** for summer season. Samples were also collected from the area near mine voids and existing ash dyke. Summary of different types of samples of edible and non-edible floral species collected during winter and summer is given in **Table 2.5.5**.

2.5.2 Processing of Samples

All the collected samples were initially air dried and then further dried in hot air oven at 80°C for 24 hours.All the air dried samples were ground and digested using Microwave digester. 0.5g of sample was added to each digester vessel along with 5ml of HNO_3 and 3ml of H_2O_2. The digestion method followed was as per standard protocol of the instrument. The digested samples were filtered twice using Whatmann filter paper (42mm) and then using syringe filter (0.45 microns). Sample volume was made up to 50ml and heavy metal analysis was done by using ICP-OES. Fluoride content was determined as per AOAC method.

2.5.3 Metal Content in Floral Species

Heavy metals concentration in edible and non-edible (biomass) portion of different samples of vegetables,fruits, cereal crops, weeds and tree species were determined in winter and summer season species. Metals content were determined in terms of As, Ba, Cd, Co, Cr, Cu, Fe, Hg, Mn, Ni, Pb and Zn in all the samples collected from different villages and mine void & ash dyke area.

Metals content in floral species collected from Mine Void area in both the seasons are given in **Table 2.5.6**, whereas the same for Ash dyke area are given in **Table 2.5.7**.

Metals content in edible and non-edible portion of floral species in each of the 14 villages, viz. Phuljhar, Naudhiya, Mahadhiya, Gorbi, Thurua, Karaila, Padri, Bastali Abad, Kathas, Parsohar, Khirwa, Dadar, Singrauli and Baliyari during winter season is given in **Tables 2.5.8-2.5.21**, respectively.

Similarly, metals content in edible and non-edible portion of floral species in each of the 14 villages, viz. Phuljhar, Naudhiya, Mahadhiya, Gorbi, Thurua, Karaila, Padri, Bastali Abad, Kathas, Parsohar, Khirwa, Dadar, Singrauli and Baliyari during summer season is given in **Tables 2.5.22-2.5.35**, respectively.

Level of metals content present in different floral species were compared with a permissible limit suggested by Food Safety and Standards Authority of India (FSSAI, 2011). Among the total 12 metals determined in the present study, wherein FSSAI Standards are available for As, Cd, Cu, Hg, Ni, Pb and Zn.

Village-wise total number of samples exceeding the FSSAI limit, type of floral species and metals of concern in that species in the edible and non-edible portion of the samples collected during winter and summer are summarized in **Tables 2.5.36 and 2.5.37**, respectively.

Ni content in edible portion of Arhar exceeded FSSAI limit in 6 villages. Ni levels also exceeded in Karonda, Lakra &Sem, whereas Pb exceeded only in two samples of Lakra and Arhar. Cu exceeded in two samples of Zizipus and Lakra, whereas As exceeded only in one sample of Zizipus. During winter, out of 65 samples of edible portion of different species, high levels (exceeding FSSAI limit) of different metals were obsered in 15 samples.

Among the 152 samples of non-edible portion (biomass), high levels of metals were observed in as many as 68 samples during winter. Metals like Ni, Cu, Pb, As and Zn exceeded in the different species of vegetables, fruits, cereal crops and weeds.

Similarly, during summer, 15 samples of edible portion of different floral species exceeded the FSSAI limits in different villages. Metals like Ni, Pb, As, Zn and Hg were found exceeding the permissible limit in different species like, Arhar, Sarson, Bel, Onion, Tomato, Kathal, Mango, and Brinjal.

Among the 97 samples of non-edible portion (biomass), high levels of metals were observed in as many as 33 samples during summer. Metals like Ni, As, Pb, Cu, Zn and Hg were found exceeding the FSSAI limit in the different species of vegetables, fruits, cereal crops and weeds, almost in all the villages.

Table 2.5.1: Types of Edible Portion (Vegetable/ Fruits/ Grains) Collected from the Study Area for Heavy Metal Analysis (Winter)

Sr. No.	Plant Species (Common Name)	Sampling Location / Village															
		Mine Void	Phuljhar	Naudhiya	Mahadhiya	Gorbi	Thurua	Karaila	Padri	Bastali Abad	Kathas	Parsohar	Khirwa	Dadar	Singrauli	Ash Dyke	Baliyari
A.	**Vegetables**																
1.	Brinjal		+	+			+	+	+	+	+	+	+	+			
2.	Karonda					+											
3.	Kathal														+		
4.	Lakra		+		+	+		+			+	+		+			+
5.	Lauki		+										+	+			
6.	Sem			+	+	+		+			+		+				+
7.	Tomato		+				+	+	+		+	+	+	+			+
B.	**Fruits**																
7.	Amrud		+	+		+					+	+			+		
8.	Lemon			+													
9.	Zizipus		+	+	+			+	+		+	+	+	+			
C.	**Cereal Crops**																
10.	Arhar			+		+	+	+	+		+	+	+	+			
D.	**Weeds**																
11.	Castor/ Arand							+									
Total		**0**	**6**	**6**	**3**	**5**	**3**	**7**	**4**	**1**	**7**	**6**	**6**	**6**	**2**	**0**	**3**

Table 2.5.2: Types of Plants Species (Biomass) Collected from the Study Area for Heavy Metal Analysis (Winter)

Sr. No.	Plant Species (Common Name)	Sampling Location / Village															
		Mine Void	Phuljhar	Naudhiya	Mahadhiya	Gorbi	Thurua	Karaila	Padri	Bastali Abad	Kathas	Parsohar	Khirwa	Dadar	Singrauli	Ash Dyke	Baliyari
A.	**Vegetables**																
1.	Brinjal		+	+			+	+	+	+	+	+	+	+	+		
2.	Karonda					+											
3.	Kathal		+		+		+				+	+		+	+		
4.	Lakara		+		+	+		+			+	+		+			+
5.	Lauki		+						+	+	+		+	+	+		
6.	Potato				+	+	+	+	+		+	+	+		+		+
7.	Pumpkin		+							+							
8.	Sarson					+											
9.	Sem		+	+	+	+	+	+	+	+	+		+		+		+
10.	Tomato		+	+			+	+	+	+	+	+	+	+	+		+
11.	Turaii					+											
B.	**Fruits**																
12.	Amrud		+	+	+	+	+		+		+	+		+	+		
13.	Lemon			+													
14.	Mango		+		+	+		+	+	+		+	+	+	+		
15.	Papaya			+	+		+										
16.	Zizipus		+	+	+		+	+	+	+	+	+	+	+			
C.	**Trees**																
17.	Acacia	+															
18.	Babul	+															
19.	Bamboo	+															
20.	Neem	+	+	+	+		+	+	+			+			+		+
D.	**Cereal Crops**																
21.	Arhar		+	+	+	+	+	+	+	+	+	+	+	+			+
E.	**Weeds**																
22.	Ban-tulsi	+	+			+					+		+			+	
23.	Castor/ Arand		+		+			+			+	+	+		+		
24.	Sessile joy weed	+	+	+	+	+	+	+	+	+	+	+	+	+		+	
	Total	**6**	**15**	**10**	**12**	**11**	**11**	**11**	**11**	**9**	**13**	**12**	**11**	**10**	**10**	**2**	**6**

Table 2.5.3: Types of Edible Portion (Vegetable/ Fruits/ Grains) Collected from the Study Area for Heavy Metal Analysis (Summer)

Sr. No.	Plant Species (Common Name)	Sampling Location / Village															
		Mine Void	Phuljhar	Naudhiya	Mahadhiya	Gorbi	Thurua	Karaila	Padri	Bastali Abad	Kathas	Parsohar	Khirwa	Dadar	SIngrauli	Ash Dyke	Baliyari
A.	**Vegetables**																
1.	Bhindi							+		+		+	+	+			+
2.	Brinjal			+						+			+				+
3.	Kathal						+		+			+	+	+			
4.	Matar			+													
5.	Mirch			+	+									+			
6.	Onion Bulb			+	+	+	+	+		+		+	+				+
7.	Sarson			+		+		+		+		+					
8.	Tomato			+		+		+		+		+	+	+	+		+
B.	**Fruits**																
9.	Amrud										+	+					
10.	Bel				+	+											
11.	Lemon			+					+								
12.	Mango				+	+		+	+			+	+	+			
C.	**Cereal Crops**																
13.	Arhar		+	+		+		+		+							
14.	Chana			+													
15.	Wheat		+	+	+	+		+		+		+					
D.	**Weeds**																
16.	Castor/ Arand		+														
Total		**0**	**3**	**10**	**5**	**7**	**2**	**7**	**3**	**7**	**1**	**8**	**6**	**5**	**1**	**0**	**4**

Table 2.5.4: Types of Plants Species (Biomass) Collected from the Study Area for Heavy Metal Analysis (Summer)

Sr. No.	Plant Species (Common Name)	Sampling Location / Village															
		Mine Void	Phuljhar	Naudhiya	Mahadhiya	Gorbi	Thurua	Karaila	Padri	Bastali Abad	Kathas	Parsohar	Khirwa	Dadar	Singrauli	Ash Dyke	Baliyari
A.	**Vegetables**																
1.	Amaranthus					+											
2.	Bhindi					+		+		+		+	+	+			+
3.	Brinjal			+						+			+	+			+
4.	Corriander			+													
5.	Kathal		+		+		+		+			+	+	+	+		
6.	Matar			+													
7.	Mirch			+	+									+			
8.	Onion			+		+	+	+		+		+	+				+
9.	Sarson			+		+		+		+		+					
10.	Sem		+		+												
11.	Tomato			+		+		+		+		+	+	+	+		+
B.	**Fruits**																
12.	Amrud		+	+		+	+		+		+		+		+		
13.	Bel					+											
14.	Karonda					+											
15.	Lemon			+					+		+						
16.	Mango		+		+	+		+	+	+		+	+	+	+		
C.	**Trees**																
17.	Accacia	+															
18.	Bamboo	+															
19.	Neem	+		+	+				+		+			+	+		+
D.	**Cereal Crops**																
20.	Arhar		+	+		+		+		+							
21.	Chana			+													
22.	Wheat		+	+	+	+		+		+		+					
E.	**Weeds**																
23.	Ban tulsi															+	
24.	Castor/Arand		+	+													
25.	Lantana	+															
26.	Sessile joy weed			+		+										+	
	Total	**4**	**7**	**15**	**6**	**12**	**3**	**7**	**5**	**8**	**3**	**7**	**7**	**7**	**5**	**2**	**5**

Table 2.5.5: Summary of Edible and Non-edible Species Samples Collected during Winter and Summer Seasons

Winter Season Species		**Summer Season Species**	
Edible	**Non-Edible**	**Edible**	**Non-Edible**
Vegetables			
Brinjal, Karonda, Kathal, Lakra, Lauki, Sem, Tomato	Brinjal, Karonda, Kathal, Lakara, Lauki, Potato, Pumpkin, Sarson, Sem, Tomato, Turai	Bhindi, Brinjal, Kathal, Matar, Mirch, Onion Bulb, Sarson, Tomato	Amaranthus, Bhindi, Brinjal, Corriander, Kathal, Matar, Mirch, Onion, Sarson, Sem, Tomato
Fruits			
Amrud, Lemon, Zizipus	Amrud, Lemon, Mango, Papaya, Zizipus	Amrud, Bel, Lemon, Mango	Amrud, Bel, Karonda, Lemon, Mango
Cereal Crops			
Arhar	Arhar	Arhar, Chana, Wheat	Arhar, Chana, Wheat
Weeds			
Castor/ Arand	Ban-tulsi, Castor/ Arand, Sessile joy weed	Castor/ Arand	Ban tulsi, Castor/ Arand, Lantana, Sessile joy weed
Trees			
--	Acacia, Babul, Bamboo, Neem	**--**	Accacia, Bamboo, Neem

Table 2.5.6: Heavy Metal Concentration in Non-edible Portion of Floral Biomass in Mine Void Area during Winter & Summer Season

Sr. No.	Item	Metal Concentration (mg/kg)											
		As	Ba	Cd	Co	Cr	Cu	Fe	Hg	Mn	Ni	Pb	Zn
	Winter Season												
A.	**Trees**												
1.	Acacia Spp.	0.2	4.7	BDL	1.63	7.4	10	194	0.049	175	6.2	BDL	65
2.	Babul	0.5	8.6	BDL	0.34	5.9	32	700	0.033	101	2.0	BDL	51
3.	Bamboo	0.4	1.4	BDL	0.32	6.8	6	692	0.078	114	1.9	3.5	72
4.	Neem	0.1	4.2	BDL	0.19	3.8	7	520	0.085	44	2.3	BDL	31
B.	**Weed**												
5.	Ban Tulsi	0	15.3	0.71	1.6	3.0	16	191	0.056	92	0.8	BDL	20
6.	Sessile joy weed	0.1	9.4	BDL	1.32	6.5	8	402	0.039	147	3.6	BDL	59
	Summer Season												
A.	**Trees**												
1.	Acacia	0.7	1.3	0	0	4.7	5	196	0.022	180	7.5	1.0	43
2.	Bamboo	0.4	1.6	0	0	3.6	7	316	0.099	174	1.4	1.3	25
3.	Neem	0.4	6.0	0	0	3.3	4	282	0.063	65	3.2	1.7	28
B.	**Weed**												
4.	Lantana	1.0	10.1	0	0	3.8	12	612	0.052	323	15.2	7.6	38
FSSAI 2011		**1.1**	**-**	**1.5**	**-**	**-**	**30**	**-**	**1**	**-**	**1.5**	**2.5**	**50**

Table 2.5.7: Heavy Metal Concentration in Non-edible Portion of Floral Species in Ash Dyke Area during Winter& Summer Season

Sr. No.	Item	Metal Concentration (mg/kg)											
		As	Ba	Cd	Co	Cr	Cu	Fe	Hg	Mn	Ni	Pb	Zn
	Winter Season												
A.	**Weeds**												
1.	Ban Tulsi	0.2	28.4	0.1	BDL	2.3	10	375	0.041	28	0.4	0.5	24
2.	Sessile joy weed	1	31.9	0.2	BDL	2.6	8	717	0.031	61	1.4	0.7	25
	Summer Season												
A.	**Weeds**												
1.	Bantulsi	0.7	24.3	0.1	0.7	3.5	28	464	0.046	29	2.05	1.4	35
2.	Sessile Joy Weed	0.4	36	0.1	0.5	3.3	18	1035	0.031	53	1.7	4.1	32
FSSAI 2011		**1.1**	**-**	**1.5**	**-**	**-**	**30**	**-**	**1**	**-**	**1.5**	**2.5**	**50**

Values in red color indicate exceedance to FSSAI Standards.

Table 2.5.8: Heavy Metal Concentration in Edible and Non-Edible Portion of Floral Species during Winter: Phuljhar Village

Sr. No.	Item	Metal Concentration (mg/kg)											
		As	Ba	Cd	Co	Cr	Cu	Fe	Hg	Mn	Ni	Pb	Zn
	Edible Portion												
A.	**Vegetables**												
1.	Brinjal	0.1	5	BDL	BDL	2.0	13	72	0.021	9	BDL	0.2	28
2.	Lakra	0.5	12.2	0.9	BDL	1.9	13	165	0.183	46	1.01	2.9	17
3.	Lauki	0.1	6.7	BDL	BDL	3.7	11	72	0.107	16	1.5	0.3	21
4.	Tomato	0.2	0.8	BDL	BDL	2.0	8	59	0.025	5	0.07	0.01	17
B.	**Fruits**												
5.	Amrud	0.07	1.9	0.2	BDL	0.7	10	41	0.045	7	0.4	0.8	6
6.	Zizipus	2.04	3.4	0.1	BDL	0.7	35	30	0.101	9	0.3	0.9	9
	Non-Edible Portion (Biomass)												
A.	**Vegetables**												
1.	Brinjal	1.0	29.9	BDL	0.15	4.5	20	1141	0.046	43	1.8	1.1	46
2.	Kathal	0.5	19	0.09	BDL	0.5	7	286	0.076	36	0.4	0.5	8
3.	Lakra (Stem)	1.1	16.4	0.1	BDL	0.7	29	106	0.354	14	0.3	0.1	10
4.	Lauki	1.05	18.6	BDL	0.29	2.9	15	1389	0.127	43	2.8	1.5	26
5.	Pumpkin	0.4	28.1	BDL	BDL	2.2	18	561	0.095	27	3.0	0.2	27
6.	Sem	0.5	29.5	BDL	BDL	1.8	7	701	0.042	40	0.8	0.6	12
7.	Tomato	0.6	15.8	0.1	0.01	2.3	12	808	0.107	33	0.8	0.6	21
B.	**Fruits**												
8.	Amrud	0.4	14	0.04	BDL	1.3	22	626	0.07	29	1.1	2.0	21
9.	Mango	1.2	19.8	0	BDL	0.5	5	548	0.114	109	1.4	0.6	7
10.	Zizipus	6.5	14.3	0.8	0.14	1.1	55	508	0.222	24	0.6	1.2	11
C.	**Trees**												
11.	Neem	0.3	17.8	BDL	BDL	2.7	12	585	0.107	28	1	0.5	15
D.	**Cereal Crops**												
12.	Arhar	0.8	14.8	0.1	BDL	1.5	9	787	0.032	65	1.6	1.7	18
E.	**Weed**												
13.	Ban Tulsi	3.0	20.2	0.2	0.14	2.1	25	440	0.087	25	1.5	0.5	21
14.	Castor	0.4	20.3	BDL	BDL	2.8	28	466	0.086	39	1.6	0.2	32
15.	Sessile joy weed	0.5	19.3	BDL	0.04	1.3	7	568	0.047	43	0.8	0.3	14
FSSAI 2011		**1.1**	**-**	**1.5**	**-**	**-**	**30**	**-**	**1**	**-**	**1.5**	**2.5**	**50**

Values in red color indicate exceedance to FSSAI Standards.

Table 2.5.9: Heavy Metal Concentration in Edible and Non-Edible Portion of Floral Species during Winter: Naudhiya Village

Sr. No.	Item	Metal Concentration (mg/kg)											
		As	Ba	Cd	Co	Cr	Cu	Fe	Hg	Mn	Ni	Pb	Zn
	Edible Portion												
A.	**Vegetables**												
1.	Brinjal	0.18	12	0.45	0.84	1.3	14	113	0.057	16	BDL	BDL	26
2.	Sem	BDL	7.8	0.02	BDL	2.4	13	96	0.081	27	1.0	0.1	27
B.	**Fruits**												
3.	Amrud	0.04	2.3	0.03	0.12	1.1	9	30	0.032	7	0.3	BDL	14
4.	Lemon	0.01	9.3	BDL	0.06	0.7	5	26	0.032	4	0.5	BDL	9
5.	Zizipus	BDL	12.4	BDL	0.02	2.0	8	54	0.036	22	0.6	BDL	21
C.	**Cereal Crops**												
6.	Arhar	0.1	5.7	BDL	0.19	1.9	8	352	0.035	19	1.7	0.4	23
	Non-Edible Portion (Biomass)												
A.	**Vegetables**												
1.	Brinjal	0.7	40	0.43	1.58	1.9	23	3015	0.12	74	3.6	1.4	38
2.	Sem	0.3	24.1	0.12	0.44	2.1	10	923	0.14	41	1.8	0.8	26
3.	Tomato	BDL	94.8	0.1	0.29	2.7	20	1702	0.121	62	1.5	0.7	22
B.	**Fruits**												
4.	Amrud	0.1	21.3	0.01	0.29	1.3	11	263	0.061	43	0.5	BDL	17
5.	Lemon	0.2	71.6	BDL	0.28	1.0	11	489	0.071	27	1.6	0.5	12
6.	Papaya	0.6	30.6	0.1	0.42	2.1	8	1017	0.067	31	1.3	0.5	25
7.	Zizipus	BDL	42.6	BDL	0.14	2.4	11	368	0.095	66	0.9	BDL	24
C.	**Trees**												
8.	Neem	0.2	32.8	0.04	0.22	3.4	7	528	0.06	36	1.1	0.3	38
D.	**Cereal Crops**												
9.	Arhar	0.5	26	0.1	0.84	2.1	11	2401	0.065	72	2.5	1.8	25
E.	**Weed**												
10.	Sessile joy weed	BDL	18.8	BDL	0.27	2.7	12	373	0.067	31	0.9	0.03	16
FSSAI 2011		**1.1**	**-**	**1.5**	**-**	**-**	**30**	**-**	**1**	**-**	**1.5**	**2.5**	**50**

Values in red color indicate exceedance to FSSAI Standards.

Table 2.5.10: Heavy Metal Concentration in Edible and Non-Edible Portion of Floral Species during Winter: Mahadhiya Village

Sr. No.	Item	Metal Concentration (mg/kg)											
		As	Ba	Cd	Co	Cr	Cu	Fe	Hg	Mn	Ni	Pb	Zn
	Edible Portion												
A.	**Vegetables**												
1.	Lakra	0.1	16.2	0.08	BDL	1.7	21	101	0.093	28	1.1	0.7	17
2.	Sem	0.1	6.2	0.04	0.08	2.1	20	193	0.065	26	1.1	BDL	25
B.	**Fruits**												
3.	Zizipus	0.04	5.5	0.01	BDL	1.9	23	74	0.087	9	0.8	1.4	19
	Non-Edible Portion (Biomass)												
A.	**Vegetables**												
1.	Kathal	0.3	37	0.03	0.1	0.1	6	358	0.096	18	0.5	BDL	1
2.	Lakra(Stem)	0.2	14.4	0.03	BDL	0.8	56	108	0.091	9	0.5	0.9	8
3.	Potato	0.6	53.1	0.2	0.8	1.9	17	1081	0.123	75	1.8	0.5	22
4.	Sem	0.3	32.7	0.1	0.5	1.4	28	1570	0.098	55	1.6	0.7	16
B.	**Fruits**												
5.	Amrud	0.2	34.1	0.07	0.26	1.0	17	655	0.064	25	1.3	0.6	11
6.	Mango	0.2	26.9	0.05	BDL	1.2	2	451	0.082	59	0.6	0.3	12
7.	Papaya	0.5	49.4	0.1	0.7	1.9	16	2063	0.103	48	2.3	0.9	22
8.	Zizipus	0.2	32.2	0.06	BDL	2.0	17	1104	0.106	37	1.07	1.7	20
C.	**Trees**												
9.	Neem	0.5	47.7	0.2	0.5	2.4	9	200	0.083	41	1.6	2.5	25
D.	**Cereal Crops**												
10.	Arhar	0.4	25.1	0.2	0.7	1.8	15	2352	0.108	75	2.9	1.5	20
E.	**Weed**												
11.	Castor	0.5	32.6	0.2	0.6	1.4	12	357	0.096	64	2.8	0.4	16
12.	Sessile joy weed	0.2	21.7	0.1	0.2	1.5	9	583	0.079	41	0.9	0.9	18
FSSAI 2011		**1.1**	**-**	**1.5**	**-**	**-**	**30**	**-**	**1**	**-**	**1.5**	**2.5**	**50**

Values in red color indicate exceedance to FSSAI Standards.

Table 2.5.11: Heavy Metal Concentration in Edible and Non-Edible Portion of Floral Species during Winter: Gorbi Village

Sr. No.	Item	Metal Concentration (mg/kg)											
		As	Ba	Cd	Co	Cr	Cu	Fe	Hg	Mn	Ni	Pb	Zn
	Edible Portion												
A.	**Vegetables**												
1.	Karonda	BDL	32.9	BDL	0.4	1.6	6	37	0.044	32	4.6	0.2	21
2.	Lakra	BDL	22.8	1	0.1	2.8	21	144	0.036	22	1.8	0.5	22
3.	Sem	BDL	12.2	BDL	0.03	2.0	5	43	0.036	15	1.9	BDL	21
B.	**Fruits**												
4.	Amrud	BDL	2.2	BDL	0.05	0.2	6	27	0.028	6	0.4	BDL	1
C.	**Cereal Crop**												
5.	Arhar	BDL	16.4	BDL	0.2	2.0	11	178	0.051	17	2.6	0.4	18
	Non-Edible Portion (Biomass)												
A.	**Vegetables**												
1.	Karonda	BDL	22.5	1	0.1	1.9	7	294	0.051	15	0.7	0.7	17
2.	Lakra Stem	BDL	18.7	0.2	0.2	2.4	57	90	0.061	7	0.9	0.2	32
3.	Potato	BDL	45.3	BDL	0.4	2.7	14	591	0.049	35	0.9	BDL	25
4.	Sarson	BDL	36.5	BDL	0.3	3.8	13	541	0.052	30	0.9	BDL	38
5.	Sem	BDL	43.2	BDL	0.1	0.8	4	250	0.065	21	1.8	0.2	11
6.	Turaii	BDL	2.6	0.8	0.01	1.0	3	73	0.058	7	0.4	0.03	14
B.	**Fruits**												
7.	Amrud	BDL	24.7	BDL	0.2	0.8	9	323	0.043	33	1.4	BDL	7
8.	Mango	BDL	53.3	BDL	0.07	1.0	5	211	0.092	119	1.7	BDL	9
C.	**Cereal Crop**												
9.	Arhar	1.5	43.4	BDL	0.7	2.0	11	1540	0.075	52	2.7	3.7	17
D.	**Weed**												
10.	Ban Tulsi	0.6	26.5	BDL	0.2	2.9	23	374	0.092	27	0.4	0.6	23
11.	Sessile joy weed	0.02	38.5	BDL	0.3	1.9	5	197	0.093	44	1.1	0.3	16
FSSAI 2011		**1.1**	**-**	**1.5**	**-**	**-**	**30**	**-**	**1**	**-**	**1.5**	**2.5**	**50**

Values in red color indicate exceedance to FSSAI Standards.

Table 2.5.12: Heavy Metal Concentration in Edible and Non-Edible Portion of Floral Species during Winter: Thurua Village

Sr. No.	Item	Metal Concentration (mg/kg)											
		As	Ba	Cd	Co	Cr	Cu	Fe	Hg	Mn	Ni	Pb	Zn
	Edible Portion												
A.	**Vegetables**												
1.	Brinjal	0.4	7	0.15	BDL	2.0	13	104	0.023	21	0.5	BDL	20
2.	Tomato	0.2	2	0.1	BDL	0.3	11	109	0.078	12	0.5	0.5	29
B.	**Cereal Crop**												
3	Arhar (Pod)	0.09	18	0.06	BDL	0.3	13	322	0.03	23	2.3	0.2	24
	Non-Edible Portion (Biomass)												
A.	**Vegetables**												
1.	Brinjal	1.3	25	0.17	BDL	2.4	16	754	0.05	36	0.9	0.7	22
2.	Kathal	0.2	19	0.02	BDL	1.0	5	338	0.061	24	0.4	0.7	10
3.	Potato	0.5	69	0.2	0.54	2.8	28	1403	0.06	53	2.0	0.8	28
4.	Sem	0.2	8	0.04	BDL	2.5	23	566	0.045	31	2.3	0.8	24
5.	Tomato	0.8	55	0.4	1.06	3.1	17	1975	0.11	103	3.6	2.0	32
B.	**Fruits**												
6.	Amrud	0.3	30	0.1	BDL	1.0	11	625	0.066	35	1.7	0.3	19
7.	Papaya	0.4	31	0.1	0.31	1.5	9	1123	0.049	48	1.4	0.7	18
8.	Zizipus	0.1	22	0.1	BDL	1.8	30	428	0.068	64	0.8	0.2	20
C.	**Trees**												
9.	Neem	0.3	25	0.1	BDL	1.7	7	992	0.034	31	0.9	0.9	17
D.	**Cereal Crop**												
10.	Arhar	0.4	39	0.09	BDL	1.7	19	1222	0.053	83	1.6	1.2	17
E.	**Weed**												
11.	Sessile joy weed	0.17	19.7	0.24	BDL	2.2	11	330	0.082	35	0.6	0.1	22
FSSAI 2011		**1.1**	**-**	**1.5**	**-**	**-**	**30**	**-**	**1**	**-**	**1.5**	**2.5**	**50**

Values in red color indicate exceedance to FSSAI Standards.

Table 2.5.13: Heavy Metal Concentration in Edible and Non-Edible Portion of Floral Species during Winter: Karaila Village

Sr. No.	Item	Metal Concentration (mg/kg)											
		As	Ba	Cd	Co	Cr	Cu	Fe	Hg	Mn	Ni	Pb	Zn
	Edible Portion												
A.	**Vegetables**												
1.	Brinjal	BDL	2.8	0.2	BDL	3.9	21	67	0.051	27	0.2	BDL	40
2.	Lakra	BDL	10.5	0.05	BDL	2.6	21	174	0.109	24	0.6	0.3	36
3.	Sem	0.08	2.1	BDL	BDL	2.6	6	72	0.041	20	1.4	0.07	28
4.	Tomato	BDL	2.2	0.05	BDL	2.8	12	73	0.029	20	0.3	0.2	28
B.	**Fruit**												
5.	Zizipus	BDL	4.6	0.01	BDL	1.2	14	33	0.067	14	0.7	0.6	13
C.	**Cereal Crop**												
6.	Arhar (Pod)	BDL	6	0.02	BDL	2.6	10	245	0.055	25	1	0.2	26
D.	**Weed**												
7.	Caster	0.09	4.4	BDL	BDL	2.2	6	47	0.039	16	0.8	0.03	24
	Non-Edible Portion (Biomass)												
A.	**Vegetables**												
1.	Brinjal	0.3	41.6	0.2	BDL	4.9	23	885	0.067	47	1.03	0.6	53
2.	Lakra	BDL	7.6	0.03	BDL	1.7	21	55	0.101	9	0.4	0.1	17
3.	Potato	BDL	24.4	0.1	0.4	3.4	17	815	0.055	45	0.8	0.0	34
4.	Sem	0.4	30.2	0.04	BDL	1.7	9	836	0.041	64	1.4	0.8	19
5.	Tomato	0.9	68.7	0.3	1	4.1	17	1859	0.211	120	2.2	1.3	43
B.	**Fruits**												
6.	Mango	BDL	18.4	0	BDL	0.5	3	125	0.074	63	0.4	0.1	6
7.	Zizipus	0.01	25.7	0.04	BDL	1.9	17	274	0.076	60	1.2	0.8	20
C.	**Trees**												
8.	Neem	0.2	21.6	0.09	BDL	2.0	5	228	0.043	35	0.5	0.5	21
D.	**Cereal Crops**												
9.	Arhar	0.4	16.9	0.04	BDL	1.9	12	755	0.061	68	1.7	0.9	21
E.	**Weed**												
10.	Caster	0.2	34.4	BDL	BDL	3.0	8	234	0.071	95	1.01	0.2	33
11.	Sessile joy weed	0.4	21.1	0.1	BDL	1.6	6	836	0.048	42	1.1	0.6	19
FSSAI 2011		**1.1**	**-**	**1.5**	**-**	**-**	**30**	**-**	**1**	**-**	**1.5**	**2.5**	**50**

Values in red color indicate exceedance to FSSAI Standards.

Table 2.5.14: Heavy Metal Concentration in Edible and Non-Edible Portion of Floral Species during Winter: Padri Village

Sr. No.	Item	Metal Concentration (mg/kg)											
		As	Ba	Cd	Co	Cr	Cu	Fe	Hg	Mn	Ni	Pb	Zn
	Edible Portion												
A.	**Vegetables**												
1.	Brinjal	0.5	7.5	BDL	0.13	2.6	10	90	0.057	18	0.9	BDL	28
2.	Tomato	0.8	4.8	BDL	0.02	1.8	12	70	0.066	13	0.2	0.9	13
B.	**Fruits**												
3.	Zizipus	1.0	7	BDL	0.07	2.1	17	51	0.057	12	0.2	0.4	15
C.	**Cereal Crop**												
4.	Arhar	0.2	7.4	0.02	0.11	2.4	6	281	0.032	22	1.3	3.7	19
	Non-Edible Portion (Biomass)												
A.	**Vegetables**												
1.	Brinjal	0.8	50.5	1.6	0.33	3.3	26	1305	0.099	36	2.0	8.8	32
2.	Lauki	0.6	39.1	0.4	0.54	3.6	8	1736	0.102	62	3.4	0.9	30
3.	Potato	0.8	37.4	0.4	0.45	2.7	14	1295	0.101	39	1.8	10.1	21
4.	Sem	0.2	20.4	BDL	0.23	1.8	16	506	0.077	23	1.9	BDL	15
5.	Tomato	1	67.9	0.3	0.38	1.9	26	1110	0.077	96	0.9	1.4	17
B.	**Fruits**												
6.	Amrud	0.2	28.9	BDL	0.13	1.2	13	341	0.066	24	0.7	BDL	15
7.	Mango	0	22.5	BDL	0.07	0.6	4	346	0.08	71	1.1	BDL	6
8.	Zizipus	2.3	19.3	BDL	0.12	2.3	22	424	0.095	29	1	1.7	12
C.	**Trees**												
9.	Neem	1.7	35	BDL	0.15	1.6	6	790	0.054	34	1	1.1	24
D.	**Cereal Crop**												
10.	Arhar	0.4	15	0.08	0.24	1.7	13	1030	0.031	43	0.9	4.1	23
E.	**Weed**												
11.	Sessile joy weed	0.7	18.8	0.5	BDL	1.3	8	955	0.067	33	1	1.6	18
FSSAI 2011		**1.1**	**-**	**1.5**	**-**	**-**	**30**	**-**	**1**	**-**	**1.5**	**2.5**	**50**

Values in red color indicate exceedance to FSSAI Standards.

Table 2.5.15: Heavy Metal Concentration in Edible and Non-Edible Portion of Floral Species during Winter: Bastali Abad Village

Sr. No.	Item	Metal Concentration (mg/kg)											
		As	Ba	Cd	Co	Cr	Cu	Fe	Hg	Mn	Ni	Pb	Zn
	Edible Portion												
A.	**Vegetables**												
1.	Brinjal	0.2	21.2	0.2	BDL	3.5	18	74	0.053	16	1.5	BDL	35
	Non-Edible Portion (Biomass)												
A.	**Vegetables**												
1.	Brinjal	0.6	49.7	0.3	BDL	4.6	25	3011	0.086	65	3.8	1.4	49
2.	Lauki	0.5	46.9	0.2	1.28	4.1	24	2031	0.045	62	4.3	1.5	42
3.	Pumpkin	0.3	31.3	0.06	0.41	3.3	13	2172	0.041	29	3.4	0.5	33
4.	Sem	0.3	19.7	0.1	0.46	3.0	19	1411	0.04	35	2.5	0.5	30
5.	Tomato	1.0	68.2	0.9	2.36	4.6	32	2067	0.065	128	5.3	2.4	53
B.	**Fruits**												
6.	Mango	0.3	24.6	0.03	BDL	1.0	5	1052	0.03	65	1	0.7	10
7.	Zizipus	0.2	21.2	0.07	BDL	1.7	50	1051	0.066	63	1.4	0.5	17
C.	**Cereal Crops**												
8.	Arhar	0.4	24.9	0.1	0.9	2.3	27	2581	0.051	100	3.3	1.5	23
D.	**Weed**												
9.	Sessile joy weed	0.1	21.1	0.1	BDL	2.7	7	667	0.035	38	1.8	0.5	27
FSSAI 2011		**1.1**	**-**	**1.5**	**-**	**-**	**30**	**-**	**1**	**-**	**1.5**	**2.5**	**50**

Values in red color indicate exceedance to FSSAI Standards.

Table 2.5.16: Heavy Metal Concentration in Edible and Non-Edible Portion of Floral Species during Winter: Kathas Village

Sr. No.	Item	Metal Concentration (mg/kg)											
		As	Ba	Cd	Co	Cr	Cu	Fe	Hg	Mn	Ni	Pb	Zn
	Edible Portion												
A.	**Vegetables**												
1.	Brinjal	0.2	21.4	0.06	BDL	2.0	15	53	0.038	24	0.4	0.1	31
2.	Lakra	0.1	27	0.1	0.11	1.9	14	116	0.05	24	0.6	0.5	20
3.	Sem	0.1	8.4	BDL	BDL	2.4	20	144	0.047	30	1.1	0.2	24
4.	Tomato	0.2	9.4	0.04	BDL	1.7	9	69	0.051	14	1	0.3	18
B.	**Fruits**												
5.	Amrud	0	3.9	0.04	BDL	0.9	8	14	0.03	5	0.2	0.02	9
6.	Ziziphus	0.01	15.7	0.02	BDL	0.9	6	16	0.038	8	0.6	0.1	9
C.	**Cereal Crop**												
7.	Arhar	0	23.1	0.03	BDL	1.3	6	169	0.033	29	1	0.3	13
	Non-Edible Portion (Biomass)												
A.	**Vegetables**												
1.	Brinjal	0.4	51.2	0.09	0.45	3.1	21	746	0.071	48	1.3	0.8	33
2.	Kathal	0.1	39.5	0.1	BDL	1.3	5	116	0.06	62	0.5	0.1	15
3.	Lakra	0.1	36.3	0.05	0.18	1.0	42	83	0.049	24	0.4	0.4	10
4.	Lauki	0.2	46.5	0.1	0.33	3.1	13	493	0.047	40	1.8	0.8	31
5.	Potato	0.6	57.2	0.3	1	4.7	29	1289	0.051	92	2.1	1.5	46
6.	Sem	0.2	35.7	0.1	BDL	1.5	21	634	0.055	82	0.9	0.8	17
7.	Tomato	0.6	49.1	0.1	BDL	1.8	16	820	0.053	52	1.4	0.9	28
B.	**Fruits**												
8.	Amrud	0.1	41.3	0	BDL	1.0	11	222	0.04	28	0.8	0.2	11
9.	Ziziphus	0.1	43.9	0.1	BDL	1.9	11	220	0.057	71	1.2	0.3	21
C.	**Cereal Crop**												
10.	Arhar	0.2	50.2	0.1	0.43	2.0	11	689	0.077	110	1.4	0.9	21
D.	**Weed**												
11.	Ban Tulsi	0.2	10.2	0.06	BDL	2.9	14	337	0.065	24	1.2	1.0	29
12.	Castor	0.2	52.3	0.1	BDL	2.8	11	278	0.078	102	1.1	0.3	30
13.	Sessile joy weed	0.3	37	0.1	BDL	2.3	7	404	0.043	43	0.6	0.5	24
FSSAI 2011		**1.1**	**-**	**1.5**	**-**	**-**	**30**	**-**	**1**	**-**	**1.5**	**2.5**	**50**

Values in red color indicate exceedance to FSSAI Standards.

Table 2.5.17: Heavy Metal Concentration in Edible and Non-Edible Portion of Floral Species during Winter: Parsohar Village

Sr. No.	Item	Metal Concentration (mg/kg)											
		As	Ba	Cd	Co	Cr	Cu	Fe	Hg	Mn	Ni	Pb	Zn
	Edible Portion												
A.	**Vegetables**												
1.	Brinjal	0.1	4.1	0.06	BDL	1.5	14	100	0.045	16	0.3	BDL	14
2.	Lakra	0.08	12	0.2	BDL	3.9	33	79	0.069	64	2.8	0.3	32
3.	Tomato	0.06	5.3	0.1	BDL	1.6	15	80	0.103	15	0.5	BDL	13
B.	**Fruit**												
4.	Amrud	BDL	3.5	0.4	BDL	0.5	6	29	0.031	6	0.2	BDL	4
5.	Zizipus	0	6	0.01	BDL	1.1	10	53	0.051	8	0.5	BDL	10
C.	**Cereal Crop**												
6.	Arhar	0.1	6.8	BDL	BDL	2.6	9	176	0.066	19	1.9	0.9	23
	Non-Edible Portion (Biomass)												
A.	**Vegetables**												
1.	Brinjal	1.3	25.7	0.1	0.56	2.1	16	1551	0.079	39	1.1	1.2	18
2.	Kathal	0.2	41.1	0.03	BDL	1.6	6	99	0.073	30	0.6	0.3	14
3.	Lakra	0.3	16.5	0.05	BDL	2.8	21	47	0.055	38	1.9	0.5	19
4.	Potato	0.7	25.7	0.2	1.18	1.6	18	922	0.039	73	1.2	0.6	13
5.	Tomato	1	110.7	0.6	0.84	4.4	31	1562	0.112	108	1.6	1.4	39
B.	**Fruits**												
6.	Amrud	0.2	35.3	0.02	BDL	1.4	12	280	0.055	47	1.1	0.6	11
7.	Mango	0.3	51.3	0.09	BDL	1.1	5	690	0.1	148	0.7	0.6	9
8.	Zizipus	0.2	25.9	0.09	BDL	1.3	31	428	0.068	31	0.6	BDL	10
C.	**Tree**												
9.	Neem	0.1	25.9	0.07	BDL	1.3	8	109	0.104	19	0.3	0.2	11
D.	**Cereal Crop**												
10.	Arhar	0.4	16.4	0.03	BDL	1.5	11	674	0.078	42	1.3	1.4	14
E.	**Weed**												
11.	Castor	0.1	11.6	BDL	BDL	3.5	10	197	0.077	56	1.7	0.02	29
12.	Sessile joy weed	0.4	15.1	0.1	BDL	1.5	10	519	0.056	28	0.4	0.5	13
FSSAI 2011		**1.1**	**-**	**1.5**	**-**	**-**	**30**	**-**	**1**	**-**	**1.5**	**2.5**	**50**

Values in red color indicate exceedance to FSSAI Standards.

Table 2.5.18: Heavy Metal Concentration in Edible and Non-Edible Portion of Floral Species during Winter: Khirwa Village

Sr. No.	Item	Metal Concentration (mg/kg)											
		As	Ba	Cd	Co	Cr	Cu	Fe	Hg	Mn	Ni	Pb	Zn
	Edible Portion												
A.	**Vegetables**												
1.	Brinjal	0.2	4.9	0.02	BDL	3.0	18	69	0.033	19	0.8	0.1	29
2.	Lauki	0.2	5.2	0.02	BDL	3.1	13	74	0.04	19	2.7	0.3	30
3.	Sem	0	9.7	0.01	BDL	2.0	11	62	0.036	24	1.4	0.02	19
4.	Tomato	0.2	3.5	0.04	BDL	1.9	14	101	0.045	15	0.8	0.3	19
B.	**Fruit**												
5.	Zizipus	0.1	3.8	BDL	BDL	1.2	7	29	0.031	13	0.4	0.3	11
C.	**Cereal Crop**												
6.	Arhar (Pod)	0.1	4.5	0.04	BDL	2.3	11	344	0.03	29	2.5	0.3	23
	Non-Edible Portion (Biomass)												
A.	**Vegetables**												
1.	Brinjal	0.9	40.4	0.16	0.74	4.0	20	3292	0.034	67	2.8	1.4	40
2.	Lauki	0.6	38.3	0.1	0.55	2.2	12	1917	0.055	46	2.3	1.4	22
3.	Potato	0.4	37.5	0.1	0.66	3.2	19	878	0.049	42	1.2	0.6	31
4.	Sem	0.2	44.3	0	BDL	1.6	13	762	0.045	96	1.2	0.7	15
5.	Tomato	0.5	67.8	0.2	0.63	2.7	22	1336	0.089	65	1.8	0.9	27
B.	**Fruit**												
6.	Mango	0.1	15.6	0.1	BDL	1.4	4	121	0.064	82	0.3	0.4	14
7.	Zizipus	0.3	12.2	0	BDL	1.5	11	426	0.079	33	0.8	0.8	14
C.	**Cereal Crop**												
8.	Arhar	0.4	17	0.1	BDL	1.7	17	1515	0.064	92	1.7	1.2	18
D.	**Weed**												
9.	Ban Tulsi	0.2	13.9	0.1	BDL	2.1	10	454	0.06	26	1	1.2	21
10.	Caster	0.2	14.9	0	BDL	3.6	11	385	0.049	41	2.3	0.2	35
11.	Sessile joy weed	0.3	21.5	0.1	BDL	1.9	8	531	0.033	60	0.7	0.5	19
FSSAI 2011		**1.1**	**-**	**1.5**	**-**	**-**	**30**	**-**	**1**	**-**	**1.5**	**2.5**	**50**

Values in red color indicate exceedance to FSSAI Standards.

Table 2.5.19: Heavy Metal Concentration in Edible and Non-Edible Portion of Floral Species during Winter: Dadar Village

Sr. No.	Item	Metal Concentration (mg/kg)											
		As	Ba	Cd	Co	Cr	Cu	Fe	Hg	Mn	Ni	Pb	Zn
	Edible Portion												
A.	**Vegetables**												
1.	Brinjal	0.1	5.9	0.09	BDL	2.3	19	99	0.039	12	0.5	0.3	23
2.	Lakra	0.1	26.4	0.04	BDL	1.3	14	288	0.05	28	0.8	0.3	15
3.	Lauki	0.08	2.2	0.06	BDL	3.7	11	104	0.068	24	1.3	0.03	36
4.	Tomato	0.1	2.1	0.07	BDL	1.4	8	66	0.107	8	0.1	0.2	13
B.	**Fruit**												
5.	Zizipus	BDL	7.7	0.04	BDL	0.3	6	35	0.118	15	0.2	BDL	4
C.	**Cereal Crop**												
6.	Arhar (Pod)	0.06	8.4	0.01	BDL	1.3	6	253	0.03	24	1.8	0.2	14
	Non-Edible Portion (Biomass)												
A.	**Vegetables**												
1.	Brinjal		31.8	0.1	BDL	3.0	31	972	0.076	40	1.5		33
2.	Kathal	0.1	18.9	0.1	BDL	0.7	6	280	0.084	23	0.3	0.1	7
3.	Lakra	0.1	20.6	0	BDL	1.3	16	61	0.045	11	1	0.2	15
4.	Lauki	0.1	13.9	0.1	BDL	3.3	23	522	0.115	34	1.5	0.3	33
5.	Tomato	0.4	47	0.2	BDL	2.3	15	978	0.173	45	1.7	0.7	24
B.	**Fruits**												
6.	Amrud	0.2	28	0.1	BDL	1.5	12	257	0.059	47	1.2	0.4	15
7.	Mango	0.1	31.4	0	BDL	1.2	16	916	0.06	44	0.3	0.4	13
8.	Zizipus	0.1	24.6	0.1	BDL	1.7	10	368	0.129	45	0.5	0.2	8
C.	**Cereal Crop**												
9.	Arhar	0.4	24.3	0.1	0.38	1.9	8	1161	0.064	73	2.8	1.2	21
D.	**Weed**												
10.	Sessile joy weed	2.4	14.7	0.2	0.76	4.0	20	444	0.065	77	3.1	0.5	39
FSSAI 2011		**1.1**	**-**	**1.5**	**-**	**-**	**30**	**-**	**1**	**-**	**1.5**	**2.5**	**50**

Values in red color indicate exceedance to FSSAI Standards.

Table 2.5.20: Heavy Metal Concentration in Edible and Non-Edible Portion of Floral Species during Winter: Singrauli Village

Sr. No.	Item	Metal Concentration (mg/kg)											
		As	Ba	Cd	Co	Cr	Cu	Fe	Hg	Mn	Ni	Pb	Zn
	Edible Portion												
A.	**Vegetables**												
1.	Kathal	BDL	18.9	0.1	BDL	1.2	15	25	0.017	34	0.6	BDL	10
B.	**Fruit**												
2.	Amrud	-	2.8	0.05	BDL	0.6	11	14	0.033	8	0.2	BDL	5
	Non-Edible Portion (Biomass)												
A.	**Vegetables**												
1.	Brinjal	0.9	62.8	0.02	1.47	2.4	16	3341	0.08	78	3.5	BDL	20
2.	Kathal	BDL	28.1	0.1	BDL	3.8	6	270	0.058	68	0.1	0.2	30
3.	Lauki	0.1	14.9	0.01	0.57	3.4	13	463	0.033	50	1.8	BDL	28
4.	Potato	0.6	95.5	0.06	1.54	3.4	12	1831	0.067	99	3.6	BDL	28
5.	Sem	0.2	36.7	0.04	0.39	1.8	9	1295	0.058	87	1.5	BDL	15
6.	Tomato	0.4	42.6	0.2	1.48	2.4	27	1235	0.051	53	1.1	BDL	20
B.	**Fruit**												
7.	Amrud	0.1	28	0.03	BDL	0.9	21	399	0.049	47	0.8	BDL	8
8.	Mango	BDL	63	0.1	BDL	1.0	3	237	0.066	58	0.7	0.4	8
C.	**Tree**												
9.	Neem	BDL	32.5	0.1	BDL	1.8	8	633	0.069	67	0.7	0.6	15
D.	**Weed**												
10.	Castor	0.3	52.8	BDL	0.23	1.0	11	580	0.069	70	0.7	BDL	9
FSSAI 2011		**1.1**	**-**	**1.5**	**-**	**-**	**30**	**-**	**1**	**-**	**1.5**	**2.5**	**50**

Values in red color indicate exceedance to FSSAI Standards.

Table 2.5.21: Heavy Metal Concentration in Edible and Non-Edible Portion of Floral Species during Winter: Baliyari Village (Near Ash Dyke)

Sr. No.	Item	Metal Concentration (mg/kg)											
		As	**Ba**	**Cd**	**Co**	**Cr**	**Cu**	**Fe**	**Hg**	**Mn**	**Ni**	**Pb**	**Zn**
	Edible Portion												
A.	**Vegetables**												
1.	Lakara	0.1	17.8	0.09	BDL	3.0	25	340	0.044	62	2.1	1.5	18
2.	Sem	0.1	5.5	BDL	BDL	3.1	12	60	0.05	25	1.3	0.3	21
3.	Tomato	0.2	2	0.01	BDL	1.8	11	94	0.034	13	0.3	0.1	17
	Non-Edible Portion (Biomass)												
A.	**Vegetables**												
1.	Lakara	0.2	20.1	0.1	BDL	1.7	30	179	0.08	33	2.0	0.3	16
2.	Potato	0.4	55	0.2	BDL	4.2	24	640	0.047	34	1.2	3.4	41
3.	Sem	0.2	21.1	0.05	BDL	1.7	11	575	0.056	36	0.8	0.5	18
4.	Tomato	0.4	37.6	0.1	BDL	2.1	16	472	0.04	39	0.6	0.8	21
B.	**Tree**												
5.	Neem	0.2	22.7	0.03	BDL	1.7	8	190	0.034	25	0.3	0.3	16
C.	**Cereal Crop**												
6.	Arhar	0.2	17.6	0.06	BDL	2.2	13	785	0.078	45	1.4	1.1	21
FSSAI 2011		**1.1**	**-**	**1.5**	**-**	**-**	**30**	**-**	**1**	**-**	**1.5**	**2.5**	**50**

Values in red color indicate exceedance to FSSAI Standards.

Table 2.5.22: Heavy Metal Concentration in Edible and Non-Edible Portion of Floral Species during Summer: Phuljhar Village

Sr. No.	Item	Metal Concentration (mg/kg)											
		As	Ba	Cd	Co	Cr	Cu	Fe	Hg	Mn	Ni	Pb	Zn
	Edible Portion												
A.	**Cereal Crops**												
1.	Arhar	BDL	2.6	0	0	1.8	7	18	0.021	8	1.6	0.2	17
2.	Wheat	BDL	4.5	0	0	2.01	3	121	0.038	27	BDL	0.2	19
B.	**Weed**												
3.	Castor	0.06	4.7	0	0	1.4	5	14	0.031	6	BDL	1.1	14
	Non-Edible Portion (Biomass)												
A.	**Vegetables**												
1.	Kathal	0.0	16.8	0	0	0.9	8	123	0.056	49	BDL	2.1	9
2.	Sem	0.1	26.9	0	0	1.5	6	407	0.065	44	0.2	2.2	15
B.	**Fruits**												
3.	Amurd	0.1	8	0	0	0.9	5	304	0.025	17	0	2.1	9
4.	Mango	0.1	9.4	0	0	3.5	4	270	0.032	29	BDL	0.6	4
C.	**Cereal Crops**												
5.	Arhar	0.1	5.1	1	0.36	1.0	4	95	0.034	49	0.3	0.6	9
6.	Wheat	0.3	37.3	0	0	0.5	4	491	0.1	27	0.3	0.6	3
D.	**Weed**												
7.	Castor	1.5	31.2	0	0	2.3	6	335	0.051	36	0.09	1.5	23
FSSAI 2011		**1.1**	**-**	**1.5**	**-**	**-**	**30**	**-**	**1**	**-**	**1.5**	**2.5**	**50**

Values in red color indicate exceedance to FSSAI Standards.

Table 2.5.23: Heavy Metal Concentration in Edible and Non-Edible Portion of Floral Species during Summer: Naudhiya Village

Sr. No.	Item	Metal Concentration (mg/kg)											
		As	Ba	Cd	Co	Cr	Cu	Fe	Hg	Mn	Ni	Pb	Zn
	Edible Portion												
A.	**Vegetables**												
1.	Brinjal	0.7	3.1	0.04	0.1	3.2	20	71	0.031	11	0.3	0.9	32
2.	Matar	0.4	3.3	0.02	0.2	2.9	5	51	0.014	7	1.1	0.5	28
3.	Mirch	0.2	2.6	0.02	0.1	1.8	8	73	0.146	9	0.5	0.1	18
4.	Onion Bulb	0.2	4.8	0.05	0.2	2.3	4	121	0.037	8	0.6	0.1	22
5.	Sarson	0.1	7.04	0.03	0.08	5.3	4	97	0.034	25	0.8	0.5	52
6.	Tomato	0.5	3.2	0.04	0.1	1.6	7	92	0.058	10	0.3	1.2	18
B.	**Fruits**												
7.	Lemon	1.0	10.2	0.03	0.3	0.7	2	103	0.08	5	BDL	0.6	7
C.	**Cereal Crops**												
8.	Arhar	0.2	3.2	0.01	0.1	2.1	9	40	0.018	10	3.2	0.6	22
9.	Chana	0.1	3.03	0.01	0.2	3.3	8	93	0.049	18	0.7	0.6	33
10.	Wheat	0.1	6.9	BDL	0.1	3.0	4	92	0.035	26	0.4	0.6	29
	Non-Edible Portion (Biomass)												
A.	**Vegetables**												
1.	Brinjal	1.6	41.8	0	0	2.9	12	1027	0.052	26	0.4	1.3	28
2.	Corriander	0.3	8.1	0.2	0.1	1.7	7	440	0.075	30	1.2	0.4	17
3.	Matar	0.2	23.7	0.06	0.3	1.4	4	412	0.056	23	1.3	1	14
4.	Mirch	0.2	11.9	0.1	0.3	2.6	8	296	0.054	22	1.2	0.3	26
5.	Onion	0.4	20.03	0.07	0.4	0.3	3	395	0.088	19	0.7	0.4	3
6.	Sarson	0.3	21.6	0.2	0.07	1.0	3	74	0.071	5	0.6	0.9	10
7.	Tomato	0.6	46.2	0.2	0.4	1.9	7	1107	0.095	46	1.5	1.3	16
B.	**Fruits**												
8.	Amrud	0.2	26.7	0.06	0.3	1.8	10	554	0.056	59	1.6	0.6	19
9.	Lemon	0.2	24.3	BDL	BDL	2.3	6	378	0.046	14	1.4	4.2	22
C.	**Trees**												
10.	Neem	0.2	12.5	0.04	0.04	1.5	6	260	0.073	15	0.6	0.4	15
D.	**Cereal Crops**												
11.	Arhar	0.3	14.7	0.1	0.5	2.1	8	128	0.048	42	2.6	1.7	21
12.	Chana	0.1	23.3	0.04	0.1	0.8	4	254	0.028	14	0.5	0.7	8
13.	Wheat	0.1	40.8	0.06	0.2	0.6	3	382	0.031	25	0.8	0.9	6
E.	**Weed**												
14.	Castor	2.0	18.08	0.1	0.2	3.1	5	548	0.037	44	1.3	0.8	31
15.	Sessile joy Weed	1.0	10.05	0.3	0.3	2.1	4	456	0.805	37	1.0	0.6	21
FSSAI 2011		**1.1**	**-**	**1.5**	**-**	**-**	**30**	**-**	**1**	**-**	**1.5**	**2.5**	**50**

Values in red color indicate exceedance to FSSAI Standards.

Table 2.5.24: Heavy Metal Concentration in Edible and Non-Edible Portion of Floral Species during Summer: Mahadhiya Village

Sr. No.	Item	Metal Concentration (mg/kg)											
		As	Ba	Cd	Co	Cr	Cu	Fe	Hg	Mn	Ni	Pb	Zn
	Edible Portion												
A.	**Vegetables**												
1.	Mirch	0.2	8.4	0.05	0.1	2.2	13	186	0.087	11	0.9	1.0	22
2.	Onion bulb	0.2	6.2	0	0.2	2.1	7	60	0.741	9	0.4	0.6	21
B.	**Fruits**												
3.	Bel	4.5	1.5	0	BDL	0.6	4	22	0.119	BDL	4.0	0.5	6
4.	Mango	0.1	3.01	0.04	BDL	1.7	5	49	0.178	3	0.7	0.9	12
C.	**Cereal Crops**												
5.	Wheat	0.2	10.24	0.06	BDL	2.8	6	177	0.053	23	1.0	1.3	28
	Non-Edible Portion (Biomass)												
A.	**Vegetables**												
1.	Kathal	0.4	11.1	0.07	0.3	2.1	12	485	0.066	39	1.8	1.3	21
2.	Mirch	0.4	25.7	0	0.3	3.5	10	410	0.078	31	1.06	1.7	36
3.	Sem	0.4	41.3	0.04	0.2	2.4	12	579	0.173	72	1.4	2.0	25
B.	**Fruits**												
4.	Mango	0.2	17.6	0.11	0.1	1.1	9	528	0.104	35	1.4	0.9	17
C.	**Trees**												
5.	Neem	0.5	13.5	0.01	0.2	2.2	8	495	0.07	20	1.09	1.4	23
D.	**Cereal Crops**												
6.	Wheat	0.3	33.2	0	0.06	1.6	6	305	0.149	24	1.1	1.6	16
FSSAI 2011		**1.1**	**-**	**1.5**	**-**	**-**	**30**	**-**	**1**	**-**	**1.5**	**2.5**	**50**

Values in red color indicate exceedance to FSSAI Standards.

Table 2.5.25: Heavy Metal Concentration in Edible and Non-Edible Portion of Floral Species during Summer:Gorbi Village

Sr. No.	Item	Metal Concentration (mg/kg)											
		As	Ba	Cd	Co	Cr	Cu	Fe	Hg	Mn	Ni	Pb	Zn
	Edible Portion												
A.	**Vegetables**												
1.	Onion Bulb	0.2	2.5	0	0	2.4	4	10	0.045	6	BDL	0.6	23
2.	Sarson	0.09	2.6	0	0	1.0	3	107	0.015	23	BDL	0.2	10
3.	Tomato	0.3	0.1	0	0	0.8	4	48	0.346	7	BDL	0.4	14
B.	**Fruits**												
4.	Bel	0.1	1.4	0	0	1.5	4	BDL	0.032	1	1.9	0.4	14
5.	Mango	0.09	2.5	0	0	2.1	3	19	0.069	4	0.1	1.2	15
C.	**Cereal Crops**												
6.	Arhar	0.07	1.6	0	0	0.8	5	29	0.038	6	0.8	0.1	14
7.	Wheat	0.07	2.9	0	0	1.4	2	115	0.044	28	BDL	0.3	13
	Non-Edible Portion (Biomass)												
A.	**Vegetables**												
1.	Amarnthus	0.6	54.5	0	0	1.2	5	417	0.044	36	0.05	0.2	11
2.	Bhindi	0.7	56.6	0	0	1.2	5	442	0.051	40	0	0.1	10
3.	Onion	0.7	30.7	0	0	1.9	1	191	0.123	9	BDL	BDL	18
4.	Sarson	0.5	42.01	0	0	0.6	3	98	0.14	5	BDL	0.6	6
5.	Tomato	1.1	81.01	0	0	1.2	5	834	0.221	29	0.7	0.7	21
B.	**Fruits**												
6.	Amrud	1.0	53.3	0	0	3.5	6	489	0.015	41	BDL	0.4	34
7.	Bel	0.6	55	0	0	0.4	6	323	0.03	14	1.1	0.5	3
8.	Karonda	0.3	16.8	0	0	3.2	5	258	0.051	11	BDL	0.5	31
9.	Mango	0.5	17.03	0	0	1.1	6	250	0.074	28	0.8	0.6	11
C.	**Cereal Crops**												
10.	Arhar	0.3	12.2	0	0	1.1	6	375	0.055	11	0.05	1	10
11.	Wheat	0.5	28	0	0	0.9	4	1005	0.123	42	0.8	1.2	8
D.	**Weed**												
12.	Sessile joy Weed	0.6	20.04	0	0	3.5	3	565	0.04	32	0.6	0.8	35
FSSAI 2011		**1.1**	**-**	**1.5**	**-**	**-**	**30**	**-**	**1**	**-**	**1.5**	**2.5**	**50**

Values in red color indicate exceedance to FSSAI Standards.

Table 2.5.26: Heavy Metal Concentration in Edible and Non-Edible Portion of Floral Species during Summer: Thurua Village

Sr. No.	Item	Metal Concentration (mg/kg)											
		As	Ba	Cd	Co	Cr	Cu	Fe	Hg	Mn	Ni	Pb	Zn
	Edible Portion												
A.	**Vegetables**												
1.	Kathal	0.06	3	0.04	BDL	1.5	5	51	0.107	5	0.4	0.3	16
2.	Onion bulb	0.2	4.8	0.06	BDL	2.2	6	41	1.08	12	0.4	0.6	22
	Non-Edible Portion (Biomass)												
A.	**Vegetables**												
1.	Kathal	0.09	6.7	0.3	1.12	1.4	14	245	0.62	23	0.03	1.1	14
2.	Onion	0.4	27.3	1.0	0.08	1.7	44	444	5.44	12	0.6	12.3	18
B.	**Fruits**												
3.	Amrud	0.3	12.6	0.02	0.57	2.1	15	367	0.08	28	0.9	3.5	21
FSSAI 2011		**1.1**	**-**	**1.5**	**-**	**-**	**30**	**-**	**1**	**-**	**1.5**	**2.5**	**50**

Values in red color indicate exceedance to FSSAI Standards.

Table 2.5.27: Heavy Metal Concentration in Edible and Non-Edible Portion of Floral Species during Summer: Karaila Village

Sr. No.	Item	Metal Concentration (mg/kg)											
		As	**Ba**	**Cd**	**Co**	**Cr**	**Cu**	**Fe**	**Hg**	**Mn**	**Ni**	**Pb**	**Zn**
	Edible Portion												
A.	**Vegetables**												
1.	Bhindi	BDL	9.9	0.05	0.2	2.6	9	119	0.039	17	0.6	BDL	26
2.	Onion	BDL	3.06	0.01	0.01	1.1	4	38	0.058	6	0.2	0.1	15
3.	Sarson	0.09	7.5	0.02	0.2	4.0	4	128	0.031	29	0.6	0.2	38
4.	Tomato	BDL	2.6	0.07	0.2	1.0	7	113	0.135	10	0.5	0.2	10
B.	**Fruits**												
5.	Mango	BDL	6.8	0.04	BDL	0.8	6	39	0.076	75	1.1	0.3	6
C.	**Cereal Crops**												
6.	Arhar	0.07	1.4	0.01	0.2	2.6	8	40	0.083	7	4.1	0.3	26
7.	Wheat	0.07	4.5	0.01	0.09	2.7	4	54	0.051	29	0.5	0.7	26
	Non-Edible Portion (Biomass)												
A.	**Vegetables**												
1.	Bhindi	0.9	41.6	0.3	1.4	4.6	12	1177	0.028	67	2.9	1.6	47
2.	Onion	0.5	17.2	0.08	0.4	0.5	4	553	0.339	21	0.8	0.4	11
3.	Sarson	0.1	10.8	0.04	0.1	0.5	4	104	0.158	9	0.5	1.1	5
4.	Tomato	0.7	61.9	0.2	0.6	1.9	16	943	0.071	41	2.0	0.7	20
B.	**Fruits**												
5.	Mango	2.1	29.0	0.09	0.1	1.5	5	242	0.049	372	0.8	0.7	15
C.	**Cereal Crops**												
6.	Arhar	0.1	3.9	0.2	0.8	0.7	6	96	0.506	13	1.7	0.9	11
7.	Wheat	0.3	35.4	0.05	0.02	0.9	4	500	0.099	43	0.9	1.4	8
FSSAI 2011		**1.1**	**-**	**1.5**	**-**	**-**	**30**	**-**	**1**	**-**	**1.5**	**2.5**	**50**

Values in red color indicate exceedance to FSSAI Standards.

Table 2.5.28: Heavy Metal Concentration in Edible and Non-Edible Portion of Floral Species during Summer: Padri Village

Sr. No.	Item	Metal Concentration (mg/kg)											
		As	**Ba**	**Cd**	**Co**	**Cr**	**Cu**	**Fe**	**Hg**	**Mn**	**Ni**	**Pb**	**Zn**
	Edible Portion												
A.	**Vegetables**												
1.	Kathal	0.4	10.59	0	0	1.0	14	142	0.065	8	0.04	0.7	7
B.	**Fruits**												
2.	Lemon	0.3	8.97	0	0	BDL	3	47	0.046	2	BDL	1.4	1
3.	Mango	BDL	7.85	0	0	1.3	4	27	0.041	12	0.6	1.5	13
	Non-Edible Portion (Biomass)												
A.	**Vegetables**												
1.	Kathal	0.4	32.4	0	0	0.4	14	370	0.044	20	0.02	2.5	5
B.	**Fruits**												
2.	Amurd	0.7	10.7	0	0	0.6	10	431	0.026	14	BDL	0.9	6
3.	Lemon	0.3	49.2	0	0	0.1	7	489	0.035	15	0.5	2	5
4.	Mango	0.3	34.8	0	0	0.9	17	168	0.061	44	0.5	2.1	9
C.	**Trees**												
5.	Neem	0.8	15.9	0	0	0.8	9	506	0.058	18	0.2	0.7	8
FSSAI 2011		**1.1**	**-**	**1.5**	**-**	**-**	**30**	**-**	**1**	**-**	**1.5**	**2.5**	**50**

Values in red color indicate exceedance to FSSAI Standards.

Table 2.5.29: Heavy Metal Concentration in Edible and Non-Edible Portion of Floral Species during Summer: Bastali Abad Village

Sr. No.	Item	Metal Concentration (mg/kg)											
		As	**Ba**	**Cd**	**Co**	**Cr**	**Cu**	**Fe**	**Hg**	**Mn**	**Ni**	**Pb**	**Zn**
	Edible Portion												
A.	**Vegetables**												
1.	Bhindi	0.2	10	BDL	BDL	3.1	11	148	0.149	20	0.7	0.1	30
2.	Brinjal	0.3	2.3	BDL	BDL	2.1	16	85	0.196	13	0.6	BDL	20
3.	Onion	0.2	6.8	BDL	BDL	1.9	8	97	0.153	12	0.6	4.9	18
4.	Sarson	0.2	8.9	BDL	0.39	2.8	5	244	0.033	57	1.2	0.5	27
5.	Tomato	0.4	3.07	0.03	1.4	2.4	12.8	108	0.153	14	0.9	3.3	23
B.	**Cereal Crops**												
6.	Arhar	0.01	2.7	BDL	BDL	1.3	9	35	0.046	9	2.2	0.1	12
7.	Wheat	0.07	8.5	BDL	BDL	2.0	4	60	0.019	29	0.6	0.3	29
	Non-Edible Portion (Biomass)												
A.	**Vegetables**												
1.	Bhindi	0.8	43.2	0	0.7	4.4	18	1917	0.137	59	2.3	3.2	45
2.	Brinjal	1.0	13.3	0.04	0.3	1.7	14	497	0.79	34	0.9	1.7	17
3.	Onion	0.4	24	1.1	0.06	1.2	57	530	3.602	25	0.9	15.1	12
4.	Sarson	0.3	16.6	BDL	BDL	0.5	4	179	0.057	10	0.4	0.8	5
5.	Tomato	1.5	63.3	0.5	1.8	3.2	35	1960	0.445	75	5.4	4.9	34
B.	**Fruits**												
6.	Mango	0.2	22.9	BDL	BDL	1.3	16	421	0.134	34	1.6	3.7	13
C.	**Cereal Crops**												
7.	Arhar	0.3	18.3	BDL	BDL	1.2	11	373	0.186	45	0.9	5.0	12
8.	Wheat	0.5	59.2	BDL	BDL	1.4	4	367	0.138	25	1.03	0.8	13
FSSAI 2011		**1.1**	**-**	**1.5**	**-**	**-**	**30**	**-**	**1**	**-**	**1.5**	**2.5**	**50**

Values in red color indicate exceedance to FSSAI Standards.

Table 2.5.30: Heavy Metal Concentration in Edible and Non-Edible Portion of Floral Species during Summer: Kathas Village

Sr. No.	Item	Metal Concentration (mg/kg)											
		As	Ba	Cd	Co	Cr	Cu	Fe	Hg	Mn	Ni	Pb	Zn
	Edible Portion												
A.	**Fruits**												
1.	Amrud	BDL	4.9	0.09	0.2	1.2	8	55	0.029	17	0.7	0.2	12
	Non-Edible Portion (Biomass)												
A.	**Fruits**												
1.	Amrud	BDL	16.3	0.04	0.07	0.4	8	137	0.038	20	0.6	0.4	4
2.	Lemon	BDL	89.2	0.07	BDL	0.04	5	173	0.049	12	0.8	0.3	1
B.	**Trees**												
3.	Neem	BDL	29.04	0.1	0.11	1.3	6	258	0.056	21	1.2	1.4	14
FSSAI 2011		**1.1**	**-**	**1.5**	**-**	**-**	**30**	**-**	**1**	**-**	**1.5**	**2.5**	**50**

Values in red color indicate exceedance to FSSAI Standards.

Table 2.5.31: Heavy Metal Concentration in Edible and Non-Edible Portion of Floral Species during Summer: Parsohar Village

Sr. No.	Item	Metal Concentration (mg/kg)											
		As	Ba	Cd	Co	Cr	Cu	Fe	Hg	Mn	Ni	Pb	Zn
	Edible Portion												
A.	**Vegetables**												
1.	Bhindi	0.2	13.8	0.2	0.1	4.5	13	129	0.14	16	0.3	0.03	45
2.	Kathal	0.2	15.6	0.04	0.03	2.4	7	69	0.066	16	0.7	0.1	24
3.	Onion bulb	0.1	5.8	0.06	0.03	1.3	4	21	0.027	9	0.5	0.1	13
4.	Sarson	0.1	6.3	0.03	0.4	2.9	4	155	0.025	62	0.4	0.3	30
5.	Tomato	0.1	2.5	0.1	0.1	2.5	12	163	0.130	15	0.5	0.3	24
B.	**Fruits**												
6.	Amrud	0.0	5.0	0.05	0.1	1.0	5	23	0.04	9	0.5	BDL	10
7.	Mango	0.1	9.9	0.06	BDL	0.9	4	18	0.134	17	1.03	0.2	9
C.	**Cereal Crops**												
8.	Wheat	1.1	7.5	0.04	0.4	2.9	6	65.2	0.03	42	0.5	0.7	28
	Non-Edible Portion (Biomass)												
A.	**Vegetables**												
1.	Bhindi	1.4	32.7	0.3	0.67	5.2	12	1209	0.086	53	1.2	1.2	53
2.	Kathal	0.6	32.9	0.1	BDL	1.6	17	333	0.04	37	0.8	0.4	16
3.	Onion	0.3	35.2	0.07	0.06	0.1	9	195	0.513	15	0.5	0.5	1
4.	Sarson	0.2	12.5	0.2	0.5	1.5	4	86	0.144	46	0.1	0.9	15
5.	Tomato	4.1	25.1	0.5	1.29	2.9	17	1579	0.048	106	3.0	3.1	29
B.	**Fruits**												
6.	Mango	0.2	54.7	0.08	BDL	1.2	8	253	0.033	136	1.1	0.8	12
C.	**Cereal Crops**												
7.	Wheat	0.4	43.4	0.09	0.11	0.8	4	216	0.027	58	0.7	0.8	8
FSSAI 2011		**1.1**	**-**	**1.5**	**-**	**-**	**30**	**-**	**1**	**-**	**1.5**	**2.5**	**50**

Values in red color indicate exceedance to FSSAI Standards.

Table 2.5.32: Heavy Metal Concentration in Edible and Non-Edible Portion of Floral Species during Summer: Khirwa Village

Sr. No.	Item	Metal Concentration (mg/kg)											
		As	Ba	Cd	Co	Cr	Cu	Fe	Hg	Mn	Ni	Pb	Zn
	Edible Portion												
A.	**Vegetables**												
1.	Brinjal	0.3	4.3	0.05	0.2	3.1	29	212	0.144	19	0.8	3.5	30
2.	Bhindi	0.3	13	0.09	0.2	3.9	10	237	0.178	16	0.7	0.02	39
3.	Kathal	0.08	7.5	0.05	0.03	3.2	18	65	0.071	12	2.4	0.8	32
4.	Onion Bulb	0.1	3.9	0.02	0.1	2.3	6	115	0.093	14	0.7	0.2	23
5.	Tomato	0.2	1.8	0.07	0.08	1.0	12	60	0.068	10	0.4	1.2	25
B.	**Fruits**												
6.	Mango	0.07	5.1	BDL	0.04	2.2	9	39	0.232	35	2.05	1.8	15
	Non-Edible Portion (Biomass)												
A.	**Vegetables**												
1.	Bhindi	0.4	26.5	0.2	0.2	4.9	25	525	0.18	35	1.0	4.1	51
2.	Brinjal	0.6	23.1	0.2	1.1	1.5	37	1223	0.164	40	1.2	8.3	16
3.	Kathal	0.2	33.5	0.04	0.1	1.3	25	174	0.075	49	0.7	5.8	14
4.	Onion	0.5	13.6	0.0	0.2	0.8	8	477	0.314	13	0.9	1.7	8
5.	Tomato	0.4	39.9	0.2	0.4	2.6	18	936	0.086	31	1.6	2.7	11
B.	**Fruits**												
6.	Amrud	0.3	13.1	0.03	0.2	1.2	21	320	0.054	36	1.3	6.2	12
7.	Mango	0.4	52.9	0.05	0.05	1.5	17	398	0.08	289	1.7	3.9	22
FSSAI 2011		**1.1**	**-**	**1.5**	**-**	**-**	**30**	**-**	**1**	**-**	**1.5**	**2.5**	**50**

Values in red color indicate exceedance to FSSAI Standards.

Table 2.5.33: Heavy Metal Concentration in Edible and Non-Edible Portion of Floral Species during Summer: Dadar Village

Sr. No.	Item	Metal Concentration (mg/kg)											
		As	**Ba**	**Cd**	**Co**	**Cr**	**Cu**	**Fe**	**Hg**	**Mn**	**Ni**	**Pb**	**Zn**
	Edible Portion												
A.	**Vegetables**												
1.	Bhindi	0.3	20.1	0.03	0.3	2.5	3	169	0.084	30	0.9	0.9	25
2.	Kathal	0.07	7.5	0.07	0.03	3.1	12	71	0.072	35	0.6	0.2	30
3.	Mirch	0.2	8.6	BDL	0.1	2.6	15	141	0.112	20	0.8	0.5	25
4.	Tomato	0.2	2.4	BDL	0.1	1.7	17	138	0.122	17	0.9	1.2	26
B.	**Fruits**												
5.	Mango	0.2	10.2	BDL	BDL	0.9	13	67	0.107	11	1.8	1.4	9
	Non-Edible Portion (Biomass)												
A.	**Vegetables**												
1.	Bhindi	0.5	51.9	0.1	0.2	2.7	11	651	0.12	91	2.6	3.4	28
2.	Brinjal	0.6	23.7	0.03	0.3	2.2	12	703	0.497	36	0.9	0.9	22
3.	Kathal	0.3	23.5	0.4	0.1	1.1	15	251	0.04	37	0.3	2.3	11
4.	Mirch	0.3	20.7	0.01	0.2	3.3	14	459	0.061	30	0.8	0.6	32
5.	Tomato	0.7	66.0	0.2	0.6	2.7	20	1499	0.029	65	1.9	3.5	17
B.	**Fruits**												
6.	Mango	0.3	81.1	0.08	BDL	1.6	26	387	0.065	114	1.5	0.6	36
C.	**Trees**												
7.	Neem	0.2	25.6	BDL	0.1	2.0	5	464	0.04	40	0.8	0.5	20
FSSAI 2011		**1.1**	**-**	**1.5**	**-**	**-**	**30**	**-**	**1**	**-**	**1.5**	**2.5**	**50**

Values in red color indicate exceedance to FSSAI Standards.

Table 2.5.34: Heavy Metal Concentration in Edible and Non-Edible Portion of Floral Species during Summer: Singrauli Village

Sr. No.	Item	Metal Concentration (mg/kg)											
		As	Ba	Cd	Co	Cr	Cu	Fe	Hg	Mn	Ni	Pb	Zn
	Edible Portion												
A.	**Vegetables**												
1.	Tomato	0.07	2.7	0.03	0.1	2.0	10	91	0.186	15	0.2	1.4	20
	Non-Edible Portion (Biomass)												
A.	**Vegetables**												
1.	Kathal	0.1	33.4	0.04	0.2	1.8	9	338	0.052	23	1.3	1.8	18
2.	Tomato	0.7	66.1	0.1	1.09	3.7	15	1935	0.061	99	2.8	5.0	39
B.	**Fruits**												
3.	Amrud	0.1	27.0	0.1	0.3	1.5	12	324	0.036	50	1.4	1.4	15
4.	Mango	6.7	20.5	0.2	0.1	0.7	12	304	0.034	135	1.0	6.0	8
C.	**Trees**												
5.	Neem	0.4	24.3	0.06	0.5	2.9	13	789	0.064	81	1.3	4.3	29
FSSAI 2011		**1.1**	**-**	**1.5**	**-**	**-**	**30**	**-**	**1**	**-**	**1.5**	**2.5**	**50**

Values in red color indicate exceedance to FSSAI Standards.

Table 2.5.35: Heavy Metal Concentration in Edible and Non-Edible Portion of Vegetables & Fruits and Biomass during Summer: Baliyari Village (Near Ash Dyke)

Sr. No.	Item	Metal Concentration (mg/kg)											
		As	Ba	Cd	Co	Cr	Cu	Fe	Hg	Mn	Ni	Pb	Zn
	Edible Portion												
A.	**Vegetables**												
1.	Bhindi	0.2	16.2	0.06	0.1	2.5	9	169	0.056	10	0.8	0.2	25
2.	Brinjal	0.2	7.3	0.04	0.02	2.7	18	125	0.091	12	0.5	0.8	27
3.	Onion Bulb	0.08	2.2	0.01	0	2.1	5	24	0.104	6	0.3	0.7	20
4.	Tomato	0.2	1.7	0.08	0.03	2.3	13	68	0.040	5	0.4	2.6	31
	Non-Edible Portion (Biomass)												
A.	**Weeds**												
1.	Bhindi	0.5	38.3	0.09	0.2	3.8	12	370	0.104	38	0.6	1.6	39
2.	Brinjal	0.5	33.6	0.08	0.3	2.2	15	648	0.053	43	0.8	1.6	22
3.	Onion	0.2	10.6	BDL	0.06	1.5	23	148	0.223	13	0.4	6.6	15
4.	Tomato	0.7	37.3	0.2	0.4	3.1	24	1017	0.049	30	1.4	4.9	24
B.	**Trees**												
5.	Neem	0.2	39.1	0.03	BDL	1.7	6	199	0.03	58	0.6	1.5	17
FSSAI 2011		**1.1**	**-**	**1.5**	**-**	**-**	**30**	**-**	**1**	**-**	**1.5**	**2.5**	**50**

Table 2.5.36: Village-wise Status of Exceedance of Heavy Metals in Edible and Non Edible Portion (biomass) of Floral Species during Winter Season

Sr. No.	Village	Total No. of Samples	No. of Samples Exceeding FSSAI Limits	Floral Species and Metals of Concern (with values in mg/kg)
A.	**Edible Portion**			
1.	Phuljhar	6	2	Zizipus: **As** (2.04) & **Cu** (35); Lakra: **Pb** (2.9)
2.	Naudhaiya	6	1	Arhar: **Ni** (1.7)
3.	Mahadhaiya	3	0	--
4.	Gorbi	5	4	Karonda (4.6), Lakra (1.8), Sem (1.9) & Arhar (2.6): **Ni**
5.	Thurua	3	1	Arhar: **Ni** (2.3)
6.	Karaila	7	0	--
7.	Padri	4	1	Arhar: **Pb** (3.7)
8.	Bastali Abad	1	0	--
9.	Kathas	7	0	--
10.	Parsohar	6	2	Lakra: **Cu** (33) & **Ni** (2.8); Arhar: **Ni** (1.9)
11.	Khirwa	6	2	Lauki (2.7) & Arhar (2.5): **Ni**
12.	Dadar	6	1	Arhar: **Ni** (1.8)
13.	Singrauli	2	0	--
14.	Baliyari	3	1	Lakra: **Ni** (2.1)
	Total	**65**	**15**	
B.	**Non-Edible Portion (Biomass)**			
1.	Phuljhar	15	**8**	Mango (1.2), Ban Tulsi (3): **As**; Zizipus: **As** (6.5) & **Cu** (55); Brinjal (1.8), Lauki (2.8), Pumpkin (3), Arhar(1.6), Castor (1.6): **Ni**
2.	Naudhaiya	10	4	Arhar (2.5), Sem (1.8), Lemon (1.6), Brinjal (3.6): **Ni**
3.	Mahadhaiya	12	7	Lakra: **Cu** (56); Arhar (2.9), Neem (1.6), Papaya (2.3), Castor (2.8), Sem (1.6), Potato (1.8): **Ni**
4.	Gorbi	11	4	Arhar:**As**(1.5), **Ni** (2.7), **Pb** (3.7); Lakra: **Cu** (57) Mango (1.7) & Sem (1.8): **Ni**
5.	Thurua	11	6	Brinjal: **As** (1.3); Potato (2), Sem (2.3), Tomato (3.6), Amrud (1.7), Arhar(1.6): **Ni**
6.	Karaila	11	3	Brinjal: **Zn**(53); Tomato (2.2) & Arhar (1.7): **Ni**
7.	Padri	11	7	Zizipus (2.3) & Neem (1.7): **As**; Brinjal: **Cd** (3.6)**, Ni** (2)**, Pb** (8.8); Potato: **Ni** (1.8)**, Pb** (10.1); Lauki (3.4) & Sem (1.9): **Ni**; Arhar: **Pb** (4.1)
8.	Bastali	9	7	Tomato: **Cu** (32), **Ni** (5.3) & **Zn** (53)**;**

	Abad			Brinjal (3.8), Lauki (4.3), Pumpkin (3.4), Sem (2.5), Arhar (3.3), Sessile joy weed (1.8): **Ni**
9.	Kathas	13	3	Lakra: **Cu** (42); Lauki (1.8) & Potato (2.1): **Ni**
10.	Parsohar	12	5	Brinjal: **As** (1.3); Tomato: **Cu** (31)**, Ni** (1.6) Lakra (1.9) & Castor (1.7): **Ni**; Zizipus: **Cu** (31)
11.	Khirwa	11	5	Brinjal (2.8), Lauki (2.3), Tomato (1.8), Arhar (1.7), Castor (2.3): **Ni**
12.	Dadar	10	4	Brinjal: **Cu** (31); Tomato (1.7) & Arhar (2.8): **Ni** Sessile Joy weed: **As** (2.4) & **Ni** (3.1)
13.	Singrauli	10	3	Brinjal (3.5), Lauki (1.8), Potato (3.6): **Ni**
14.	Baliyari	6	2	Lakara: **Ni** (2); Potato: **Pb** (3.4)
	Total	**152**	**68**	

Table 2.5.37: Village-wise Status of Exceedance of Heavy Metals in Edible and Non Edible Portion (biomass) of Floral Species during Summer Season

Sr. No.	Village	Total No. of Samples	No. of Samples Exceeding FSSAI Limits	Floral Species & Metals of Concern
A.	**Edible Portion**			
1.	Phuljhar	3	1	Arhar: **Ni** (1.6)
2.	Naudhaiya	10	2	Sarson: **Zn** (52); Arhar: **Ni** (3.2)
3.	Mahadhaiya	5	1	Bel: **As** (4.5) & **Ni** (4)
4.	Gorbi	7	1	Bel: **Ni** (1.9)
5.	Thurua	2	1	Onion: **Hg** (1.08)
6.	Karaila	7	1	Arhar: **Ni** (4.1)
7.	Padri	3	0	--
8.	Bastali Abad	7	3	Onion (4.9) & Tomato (3.3): **Pb**; Arhar: **Ni** (2.2)
9.	Kathas	1	0	--
10.	Parsohar	8	0	--
11.	Khirwa	6	3	Kathal (2.4) & Mango (2.05): **Ni**; Brinjal: **Pb** (3.5)
12.	Dadar	5	1	Mango: **Ni** (1.8)
13.	Singrauli	1	0	--
14.	Baliyari (A.D)	4	1	Tomato: **Pb** (2.6)
	Total	**69**	**15**	
B.	**Non-Edible Portion (Biomass)**			
1.	Phuljhar	7	1	Castor: **As** (1.5)
2.	Naudhaiya	15	5	Brinjal (1.6) & Castor (2): **As** Amrud (1.6) & Arhar (2.6): **Ni**; Lemon: **Pb** (4.2)
3.	Mahadhaiya	6	1	Kathal: **Ni** (1.8)
4.	Gorbi	12	0	--
5.	Thurua	3	2	Onion: **Cu** (44), **Hg** (5.44), **Pb** (12.3); Amrud: **Pb** (3.5)
6.	Karaila	7	4	Bhindi (2.9), Tomato (2) & Arhar (1.7): **Ni**; Mango: **As** (2.1)
7.	Padri	5	0	--
8.	Bastali Abad	8	5	Onion: **Cu** (57) & **Pb** (15.1) Tomato: **As** (1.5), **Cu** (35), **Ni** (5.4) & **Pb** (4.9) Bhindi: **Ni** (2.3), **Pb** (3.2) Mango: **Ni** (1.6), **Pb** (3.7); Arhar: **Pb** (5)
9.	Kathas	3	0	--
10.	Parsohar	7	2	Bhindi: **As** (1.4) & **Zn** (53) Tomato: **As** (4.1), **Ni** (3), **Pb** (3.1)
11.	Khirwa	7	6	Brinjal: **Cu** (37), **Pb** (8.3); Bhindi: **Pb** (4.1), **Zn** (51) Kathal (5.8) & Amrud (6.2): **Pb**

				Tomato: **Ni** (1.6)**, Pb** (2.7) & Mango: **Ni** (1.7)**, Pb** (3.9)
12.	Dadar	7	2	Bhindi: **Ni** (2.6)**, Pb** (3.4) & Tomato: **Ni** (1.9)**, Pb** (3.5)
13.	Singrauli	5	3	Mango: **As** (6.7)**, Pb** (6); Tomato: **Ni** (2.8)**, Pu** (5) Neem: **Pub** (4.3)
14.	Baliyari	5	2	Onion (6.6) & Tomato (4.9): **Pb**
	Total	**97**	**33**	

Note: Different plant species respond differently on uptake of different metals. Bioaccumulation of metals from soil to plant is effected by soil physic-chemical parameters, type & age of plant and bioavailability of metal from soil (Islam et al., 2016, Proshad et al., 2019, Kormoker et al., 2020). Hence a detailed study for 2-3 years is required to conclude the response of different trace metals on different plant species.

2.6 Bio-accumulation of Metals in Floral Species

The bio-accumulation factor (BAF) in a floral species is estimated as the ratio of metal concentration in plant species to the concentration of metal in the same soil where the plant is grown. It is expressed as:

$$BAF = C_{plant}/C_{Soil}$$

Where, C_{plant} is mean concentration (mg/kg) of an element in the plant material (dry weight basis) and C_{soil} is mean concentration (mg/kg) of the same element in the soil (dry weight basis).

The higher values of bio-accumulation factor (BAF) indicate more mobility or availability of a particular metal to the plants. Therefore, high BAF values may put forth the potential health risks to the consumers (Wang et al., 2006). Plants with BAF > 1 are termed as accumulators; plants with BAF = 1 have no influences and plants with BAF < 1 are termed as "excluder" (Radulescu et al., 2013).

Bioaccumulation factor (BAF) was calculated for the edible portion in plants for both the seasons because it is related to human consumption. Bioaccumulation factors were calculated for different vegetables, fruits and cereals for the respective villages wherever samples were available. Bio-accumulation factors for different vegetables, fruits and cereal crops are given in **Tables 2.6.1 and 2.6.2,** respectively for winter and summer season.

The results showed bioaccumulation factor more than one only for Cu & Hg. Rest all other metals showed BAF less than 1, hence they are categorised as “excluders”.

Village-wise list of floral species having BAF between 1-2 and more than 2 is given in **Table 2.6.3**.

2.6.1 Bio-accumulation of Copper (Cu)

Most of the edible portion of plants viz., Brinjal, Lakra, Sem & Ziziphus in winter season, and Brinjal in summer season showed bio-accumulation factor marginally higher than one, and can be categorised as “no/ little influences”. A few species like Brinjal of Bastali Abad, Lakra of Mahadhiya & Baliyari and Ziziphus of Phuljhar and Mahadhiya showed BAF between 2.0 & 2.8, thus can be considered as “metal accumulators”.

2.6.2 Bio-accumulation of Mercury (Hg)

The bio-accumulation factor in edible portion of plants was observed in Brinjal, Lakra, Lauki, Sem, Tomato, Amrud, Ziziphus and Arhar in winter, and Bhindi, Brinjal, Mirch, Onion, Sarson, Tomato and Mango in summer season. It has been observed that lakra of Phuljhar, Mahadhiya & Karaila, Lauki of Phuljhar, Sem of Naudhiya, Tomato of Thurua, Parsohar & Dadar and Ziziphus of Phuljhar, Mahadhiya & Karaila in winter season and Brinjal of Bastali Abad, Mirch of Naudhiya, Onion of Mahadhiya & Thurua, Tomato of Gorbi and Mango of Khirwa in summer season showed BAF more than 2.0, and can be categorised as “metal accumulators”.

Most of the other plants showed BAF = 1 or slightly more than one, and can be considered as “no influences”. Further onion in Mahadhiya and Thurua showed BAF of 7.0 & 9.1 respectively which was higher. However mercury concentration did not exceed the FSSAI standard of 1.0 mg/kg in the edible portion of any plant.

It is to be noted that the purpose of the present study was to assess the metal concentration and thereby accumulation in the edible part of the species so as to generate a baseline data in the plants collected, as available/grown during winter and summer season. Besides vegetable and cereal crops, trees and weeds growing in the villages were also included in the study. As we have different crops/species in different seasons, study on seasonal effect was not possible for similar species.

Table 2.6.1: Bio-accumulation Factor for Edible Portion of Floral Species of Winter Season

Sr. No.	Villages	Bio-accumulation Factor											
		As	Ba	Cd	Co	Cr	Cu	Fe	Hg	Mn	Ni	Pb	Zn
A.	**Brinjal**												
1.	Phuljhar	0.009	0.045	-	-	0.052	1.040	0.002	0.677	0.055	-	0.015	0.875
2.	Naudhaiya	0.049	0.106	0.225	0.323	0.033	1.250	0.003	1.966	0.113	-	-	0.536
3.	Thurua	0.103	0.050	0.075	-	0.045	1.000	0.003	0.836	0.122	0.042	-	0.360
4.	Karaila	-	0.025	0.067	-	0.096	1.448	0.002	1.586	0.109	0.017	-	0.828
5.	Padri	0.097	0.072	-	0.035	0.056	0.806	0.002	0.919	0.095	0.082	-	0.785
6.	Bastali Abad	0.027	0.104	0.100	-	0.064	2.000	0.003	1.683	0.081	0.115	-	0.864
7.	Kathas	0.102	0.083	0.017	-	0.035	0.811	0.002	1.000	0.085	0.025	0.006	0.620
8.	Parsohar	0.024	0.031	0.017	-	0.031	0.483	0.003	1.047	0.068	0.026	-	0.394
9.	Khirwa	0.022	0.042	0.004	-	0.065	1.059	0.002	1.435	0.089	0.052	0.007	0.707
10.	Dadar	0.022	0.057	0.054	-	0.061	0.848	0.003	0.967	0.041	0.040	0.031	0.530
B.	**Lakra**												
1.	Phuljhar	0.045	0.111	0.300	-	0.049	1.040	0.004	5.903	0.284	0.101	0.212	0.531
2.	Mahadhaiya	0.022	0.104	0.080	-	0.050	2.000	0.003	2.818	0.184	0.129	0.074	0.410
3.	Gorbi	-	0.191	0.300	0.032	0.102	1.340	0.003	0.878	0.156	0.208	0.045	0.805
4.	Karaila	-	0.093	0.017	-	0.062	1.448	0.005	3.390	0.097	0.050	0.021	0.745
5.	Kathas	0.051	0.105	0.029	0.016	0.034	0.757	0.004	1.316	0.085	0.038	0.029	0.400
6.	Parsohar	0.019	0.091	0.057	-	0.081	1.138	0.002	1.605	0.273	0.243	0.014	0.901
7.	Dadar	0.022	0.256	0.024	-	0.034	0.625	0.009	1.240	0.096	0.064	0.031	0.346
8.	Baliyari	0.033	0.325	0.082	-	0.101	2.000	0.011	0.957	0.519	0.420	0.167	0.537
C.	**Lauki**												
1.	Phuljhar	0.009	0.061	-	-	0.094	0.880	0.002	3.452	0.099	0.150	0.022	0.656
2.	Khirwa	0.022	0.044	0.004	-	0.068	0.765	0.002	1.739	0.089	0.174	0.021	0.732
3.	Dadar	0.018	0.021	0.036	-	0.096	0.491	0.003	1.687	0.082	0.104	0.003	0.829
D.	**Sem**												
1.	Naudhaiya	-	0.069	0.010	-	0.063	1.161	0.002	2.793	0.190	0.101	0.013	0.557
2.	Mahadhaiya	0.022	0.040	0.040	0.036	0.062	1.905	0.006	1.970	0.171	0.129	-	0.602
3.	Gorbi	-	0.102	-	0.010	0.074	0.319	0.001	0.878	0.106	0.219	-	0.768
4.	Karaila	0.043	0.019	-	-	0.064	0.414	0.002	1.275	0.081	0.117	0.005	0.579
5.	Kathas	0.051	0.033	-	-	0.042	1.081	0.004	1.237	0.106	0.069	0.011	0.480
6.	Khirwa	0.000	0.082	0.002	-	0.044	0.647	0.002	1.565	0.112	0.090	0.001	0.463
7.	Baliyari(A.D)	0.033	0.100	-	-	0.105	0.960	0.002	1.087	0.209	0.260	0.033	0.627
E.	**Tomato**												
1.	Phuljhar	0.018	0.007	-	-	0.051	0.640	0.001	0.806	0.031	0.007	0.001	0.531
2.	Thurua	0.051	0.014	0.050	-	0.066	0.846	0.003	2.836	0.070	0.042	0.029	0.523
3.	Karaila	-	0.019	0.017	-	0.068	0.828	0.002	0.902	0.081	0.025	0.014	0.579
4.	Padri	0.156	0.046	-	0.005	0.039	0.968	0.002	1.065	0.069	0.018	0.084	0.364
5.	Kathas	0.102	0.036	0.011	-	0.030	0.486	0.002	1.342	0.050	0.063	0.017	0.360

6.	Parsohar	0.014	0.040	0.029	-	0.033	0.517	0.002	2.395	0.064	0.043	-	0.366
7.	Khirwa	0.022	0.030	0.008	-	0.042	0.824	0.003	1.957	0.070	0.052	0.021	0.463
8.	Dadar	0.022	0.020	0.042	-	0.035	0.357	0.002	2.654	0.027	0.008	0.021	0.300
9.	Balayari	0.066	0.036	0.009	-	0.060	0.880	0.003	0.739	0.109	0.060	0.011	0.507
F.	**Amrud**												
1.	Phuljhar	0.006	0.017	0.067	-	0.019	0.800	0.001	1.452	0.043	0.040	0.059	0.188
2.	Naudhaiya	0.011	0.020	0.015	0.046	0.028	0.804	0.001	1.103	0.049	0.035	-	0.289
3.	Gorbi	-	0.018	-	0.016	0.008	0.383	0.001	0.683	0.042	0.046	-	0.037
4.	Kathas	0.000	0.015	0.011	-	0.015	0.432	0.000	0.789	0.018	0.013	0.001	0.180
5.	Parsohar	-	0.026	0.114	-	0.010	0.207	0.001	0.721	0.026	0.017	-	0.113
6.	Singrauli	0.000	0.019	0.015	-	0.012	0.846	0.000	0.623	0.028	0.015	-	0.094
G.	**Zizipus**												
1.	Phuljhar	0.185	0.031	0.033	-	0.018	2.800	0.001	3.258	0.055	0.030	0.066	0.281
2.	Naudhaiya	-	0.110	-	0.008	0.052	0.714	0.001	1.241	0.155	0.067	-	0.433
3.	Mahadhaiya	0.009	0.035	0.010	-	0.058	2.190	0.002	2.636	0.059	0.094	0.147	0.458
4.	Karaila	-	0.041	0.003	-	0.030	0.966	0.001	2.084	0.057	0.058	0.041	0.269
5.	Padri	0.195	0.068	-	0.019	0.045	1.371	0.001	0.919	0.064	0.018	0.038	0.421
6	Kathas	0.005	0.061	0.006	-	0.016	0.324	0.000	1.000	0.028	0.038	0.006	0.180
7.	Parsohar	0.000	0.045	0.003	-	0.024	0.345	0.001	1.186	0.034	0.043	-	0.282
8.	Khirwa	0.011	0.032	-	-	0.026	0.412	0.001	1.348	0.061	0.026	0.021	0.268
9.	Dadar	-	0.075	0.024	-	0.009	0.268	0.001	2.927	0.051	0.016	-	0.092
H.	**Arhar**												
1.	Naudhaiya	0.027	0.050	-	0.073	0.048	0.714	0.009	1.207	0.134	0.179	0.050	0.474
2.	Gorbi	-	0.137	-	0.064	0.071	0.702	0.004	1.244	0.120	0.300	0.036	0.659
3.	Thurua	0.023	0.128	0.030	-	0.057	1.000	0.010	1.091	0.134	0.192	0.011	0.432
4.	Karaila	-	0.053	0.007	-	0.062	0.690	0.007	1.711	0.101	0.083	0.014	0.538
5.	Padri	0.039	0.071	0.010	0.029	0.052	0.484	0.007	0.516	0.117	0.118	0.347	0.533
6.	Kathas	0.000	0.090	0.009	-	0.023	0.324	0.005	0.868	0.103	0.063	0.017	0.260
7.	Parsohar	0.024	0.051	-	-	0.054	0.310	0.005	1.535	0.081	0.165	0.041	0.648
8.	Khirwa	0.011	0.038	0.008	-	0.051	0.647	0.009	1.304	0.136	0.161	0.021	0.561
9.	Dadar	0.013	0.082	0.006	-	0.032	0.268	0.008	0.744	0.082	0.144	0.021	0.323

Values in red color indicate metal bio-accumulation.

Table 2.6.2: Bio-accumulation Factor for Edible Portion of Floral Species of Summer Season

Sr. No.	Villages	Bio-accumulation Factor											
		As	Ba	Cd	Co	Cr	Cu	Fe	Hg	Mn	Ni	Pb	Zn
A.	**Bhindi**												
1.	Karaila	-	0.100	0.036	0.017	0.051	0.443	0.004	0.357	0.040	0.028	-	0.441
2.	Bastali Abad	0.014	0.079	-	-	0.053	0.786	0.007	1.840	0.060	0.028	0.010	0.769
3.	Parsohar	0.052	0.120	0.071	0.008	0.083	0.382	0.003	1.972	0.037	0.014	0.001	0.882
4.	Khirwa	0.040	0.182	0.086	0.021	0.078	0.556	0.008	1.633	0.069	0.037	0.002	0.696
5.	Dadar	0.073	0.148	0.013	0.016	0.051	0.106	0.004	0.884	0.053	0.036	0.079	0.439
6.	Baliyari	0.038	0.298	0.043	0.018	0.070	0.643	0.007	0.762	0.048	0.070	0.027	0.641
B.	**Brinjal**												
1.	Naudhaiya	0.264	0.032	0.089	0.016	0.085	1.176	0.003	0.554	0.048	0.019	0.144	0.607
2.	Bastali Abad	0.021	0.018	-	-	0.036	1.143	0.004	2.420	0.039	0.024	-	0.513
3.	Khirwa	0.041	0.060	0.048	0.021	0.062	1.611	0.007	1.321	0.082	0.042	0.269	0.536
4.	Baliyari	0.038	0.134	0.029	0.004	0.076	1.286	0.005	1.238	0.058	0.043	0.107	0.692
C.	**Kathal**												
1.	Thurua	0.005	0.024	0.010	-	0.029	0.278	0.002	0.899	0.014	0.018	0.027	0.281
2.	Padri	0.030	0.102	0.000	0.000	0.018	0.824	0.005	0.765	0.019	0.002	0.064	0.144
3.	Parsohar	0.052	0.136	0.014	0.002	0.044	0.206	0.002	0.930	0.037	0.033	0.004	0.471
4.	Khirwa	0.011	0.105	0.048	0.003	0.064	1.000	0.002	0.651	0.052	0.126	0.062	0.571
5.	Dadar	0.017	0.055	0.029	0.002	0.063	0.424	0.002	0.758	0.061	0.024	0.018	0.526
D.	**Mirch**												
1.	Naudhaiya	0.075	0.027	0.044	0.016	0.048	0.471	0.003	2.607	0.039	0.031	0.016	0.342
2.	Mahadhaiya	0.091	0.074	0.100	0.015	0.056	0.813	0.007	0.829	0.037	0.053	0.125	0.550
3.	Dadar	0.048	0.063	-	0.005	0.053	0.529	0.004	1.179	0.035	0.032	0.044	0.439
E.	**Onion**												
1.	Naudhaiya	0.075	0.049	0.111	0.032	0.061	0.235	0.005	0.661	0.035	0.038	0.016	0.417
2.	Mahadhaiya	0.091	0.055	0.000	0.030	0.054	0.438	0.002	7.057	0.030	0.024	0.075	0.525
3.	Gorbi	0.051	0.028	0.000	0.000	0.088	0.239	0.000	0.317	0.027	-	0.080	0.893
4.	Thurua	0.017	0.038	0.015	-	0.043	0.333	0.002	9.092	0.035	0.018	0.054	0.386
5.	Karaila	-	0.031	0.007	0.001	0.021	0.197	0.001	0.530	0.014	0.009	0.008	0.254
6.	Bastali Abad	0.014	0.054	-	-	0.032	0.571	0.005	1.889	0.036	0.024	0.490	0.462
7.	Parsohar	0.026	0.050	0.021	0.002	0.024	0.118	0.001	0.380	0.021	0.024	0.004	0.255
8.	Khirwa	0.014	0.055	0.019	0.010	0.046	0.333	0.004	0.853	0.060	0.037	0.015	0.411
9.	Baliyari	0.015	0.040	0.007	0.000	0.059	0.357	0.001	1.415	0.029	0.026	0.093	0.513
F.	**Sarson**												
1.	Naudhaiya	0.038	0.073	0.067	0.013	0.140	0.235	0.004	0.607	0.108	0.050	0.080	0.987
2.	Gorbi	0.023	0.030	0.000	0.000	0.037	0.179	0.004	0.106	0.102	-	0.027	0.388
3.	Karaila	0.023	0.076	0.014	0.017	0.078	0.197	0.004	0.284	0.068	0.028	0.016	0.644

4.	Bastali Abad	0.014	0.071	-	0.044	0.047	0.357	0.011	0.407	0.170	0.048	0.05	0.692
5.	Parsohar	0.026	0.055	0.011	0.032	0.054	0.118	0.004	0.352	0.143	0.019	0.012	0.588
G.	**Tomato**												
1.	Naudhaiya	0.189	0.033	0.089	0.016	0.042	0.412	0.004	1.036	0.043	0.019	0.192	0.342
2.	Gorbi	0.076	0.001	0.000	0.000	0.029	0.239	0.002	2.437	0.031	-	0.053	0.544
3.	Karaila	-	0.026	0.050	0.017	0.019	0.344	0.004	1.235	0.023	0.023	0.016	0.169
4.	Bastali Abad	0.028	0.024	0.033	0.159	0.041	0.914	0.005	1.889	0.042	0.036	0.33	0.590
5.	Parsohar	0.026	0.022	0.036	0.008	0.046	0.353	0.004	1.831	0.035	0.024	0.012	0.471
6.	Khirwa	0.027	0.025	0.067	0.008	0.020	0.667	0.002	0.624	0.043	0.021	0.092	0.446
7.	Dadar	0.048	0.018	-	0.005	0.035	0.600	0.004	1.284	0.030	0.036	0.106	0.456
8.	Singrauli	0.008	0.020	0.018	0.009	0.036	0.625	0.003	1.338	0.039	0.008	0.068	0.313
9.	Baliyari	0.038	0.031	0.057	0.005	0.065	0.929	0.003	0.544	0.024	0.035	0.346	0.795
H.	**Mango**												
1.	Mahadhaiya	0.045	0.027	0.080	-	0.044	0.313	0.002	1.695	0.010	0.041	0.112	0.300
2.	Gorbi	0.023	0.028	0.000	0.000	0.077	0.179	0.001	0.486	0.018	0.009	0.160	0.583
3.	Karaila	-	0.069	0.029	-	0.016	0.295	0.001	0.695	0.176	0.052	0.024	0.102
4.	Padri	-	0.075	0.000	0.000	0.023	0.235	0.001	0.482	0.028	0.025	0.136	0.268
5.	Parsohar	0.026	0.086	0.021	-	0.017	0.118	0.000	1.887	0.039	0.049	0.008	0.176
6.	Khirwa	0.009	0.072	-	0.004	0.044	0.500	0.001	2.128	0.150	0.108	0.138	0.268
7.	Dadar	0.048	0.075	-	-	0.018	0.459	0.002	1.126	0.019	0.072	0.124	0.158
I.	**Arhar**												
1.	Phuljhar	-	0.031	0.000	0.000	0.040	0.362	0.001	0.284	0.024	0.073	0.015	0.505
2.	Naudhaiya	0.075	0.033	0.022	0.016	0.056	0.529	0.002	0.321	0.043	0.200	0.096	0.417
3.	Gorbi	0.018	0.018	0.000	0.000	0.029	0.299	0.001	0.268	0.027	0.070	0.013	0.544
4.	Karaila	0.018	0.014	0.007	0.017	0.051	0.393	0.001	0.759	0.016	0.192	0.024	0.441
5.	Bastali Abad	0.001	0.021	-	-	0.022	0.643	0.002	0.568	0.027	0.088	0.010	0.308
J.	**Wheat**												
1.	Phuljhar	-	0.053	0.000	0.000	0.045	0.155	0.004	0.514	0.080	-	0.015	0.564
2.	Naudhaiya	0.038	0.071	-	0.016	0.079	0.235	0.004	0.625	0.113	0.025	0.096	0.550
3.	Mahadhaiya	0.091	0.090	0.120	-	0.072	0.375	0.007	0.505	0.076	0.059	0.163	0.700
4.	Gorbi	0.018	0.033	0.000	0.000	0.051	0.119	0.004	0.310	0.124	-	0.040	0.505
5.	Karaila	0.018	0.045	0.007	0.008	0.053	0.197	0.002	0.466	0.068	0.023	0.057	0.441
6.	Bastali Abad	0.005	0.067	-	-	0.034	0.286	0.003	0.235	0.086	0.024	0.030	0.744
7.	Parsohar	0.287	0.065	0.014	0.032	0.054	0.176	0.002	0.423	0.097	0.024	0.029	0.549

Values in red color indicate metal bio-accumulation.

Table 2.6.3: Summary of Floral Species having Bio-Accumulation Factor more than 1.0 in Edible Portion

Sr. No.	Village	Species and Bio-accumulation Factor for	
		Copper (Cu)	Mercury (Hg)
A.	Winter Season		
1.	Phuljhar	Brinjal (1.04), Lakra (1.04), Zizipus (2.80)	Lauki (3.45), Lakra (5.90), Amrud (1.45), Zizipus (3.26),
2.	Naudhaiya	Brinjal (1.25), Sem (1.16)	Brinjal (1.97), Amrud (1.10), Zizipus (1.24), Arhar (1.21), Sem (2.79)
3.	Mahadhaiya	Sem (1.91), Zizipus (2.19), Lakra (2.00)	Sem (1.97), Lakra (2.82), Zizipus (2.64)
4.	Gorbi	Lakra (1.34)	Arhar (1.24)
5.	Thurua	Brinjal (1.00), Arhar (1.00)	Arhar (1.09), Tomato (2.84)
6.	Karaila	Brinjal (1.45), Lakra (1.45)	Brinjal (1.59), Sem (1.28), Arhar (1.71), Lakra (3.39), Zizipus (2.08)
7.	Padri	Zizipus (1.37)	Tomato (1.07)
8.	Bastali Abad	Brinjal (2.00)	Brinjal (1.68)
9.	Kathas	Sem(1.08)	Brinja l(1.00), Sem (1.24),Tomato (1.34), Zizipus (1.00), Lakra (1.32)
10.	Parsohar	Lakra (1.14)	Brinjal (1.05), Lakra (1.61), Zizipus (1.19), Arhar (1.54), Tomato (2.40)
11.	Khirwa	Brinjal (1.06)	Brinjal (1.44), Lauki (1.74), Sem (1.57), Tomato (1.96), Zizpus (1.35), Arhar (1.30)
12.	Dadar	-	Lauki (1.69), Lakra (1.24), Tomato (2.65), Zizipus (2.93)
13.	Singrauli	-	-
14.	Baliyari	Lakra (2.00)	Sem (1.09)
B.	Summer Season		
1.	Phuljhar	-	-
2.	Naudhaiya	Brinjal (1.18)	Tomato(1.04), Mirch (2.61)
3.	Mahadhaiya	-	Mango(1.70), Onion (7.06)
4.	Gorbi	-	Tomato (2.44)
5.	Thurua	-	Onion (9.09)
6.	Karaila	-	Tomato (1.24)
7.	Padri	-	-
8.	Bastali Abad	Brinjal (1.14)	Bhindi (1.84), Onion (1.89), Tomato (1.89), Brinjal (2.42)
9.	Kathas	-	-
10.	Parsohar	-	Bhindi (1.97), Tomato (1.83), Mango (1.89)
11.	Khirwa	Brinjal (1.61), Kathal (1.00)	Bhindi (1.63), Brinjal (1.32), Mango (2.13)
12.	Dadar	-	Mirch (1.18), Tomato (1.28), Mango (1.13)
13.	Singrauli	-	Tomato (1.34)
14.	Baliyari	Brinjal (1.29)	Brinjal (1.24), Onion (1.42)

2.7 Status of Fluoride in Edible Part of Different Plant Species

Fluoride content was determined in the edible part of the plant samples collected from different villages during winter and summer seasons. Fluoride levels are given in **Tables 2.7.1** and **2.7.2** respectively for winter and summer seasons. In most of the cases, concentration of fluoride in both the seasons was found below the detection limit (BDL). During Winter, Lakra, Sem and Arhar pods showed fluoride concentration ranging between 0.97 mg/kg - 2.2 mg/kg, whereas during Summer all the samples in different villages showed fluoride concentration below detectable limit.

Further, bio-accumulation factor (BAF) for Fluoride was estimated and the values for Lakra (Phuljhar village) and Sem (Naudhiya village) showed slight bioaccumulation with BAF value of 1.44 and 1.55 respectively (**Table 2.7.3**). As the fluoride concentration was found below the detection limit in plants of summer season, hence no bio-accumulation was found in the edible part of different species.

Table 2.7.1: Concentration of Fluoride in Edible Part of different Plants Species collected within the study area during Winter Season

Sr. No.	Plant Species	Villages and Fluoride Conc. (mg/kg)	
A.	**Vegetables**		
1.	Brinjal	Dadar - BDL	Padri - BDL
2.	Karonda	Gorbi - BDL	-
3.	Kathal	Singrauli - BDL	
4.	Lakra	Phuljhar - 2.2	Parsohar -1.6
5.	Lauki	Phuljhar - BDL	Dadar - BDL
6.	Sem	Naudhiya -1.6	Khriwa - 1.89
7.	Tomato	Dadar - BDL	Kairarla - BDL
B.	**Fruits**		
8.	Amrud	Phuljhar - BDL	Parsohar - BDL
9.	Lemon	Naudhiya - BDL	
10.	Zizipus	Phuljhar - BDL	Parsohar - BDL
C.	**Cereal Crops**		
11.	Arhar Pod	Naudhiya - 0.97	Parsohar -1.04
D.	**Weed**		
12.	Castor/ Arand	Kariala - BDL	-

Table 2.7.2: Concentration of Fluoride in Edible Part of different Plants Species collected within the study area during Summer Season

Sr. No.	Plant Species	Villages and Fluoride Conc. (mg/kg)	
A.	**Vegetables**		
1.	Bhindi	Kairala - BDL	Parsohar - BDL
2.	Brinjal	Naudhiya - BDL	Khirwa - BDL
3.	Kathal	Thurua - BDL	Parsohar - BDL
4.	Matar	Naudhiya - BDL	
5.	Mirch	Naudhiya - BDL	Dadar - BDL
6.	Onion Bulb	Naudhiya - BDL	Parsohar - BDL
7.	Sarson	Naudhiya - BDL	Parsohar - BDL
8.	Tomato	Naudhiya - BDL	Parsohar - BDL
B.	**Fruits**		
9.	Amrud	Kathas - BDL	Parsohar - BDL
10.	Bel	Mahadhiya - BDL	Gorbi - BDL
11.	Lemon	Naudhiya - BDL	Padri - BDL
12.	Mango	Mahadhiya - BDL	Parsohar - BDL
C.	**Cereal Crops**		
13.	Arhar grain	Phuljhar - BDL	Kairala - BDL
14.	Chana	Naudhiya - BDL	-
15.	Wheat	Phuljhar - BDL	Parsohar - BDL
D.	**Weed**		
12.	Castor/ Arand	Phuljhar - BDL	-

Table 2.7.3: Bioaccumulation of Fluoride in Edible part in Winter and Summer Seasons

Sr. No.	Plant Species	Villages and Bioaccumulation Factor	
		Winter	**Summer**
1	Lakra	Phuljhar - 1.44; Parsohar - 0.81	Nil for any specie as per Table 2.7.2
2	Sem	Naudhiya - 1.55; Khriwa - 0.90	
3	Arhar pod	Naudhiya - 0.94; Parsohar - 0.52	

2.8 Summary and Recommendations

The chapter deals with the assessment of water quality of mine voids and drinking water in the surrounding villages, soil quality status and status of flora in terms of trees, shrubs, herbs, crops. The focus of the study has been on assessment of metal content in water, soil and different floral species(edible and non-edible portion) in 10 km radius of the region.

Samples of water, soil and floral species were collected from 13 villages, besides the mine void and ash dyke area. The samples were collected during winter and summer seasons, wherein floral samples of seasonal fruits, vegetables and crops were collected.

2.8.1 Water Quality Status

1. In all 19 samples were collected, which included 3 samples from mine voids pond, one sample fom ash dyke pond and 15 samples from hand pumps/dug wells/bore well in different villages, where it is the main souce of water for drinking/irrigation.

2. The collected samples were analysed for physico-chemical parameters (temperature, pH, EC,TDS and F) and heavy metals (As, Ba, Cd, Co, Cr, Cu, Fe, Hg, Mn, Ni, Pb and Zn) following the standard procedures. Water quality parameters are compared to drinking water quality standards and Irrigation water quailty standard.

3. **Mine Voids Water:** Water samples were collected from three Mine Voids which were adjacent to each other in Gorbi mines area. Water present in the Mine Voids was found highly acidic in nature (pH range 2.5-3.0) in both the seasons. TDS varied in the range of 750-1580 mg/l during winter and 790-1750 mg/l during summer. Trace metal concentration was found considerably higher with respect to Co, Cr, Fe, Mn, Ni and Zn in both the seasons. In general, trace metal concentration was higher in Mine Void 1 as compared to Mine Voids 2 & 3. At present, the water present in the Mine Voids is not used for any purpose.

4. **Ash Dyke Pond Water:** Water sample was collected from Ash dyke after treatment. Water was neutral in pH with EC 460 μS/cm (TDS – 240 mg/l) in winter and 550 μS/cm (TDS – 280 mg/l) in summer season. All the trace metals were also found within the standard limits of irrigation water quality.

5. **Drinking Water Quality in Villages:** The water samples in both the seasons were within the acceptable limits with respect to pH and TDS. However, TDS in few villages (Phuljhar, Naudhaiya, Mahadhiya, Padri and Thurua) was found to be more than the acceptable limit of 500 mg/l, but was very much within the permissible limit of 2000 mg/l, as there is no other alternate source of water.

6. Among the trace metals, the concentration of Cr and Fe was found above the acceptable limits in case of handpump samples of most of the villages in the winter season. Hg concentration was found slightly above the standard limit of 0.001 mg/l in almost all the villages. During summer season, the concentration of Cr and Fe was found higher than the acceptable limits in Handpump of Mahadhaiya, Thurua, Padri, Parsohar, Dadar and Singrauli. However, unlike winter season, Hg was found within the standard limit in all the villages, except in Phuljhar, Mahadhaiya and Bastali Abad.

7. **Irrigation Water Quality in Villages:** The water samples of both the seasons were assessed on the basis of pH, EC and TDS and it has been observed that pH of the samples in the villages were within limits (6.5-8.5), except for Parsohar (6.2) and Singraulii (6.4) during winter, and Parsohar (6.2), Singrauli (6.3) and Phuljhar (6.4). On the basis of TDS, except for few villages where it was catergorised under "no resitriction in use (TDS < 450 mg/l)" viz, Parsohar, Kathas,Bastali Abad, Kairala, Khirwa, Singrauli and Baliyari, rest of all the villages showed water under the category of "slight to moderate restriction in use (TDS in the range of 450-2000 mg/l)."

8. Among the trace metals, except for Cr (which was found above the standard limit of 0.1mg/l), all the other trace metals were within the irrigation water standard limits. Although Cr is not recognized as an essential growth element, standard limit is recommended due to lack of knowledge on its toxicity to plants. Zn was found above limits in village Padri during both the seasons, whereas Cu was marginally above the limits in Kathas during winter and Mn was marginally above in Gorbi and Kathas during summer.

9. Fluoride concentration was found to be above the acceptable limit of 1.0 mg/L at the Dadar Village dug well and in the ash dyke pond, whereas it was within limit in rest of the villages including the Mine Voids. The pattern was found similar in both the seasons.

2.8.2 Soil Quality Status

1. The soil samples were collected from the respective vegetables fields from where the plant samples were collected. After necessary processing, samples were analysed for physical parameters, viz. texture, colour, pH & electrical conductivity (EC) for one winter season only.

2. The collected soils from the study area were moderate textured with pale brown to brown in color. Texture of soil samples of 12 villages was sandy loam (sand content: 56-70%, silt: 22-38%, clay: 4-16%), whereas 2 samples/villages (Phuljhar & Baliyari) have loamy sand. Soil near the mine voids was mostly sandy (sand content: 88-90%) in nature.

3. pH of the soil samples was neutral ranging between 6.5 to 7.7, whereas near mine voids, pH of soil was found in the range of 2.8-3.5. The EC of the soils ranged from 263 µS/cm (Khriwa village) to 1949 µS/cm (Bastali Abad village).

4. Soil samples collected from different locations/villages of study area were analyzed for different heavy metals (As, Ba, Cd, Co, Cr, Cu, Fe, Hg, Mn, Ni, Pb and Zn) for both, winter and summer seasons. The results are compared with the available Indian Standards, Awasthi, 2000. Analysis of results indicated that all the metals for which Indian Standards are available, were well below the limits in all the villages.

5. Cd content was in the range 0.4-5 mg/kg against the limit of 3-6 mg/kg. Cu content was in the range of 9-32 mg/kg against the limit of 135-270 mg/kg. Ni content was in the range of 5-28 mg/kg against the limit of 75-150 mg/kg. Pb content was in the range of 6-24 mg/kg against the limit of 250-500 mg/kg.

6. All the metals in the soils near mine voids were also found well below the limits in both the seasons.

7. Fluoride content was found to be in the range of 0.53 mg/kg at Thurua to 2.09 mg/kg at Khirwa. Near the Mine Voids 1 & 2, the fluoride content in soil was found to be 0.98 and 1.11 mg/kg respectively. Further, there is no standard limit for fluoride in soil.

2.8.3 Status of Flora in the Study Region

1. Field survey was conducted in the study area, wherein 92 types of different plant species belonging to 40 families were identified. Of the total families, the dominant families of the flora were found belonging to Fabaceae, Malvaceae, Poaceae, and Asteraceae.

2. It has been observed that maximum plants listed were observed in Mahadhiya, Thurua, Karaila, Bastali Abad and Baliyari village (near Ash dyke). The tree species which were commonly found in the villages were *Acacia nilotica, Acacia Catechu, Azadirachta indica, Artocarpus heterophyllus, Butea monosperma, Cassia fistula, Ficus religiosa, Gmelina arborea,Madhuca indica,Mangifera indica, Terminalia bellirica,*and *Ziziphus mauritiana.*

3. Among the commonly found shrubs were *Ricinus communis, Psidium guajava, Calotropis spp., Lantana camara, Jatrophagossypifolia, Grewia asiatica* and Herbs were *Achyranthes aspera, Alternanthera sessilis, Cassia tora, Desmodium triflorum Euphorbia hirta Scoparia dulcis Sterculia vilosa, Xanthium strumarium.*

4. Listing and survey of the plant species carried out was a part of natural vegetation found in the study area. Hence only selective Trees/ shrubs/ herbs

were included in the trace metal study which were growing in the vicinity of the inhabited area. They included Bel, Ber (Zizipus), Kathal, Mango, Guvava, Papya, Karonda, Castor (Arand), Neem, Sessile joy weed, Ban-tulsi. A few tree species besides other plants growing in the Mine Void area were also collected viz., Acacia, Babul, Bamboo for metals content analysis.

2.8.4 Metal Content in the Floral Species

1. Floral species samples of herbs, shrubs and trees were collected from different villages during winter & summer season, depending upon the availability in that particular season. Also few fruit trees and weeds used as fodder were also included in the samples.

2. The collected samples were categorised as Edible portion of Fruit/ vegetables/ grains and non-Edible Portion (biomass samples - leaf & stem only). The availability of the edible portion in the plants depended on the stage of plant growth (vegetative/ fruiting) and season. Hence edible portion was collected whereever available in order to assess the bioaccumulation of metals in the edible portion which is consumed by the human beings.

3. Accordingly, total 225 number of samples (65 samples of edible portion and 160 samples of non-edible portion) were collected during winter season, and 172 number of samples (69 samples of edible portion and 103 samples of non-edible portion) were collected during summer. Samples were also collected from the area near mine voids and existing ash dyke.

4. All the collected samples were proceesed as per standard procedure for determination of metal content in edible and non-edible (biomass) portion of different samples of vegetables, fruits, cereal crops, weeds and tree species. Metals content were determined in terms of As, Ba, Cd, Co, Cr, Cu, Fe, Hg, Mn, Ni, Pb and Zn in all the samples collected from different villages and mine void & ash dyke area.

5. Metals content in edible and non-edible portion of floral species in each of the 14 villages, viz. Phuljhar, Naudhiya, Mahadhiya, Gorbi, Thurua, Karaila, Padri, Bastali Abad, Kathas, Parsohar, Khirwa, Dadar, Singrauli and Baliyari.

6. Level of metals content present in different floral species were compared with the permissible limit suggested by Food Safety and Standards Authority of India (FSSAI, 2011). Among the total 12 metals determined in the present study, FSSAI Standards are available only 7 metals (As, Cd, Cu, Hg, Ni, Pb and Zn).

7. Analysis of data indicated that Ni content in edible portion of Arhar exceeded FSSAI limit in 6 villages. Ni levels also exceeded in Karonda, Lakra & Sem, whereas Pb exceeded only in two samples of Lakra and Arhar. Cu exceeded in two samples of Zizipus and Lakra, whereas As exceeded only in one sample of Zizipus. During winter, out of 65 samples of edible portion of different species,

high levels (exceeding FSSAI limit) of different metals were obsered in 15 samples.

8. Among the 152 samples of non-edible portion (biomass), high levels of metals were observed in as many as 68 samples during winter. Metals like Ni, Cu, Pb, As and Zn exceeded in the different species of vegetables, fruits, cereal crops and weeds.

9. Similarly, during summer, 15 samples of edible portion of different floral species exceeded the FSSAI limits in different villages. Metals like Ni, Pb, As, Zn and Hg were found exceeding the permissible limit in different species like, Arhar, Sarson, Bel, Onion, Tomato, Kathal, Mango and Brinjal.

10. Among the 97 samples of non-edible portion (biomass), high levels of metals were observed in as many as 33 samples during summer. Metals like Ni, As, Pb, Cu, Zn and Hg were found exceeding the FSSAI limit in the different species of vegetables, fruits, cereal crops and weeds, almost in all the villages.

2.8.5 Bio-accumulation of Metals in Floral Species

1. The bio-accumulation factor (BAF) in a floral species is estimated as the ratio of metal concentration in plant species to the concentration of metal in the same soil where the plant is grown.

2. The higher values of bio-accumulation factor (BAF) indicate more mobility or availability of a particular metal to the plants. Therefore, high BAF values may put forth the potential health risks to the consumers (Wang et al., 2006). Plants with BAF > 1 are termed as accumulators; plants with BAF = 1 have no influences and plants with BAF < 1 are termed as "excluder” (Radulescu et al., 2013).

3. Bioaccumulation factor (BAF) was calculated in both the seasons for the edible portion in different vegetables, fruits and cereals of different villages. The results showed bioaccumulation factor more than one only for Cu & Hg. Rest all other metals showed BAF less than 1, hence they are categorised as “excluders”.

4. **Bio-accumulation of Copper (Cu):** Most of the edible portion of plants viz., Brinjal, Lakra, Sem & Ziziphus in winter season, and Brinjal in summer season showed bio-accumulation factor marginally higher than one. A few species like Brinjal of Bastali Abad, Lakra of Mahadhiya & Baliyari and Ziziphus of Phuljhar and Mahadhiya showed BAF between 2.0 & 2.8, thus can be considered as “metal accumulators”.

5. **Bio-accumulation of Mercury (Hg):** Bio-accumulation factor in edible portion of plants was observed in Brinjal, Lakra, Lauki, Sem, Tomato, Amrud, Ziziphus and Arhar in winter, and Bhindi, Brinjal, Mirch, Onion, Sarson, Tomato and Mango in summer season. It has been observed that Lakra of Phuljhar, Mahadhiya &

Karaila, Lauki of Phuljhar, Sem of Naudhiya, Tomato of Thurua, Parsohar & Dadar and Ziziphus of Phuljhar, Mahadhiya & Karaila in winter season and Brinjal of Bastali Abad, Mirch of Naudhiya, Onion of Mahadhiya & Thurua, Tomato of Gorbi and Mango of Khirwa in summer season showed BAF more than 2.0, and can be categorised as "metal accumulators".

2.8.6 Status of Fluoride and Bio-accumulation

- Fluoride content was determined in the edible part of the plant samples collected from different villages during winter and summer seasons. In most of the cases, concentration of fluoride in both the seasons was found below the detection limit (BDL). During Winter, Lakra, Sem and Arhar pods collected in winter season showed fluoride concentration ranging between 0.97 mg/kg - 2.2 mg/kg, whereas during Summer all the samples in different villages showed fluoride concentration below detectable limit.

- Further, bio-accumulation factor (BAF) for Fluoride was estimated and the values for Lakra (Phuljhar village) and Sem (Naudhiya village) showed slight bioaccumulation with BAF value of 1.44 and 1.55 respectively. As the fluoride concentration was found below the detection limit in plants of summer season, hence no bio-accumulation was found in the edible part of different species.

2.8.7 Recommendations

- Analysis of detailed study indicates need for more frequent and regular monitoring of water quality and soil quality parameters in the region.

- Futher, monitoring for metals content in different vegetables, fruits, cereals/crops as well as fodder in different seasons should be monitored on regular basis to determine persistent bio-accumulation of metals in different species in the study region.

Annexure 2.1

Table A: List of Various Floral Species observed in the Study Area during Survey

Sr. No.	Plant Species	Common Name	Family	IUCN Status	Remarks / Importance
A.	**Trees**				
1.	*Acacia auriculiformis*	Acacia/ Austrailian Babul	Mimosaceae	NT	Conjunctivitis, Rheumatisim
2.	*Acacia nilotica*	Babul	Mimosaceae	LC	Fast biological Nitrogen fixation
3.	*Acacia ferruginea*	SafedKhair	Mimosaceae	VU	Nitrogen fixing
4.	*Adina cordifolia*	Haldu	Rubiaceae		Antianemic, Antibacterial
5.	*Aegle marmelos*	Bel	Rutaceae	NT	Analgesic, Anthelmintic
6.	*Albizia lebbeck*	Lebbek tree	Mimosaceae	VU	Kidney disease, Asthama
7.	*Artocarpus heterophyllus*	Jackfruit	Moraceae		Colon Cancer, Anemia
8.	*Azadirachta indica*	Neem	Miliaceae	LC	Skin Disease, Candidasis
9.	*Bauhinia*	Kachnaar	Caesalpiniaceae	LC/NT	Hypothyroidism, Hyperthyroidism
10.	*Bridelia squamosa*	Kasai	Euphorbiaceae		---
11.	*Butea monosperma*	Palash	Fabaceae	LC	Kidney Disease, Tuberculosis
12.	*Cassia fistula*	Amaltas	Caesalpiniaceae	LC	Acne, Abdominal Disorder
13.	*Cassia siamea*	Kassod	Caesalpiniaceae	LC	Anxiety, Insomnia
14.	*Casurina Equisetlfolia*	JangliSem	Casuarinacea		---
15.	*Ceiba pentandra*	Kapok tree	Bombacaceae	LC	Abscess, Asthama
16.	*Dalbergia sissoo*	Sheesam	Fabaceae		Blood Disease, Excessive Sweating
17.	*Delonix regia*	Gulmohar	Caesalpiniaceae	LC	Arthritis, Earache
18.	*Diospyros Melanoxylon*	Tendu	Ebenaceae		Antiseptic, Anemia
19.	*Embalica oficinalis*	Amla	Euphorbeaceae		Baldness, Asthama
20.	*Eucalyptus globulus*	Eucalyptus	Mynaceae		Blocked Nose, Whooping Cough
21.	*Ficus benghalensis*	Banyan Tree	Moraceae	LC	Alzhemier, Abscess
22.	*Ficus religiosa*	Peepal	Moraceae	LC	Heart Disease, Heavy Menstrual Bleeding
23.	*Gmelina arborea*	Gambhar/ Khomer	Verbenacea	LC	Piles, Bad Breath
24.	*Holoptelea integrifolia*	Chilbil	Ulmaceae	NT	Anorexia, Ascaris
25.	*Madhuca indica*	Mahua	Sapotaceae	LC	Lung Disease, Diabetes
26.	*Mangifera indica*	Mango	Anacardiaceae	DD	Anemia, Alzhemier
27.	*Melia azadirachta*	MahaNeem/ Babin	Meliaceae		Abdominal Disease, Acne
28.	*Moringa oleifera*	Drumstick	Moringaceae		Kidney Disease, Obesity
29.	*Neolamarckia*	Kadamb	Rubiaceae		Anemia, Arthritis

	cadamba				
30.	*Parkinsonia aculeata*	Jelly bean tree	Fabaceae	LC	Fever, Inflammation
31.	*Peltophorum pterocarpum*	Radhachura	Caesalpiniaceae		----
32.	*Pithecellobium dulce*	Jungle jalebi	Mimosaceae	LC	Sore Throat, Constipation
33.	*Pongamia pinnata*	Karanj	Fabaceae	LC	Gum Disease, Scabies
34.	*Prosopis juliflora*	Jungleekikar	Mimosaceae		Conjunctivitis, Itching
35.	*Saraca asoka*	Ashok	Caesalpiniaceae		Infertility, Arthritis
36.	*Schleichera oleosa*	Kusum/Lac Tree	Sapindaceae	NT	Anorexia, Blood Disorder
37.	*Semicarpus anacardium*	Bhela/ Varnish Tree	Anacardiaceae		Leprosy, Elephantasis
38.	*Shorea robusta*	Sal	Dipterocarpaceae	LC	Anemia, Blood Disorder
39.	*Syzygium cumini*	Jamun	Myrtaceae	LC	Diabetes, Panophthalmitis
40.	*Tamarindus indica*	Tamarind	Caesalpiniaceae	LC	Heat Stroke, Biliousness
41.	*Tectonagrandis*	Sagaon	Verbenaceae	LC	Leucoderma, Leprosy
42.	*Terminalia arjuna*	Arjuna	Combretaceae		Aphthous ulcers, Pericarditis
43.	*Terminalia bellirica*	Bahera	Combretaceae		Weak Eyesight, Gray Hair
44.	*Ziziphus mauritiana*	Ber	Rhamnaceae	LC	Amblopiya, Anemia
B.	**SHURBS**				
1.	*Annona squamosa*	Shareefa	Annonaceae		Diarrhea, Head Lice
2.	*Barleria prionitis*	Yellow December	Acanthaceae		Tooth Ache, Anemia
3.	*Bougainvellia*	Glory of the garden	Nyctaginaceae		Inflammation, Low Blood Pressure
4.	*Calotropis*	Aak/Madaar	Asclepiadaceae	VU/LC	Eye Disease, Malaria
5.	*Carica papaya*	Papaya	Caricaceae		Dengue, Low Platelet count
6.	*Carissa carandas*	Karonda	Apocynaceae		Anemia, Anxiety
7.	*Grewia hirsuta*	*Falsa*	Tiliaceae	NT	Heat stroke, Alcoholism
8.	*Jatropha gossypifolia*	Lalbherenda	Euphorbiaceae		Abdominal Disease, Arthritis
9.	Lantana camara	Raimuniya	Verbenaceae		Ulcer, Chicken Pox
10	*Leucaena leucocephala*	Subabul	Fabaceae		Inflammation, Bronchitis
11.	*Linum usitatissimum*	Flax	Linaceae		Thyroid Problem, Constipation
12.	*Haplophragma adenophyllum*	Maror Phali	Bignoniaceae	NT	Ascaris,Diarrhea
13.	*Musa*	Banana	Musaceae		Calcium Deficiency, Morning sickness
14.	*Psidium guajava*	Guava	Myrtaceae		Frizzy Hair, Epilepsy
15.	*Ricinus communis*	Castor oil plant	Euphorbiaceae	NT	Liver Disease, Abdomial Diseases
16.	*Sida cordifolia*	Bala	Malvaceae	LC	Arthritis,Osteoporosis
C.	**HERBS**				
1.	*Achyranthes aspera*	Aapamar/	Amanthaceae	LC	Kidney Diseases,

		Chirchiri			Spleen Enlargement
2.	*Alternanthera sessilis*	Sessile joy Weed	Amaranthaceae	LC	Asthama, Acene
3.	*Argemone mexicana*	Prickly poppy	Papaveraceae	LC	Abscess
4.	*Cassia tora*	Chekor	Caesalpiniaceae	LC	Ascaris, Asthama
5.	*Canabbis sativa*	Sohari	Canabaceae		Anxitey, Anorexia
6.	*Desmodium* trifolium	beggarweed,	Fabaceae	LC	Asthama, Convulsion
7.	*Echinops echinatus*	Thorny Ball	Asteraceae		Alcoholism, Anorexia
8.	*Euphorbia hirta*	Dudhi	Euphorbiaceae	LC	Abscess, Bronchitis
9.	*Evolvus alsenoides*	Shankhpushpa	Convolvulaceae	LC	Alzheimer, Blood impurity
10	*Pteris sp.*	Fern	Pteridaceae	LC	Appendictis, Acne
11.	*Hibiscus rosa-sinensis*	Shoe flower	Malvaceae		Baldness, Anemia
12.	*Ipomea*	Morning glory	Convolvulaceae	LC	Diuretic, Anti-inflammatory
13.	*Ocimum basilicum*	Ban Tulasi	lamiaceae		Abdominal disease, Acne
14.	*Peristrophe bicalculata*	Pink Weed	Acanthaceae		---
15.	*Scoparia dulcis*	Ban Mirach	Scrophulariaceae	NT	Swelling, Poor blood Circulation
16.	*Sida acuta*	wireweed	Malvaceae	LC	Liver disease, Indigestion
17.	*Sida cordifolia*	Heart-leaf sida	Malvaceae	LC	Osteoporosis, Hemiplegia
18.	*Solanum virginianum*	BhatKattaiya	Solanaceae	LC	Anorexia, Ascaris
19.	*Sterculia urens*	Kulu	Sterculiaceae		Diarrhea, Sore throrat
20.	*Sterculia vilosa*	Udal	Sterculiaceae		----
21.	*Tridax procumbens*	Tridax daisy	Asteraceae	LC	Acid Reflux, Blister
22.	*Xanthium strumarium*	Rough cocklebur	Asteraceae		Blocked Nose, Sinusitis
D.	**OTHER PLANTS (Grasses & Weeds)**				
1.	*Cynodon dactylon*	DoobGhass	Poaceae	LC	Leucoderma, Anuria
2.	*Clitoria ternatea*	Aparajita	Fabaceae		Elephantiasis, Anxiety
3.	*Bambusa vulgaris*	Bamboo			Croup, Ulcers
4.	*Dioscorea alta*	Purple yam	Dioscoreaccae		Leprosy, Piles
5.	*Holarrhena antidvsenterica*	Koraiya	Asclepiadaceae		Acid reflux, Amebiasis
6.	*Opuntia*	Prickly pear	Cactaceae	LC	Hangover, Inflammation
7.	*Parthenium*	Congress grass	Asteraceae		Blurred Vision, Hyperlactation
8.	Pennisetumpedicellatum	Deenanath Grass	Poaceae	LC	
9.	*Saccharum spontaneum*	KansiGhass	Poaceae	LC	Kidney Stone, Blood Impurity
10	*Thysanolaena maxima*	Jharu Grass	Poaceae	LC	
11.	*Thevetia peruviana*	PiliKaner	Apocynaceae		Eye disease, Acne

IUCN Abbreviations:
RE – Regionally Extinct in Wild, CE – Critically Endangered, EN – Endangered, VU – Vulnerable, NT – Neat Threatened, LC – Least Concern, DD – Data Deficient

Chapter 3

Study of Fauna

(with focus on assessment of metal content and bio-accumulation)

The chapter deals with the assessment of metal content in aquatic and terrestrial fauna. Different aquatic species like variety of fishes and benthic invertebrates were found in different water bodies. Terrestrial fauna covered different types of invertebrates/ insects. Metal content was also determined in fodder samples, milk, urine and scat of animals, and soil samples. Based on the assessment of metals content in different species/ samples, bioaccumulation in fishes and macro-vertebrates was determined. Samples were collected in winter and summer seasons. The study is presented in the following sections:

- Details of Sample Collection and Analysis
- Status of Aquatic Fishes and Metal Content
- Metal Content in Benthic Invertebrates
- Metal Content in Terrestrial Invertebrates
- Metal Content in Fodder Samples
- Metal Contentin Milk, Urine and Scat Samples
- Metal Content in Soil Samples
- Bio-accumulation of Metals in Aquatic & Terrestrial Species

3.1 Details of Sample Collection and Analysis

3.1.1 Sampling Locations

Sampling of aquatic and terrestrial fauna was carried out within 10 km radius of Gorbi mines as per the scope of the study. Aquatic samples were also collected from Jayant Morwani dam, Jhigurda dam and Rihand dam located at distance a of 12.2 km, 15.8 km and 19 km respectively from the mine voids.These locations can be considered as reference/ control sites from bioaccumulation and bio-magnification point of view in future. Samples were collected from individual sampling locations following the standard sampling protocols. The samples were properly preserved and brought to the laboratory for further analysis for metals content.

The details of the sampling sites along with their coordinates, average distance from the mine void and number of samples collected during winter (December 2018) and summer (May 2019) season is summarized in **Table 3.1.1**. Sampling locations are also marked on Google Earth Map upto 20 km radial area, as shown in **Fig. 3.1.1**.

Table 3.1.1: Details of Sampling Sites and Number of Samples Collected

Sr. No.	Sampling Locations	Latitude	Longitude	Approx. Distance from Mine Void (km)	No. of Samples	
					Winter	Summer
A.	**Fish Species**					
1.	Kachan River	24°11'6"N	82°33'9"E	5.2	1	2
2.	Bijul River	24°14'1"N	82°38'55"E	6.4	1	3
3.	JayantMorvani Dam	24°7'55"N	82°39'17"E	12.2	2	2
4.	Rihand Dam	24°06'7"N	82°43'27"E	19.0	3	5
B.	**Aquatic Macro Vertebrates / Benthic Invertebrates**					
1.	Mine Void 1	24°13'12"N	82°34'50"E	0.7	1	2
2.	Mine Void 2	24°13'6"N	82°34'55"E	0.6	1	1
3.	Mine Void 3	24°12'55"N	82°35'13"E	0.4	1	3
4.	Kachan River	24°11'6"N	82°33'9"E	5.2	2	-
5.	Chaturbhuj Temple Pond	24°11'43"N	82°32'30"E	5.5	1	1
6.	JayantMorvani Dam	24°7'55"N	82°39'17"E	12.2	1	1
7.	Jhigurda Dam	24°11'6"N	82°44'22"E	15.8	0	1
C.	**Terrestrial Invertebrates (Insects)**					
1.	Gorbi Village	24°12'25"N	82°36'60"E	3.1	4	4
2.	Naudiya Village	24°12'25"N	82°33'59"E	2.5	3	6
D.	**Fodder, Milk, Urine, Scat, Soil (each)**					
1.	Gorbi Village	24°12'25"N	82°36'60"E	3.1	1 each	1 each
2.	Naudhiya Village	24°12'32"N	82°34'14"E	2.0	1 each	1 each
3.	Chaturbhuj Temple	24°11'43"N	82°32'30"E	5.5	1 each	1 each

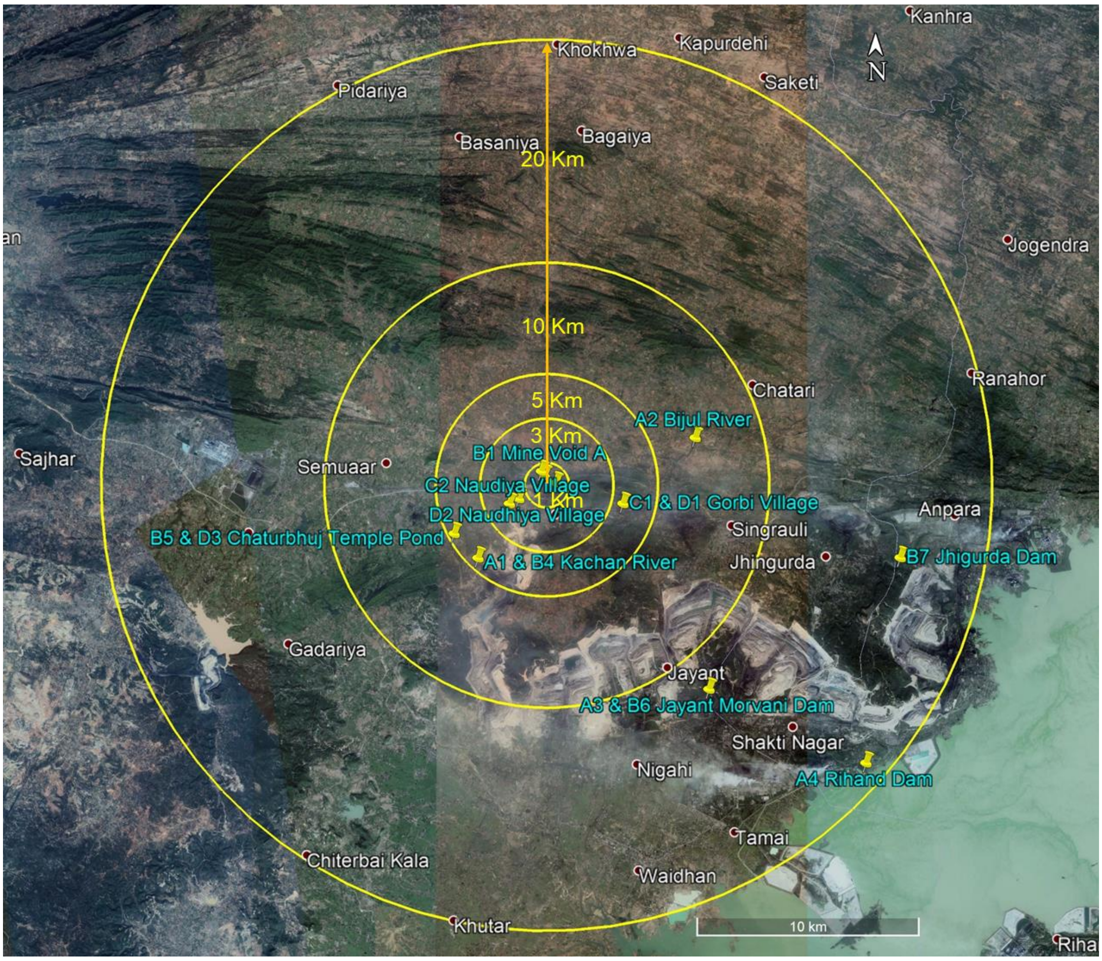


Fig. 3.1.1: Sampling LocationsIndicated on Google Earth Map upto 20 km Radial Area

3.1.2 Sample Collection

A. Soil & Water Samples

Sampling of soil and water was carried out at respective sites for determination of bioaccumulation factor (**Plates 3.1.1 & 3.1.2)**. Sampling was carried out using standard sampling protocol. Physical observations like soil colour, crop type, use of chemical fertilizers, water temperature, pH, discharges, confluence, surrounding vegetation were also taken in account for drawing necessary conclusions.

B. Aquatic Fauna

Fish Species: Fish samples (*C. catla, L rohita, S. silondia, P. argenteus* etc.) were collected from the respective water sampling sites (ponds and rivers) using cast net and with the help of local fishermen. Samples were stored in ice box and brought to laboratory preserved at -20°C in deep freezer (make Hoshizaki, Japan) for further analysis (**Plate 3.1.3**).

Benthic Invertebrates: The benthos samples were collected as per the standard sampling protocol of CPCB, New Delhi. Samples were collected from Mine Voids (1, 2 & 3), Kachan river (upstream/downstream), pond at Chaturbhuj temple and Jayant Morwani dam using hand net and kick net. All the collected samples were identified and stored in 4% formaldehyde solution in sample containers, stored in icebox and transported to laboratory for further analysis (**Plates 3.1.4 & 3.1.5**).

C. Terrestrial Fauna

In order to study the bioaccumulation and bio-magnification of trace elements, in terrestrial fauna, Cow (*bostaurus sp.*) and Buffalo (*bubalus sp.*) were identified at individual sampling locations. Samples of fodder, and other biological samples such as milk, urine and scat were collected from each representative species. A survey and a short questionnaire was also accounted with the cattle owners like average age, milk production and health status of fauna for documentation purpose (**Plate 3.1.6**).

Fodder, Milk, Urine and Scat Samples

Fodder comprising of dry husk, given to the fauna were collected in plastic zip-lock bags from individual sampling locations, labeled and brought to lab under stored conditions for further analysis (**Plate 3.1.7**).

Milk samples were taken from individual faunas as per the standard protocol with the help of cattle owners. Prior to collection, cow's udder was washed with distilled water and few initial drops of milk was discarded to avoid sampling error. Milk samples were collected in 250 ml acid rinsed glass bottles, labeled and preserved in ice box and brought to lab and stored at -20^{o}C in deep freezer (make Hoshizaki, Japan) till further analysis (Meshref*et al*, 2014).

Urine samples were collected with the help of local peoples. Faunal urethra was washed with water prior to sampling. Similar to milk sampling, initial few drops were discarded and then fresh samples were taken, and preserved with addition of 2-3 ml of nitric acid and brought to lab for further analysis (Willis, 1962).

Fresh faecal (scat) samples were collected belonging to the respective faunal species in zip-lock bags and stored in ice box, brought to lab and stored in refrigerator till further analysis. Collection of urine and fecal sample is shown in **Plate 3.1.8**.

D. Terrestrial Invertebrates

For bio-magnification studies, invertebrates were collected from Bargaon – Singrauli Road) and Naudhiya Village.

Insects: Detrivores like field crickets (*Gryllus sp.*), Grasshopper (*Chorthippus-brunneus*), Moth (*Ascalaphaodorata sp*.), were collected from soil while Dragonfly (*Anisoptera sp*.) and Common grass yellow butterfly (*Phoebis sp*.) were collected with the help of insect net. All the samples were stored in plastic zip-lock bags and were brought to lab under storage conditions in an ice box and further preserved at -20°C till further analysis (**Plate 3.1.9**).

Earthworm: Earthworm species were collected only from two locations; Gorbi and Naudhiya village as these are the nearest villages to the Mine voids, and agricultural practices were being carried out at these villages (average distance 3.1 km and 2.4 km respectively). Earthworms were collected after removal of top layer of soil (15-20 cm). The soil was hand processed to remove earthworms (**Plate 3.1.10**). Samples were washed using distilled water and stored in Glass bottlesand were brought to lab under storage conditions in an ice box and further preserved at -20°C till further analysis (Wang et al, 2018).

3.1.3 Sample Analysis for Metal Content

The trace elements/metals such as As, Ba, Cd, Co, Cr, Cu, Fe, Hg, Mn, Ni, Pb, Zn were analysed in the present study. Further, Fluoride content was also determined.

A. Aquatic Fauna

Fishes: The frozen fish samples were taken out and kept at room temperature. After defrosting, fishes were dissected using scissors and forceps. After dissection, fish muscles, gills, brain and liver were carefully removed and washed with distilled water. Each organ was digested separately with nitric acid. After cooling, the samples were filtered and volume was raised up to 25 ml and stored at 4°C (Kumari et al, 2014; Rajeshkumar and Li, 2018).

Benthic macro-invertebrates: The samples collected were washed with distilled water and chopped into smaller pieces and later digested with nitric acid and perchloric acid in the ratio 2:3 on the hot plate. After that, 2-3 drops of H_2O_2 was added and heated till the solution turned colourless. The samples were cooled, filtered and volume makeup was done up to 50 ml and stored at refrigerating condition (4°C) (Santoro et al, 2009; Saghali et al, 2014).

B. Terrestrial Invertebrates

The collected invertebrates were washed with distilled water gently to remove attached soil particles. The invertebrates were weighed and chopped into pieces with the help of forceps and dissection scissors. Later, these were subjected to acid digestion with nitric and perchloric acid in the ratio 4:1 on the hot plate at 200 °C. 2-3 drops of H_2O_2 was added to the solution and heated till the solution turned colourless. After cooling the samples was filtered and volume was raised up to 100 ml and stored at 4°C (Azam et al, 2015).

3.1.4 Instrumental Analysis

- **Analysis of Trace Metals by ICP-OES Method**

The aliquots of samples were prepared and subjected to ICP-OES (Model iCAP 6000, Thermo Scientific) for determination of trace metals (As, Fe, Cu, Co, Mn, Pb, Zn, Ni, Cr, Cd, Ba). The standard range was determined as per the multi-element standard used (Merck). The concentration of metals is expressed as mg of metal /kg wet-weight for Fish, benthos samples and terrestrial insects as well.

- **Analysis of Fluoride by Ion selective electrode method**

In 20 ml of sample solution, 2 ml of TISAB buffer was added and the potential was measured with ion selective electrode. The concentration of fluoride is expressed in mg/kg and mg/l in water.

- **Analysis of Mercury by Direct Mercury Analyzer (DMA-80)**

Sample boat containing known quantity of samples were loaded in the auto sampler of Direct Mercury Analyser (DMA-80) and mercury was estimated quantitatively.

The instruments used in the study are shown in **Plate 3.1.11**.

3.1.5 Data Representation

The concentration of trace elements/metals in all the analysed samples is expressed in mg/kg-dry and weight basis, and mg/l for liquid samples like milk, water, urine. Concentration of mercury is expressed in mg/kg of sample.

Concentration levels of different metals in different species are compared with the permissible limit as suggested by WHO, and are given in **Table 3.1.2**.

Table 3.1.2: Permissible Limit of Heavy Metal/Trace Elements as per WHO Guidelines

Trace Elements	Permissible limit (in ppm)/ References			
	Fish	Milk	Scat	Urine
As	6.0 [a]	0.03-0.06 [k]	2.50 [o]	-
Ba	-	-	34.63-122.82 [p]	-
Cd	3.33 [g]	0.05 [a]	1.7-2.12 [q]	-
Co	-	-	1.97-2.09 [p]	-
Cr	1.0 [a]	0.01-0.07 [k]	37.86-57.73 [p]	-
Cu	100.0 [g]	0.1-0.9 [l]	5.57-112.0 [r]	-
Fe	333.3 [g]	2.7 [a]	Greater of equal to forage [s]	-
Mn	0.5 [h]	0.1 [a]	195.3-1167.3 [p]	-
Ni	6.99 [h]	0.03-0.1 [l]	4.30-11.66 [p]	-
Pb	6.0 [i]	0.3 [a]	6.12-11.0 [q]	-
Zn	5.0 [a]	0.3-6.0	152.5-4333.8 [t]	-
Hg (µg/kg)	500-1000 [a]	0.5 [i]	272.7-400 [t]	-
F	0.6-26 [j]	0.01-.4 [m]	Greater of equal to forage [s]	Normal < 5mg/l, border line toxicity 20-30 mg/l, systematic toxicity> 35 mg/l

Source: [a]WHO; [g]Mokhtar, 2009; [h]Tariq-Al-Najjaral*et al*, 2016; [i]FAO/WHO, 1989; [j]Loll, 1994, Camargo 2003; [k]Cerutti, 1999; [l]Bilandzic*et al*, 2011; [m]Kirchgessner 1960, bergmanm, 1995; [o]Zhang*et al*, 2012; [p]Long*et al*, 2004; [q]Gupta, 2013; [r]Xiong*et al*, 2010, [s]Winsten and Davison, 2004; [t]Ji*et al*, 2012.

Plate 3.1.1: Soil Sampling at Various Locations

Chaturbhuj Temple

Bijul river

Jhigurda Dam

JayantMorvani Dam

Plate 3.1.2: Water Sampling at Various Locations

Plate 3.1.3: Collection of Fish Samples

Plate 3.1.4: Benthos Monitoring at Gorbi Mine Voids

Plate 3.1.5: Benthos Species Collected from Mine Voids

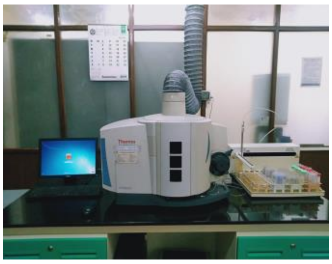
Plate 3.1.6:Terrestrial Fauna Accounted during the Study

Plate 3.1.7: Fodder Samples Collected during Sampling

Plate 3.1.8: Collection of Urine and Scat

Plate 3.1.9: Terrestrial Invertebrates Collected during the Study

Plate 3.1.10: Collection of Earthworms



ICP-OES

Ion Selective Electrode

Direct Mercury Analyser

Plate 3.1.11: Instruments used for the Analysis

3.2 Status of Aquatic Fishes and Metal Concentration

3.2.1 Status of Fish Species (Condition Factor)

Fishes are the best bio-indicator species to study bio accumulation and bio-magnification of trace elements. Fishes play an important role in bio-monitoring of aquatic ecosystem (Kumari and Khare, 2018).

In all 19 samples of different fish species were collected during winter (7 nos.) and summer (12 nos.) from four water bodies, namely Kachan river, Bijul river, JayantMorwani Dam and Rihand Dam. The fish species captured were Catla, Pomfret, Rohu, Tegra, Silan, Khursa and Tilapia. Out of total 19 fishes, 5 were Rohu, 4 were Silan, 3 Tengra, 3 Khursa, 2 Tilapia and one each of Catla and Pomfret. First the physical condition of all the fish species was assessed by measuring their length and weight, as shown in **Plate 3.2.1**.

Estimation of Length of Carps

Estimation of Weight of Carps

Plate 3.2.1: Assessment of Physical Condition of Fish Species

Further, health condition of the fishes was assessed in the form of condition factor, which is the ratio of the length to weight of the fish body. It is determined by the following formula: -

*CF = Weight of the fish (gm) / Length of the fish (cm^3) * 100*

Condition of fish in general is an expression of relative fatness of fish. The relative robustness, or degree of well-being of a fish is expressed by "coefficient of condition," denoted by 'K' (also known as Fulton's condition factor, or length-weight factor, or Ponderal Index). Variations in a fish's coefficient of condition (or K-factor) primarily reflect state of sexual maturity and degree of nourishment. Condition values may also vary with fish age, season and in some species, with sex. K- Factor shows variations with different species and size of fishes, but in general, larger values are indicative of better fish condition.

Details of various fish species collected during winter and summer from different water bodies and status of their physical condition is presented in **Table 3.2.1**.

Table 3.2.1: Condition Factor of Various Fishes collected from different Water Bodies

Sr. No.	Sampling Location	Fish Species		Average Length (cm)	Average Weight (gm)	Condition Factor (CF)
		Scientific Name	Local Name			
	Winter					
1.	Kachan River	*Catlacatla*	Catla	22.6	280	2.43
2.	Bijul River	*Pampusargenteus*	Pomfret	19.2	140	1.98
3.	JayantMorwani Dam	*Labeorohita*	Rohu	18.0	150	2.57
4.		*Labeorohita*	Rohu	19.5	180	2.43
5.	Rihand Dam	*Mystustengara*	Tengra	21.0	140	1.51
6.		*Siloniasilondia*	Silan	14.5	110	3.61
7.		*Khursa*	Khursa	23.0	280	2.30
	Summer					
1.	Kachan river	*Labeorohita*	Rohu	25.1	320	2.02
2.		*Oreochromisniloticus*	Tilapia	30.2	200	0.72
3.	Bijul river	*Labeorohita*	Rohu	17.4	90	1.70
4.		*Siloniasilondia*	Silan	35.3	300	0.68
5.		*Siloniasilondia*	Silan	25.0	180	1.15
6.	JayantMorwani Dam	*Labeorohita*	Rohu	24.6	400	2.68
7.		*Oreochromisniloticus*	Tilapia	31.3	230	0.75
8.	Rihand Dam	*Mystustengra*	Tengra	37.1	320	0.62
9.		*Mystustengra*	Tengra	31.9	200	0.61
10.		*Siloniasilondia*	Silan	32.0	290	0.88
11.		*Khursa*	Khursa	29.6	490	1.88
12.		*Khursa*	Khursa	36.5	680	1.39

The length and weight of different species varied from 14.5-23 cm and 110-280 g in winter respectively, whereas in summer, it varied in the range of 24.6-36.5 cm and 180-680 g, except for one Rohu species of 17.4 cm with 90 g weight. In general, the species of summer were found to be more matured, whereas, based on the condition factor, species in winter were observed appears to be more healthy. The condition factor for winter fish species varied from 1.51 (*Mystus tengara)* to 3.61 *(Silonia silondia)*, whereas in summer it varied from 0.61 (*Mystus tengara)* to 2.68 (*Labeo rohita*).

Out of total 19 species, only 7 species had condition factor more than 2, whereas 6 species had condition factor less than 1. Rest 6 had condition factor between 1 & 2. Species exhibiting condition factor values of greater than one is considered to be in healthy condition.

Fishes such as *Labeo rohita*, *Catla catla*, *Silonia silondia* and Khursa had the condition factor value above 2 as an indicative good health and robustness in terms of optimum physical appearance, physiological and biochemical activity and all other fishes had the condition factor value below 2, representing a comparatively low indicative value for health.

3.2.2 Trace Element Concentration in Fishes

Fish samples were collected from Kachan River, Bijul River, Jayant Morvani Dam and Rihand Dam. Fish samples were dissected and concentration levels of different trace elements/ metals (As, Ba, Cd, Co, Cr, Cu, Fe, Mn, Ni, Pb, Zn and Hg) along with Fluoride were determined in muscle, gills and liver of fishes. The results are presented for both the seasons in **Tables 3.2.2-3.2.5** for Kachan River, Bijul River, Jayant Morwani Dam and Rihand Dam, respectively. The observed concentration levels are compared with the WHO Guideline values for different metals. Salient observations are presented below:

a. Kachan River

Three samples of fishes namely Catla, Rohu and Tilapia were collected from Kachanriver in both the seasons.The weights of the fishes were in the range of and 200-320 grams and the condition factor were also above 1 for both Catla and Rohu except for Tilapia. Metals such as Cadmium (Cd), Copper (Cu), Iron (Fe), Nickel (Ni), Lead (Pb), Mercury (Hg) and Fluoride (F) were within the permissible limits whereas the levels of Chromium (Cr), Manganese (Mn), and Zinc (Zn) were considerably high as compared to the WHO Guideline values of 1 mg/kg, 0.5 mg/kg and 5 mg/kg respectively. Arsenic was not detected in any of the fish samples.

b. Bijul River

Four fish samples such as Pomfret, Rohu and two Silan were collected in the both seasons. Rohu was smallest among all the samples. Silans were 180 to 300 g in weight whereas pomfret weighed 140 g. All the metals were within the permissible limits as per the WHO guidelines except for Cr, Mn and Zn (considerably high levels). In addition, condition factor for all three fishes were also found to be above 1 however one fish sample among two silans had condition factor below 1 (i.e. 0.68). As was not detected in any of the fish samples.

c. Jayant Morwani Dam

Three fish samples of Rohu and one Tilapia was collected from Jayant Morwani Dam in both the seasons. The weights of the fishes were in the range of 150 to 400 g among which one Rohu was the healthiest as per the calculated condition factor and Tilapia showed lower value indicating poor health.In trace metal analysis, As was not detected in any of the fish samples and other metals were within the permissible limits except for Cr, Mn and Zn. Fe & Cu concentration exceeded the limit in liver of Rohu-1, and Fe exceeded in the liver of Rohu-2.

d. Rihand Dam

Total 8 fish samples were collected from Rihand dam in both the seasons. These samples included three samples of Tengra, three samples of Khursa and two Silans. All the fishes were in good health as per the calculated condition factor expect for Silan collected in summer season.Like fish samples collected from other water bodies, no metal was detected to exceed the threshold limit established as per WHO guidelines expect for Cr, Mn and Zn, and As was not detected in any of the fish samples.

The levels of Cr, Mn and Zn were found, in general, considerably above the permissible levels in all the parts of the fish, i.e. muscle, gills and liver. As was not detected in any of the 19 samples, and concentration levels of other metals (Ba, Cd, Co. Cu, Fe, Ni, Pb, and Hg) and Fluoride were within the permissible limits. Fe was found above the limits in couple of species (liber of Rohu 1 & Rohu 2).

Table 3.2.2: Heavy Metal Concentrations in Fish Species: Kachan River

Season/ Fish/ Body Part	Heavy Metal Concentration (mg/kg)											
	As	**Ba**	**Cd**	**Co**	**Cr**	**Cu**	**Fe**	**Mn**	**Ni**	**Pb**	**Zn**	**Hg**	**F**
Winter													
Catla													
Muscle	ND	0.4	0.002	0.02	3.4	0.40	23	21.0	0.13	0.11	14.8	0.043	0.012
Gills	ND	9.6	0.015	0.06	6.6	1.09	77	54.3	0.31	0.18	95.2		
Liver	ND	ND	0.018	0.04	5.1	2.68	30	21.7	0.19	0.26	43.3		
Summer													
Rohu													
Muscle	ND	1.9	0.179	ND	3.5	1.48	63	0.8	ND	ND	10.2	0.035	0.008
Gills	ND	6.1	0.012	0.03	7.6	5.79	178	26.1	ND	ND	69.1		
Tilapia													
Muscle	ND	1.0	ND	0.28	3.1	1.34	43	1.9	ND	0.02	12.3	0.025	0.015
Gills	ND	32.8	ND	0.37	4.2	2.69	82	4.4	ND	0.07	25.1		
Liver	ND	13.1	ND	0.56	12.7	1.05	37	8.1	ND	ND	4.7		
WHO Guidelines	**6**	**-**	**3.33**	**-**	**1.0**	**100**	**333**	**0.5**	**6.99**	**6.0**	**5**	**0.5-1.0**	**0.6-26**

Table 3.2.3: Heavy Metal Concentrations in Fish Species: Bijul River

Season/ Fish/ Body Part	Heavy Metal Concentration (mg/kg)												
	As	Ba	Cd	Co	Cr	Cu	Fe	Mn	Ni	Pb	Zn	Hg	F
Winter													
Pomfret													
Muscle	ND	0.0	0.026	0.04	8.1	1.02	64	64.9	0.20	0.24	21.5	0.054	0.028
Gill	ND	5.1	0.004	0.01	4.7	0.33	12	21.9	0.16	0.19	10.1		
Liver	ND	14.1	ND	0.04	11.0	11.60	247	67.3	0.50	0.01	34.4		
Summer													
Rohu													
Muscle	ND	0.5	0.024	0.01	1.7	0.82	35	1.6	ND	ND	5.1	0.008	0.015
Gill	ND	1.4	0.023	0.02	1.4	1.61	151	3.0	ND	ND	4.5		
Liver	ND	12.4	1.443	1.24	6.4	5.13	368	16.3	ND	ND	20.0		
Silan-1													
Muscle	ND	1.6	ND	ND	3.6	1.33	33	2.0	ND	0.12	9.4	0.038	0.011
Gill	ND	11.5	ND	ND	3.3	1.20	60	11.2	ND	0.25	35.9		
Liver	ND	4.0	ND	ND	13.2	10.60	192	4.6	ND	ND	84.1		
Silan-2													
Muscle	ND	0.8	ND	ND	3.9	1.09	31	0.8	ND	0.15	8.4	0.043	0.018
Gill	ND	19.1	ND	0.01	3.3	1.26	66	30.1	ND	0.29	46.5		
Liver	ND	1.3	ND	ND	4.2	20.79	270	1.8	ND	ND	43.0		
WHO Guidelines	**6**	**-**	**3.33**	**-**	**1.0**	**100**	**333**	**0.5**	**6.99**	**6.0**	**5**	**0.5-1.0**	**0.6-26**

Table 3.2.4: Heavy Metal Concentrations in Fish Species: Jayant Morvani Dam

Season/ Fish/ Body Part	Heavy Metal Concentration (mg/kg)												
	As	Ba	Cd	Co	Cr	Cu	Fe	Mn	Ni	Pb	Zn	Hg	F
Winter													
Rohu-1													
Muscle	ND	10.0	0.072	0.20	12.3	1.24	102	96	0.71	0.54	20	0.053	0.028
Gill	ND	1.1	0.029	0.29	5.7	0.81	47	43	0.57	0.27	6		
Liver	ND	8.9	0.367	0.88	34.2	121	857	263	2.27	1.42	31		
Rohu -2													
Muscle	ND	ND	0.049	0.21	10.6	0.67	74	88	0.45	0.16	15	0.065	0.026
Gill	ND	4.3	0.146	0.54	9.1	1.41	45	57	1.33	0.73	7		
Liver	ND	5.5	0.151	2.58	29.2	48.5	340	244	5.43	1.16	32		
Summer													
Rohu													
Muscle	ND	1.1	ND	ND	2.0	0.87	115	2.5	ND	ND	13	0.041	0.019
Gills	ND	2.3	ND	0.11	5.1	4.48	125	25	ND	ND	46		
Tilapia													
Muscle	ND	18.1	ND	0.52	3.6	1.40	221	4.8	ND	0.01	10	0.043	0.002
Gill	ND	1.3	ND	0.35	4.7	1.72	118	13.3	ND	0.24	21		
Liver	ND	16.1	ND	0.29	5.9	1.54	243	9.8	ND	0.18	26		
WHO Guidelines	**6**	**-**	**3.33**	**-**	**1.0**	**100**	**333**	**0.5**	**6.99**	**6.0**	**5**	**0.5-1.0**	**0.6-26**

Table 3.2.5: Heavy Metal Concentrations in Fish Species: Rihand Dam

Season/ Fish/ Body Part	Heavy Metal Concentration (mg/kg)												
	As	**Ba**	**Cd**	**Co**	**Cr**	**Cu**	**Fe**	**Mn**	**Ni**	**Pb**	**Zn**	**Hg**	**F**
Winter													
Tengra													
Muscle	ND	ND	ND	ND	0.3	0.11	10	20	0.01	0.01	4.3	0.072	0.050
Gill	ND	2.2	ND	ND	1.3	0.12	42	54	0.12	0.17	22		
Liver	ND	ND	ND	ND	5.7	0.24	213	172	0.64	2.75	134		
Silan													
Muscle	ND	ND	ND	ND	1.3	0.47	26	19	0.06	0.10	3.6	0.077	ND
Gill	ND	ND	0.034	ND	0.9	5.31	119	73	0.10	0.71	46		
Liver	ND	1.7	0.010	0.04	2.0	0.82	150	51	0.14	0.63	22		
Khursa													
Muscle	ND	ND	ND	ND	0.3	0.40	14	21	0.05	0.01	5.2	0.067	0.053
Gill	ND	ND	0.010	0.01	1.0	2.10	55	55	0.16	ND	17		
Summer													
Silan													
Muscle	ND	0.7	ND	ND	2.8	0.45	28	0.7	ND	0.11	7.8	0.065	0.043
Gill	ND	14.8	ND	0.02	2.7	0.66	65	14	ND	0.34	32		
Liver	ND	1.6	ND	ND	3.3	2.49	138	2.5	ND	0.53	59		
Khursa-1													
Muscle	ND	0.2	ND	ND	0.6	0.14	13	0.2	ND	0.02	3.0	0.012	0.007
Gill	ND	10.9	ND	0.02	1.5	3.96	111	11	ND	0.04	20		
Khursa-2													
Muscle	ND	0.1	ND	ND	1.2	0.63	56	7.4	ND	0.06	19	0.077	ND
Gill	ND	8.5	ND	0.90	2.9	3.24	157	6.6	ND	0.02	4.7		
Tengra-1													
Muscle	ND	0.5	ND	ND	0.6	0.29	26	0.9	ND	0.24	4.3	0.006	ND
Gill	ND	12.9	0.015	ND	2.9	0.92	90	38	ND	0.32	44		
Liver	ND	9.4	ND	ND	2.1	ND	82	13	ND	ND	11		
Tengra-2													
Muscle	ND	0.2	0.018	ND	0.9	0.25	33	0.9	ND	0.04	5.3	0.025	0.003
Gill	ND	14.4	0.056	ND	2.8	0.88	75	36	ND	0.99	39		
Liver	ND	16.9	ND	ND	2.9	ND	136	24	ND	ND	6.9		
WHO Guidelines	**6**	**-**	**3.33**	**-**	**1.0**	**100**	**333**	**0.5**	**6.99**	**6.0**	**5**	**0.5-1.0**	**0.6-26**

3.3 Metal Concentration in Benthic Invertebrates

Samples of benthic macro-invertebrates (Aeshna, Ranatrasp & Mollusca) were collected from Mine Voids, Kachan river, Chaturbhuj temple pond and Jayant Morwani Dam during both the seasons. Among the different metals determined, As, Ba, Cd, Cr, Pb, Ni & Hg and Fluoride were not detected in any of the benthic species at any of the sites. Fe, Mn and Zn were found highest among all the metals in all the benthic invertebrates, however in some species at some sites Mn was also not detected such as in *Aschena sp.* at mine voids. Co and Cu was least detected in benthic macro invertebrates (**Table 3.3.1**).

Table 3.3.1: Heavy Metal Concentrations in Benthic Invertebrates

Season/ Site	Species	Heavy Metal Concentration (mg/kg)												
		As	Ba	Cd	Co	Cr	Cu	Fe	Mn	Ni	Pb	Zn	Hg	F
Winter														
Mine Void A	*Aeshna sp.*	ND	ND	ND	ND	ND	ND	83	ND	ND	ND	4.7	ND	ND
Mine Void B	*Aeshna sp.*	ND	ND	ND	ND	ND	ND	70	ND	ND	ND	24.2	ND	ND
Mine void C	*Aeshna sp.*	ND	ND	ND	0.54	ND	1.05	153	124	ND	ND	25.6	ND	ND
Kachan river	*Aeshna sp.*	ND	ND	ND	0.58	ND	1.11	149	127	ND	ND	29.0	ND	ND
	Ranatrasp.	ND	ND	ND	0.36	ND	1.08	122	91	ND	ND	11.8	ND	ND
Chaturbhuj temple Pond	*Mollusca sp.*	ND	ND	ND	0.1	ND	0.15	74	20	ND	ND	0.6	ND	ND
JayantMorwani Dam	*Aeshna sp.*	ND	ND	ND	0.08	ND	1.15	74	16	ND	ND	2.1	ND	ND
Summer														
Mine Void – A1	*Aeshna sp.*	ND	ND	ND	ND	ND	ND	39	ND	ND	ND	2.0	ND	ND
Mine Void – A2	*Aeshna sp.*	ND	ND	ND	ND	ND	ND	18	ND	ND	ND	12.4	ND	ND
mine Void -B	*Aeshna sp.*	ND	ND	ND	0.16	ND	0.43	13	2.9	ND	ND	4.2	ND	ND
Chaturbhuj Temple	*Mollusca bengalensis sp.*	ND	ND	ND	0.006	ND	ND	3	0.7	ND	ND	1.3	ND	ND
Jayant Morvani	*Mollusca bengalensis sp.*	ND	ND	ND	0.3	ND	1.13	102	3.8	ND	ND	17.7	ND	ND
Mine void - C1	*Aeshna sp.*	ND	ND	ND	0.01	ND	0.49	6	1.6	ND	ND	1.8	ND	ND
Mine void – C2	*Aeshna sp.*	ND	ND	ND	0.16	ND	2.67	31	3.9	ND	ND	22.8	ND	ND
Mine void – C3	*Aeshna sp.*	ND	ND	ND	ND	ND	ND	1	ND	ND	ND	0.1	ND	ND

3.4 Metal Concentration in Terrestrial Invertebrates

Terrestrial insects such as dragon flies, butterflies, moth, Hornet sp., field cricket and beetle were collected from Gorbi village, Naudhiya village, Bijul River and Jhigurda Dam. The samples were analysed for various metal contents and the results are given in **Table 3.4.1**. Perusal of table indicates that As, Cd, Hg and F was not detected in any of the terrestrial invertebrates at any of the sites. Fe, Mn and Zn were highest among all the metals in all terrestrial invertebrates. Cr, Cu and Ba were the most abundant element after Fe, Mn and Zn. Co, Pb and Ni was least detected.Earthworms had exceptionally high concentrations of Iron which may be attributed to its life time association with land (soil) as a result it is continuously exposed to concentrations in soil.

Table 3.4.1: Heavy Metal Concentrations in Terrestrial Invertebrates

Season/ Site/ Species	Heavy Metal Concentration (mg/kg)											
	As	Ba	Cd	Co	Cr	Cu	Fe	Mn	Ni	Pb	Zn	Hg	F
Winter													
Gorbi Village													
Grasshopper (*Chorthippusbrunneus*)	ND	5.5	ND	1.0	13.5	1.5	299	464	3.4	1.5	44	ND	ND
Butterfly (*Phoebis sp.*)	ND	1.2	ND	ND	6.1	1.8	123	242	3.0	1.3	41	ND	ND
Moth (*Ascala phaodorata*)	ND	ND	ND	ND	1.1	0.5	161	888	2.7	0.7	33	ND	ND
Earthworm (*Eisenea sp.)*	ND	9.6	ND	2.9	3.4	6.8	2859	78	2.8	ND	31	ND	ND
Naudiya Village													
Dragonfly (*Anisoptera sp.*)	ND	4.7	ND	ND	5.5	0.8	81	62	1.8	1.3	39	ND	ND
Field Cricket (*Gryllussp.*)	ND	3.4	ND	0.1	4.0	2.4	97	120	0.6	0.7	22	ND	ND
Earthworm (*Eisenea sp.)*	ND	3.8	ND	2.4	0.1	5.6	3023	59	2.4	ND	19	ND	ND
Summer													
Gorbi village													
Dragonfly (*Anisoptera sp.*)	ND	4.0	ND	0.2	ND	1.7	303	14	ND	0.2	6	ND	ND
Hornet sp.	ND	14.7	ND	0.1	ND	0.3	223	41	ND	0.4	19	ND	ND
Naudhiya Village													
Butterfly (*Phoebis sp.*)	ND	0.9	ND	ND	ND	1.9	125	ND	ND	0.4	4	ND	ND
Earthworm *(Eisenea sp.)*	ND	9.5	ND	3.2	0.0	0.1	2843	75	3.1	ND	27	ND	ND
Bijul river													
Dragonfly (*Anisoptera sp.*)	ND	49.9	ND	0.1	4.2	0.3	27	78	0.2	0.2	32	ND	ND
Dragonfly (*Anisoptera sp.*)	ND	ND	ND	0.1	ND	0.1	39	ND	ND	0.1	7	ND	ND
Jhigurda Dam													
Beetle (*Carabidae sp.)*	ND	7.0	ND	0.0	1.8	0.1	1116	119	ND	ND	17	ND	ND
Dragonfly (*Anisoptera sp.*)	ND	1.5	ND	ND	ND	0.2	302	16	0.0	ND	28	ND	ND
Field Cricket (*Gryllussp.*)	ND	1.9	ND	ND	ND	0.0	190	10	ND	ND	68	ND	ND
Butterfly (*Phoebis sp.*)	ND	1.7	ND	0.1	ND	0.1	244	15	ND	ND	16	ND	ND

3.5 Metal Concentration in Fodder Samples

Fodder samples were collected from Gorbi village, Naudiya village and Chaturbhuj temple during both the seasons, and samples were analysed for different metal contents. The results are summarized in **Table 3.5.1**.

Perusal of table indicates that As and Ni was not detected in any of the fodder samples. Cd was not detected at Naudiya village and Chaturbhujtemple, however the concentrations in winter exceeded at Gorbi village. Fe, Mn, and Zn were highest among all metals wherein Fe exceeded the permissible limits of WHO, and Zn and Mn were below the threshold limits. Other metals such as Cr and Hg also exceeded the permissible limits in the fodder samples.Metals such as Co, Cu, Pb and Fluoride were within the permissible limits.

Table 3.5.1: Heavy Metal Concentrations in Fodder Samples

Season/ Site/ Species	Heavy Metal Concentration (mg/kg)												
	As	**Ba**	**Cd**	**Co**	**Cr**	**Cu**	**Fe**	**Mn**	**Ni**	**Pb**	**Zn**	**Hg**	**F**
Winter													
Gorbi Village	ND	32	0.25	0.13	40.2	2.6	190	101	ND	0.04	15.7	0.042	0.21
Naudiya Village	ND	25	ND	0.46	19.8	0.9	142	123	ND	0.03	10.7	0.082	0.60
Chaturbhuj Temple	ND	20	ND	0.40	17.2	0.9	133	118	ND	0.03	9.5	0.040	0.43
Summer													
Gorbi Village	ND	31	0.01	0.42	22.2	0.4	177	123	ND	0.02	12.7	0.044	0.91
Naudiya Village	ND	42	ND	ND	24.6	0.3	190	88	ND	0.02	10.4	0.021	0.86
Chaturbhuj Temple	ND	38	ND	0.03	28.3	0.6	218	167	ND	0.05	6.9	0.072	0.53
WHO Guidelines	1.0	-	0.02	0.14-48	1.3	10	20	500	10	2.0	50	0.03	1100

3.6 Metal Concentration Milk, Urine and Scat Samples

Milk, Urine and Scat samples were collected from Gorbi village, Naudhiya village and Chaturbhuj temple area during both the seasons, and all the samples were analysed for metals content. The results are presented in **Table 3.6.1**.

Perusal of table indicates that Ni was not detected in any of the samples of milk, urine, and scat. As was not detected in any of the scat samples.All other metals were below the permissible limits except for Fe and Co which exceeded in Scat samples however the standard limit for Fe has not been described by WHO in urine and scat.Cd, Hg, F, Cu, Pb, Ni, Cr and Cu was not detected in milk and urine samples collected from all three sites but was found in scat samples.Metal concentration in faeces normally equals that in food/fodder (Leonzio*et.al*. 1989).

Table 3.6.1: Heavy Metal Concentration in Milk, Urine and Scat

Season/ Site / Item	Heavy Metal Concentration (mg/kg)												
	As	Ba	Cd	Co	Cr	Cu	Fe	Mn	Ni	Pb	Zn	Hg	F
Winter													
Gorbi Village													
Milk	0.02	0.08	ND	ND	ND	ND	0.48	0.010	ND	ND	0.71	ND	ND
Urine	0.03	0.16	ND	ND	ND	ND	0.36	0.006	ND	ND	0.03	ND	ND
Scat	ND	ND	ND	5.83	17.9	21.0	10164	279	ND	0.07	94	ND	ND
Naudhiya Village													
Milk	0.01	0.08	ND	ND	ND	ND	0.32	0.010	ND	ND	0.46	ND	ND
Urine	0.03	0.17	0.002	0.001	ND	ND	0.36	0.006	ND	ND	0.03	ND	ND
Scat	ND	ND	ND	7.87	8.6	21.4	3997	333	ND	0.18	168	ND	ND
Chaturbhuj Temple													
Milk	0.01	0.07	ND	ND	ND	ND	0.47	0.010	ND	ND	0.67	0.05	0.68
Urine	0.03	0.15	ND	ND	ND	ND	0.36	0.006	ND	ND	0.03	0.06	0.25
Scat	ND	ND	0.22	2.19	38.7	19.4	4604	171	ND	0.03	112	0.05	0.35
Summer													
Gorbi Village													
Milk	0.024	0.57	ND	ND	ND	ND	1.28	ND	ND	ND	3.52	ND	ND
Urine	0.032	0.17	ND	ND	ND	ND	0.36	0.006	ND	ND	0.03	ND	ND
Scat	ND	ND	ND	10.9	27.2	32.4	13888	316	ND	0.072	55	ND	ND
Naudiya Village													
Milk	0.013	0.08	ND	ND	ND	ND	0.37	0.005	ND	ND	0.69	ND	ND
Urine	0.006	0.19	ND	ND	ND	ND	0.12	ND	ND	ND	0.00	ND	ND
Scat	ND	ND	ND	1.36	3.7	11.5	2514	152	ND	0.001	47	ND	ND
Chaturbhuj Temple													
Milk	0.007	0.04	ND	ND	ND	ND	0.46	0.006	ND	ND	0.69	0.062	0.75
Urine	0.006	0.19	ND	ND	ND	ND	0.12	ND	ND	ND	0.00	0.068	0.33
Scat	ND	ND	0.015	0.06	2.7	9.5	180	12	ND	0.012	30	0.057	0.37
WHO Guidelines													
Milk	0.03-0.06	-	0.05	-	0.01-0.07	0.1-0.9	2.7	0.1	0.03-0.1	0.3	0.3-6.0	0.0005	0.01-4
Urine	-	-	-	-	-	-	-	-	-	-	-	-	-
Scat	2.5	35-123	1.7-2.1	2-2.1	38-58	5.6-112		195-1167	4.3-11.7	6.1-11.0	152-4333	0.27-0.4	< 5.0

3.7 Metal Concentration in Soil Samples

In all 6 soil samples were collected from Gorbi (2 nos.) and Naudhiya (4 nos.) during both the seasons and all the samples were analysed for different metal contents. Results are given in **Table 3.7.1.** Perusal of table indicates that As and Cd was not detected. All other metals were below the permissible limits at both the sites of Naudhiya village and Gorbi village during both the seasons.

Levels of Fe, Cr, Mn, and Zn were found considerably higher, though within permissible limits. The unexpectedly high concentrations of Fe, Zn, Cr and Mn may be attributed to geogenic sources or processes (Wuana, R. A., & Okieimen, F. E. (2011). Heavy metals in contaminated soils: a review of sources, chemistry, risks and best available strategies for remediation. Isrn Ecology, 2011).

Table 3.7.1: Heavy Metal Concentration in Soil Samples

Season/ Site/ Species	**Heavy Metal Concentration (mg/kg)**												
	As	**Ba**	**Cd**	**Co**	**Cr**	**Cu**	**Fe**	**Mn**	**Ni**	**Pb**	**Zn**	**Hg**	**F**
Winter													
Gorbi Village	ND	54	ND	13	17	54	13664	263	35	6.3	77	0.05	0.38
Naudiya Village - S1	ND	47	ND	10	27	40	45711	375	33	9.0	97	0.02	0.27
Naudiya Village - S2	ND	57	ND	9	20	42	42001	398	39	4.8	111	0.02	0.07
Summer													
Gorbi Village	ND	41	ND	10	24	16	15814	304	18	2.0	61	0.02	0.63
Naudiya Village - S1	ND	70	ND	20	63	52	38711	885	51	0.9	120	0.03	0.29
Naudiya Village - S2	ND	72	ND	23	66	41	31663	930	54	0.9	127	0.02	0.29
Indian Standards, Awasthi 2000	**-**	**-**	**3-6**	**-**	**-**	**135 - 270**	**-**	**-**	**75-150**	**250-500**	**-**	**-**	**-**

3.8 Bioaccumulation and Bio-accumulation Factor (BAF)

Bioaccumulation is mainly associated with the adverse effects of particular chemicals on living organisms. It is a process that causes an increased chemical concentration in an organism through all exposure routes including dietary absorption and transport across body surfaces from the surrounding media (water, sediments, etc). Relatively, BAF is a key parameter that directly links equilibrium partitioning between the environment and organisms. The present study deals with the study of bioaccumulation of trace or heavy metals (As, Pb, Ni, Cr, Co, Cd, Cu, Ba, Mn, Fe, Zn, and Hg in aquatic fauna and invertebrates.

Heavy metals are naturally occurring elements that have a high atomic weight and a density at least 5 times greater than that of water. Some of them are essential and some are non-essential for biological functioning (Tchounwou et al., 2012). The metals gain access into the ecosystem through anthropogenic source and gets distributed in the water body, suspended solids and sediments during the course of their mobility. The bioaccumulation rate of heavy metals depends on the ability of organism to digest the metals and the concentrations of metals in sediments, water or other surrounding media as well as the feeding habit (King and Jonathan, 2003; Ishaq et al., 2011).

Bio-accumulation Factor (BAF) is expressed as the ratio of the contaminant in an organism to the concentration in the ambient environment at a steady state, where the organism can take in the contaminant through ingestion with its food as well as through content i.e all routes of exposure (USEPA, 2000; Upadhi and Wokoma, 2012; Orata and Birgen, 2016). The BAF for pollutants below 1 is considered to be safer for biota whereas above 3 is considered to have high toxicity potentials (Arnot and Gobas, 2006). EPA User's Guide and Technical Documentation also states BCF values > 1 indicate that the concentration in the organism is greater than that of the medium (e.g., soil/sediment or water).

Bioaccumulation is often mistaken by Bio-concentration, but both are different in terms of exposure routes, the former counts all routes of exposure but Bio-concentration is the process by which a chemical substance is absorbed by an organism from the ambient environment only through its respiratory and dermal surfaces, wherein dietary exposure in not included. In addition, Bio-concentration factor (BCF) is expressed as the ratio of the concentration of a chemical in an organism to the concentration of the chemical in the surrounding environment (Arnot and Gobas, 2006).

The Bio-accumulation factor (BAF) is calculated as:-

BAF = Concentration in biota (mg/kg) / Concentration in sediments (or water) at steady state (mg/L)

To study bio-accumulation, the surrounding medium was taken to be sediment as the adsorption of pollutants (heavy metals in particular) sooner or later gets settled on sediment from the water column. Therefore, sediments contain significant loads of heavy metals as compared to water column acting as the major reservoir for pollutants in aquatic environments. The water is mobile and may have variable concentrations at variable times and may affect the actual bioaccumulation rates creating discrepancies is the results (Gupta et al., 2009; Friday et al., 2013). The calculated BAF in aquatic and terrestrial species samples collected from water bodies, associated sediments and soils has been shown in tables below.

The bioavailability of metals is influenced by physical, chemical and biological factors such as temperature, phase association, adsorption. It is also affected by factors that influence speciation species characteristics, biochemical/physiological adaptation and trophic interactions (Verkleji et al., 1993; Hamelink et al., 1994). Consequently, level of bioaccumulation differs from species to species based on physiology, regulatory ability, feeding habit and behaviour significantly affecting. In addition, metal ionic strength and pH is also a key variable in accumulation patterns in organisms (US EPA, 2000; Linnik and Zubenko, 2000; Friday et al., 2013). Reactive oxygen species (ROS) production and oxidative stress play a key role in the toxicity and carcinogenicity of metals.

Heavy metals such as Cadmium (Cd), Mercury (Hg), Lead (Pb) and Arsenic (As) has been listed in World Health Organization's list of 10 chemicals of major public concern (WHO, 2013) because of their high degree of toxicity. They are known to induce multiple organ damage, even at lower levels of exposure. United States Environmental Protection Agency (U.S. EPA), and the International Agency for Research on Cancer (IARC), also classified these heavy metals as either "known" or "probable" human carcinogens based on experimental and epidemiological studies (Tchounwou et al., 2012).

Based on the literature findings, the heavy metals of major concern for the present study were Cadmium (Cd), Mercury (Hg), Lead (Pb) and Arsenic (As) and there status is presented in **Tables 3.8.1** and **3.8.2** for winter and summer seasons, respectively, and is briefly summarized here for different species.

Fishes

- The BAFs was calculated for metals of concern in fish samples collected in winter s**eason** from the Kachanriver, Bijul river,JayantMorwani damand Rihand dam. The BAFs for Cd was in the range of 0 to 4.04, Hg was in the range of 0.17 to 1.2 and Pb was in the range of 0 to 0.68. Only, the Rohu fish samples collected from JayantMorwani dam had the highest BAF for Cadmium i.e. 4.04. No bioaccumulation of Aswas observed in the fish samples.
- In summer season, similar trends of bio-accumulation were observed and the BAF values for Cd, Hg and Pb in the fish samples collected from the similar

sites were found to be 0 to 3.7, 0.02 to 0.99 and 0-0.13 respectively. BAF for Cd was highest (3.79) in the fish samples collected from Kachanriver. No bio-accumulation of As was found in the fish samples. The Cadmium had highest BAF (> 1) value in both the seasons only in Rohu fish samples, which could be primary concern in terms of aquatic and human health.

Macro-invertebrates

- No bioaccumulation of Cd, Hg, As and Pb was evident in any of the invertebrate samples such as *Aschena* sp. *Mollusca bengalensis sp.* and Ranatra and the earthworm (*Eisenia sp.*) in both the season 1 and 2 at all sites. All other metals have BAF values below 1 wherein similar patterns of bioaccumulation was observed in both the seasons.

As reported in many studies that metals such as cobalt (Co), copper (Cu), chromium (Cr), iron (Fe), magnesium (Mg), manganese (Mn), molybdenum (Mo), nickel (Ni), selenium (Se) and zinc (Zn) are essential nutrients and are required for various physiological and biochemical functions therefore bioaccumulation of such metals would not be toxic (Tchounwou et al., 2012). Similarly, high bioaccumulation of metals such as Mn, Fe, Zn was found in this study in fishes are not of concern as they are essential metals.

The toxic metals also have lower bio-accumulation rates and thus BAF values below 1 possessing no major threat to aquatic species, expect for Cadmium (>4) in one sample that has high accumulation. Elevated concentrations of Cd in Rohu fish can be attributed to depuration process as Cd are non-essential metal ions to the fishes (Orata and Birgen, 2016). Findings of the present study are also consistent with other published results of Orata and Birgen wherein the BAF values for Cadmium was found to be high in fishes (Orata and Birgen, 2016). Similarly, Friday et al. also reported high bio-accumulation for lead in fish tissues (Friday et al., 2013).

Table 3.8.1: Bioaccumulation Factor of Aquatic Fishes and Macro-Invertebrate Samples Collected in Winter

Season/ Site/ Species	Bioaccumulation Factor												
	As	Ba	Cd	Co	Cr	Cu	Fe	Mn	Ni	Pb	Zn	Hg	F
Fishes													
Kachan River													
Catla	-	0.06	0.69	0.02	0.36	0.28	0.01	0.38	0.03	0.02	2.46	1.20	0.10
Bijul River													
Pomfret	-	0.58	2.31	0.01	0.87	1.39	0.02	0.34	0.06	0.05	2.77	0.64	0.18
Morwani Dam													
Rohu-1	-	0.99	4.04	0.65	1.57	4.99	1.54	0.29	0.45	0.68	1.18	0.18	0.17
Rohu-2	-	0.49	2.99	1.57	1.47	2.05	0.7	0.28	0.92	0.63	1.13	0.22	0.16
Rihand Dam													
Tengra	-	0.02	-	-	0.15	0.02	0.01	1.31	0.03	0.14	1.97	0.18	0.16
Silan	-	0.01	-	-	0.08	0.21	0.01	0.76	0.01	0.07	0.87	0.19	ND
Khursa	-	Nil	-	-	0.03	0.08	Nil	0.4	0.01	-	0.27	0.17	0.17
Aquatic Macro-invertebrates													
Mine Void - *Aeshna sp.*	-	-	-	-	-	-	-	-	-	-	0.12	-	ND
Mine Void - *Aeshna sp.*	-	-	-	-	-	-	0.01	-	-	-	1.22	-	ND
Mine Void - *Aeshna sp.*	-	-	-	0.03	-	0.05	0.01	3.26	-	-	0.3	-	ND
Kachan A1 - *Aeshna sp.*	-	-	-	0.02	-	0.06	0.01	0.13	-	-	0.25	-	ND
Kachan A2- *Ranatra sp.*	-	-	-	0.04	-	0.07	0.01	0.36	-	-	0.19	-	ND
Temple- *Mollusca*	-	-	-	0.01	-	0.01	Nil	0.09	-	-	0.01	-	ND
Morvani Dam- *Aeshna sp.*	-	-	-	-	-	0.04	Nil	0.03	-	-	0.01	-	ND
Terrestrial invertebrates													
Gorbi Basti- Earthworm	-	0.23	-	0.29	0.14	0.43	0.18	0.26	0.16	-	0.5	-	ND
Naudiya Village – Earthworm	-	0.06	-	0.12	-	0.11	0.08	0.07	0.05	-	0.16	-	ND

Table 3.8.2: Bioaccumulation Factor of Aquatic Fishes and Macro-invertebrate Samples Collected in Summer

Season/ Site/ Species	Bioaccumulation Factor												
	As	**Ba**	**Cd**	**Co**	**Cr**	**Cu**	**Fe**	**Mn**	**Ni**	**Pb**	**Zn**	**Hg**	**F**
Fish Species													
Kachan river													
Rohu	-	0.04	3.79	-	0.26	0.5	0.01	0.11	-	-	1.27	0.99	0.06
Tilapiya	-	0.26	-	0.15	0.48	0.35	0.01	0.06	-	-	0.68	0.72	0.12
Bijul River													
Rohu	-	0.43	0.37	0.16	0.35	0.81	0.03	0.05	-	-	1.25	0.10	0.18
Silan-1	-	0.51	-	-	0.74	1.41	0.02	0.04	-	0.04	5.44	0.45	0.07
Silan-2	-	0.63	-	-	0.42	2.49	0.02	0.07	-	0.05	4.11	0.51	0.12
Morwani Dam													
Rohu	-	0.17	-	0.05	0.21	0.22	0.37	0.02	-	-	1.24	0.05	0.11
Tilapiya	-	1.76	-	0.55	0.43	0.19	0.89	0.02	-	0.13	1.19	0.14	0.01
Rihand Dam													
Silan	-	0.13	-	-	0.18	0.12	0.01	0.09	-	0.05	1.21	0.16	0.13
Khursa -1	-	0.09	-	-	0.04	0.13	0.01	0.06	-	-	0.29	0.03	0.02
Khursa - 2	-	0.07	-	0.08	0.08	0.12	0.01	0.07	-	-	0.29	0.19	ND
Tengra -1	-	0.18	-	-	0.11	0.04	0.01	0.28	-	0.03	0.72	0.02	ND
Tengra -2	-	0.25	-	-	0.13	0.04	0.01	0.32	-	0.05	0.63	0.06	0.01
Aquatic Macro-invertebrates													
Mine Void A1- *Aeshna sp.*	-	-	-	-	-	-	-	-	-	-	0.05	-	ND
Mine Void A2- *Aeshna sp.*	-	-	-	-	-	-	-	-	-	-	0.62	-	ND
Mine Void B- *Aeshna sp.*	-	-	-	0.01	-	0.02	-	0.08	-	-	0.05	-	ND
Chaturbhuj Temple - *Mollusca*	-	-	-	-	-	-	-	-	-	-	0.01	-	ND
Jayant Morvani Dam- *Mollusca*	-	-	-	0.04	-	0.08	0.01	0.01	-	-	0.28	-	ND
Mine Void C1- *Aeshna sp.*	-	-	-	-	-	0.02	Nil	0.01	-	-	0.03	-	ND
Mine Void C2- *Aeshna sp.*	-	-	-	-	-	0.09	Nil	0.01	-	-	0.11	-	ND
Mine Void C3- *Aeshna sp.*	-	-	-	0.02	-	0.01	0.09	0.05	0.07	-	0.05	-	ND
Gorbi Basti – Earthworm	-	0.23	-	0.32	-	0.01	0.18	0.25	0.17	-	0.45	-	ND

3.9 Summary and Recommendations

Metal content in different aquatic and terrestrial fauna has been assessed. Aquatic species covered were different variety of fishes and benthic invertebrates found in different water bodies. Terrestrial fauna covered different types of invertebrates/ insects. Metal content was also determined in fodder samples, milk, urine and scat of animals, and soil samples. Based on the assessment of metals content in different species/ samples, bioaccumulation in fishes and macro-vertebrates were determined. Samples were collected in winter and summer seasons. Finally, bio-accumulation of metals in different aquatic & terrestrial species has been determined, which is summarised here.

- **Fishes:** In both winter and summer, the BAFs in fishes were found to be below for metals of concern except for Cadmium for which the calculated BAF was exceptionally high and only in Rohu fish collected from Jayant Morwani dam and Kachan river. Hg also has BAF values for Catla above 1 collected from Kachanriver.

- **Macro-invertebrates:** No bioaccumulation of Cd, Hg, As and Pb was evident in any of the invertebrate samples such as *Aschena* sp. *Mollusca bengalensis sp.* and Ranatra and the earthworm (*Eisenia sp.*) in both the season 1 and 2 at all sites. All other metals have BAF values below 1 wherein similar patterns of bioaccumulation was observed in both the seasons.

As reported in many studies that metals such as cobalt (Co), copper (Cu), chromium (Cr), iron (Fe), magnesium (Mg), manganese (Mn), molybdenum (Mo), nickel (Ni), selenium (Se) and zinc (Zn) are essential nutrients and are required for various physiological and biochemical functions therefore bioaccumulation of such metals would not be toxic (Tchounwou et al., 2012). Similarly, high bioaccumulation of metals such as Mn, Fe, Zn was found in this study in fishes are not of concern as they are essential metals.

The toxic metals analysed here have lower bio-accumulation rates and thus BAF values below 1 possessing no major threat to aquatic species on expect for Cadmium (>4) in one sample that has high accumulation. Elevated concentrations of Cd in Rohu fish can be attributed to depuration process as Cd are non-essential metal ions to the fishes (Orata and Birgen, 2016).

Findings of the present study are also consistent with other published results of Orata and Birgen wherein the BAF values for Cadmium was found to be high in fishes (Orata and Birgen, 2016). Similarly, Friday et al. also reported high bio-accumulation for lead in fish tissues (Friday et al., 2013).

More and frequent studies (once in two years) are needed to ensure safe levels of different metals in different faunal species, particularly, the one which are consumed by human beings.

Chapter 4

Ash Characterization and Leaching Study

This chapter deals with the characterization of flyash, bottom ash and pond ash samples with respect to elemental composition, metals content and morphologocal analysis. Further leachate study has been conducted for all the three types of ashes following TCLP (Toxic Characteristic Leaching Procedure) and WET (Waste Extraction Test) method. Details of the study along with results are presented here.

4.1 Sample collection and Analysis

4.1.1 Collection of Ash Samples

Three main types of ash samples were collected & studied as:

- **Fly Ash:** Ash extracted from flue gases by any suitable process such as by cyclone separator or electro-static precipitator.
- **Bottom Ash:** Fuel ash collected from the bottom of boilers by any suitable method.
- **Pond Ash:** Fly ash or bottom ash or both mixed in any proportion and conveyed or carried in the form of water slurry & deposited in pond.

Different types of ash samples were collected during Winter (December 2018) and Summer (May 2019). Fly ash, bottom ash and pond ash samples were collected from different storage location of NTPC, VIndhyachal and were brought to the lab for further analysis. The samples were collected in clean zipped pouches of 500 -1000 g capacity. Five grab samples were collected from each location and each sample was homogenously mixed in laboratory to obtain representative sample of each location. The samples were dried at 110°C in oven for detailed quality assessment and characterization.

4.1.2 Characterization of Ash Samples

Different types of ash samples collected in both the sampling sets (Winter & Summer) were thoroughly characterized for various physio-chemical, structural and morphological parameters. Various parameters include elemental analysis, particle size analysis (PSA), morphological analysis using Scanning electron microscopy (SEM), etc. All the parameters contribute to confirm the nature of waste and the type of ash.

Further, leaching potential of various trace and toxic elements is also assessed using standard leaching procedure, namely Toxic Characteristic Leaching Procedure (TCLP) and Waste Extraction Test (WET) as specified in Solid & Hazardous Wastes (Management and Transboundary Movement) Rules, 2016.

4.1.2.1 Determination of pH

The pH of samples was determined using pH meter. The fixed amount of sample was taken into beaker and fixed amount of deionized water was added to it, kept on shaker for 5 mins, allowed particles to settle down and the pH was measured by inserting the electrode into the beaker.

4.1.2.2 Specific Gravity

The specific gravity of different fly ash samples was determined by pycnometer. A known weight of fly ash sample was taken. Water was filled up to the mark. Specific gravity was determined by the formula as:

Specific gravity = W1 /V

Where, V = W3 – (W2- W1)

W1 = weight of the ash taken in the tube

W2 = weight of the ash + water in the tube

W3 = weight of only water in the tube

4.1.2.3 Particle Size Analysis (PSA)

Particle size analysis was done in order to determine the distribution of different sized particles in the ash samples, using particle size analyzer (Horiba Nanosizer). Particle size analysis is performed by dynamic light scattering (DLS) method. The ash sample was dispersed evenly in deionized water and sonication was done thrice in order to break the agglomerates.

4.1.2.4 Elemental Analysis

Elemental analysis was done to determine the chemical composition of the ash samples. The elemental composition of fly ash was determined by microwave acid digestion method. 300 mg of the sample was taken and 6 ml Nitric acid & 2 ml HCl was added. The program for complete acid digestion of sample was optimized and found to be 40% power rating for 10 min, 80% power rating for 10 min and 100 % power rating for 5 min. The solution was stored and diluted 10 times. All the elements were analyzed using ICP-MS (Perkin Elmer, Model NexION 300).

4.1.2.5 Leaching Tests

According to the Solid & Hazardous Wastes (Management and Transboundary Movement) Rules, 2016, Hazardous waste is defined as; any waste which by reason of characteristics such as physical, chemical, biological, reactive, toxic, flammable, explosive or corrosive, causes danger or is likely to cause danger to health or environment, whether alone or in contact with other wastes or substances & includes:

"The SCHEDULE II [rule 3 (1) (17) (ii)] of Solid & Hazardous Wastes (Management and Transboundary Movement) Rules, 2016, lists, the waste constituents with concentration limits as detailed in **Annexure 4.1**. Class A is based on leachable concentration limits using Toxicity Characteristic Leaching Procedure (TCLP) & Waste Extraction Test (WET) method. The testing method for list of constituents at A1 to A61 in Class-A is based on TCLP and for extraction of leachable constituents, USEPA Test Method 1311 is used. The testing method for list of constituents at A62 to A79 in Class-A is based on Waste Extraction Test (WET), Procedure is given in Appendix II of section 66261 of Title 22 of California Code regulation (CCR)."

The leaching potential of the elements present in the ash samples was determined using the TCLP & WET tests. Considering the nature and composition of ash samples, only metals were analyzed in the leachates since other elements and organic constituents are not expected in the ash.

A. Toxic Characteristic Leaching Procedure (TCLP)

As per the recommended procedure for solid samples, the solid to liquid ratio of 1:20 was used. Two extraction fluids were prepared (Extraction fuild-1 & Extraction fluid-2) and added to the samples depending upon their pH. Extraction experiments included addition of 5 g solid sample in a polypropylene bottle followed by the addition of 100 mL of extraction fluid. The TCLP tests were carried out in a rotary agitator maintained at a speed of 150 rpm. The mixture was then agitated for 18 h and the filtrate was collected by syringe filtration. The concentration of various metals in the leachates wasdetermined using ICP-MS (Perkin Elmer, Model NexIon 300).

B. Waste Extraction Test (WET)

Ash samples were leached in the 1:10 solid to liquid ratio using citrate buffer. 10g sample was transferred to polypropylene flasks to which 100ml citrate buffer was added and were agitated for 48 hours on rotary shaker. Leached solution was then filtered and analyzedon ICP-MS (Perkin Elmer, Model NexION 300).

4.1.2.6 Scanning Electron Microscopy (SEM)

The SEM micrographs were obtained using (Model: VEGA3TESCAN). Electron coating over the dried sample was done upto thickness of 20 nm. The working potential difference was maintained at 15 Kv and 20 Kv at vacuum depending upon the sample. Working distance was adjusted at 13 mm. Micrographs were obtained at different magnifications.

4.2 Results

During sample collection in Winter 2018, five samples each of fly ash, bottom ash and pond ash were collected, whereas during Summer 2019, one sample each of fly ash and bottom ash, and 5 samples of pond ash were collected. All the samples were analysed for various physical parameters (colour, pH, specific gravity & particle size), elemental composition (SiO_2, Al_2O_3, B, FeO, CaO& oxides of Na, K & Mg) and metal content (As, Ag, Ba, Be, Cd, Cr, Cu, Co, Mn, Ni, Pb, Ti, V, Zn & Se).

The results for each of the samples analysed for Winter 2018 and Summer 2019 are given in **Annexure 4.2** (**Tables A.1-A.6**).

Summary of ash samples analysis with respect to physical parameters, elemental composition and metal content is presented in **Table 4.2.1.** Salient observations are given here.

4.2.1 Physical Parameters

Colour & pH

Ash samples were found to have different shades of grey. Fly ash (from hopper) had muddy colour, bottom ash had light grey colour and pond ash had dark grey colour. The same colour trend was observed for both the sets of samples. The average pH of the samples varied from 3.9 to 6.8 during Winter sampling, whereas pH was found to be in the range of 6.6-7.3 for the Summer samples.

Specific Gravity

Average specific gravity of ash samples was found to be in the range of 2.0 to 2.9. These values correspond to the values reported in literature. Specific gravity of bottom ash sample collected in Summer was found to be highest (2.9 g/cc).

Particle Size

In order to assess the possibility of re-suspension of fly ash in air, particle size analysis was carried out. The values are found close to the literature values. Further, particle size distribution of fly ash, bottom ash and pond ash samples are given in **Annexure 4.2 (Figs. A.1-A.3).** The particle size was observed to vary between 300 nm to 600 nm, i.e. 0.3 µm to 0.6 µm approximately for all the types of ashes in both the sets of samples.

4.2.2 Elemental Composition

The elemental composition of the ash samples was carried out to determine the quality of ash w.r.t different elements present in the samples and to confirm the class of ash samples. The results of elemental composition of various ash samples confirm that as per ASTM C618, these ash samples are of F-grade class ash. The lime and other alkali content of all samples were found be very low (<10%). There were no significant differences among all ash samples as far as chemical composition is concerned. Three major elements were SiO_2, Al_2O_3 and Fe_2O_3, constituting more than 90% of the ash samples. Average values of these were in the range of 51.4-51.8%, 31.4-32.4% and 3.1-8.0%, respectively.

4.2.3 Metals Content

Analysis of metals content indicates that:

- In general metal content was found to be more in fly ash samples as compared to bottom ash and pond ash samples, collected during winter and summer months
- Average concentration of Ag, As, Be, Co, Pb, Ti, Se and Zn was found to be higher in Summer samples as compared to Winter samples
- Average concentration of Ni and V was found to be higher in Winter samples as compared to Summer samples
- Out of total 22 samples, Cd was detected only in one sample of pond ash in Winter
- During Summer, average concentration of Ba was found more in fly ash and pond ash samples, whereas it was less in bottom ash, as compared to winter samples
- Average concentration of Mn was found more in fly ash and bottom ash samples collected in winter, whereas it was more in pond ash samples collected in Summer season.

Table 4.2.1: Summary of Characterization of Ash Samples Collected during Winter and Summer

Sr. No.	Parameters	Winter Sampling			Summer Sampling		
		Fly Ash	Bottom Ash	Pond Ash	Fly Ash	Bottom Ash	Pond Ash
A.	**Physical Parameters**						
1.	Colour	Muddy grey	Light grey	Dark grey	Muddy grey	Light grey	Dark grey
2.	pH	6.9	6.8	6.1	6.6	6.6	7.3
3.	Specific Gravity (g/cc)	2.0	2.1	2.0	2.1	2.9	2.3
4.	Particle Size (µm)	0.3-0.6	0.3-0.6	0.3-0.6	0.3-0.6	0.3-0.6	0.3-0.6
B.	**Elemental Composition (%)**						
5.	SiO_2	51.7	51.8	51.7	51.6	51.4	51.7
6.	Al_2O_3	32.4	32.0	31.6	31.4	32.2	32.1
7.	Fe_2O_3	8.0	7.5	7.3	3.1	3.1	4.0
8.	TiO_2	1.11	1.20	1.14	0.88	1.04	1.11
9.	P_2O_5	0.61	0.55	0.69	0.67	0.63	0.63
10.	SO_3	0.064	0.065	0.050	0.049	0.071	0.067
11.	CaO	1.1	2.4	2.0	2.6	2.7	2.3
12.	Oxides of Na, K, Mg	2.0	1.9	2.4	2.0	1.8	2.1
13.	Others	3.016	2.685	3.12	7.701	6.959	5.993
C.	**Metal Content (mg/kg)**						
12.	Arsenic (As)	5.06	1.12	0.78	27.6	21.4	19.5
13.	Silver (Ag)	0.3	0.4	0.56	1.0	0.7	0.6
14.	Barium (Ba)	478	237	357	496	163	585
15.	Beryllium (Be)	1.03	0.01	0.55	1.94	1.06	0.57
16.	Cadmium (Cd)	BDL	BDL	0.73	BDL	BDL	BDL
17.	Chromium (Cr)	59	23	26	50	52	27
18.	Copper (Cu)	39.8	18.2	8.4	25.8	15.9	13.5
19.	Cobalt (Co)	5.7	4.1	3.4	6.1	6.4	5.5
20.	Manganese (Mn)	774	721	735	308	547	1166
21.	Nickel (Ni)	33	30	20	6.7	4.4	2.3
22.	Lead (Pb)	1.4	BDL	0.7	34.6	40.7	14.5
23.	Titanium (Ti)	2.8	4.4	1.2	16.7	4.6	8.5
24.	Vanadium (V)	56	19	20	0.73	0.63	0.08
25.	Zinc (Zn)	42	25	22	59	42	46
26.	Selenium (Se)	0.02	BDL	BDL	47	16.6	20.2
27.	Mercury (Hg)	0.126	0.088	0.065	-	0.062	0.092
28.	Fluoride (F)	4.69	4.53	4.36	4.14	5.22	3.66

4.3 Morphological Studies

The SEM micrographs of fly ash, bottom ash & pond ash samples are presented in **Figs. 4.3.1, 4.3.2** and 4.**3.3** respectively. It can be concluded from the SEM images, that fly ash & pond ash particles are spherical in shape with small amount of porosity, whereas in bottom ash the morphology is quite uneven and it has higher porosity.

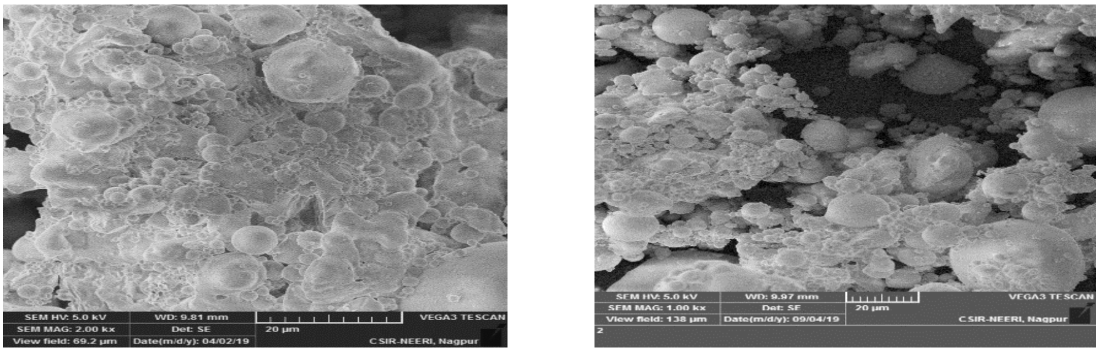


Fig. 4.3.1: SEM Micrographs of Fly Ash Samples Collected in Winter and Summer

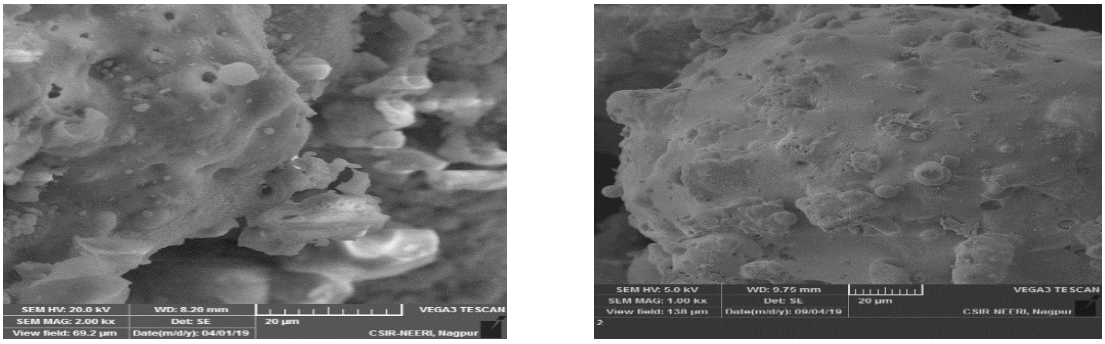


Fig.4.3.2: SEM Micrographs of Bottom Ash Samples Collected in Winter and Summer

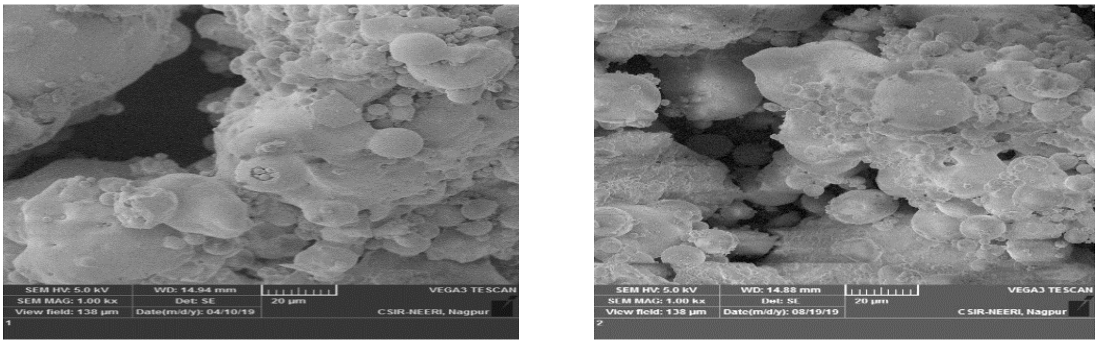


Fig. 4.3.3: SEM Micrographs of Pond Ash Samples Collected in Winter and Summer

4.4 Metal Leaching Study (TCLP & WET)

Leaching of toxic metals from ash is considered as the most potential environmental hazard associated with fly ash. Although CPCB, India and USEPA, USA have classified coal fly ash as non-hazardous waste, it is a common fear that various toxic elements present in fly ash may leach into the underground water and can travel long distances in due course of time. The mobility of different elements from coal ash is critically dependent on the pH developed within the ash–water system. Oxyanions like B, As and Se have high solubility and these tend to leach more at both low and high pH values, while cations like Ca and Sr show decrease in solubility when pH increases.

As per Solid & Hazardous Wastes (Management and Transboundary Movement) Rules, 2016 two types of leaching tests were performed (TCLP & WET) to determine the leaching of various toxic metals from ash samples. The results of these tests help in establishing the hazardous nature of the waste and also delineating the extent of leaching of the toxic elements from the waste.

A commonly used test for the determination of the leaching characteristics of ash is the Toxicity Characteristic Leaching Procedure (TCLP Method 1311) established by the US Environmental Protection Agency (US EPA). This procedure provides a uniform method to compare the tendency of inorganic elements to leach out from waste samples into moderate-to-highly acidic aqueous environments. The TCLP tests are conducted in harsher conditions and the heavy metal concentrations in the leachate are considered for describing the hazardous nature of the waste. Regulatory limits for various elements have been specified to declare the waste as hazardous or non-hazardous.

All the elements are not completely leached by TCLP method, WET method is found to be more efficient for some elements as it uses citrate buffer as leaching agent.

The results of TCLP and WET tests of Winterand Summer samples are given in **Annexure 4.2** (**Tables A.7 - A.10)**, and summary of results is presented here in **Table 4.4.1.**

Perusal of the table indicates that in both TCLP and waste extraction tests almost all the metals leached from the different ash samples in both the sets, however the concentrations of various metals in all the samples were found much below the threshold limits as per solid & hazardous waste rules.

It is to be noted that Fe is not included in the Schedule II of Hazardous and Other Wastes (Management and Transboundary Movement) Rules, 2016.

Further, Hg is analysed in TCLP extracts and the Concentrations of Hg in TCLP extracts were below the permissible limits and in many cases it was below detection limit (BDL).

Table 4.4.1: Summary of TCLP and WET Tests - Metal Concentration from Leachate of Ash Samples Collected during Winter and Summer

Unit: mg/L

Sr. No.	Metal	Threshold Value	Winter Sampling			Summer Sampling		
			Fly Ash	Bottom Ash	Pond Ash	Fly Ash	Bottom Ash	Pond Ash
A.	**TCLP Test**							
1.	Arsenic (As)	5.0	0.006	0.001	0.01	0.011	BDL	0.003
2.	Silver (Ag)	5.0	0.001	BDL	0	0.002	BDL	0.001
3.	Barium (Ba)	100.0	3.3	1.1	6.6	2.4	0.6	3.1
4.	Cadmium (Cd)	1.0	0.002	0.001	0.002	BDL	BDL	BDL
5.	Chromium (Cr)	5.0	0.025	0.029	0.034	0.022	0.021	0.02
6.	Manganese (Mn)	10.0	0.12	0.136	0.108	0.136	0.047	0.548
7.	Nickel (Ni)	20.0	0.02	0.01	0.018	0.018	0.008	0.007
8.	Lead (Pb)	5.0	0.001	0.005	0.007	0.002	0.002	0.002
9.	Selenium (Se)	1.0	0.008	BDL	0.001	BDL	BDL	BDL
B.	**WET Test**							
1.	Beryllium (Be)	0.75	0.014	BDL	BDL	0.01	0.005	0.004
2.	Chromium (Cr)	5.0	0.112	0.034	0.03	0.095	0.045	0.094
3.	Copper (Cu)	25.0	0.235	0.064	0.042	0.155	0.1	0.097
4.	Cobalt (Co)	80.0	0.042	0.005	0.008	0.028	0.015	0.014
5.	Molybydnum (Mo)	350.0	0.317	BDL	0.026	0.277	0.025	0.097
6.	Nickel (Ni)	20.0	0.306	0.042	0.052	0.086	0.048	0.092
7.	Titanium (Ti)	-	0.002	BDL	BDL	0.004	0.001	0.002
8.	Vanadium (V)	24.0	1.016	0.05	0.087	0.538	0.087	0.258
9.	Zinc (Zn)	250.0	7.636	1.538	1.792	0.244	0.108	0.125

Further, leaching experiments were also conducted using extraction fluid II having pH 2.9 (in the similar pH range of mine void water). Though concentration levels of some of the metals were found to be more, however the levels were much below the threshold values, as presented in **Table 4.4.2**.

Table 4.4.2: Summary of Leaching Tests at Low pH of 2.9 – Metal Concentration from Leachate of Ash Samples Collected during Winter and Summer

Unit: mg/L

Sr. No.	Metal	Threshold Value	Winter Sampling			Summer Sampling		
			Fly Ash	Bottom Ash	Pond Ash	Fly Ash	Bottom Ash	Pond Ash
1.	Arsenic (As)	5.0	0.098	0.018	0.031	0.156	0.032	0.035
2.	Silver (Ag)	5.0	BDL	BDL	BDL	0.005	BDL	BDL
3.	Barium (Ba)	100.0	BDL	BDL	BDL	BDL	BDL	BDL
4.	Cadmium (Cd)	1.0	0.003	0.005	BDL	0.004	BDL	0.001
5.	Chromium (Cr)	5.0	0.013	0.039	0.012	0.014	0.004	0.007
6.	Manganese (Mn)	10.0	0.411	0.01	0.187	0.337	0.212	0.300
7.	Nickel (Ni)	20.0	BDL	BDL	BDL	BDL	BDL	BDL
8.	Lead (Pb)	5.0	0.016	0.024	0.008	0.27	0.007	0.067
9.	Selenium (Se)	1.0	0.106	0.024	0.014	0.271	0.037	0.019
10.	Aluminum (Al)	-	11.72	10.03	13.94	9.175	7.353	9.205
11.	Beryllium (Be)	0.75	0.003	0.001	0.001	0.005	0.001	0.001
12.	Cobalt (Co)	80.0	0.009	0.007	0.004	0.011	0.003	0.003
13.	Copper (Cu)	25.0	0.059	3.945	0.052	0.051	0.064	0.051
14.	Iron (Fe)	-	1.117	0.336	1.778	0.853	1.449	1.956
15.	Molybydnum (Mo)	350.0	0.1	BDL	0.002	0.251	0.029	0.009
16.	Nickel (Ni)	20.0	BDL	0.008	BDL	BDL	BDL	BDL
17.	Zinc (Zn)	250.0	0.204	0.116	0.117	0.211	0.149	0.200

4.5 Conclusion & Recommendations

- The quality of various ash samples was thoroughly characterized w.r.t various physical, chemical, structural and morphological properties and leaching patterns to assess their hazardous characteristics and potential to leach toxic metals.

- Particle size analysis was carried out to assess the re-suspension of fly ash in air during handling and transportation. The specific gravity and particle size indicate that the chances of re-suspension of fly ash particles are relatively less during handling and transportation.

- All the ash samples collected from different locations were having similar chemical composition. All the samples from both the sets contain trace quantities of various toxic elements including As, Cr, Se, Pb, Ni etc.

- The morphology of ash particles was determined using Scanning Electron Microscopy which revealed that the particles (fly ash & pond ash) consisted of solid sphere and bottom ash has good porosity.

- The standard leaching tests, TCLP and WET were conducted to assess the potential of various ash samples for leaching of toxic metals. The tests revealed that the toxic metals leached from all the three types of ash samples, however the concentrations of various metals in all the samples were found to be much below the threshold/regulatory limits as per Indian Hazardous Wastes Rules 2016.

- Leaching tests at low pH of 2.9 (in similar range of present mine water) were also conducted. The results were found to be more or less in similar range, and levels were much below the threshold values.

Recommendations

As per the Indian Hazardous Wastes (Management, Handling and Transboundary Movement) Rules, and regulatory norms of other countries, fly ash is not considered as hazardous waste. However, considering the findings of the numerous previous studies and also the results of present study, particularly the potential of ash samples for leaching of toxic metals, it is recommended that:

- Detailed geochemical and hydrogeological studies may be undertaken in order to ascertain the long-term impacts of disposal of fly ash/bottom ash. The study may address determination of quality and location of groundwater, groundwater flow paths, the potential for coal ash to leach toxic elements and to react with minerals or groundwater, etc.

- It is also recommended that long term monitoring plans including frequent sampling and analysis (annually, initially for 3 years) must be undertaken to check the movement of fly ash particles and leaching of metals and other toxic elements in and around the disposal area.

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Annexure 4.1

SCHEDULE II
[See rule 3 (1) (17) (ii)]

List of waste constituents with concentration limits

Class A: Based on leachable concentration limits [Toxicity Characteristic Leaching Procedure (TCLP) or Soluble Threshold Limit Concentration (STLC)]

Class	Constituents	Concentration in mg/l
(1)	(2)	(3)
A1	Arsenic	5.0
A2	Barium	100.0
A3	Cadmium	1.0
A4	Chromium and/or Chromium (III) compounds	5.0
A5	Lead	5.0
A6	Manganese	10.0
A7	Mercury	0.2
A8	Selenium	1.0
A9	Silver	5.0
A10	Ammonia	50*
A11	Cyanide	20*
A12	Nitrate (as nitrate-nitrogen)	1000.0
A13	Sulphide (as H_2S)	5.0
A14	1,1-Dichloroethylene	0.7
A15	1,2-Dichloroethane	0.5
A16	1,4-Dichlorobenzene	7.5
A17	2,4,5-Trichlorophenol	400.0
A18	2,4,6-Trichlorophenol	2.0
A19	2,4-Dinitrotoluene	0.13
A20	Benzene	0.5
A21	Benzo (a) Pyrene	0.001
A22	Bromodicholromethane	6.0
A23	Bromoform	10.0
A24	Carbon tetrachloride	0.5
A25	Chlorobenzene	100.0
A26	Chloroform	6.0
A27	Cresol (ortho+ meta+ para)	200.0
A28	Dibromochloromethane	10.0
A29	Hexachlorobenzene	0.13
A30	Hexachlorobutadiene	0.5
A31	Hexachloroethane	3.0
A32	Methyl ethyl ketone	200.0
A33	Naphthalene	5.0
A34	Nitrobenzene	2.0
A35	Pentachlorophenol	100.0
A36	Pyridine	5.0
A37	Tetrachloroethylene	0.7
A38	Trichloroethylene	0.5

(1)	(2)	(3)
A39	Vinyl chloride	0.2
A40	2,4,5-TP (Silvex)	1.0
A41	2,4-Dichlorophenoxyacetic acid	10.0
A42	Alachlor	2.0
A43	Alpha HCH	0.001
A44	Atrazine	0.2
A45	Beta HCH	0.004
A46	Butachlor	12.5
A47	Chlordane	0.03
A48	Chlorpyriphos	9.0
A49	Delta HCH	0.004
A50	Endosulfan (alpha+ beta+ sulphate)	0.04
A51	Endrin	0.02
A52	Ethion	0.3
A53	Heptachlor (& its Epoxide)	0.008
A54	Isoproturon	0.9
A55	Lindane	0.4
A56	Malathion	19
A57	Methoxychlor	10
A58	Methyl parathion	0.7
A59	Monocrotophos	0.1
A60	Phorate	0.2
A61	Toxaphene	0.5
A62	Antimony	15
A63	Beryllium	0.75
A64	Chromium (VI)	5.0
A65	Cobalt	80.0
A66	Copper	25.0
A67	Molybdenum	350
A68	Nickel	20.0
A69	Thallium	7.0
A70	Vanadium	24.0
A71	Zinc	250
A72	Fluoride	180.0
A73	Aldrin	0.14
A74	Dichlorodiphenyltrichloroethane (DDT), Dichlorodiphenyldichloroethylene (DDE), Dichlorodiphenyldichloroethane (DDD)	0.1
A75	Dieldrin	0.8
A76	Kepone	2.1
A77	Mirex	2.1
A78	Polychlorinated biphenyls	5.0
A79	Dioxin (2,3,7,8-TCDD)	0.001

Annexure 4.2

Characterization of Fly Ash, Bottom Ash and Pond Ash Samples

Table A.1: pH and Specific Gravity of Ash Samples Collected in Winter Season

Sr. No.	Sample Number	Fly Ash		Bottom Ash		Pond Ash	
		pH	Specific Gravity (g/cc)	pH	Specific Gravity (g/cc)	pH	Specific Gravity (g/cc)
1.	S1	6.9	2.1	7.0	2.12	6.2	2.0
2.	S2	7.0	2.0	7.0	1.99	6.1	1.9
3.	S3	6.8	1.9	6.8	2.07	6.0	2.2
4.	S4	6.9	2.1	6.6	2.02	6.1	2.1
5.	S5	7.1	2.0	6.7	2.06	6.2	2.0
Average		**6.9**	**2.0**	**6.8**	**2.1**	**6.1**	**2.0**

Table A.2: pH and Specific Gravity of Ash Samples Collected in Summer Season

Sr. No.	Sample Number	Fly Ash		Bottom Ash		Pond Ash	
		pH	Specific Gravity (g/cc)	pH	Specific Gravity (g/cc)	pH	Specific Gravity (g/cc)
1.	S1	6.6	2.1	6.6	2.9	7.0	2.8
2.	S2	-	-	-	-	7.2	2.0
3.	S3	-	-	-	-	7.3	2.0
4.	S4	-	-	-	-	7.4	2.2
5.	S5	-	-	-	-	7.5	2.3
Average		**6.6**	**2.1**	**6.6**	**2.9**	**7.3**	**2.3**

Table A.3: Elemental Composition of Different Ash Samples of Winter Season

Sr. No.	Sample	SiO_2	Al_2O_3	Fe_2O_3	TiO_2	P_2O_5	SO_3	CaO	Oxides of Na, K, Mg	Others
A.	**Fly Ash**									
1.	FA1	51.2	32.5	9.9	0.91	0.78	0.063	0.7	2.0	1.947
2.	FA2	50.4	34.9	8.0	0.98	0.45	0.071	1.0	1.9	2.299
3.	FA3	52.1	31.2	6.2	1.23	0.61	0.066	1.2	2.2	5.194
4.	FA4	51.3	32.5	8.1	1.45	0.59	0.053	1.1	1.9	3.007
5.	FA5	53.4	30.8	7.7	0.98	0.62	0.065	1.3	1.8	3.335
	Average	**51.7**	**32.4**	**8.0**	**1.11**	**0.61**	**0.064**	**1.1**	**2.0**	**3.016**
B.	**Bottom Ash**									
1.	BA1	50.9	32.0	8.1	0.78	0.31	0.073	2.0	1.3	4.537
2.	BA2	53.2	31.1	7.4	1.15	0.65	0.077	1.9	2.4	2.123
3.	BA3	51.3	33.0	6.9	0.94	0.39	0.052	2.1	1.9	3.418
4.	BA4	50.8	31.3	8.3	1.71	0.77	0.069	3.5	1.6	1.951
5.	BA5	52.7	32.3	6.9	1.41	0.63	0.054	2.4	1.8	1.806
	Average	**51.8**	**32.0**	**7.5**	**1.20**	**0.55**	**0.065**	**2.4**	**1.8**	2.685
C.	**Pond Ash**									
1.	PA1	53.1	32.8	7.5	1.31	0.48	0.071	1.3	2.3	1.139
2.	PA2	50.8	30.7	7.8	0.97	0.93	0.032	1.9	2.1	4.768
3.	PA3	52.5	32.5	7.1	1.44	0.77	0.041	2.7	1.9	1.049
4.	PA4	51.7	30.8	7.2	1.07	0.58	0.057	1.9	2.7	3.993
5.	PA5	50.3	31.3	6.9	0.91	0.63	0.051	2.4	3.1	4.409
	Average	**51.7**	**31.6**	**7.3**	**1.14**	**0.69**	**0.050**	**2.0**	**2.4**	3.12

Table A.4: Elemental Composition of Different Ash Samples of Summer Season

Sr. No.	Sample	SiO_2	Al_2O_3	Fe_2O_3	TiO_2	P_2O_5	SO_3	CaO	Oxides of Na, K, Mg	Others
A.	**Fly Ash**									
1.	FA1	52.0	31.3	3.1	0.88	0.67	0.049	2.2	2.1	7.701
2.	FA2	50.7	30.7	-	-	-	-	2.9	1.9	-
3.	FA3	52.2	32.1	-	-	-	-	2.7	2.1	-
	Average	**51.6**	**31.4**	**3.1**	**0.88**	**0.67**	**0.049**	**2.6**	**2.0**	7.701
B.	**Bottom Ash**									
1.	BA1	51.0	32.3	3.1	1.04	0.63	0.071	3.1	2.4	6.359
2.	BA2	52.0	32.5	-	-	-	-	2.5	1.9	-
3.	BA3	51.3	31.8	-	-	-	-	2.4	1.5	-
	Average	**51.4**	**32.2**	**3.1**	**1.04**	**0.63**	**0.071**	**2.7**	**1.9**	6.959
C.	**Pond Ash**									
1.	PA1	52.9	32.0	3.3	1.07	0.71	0.057	1.9	2.1	5.963
2.	PA2	51.1	32.7	4.6	0.87	0.59	0.066	1.8	1.7	6.574
3.	PA3	50.9	31.7	4.3	0.94	0.63	0.072	2.6	2.1	6.758
4.	PA4	52.0	32.3	3.6	1.41	0.46	0.060	3.0	2.3	4.87
5.	PA5	51.6	31.7	4.1	1.24	0.78	0.079	2.4	2.5	5.601
	Average	**51.7**	**32.1**	**4.0**	**1.11**	**0.63**	**0.0668**	**2.3**	**2.1**	5.9932

Table A.5: Concentration of Trace Elements in Ash Samples of Winter Season

Sr. No.	Sample	Metal Concentration (mg/kg)									F (mg/kg)
		As	Ag	Ba	Be	Cd	Cr	Cu	Co	Hg	
A.	**Fly Ash**										
1.	FA1	4.62	0.20	491	0.98	BDL	47	128.5	5.9	0.131	5.14
2.	FA2	4.55	0.53	569	0.95	BDL	61	24.2	5.8	0.180	3.97
3.	FA3	6.57	0.62	462	1.26	BDL	64	16.7	6.1	0.097	4.32
4.	FA4	4.32	BDL	451	0.91	BDL	56	14.9	5.3	0.081	4.40
5.	FA5	5.24	0.14	416	1.06	BDL	66	14.7	5.3	0.143	5.61
	Average	**5.06**	**0.30**	**478**	**1.03**	**BDL**	**59**	**39.8**	**5.7**	**0.126**	**4.69**
B.	**Bottom Ash**										
1.	BA1	2.55	0.34	207	BDL	BDL	22	18.7	4.2	0.075	4.70
2.	BA2	0.00	0.38	231	BDL	BDL	22	19.1	3.9	0.029	4.36
3.	BA3	1.28	0.17	247	BDL	BDL	25	13.3	3.8	0.140	5.33
4.	BA4	1.65	0.76	263	0.07	BDL	33	16.8	4.9	0.111	4.20
5.	BA5	0.13	0.36	235	BDL	BDL	12	23.0	3.6	0.083	4.04
	Average	**1.12**	**0.40**	**237**	**0.01**	**BDL**	**23**	**18.2**	**4.1**	**0.088**	**4.53**
C.	**Pond Ash**										
1.	PA1	1.30	0.51	467	0.62	BDL	27	9.2	3.8	0.057	3.49
2.	PA2	0.00	0.98	485	0.58	BDL	33	10.8	4.7	0.074	5.08
3.	PA3	2.15	BDL	225	0.81	BDL	32	9.1	3.3	0.091	5.12
4.	PA4	0.43	BDL	392	0.54	BDL	26	8.9	3.7	0.035	4.51
5.	PA5	BDL	1.30	214	0.22	3.63	11	3.8	1.7	0.070	3.61
	Average	**0.78**	**0.56**	**357**	**0.55**	**0.73**	**26**	**8.4**	**3.4**	**0.065**	**4.36**

Table A.5 (Contd…): Concentration of Trace Elements in Ash Samples of Winter Season

Sr. No.	Sample	Metal Concentration (mg/kg)						
		Mn	Ni	Pb	Ti	V	Zn	Se
A.	**Fly Ash**							
1.	FA1	712	34	0.0	5.5	52	99	0.11
2.	FA2	901	35	3.6	0.0	55	30	BDL
3.	FA3	775	36	0.0	0.9	66	31	BDL
4.	FA4	702	30	2.7	6.9	50	27	BDL
5.	FA5	779	30	0.9	0.5	56	25	BDL
	Average	**774**	**33**	**1.4**	**2.8**	**56**	**42**	**0.02**
B.	**Bottom Ash**							
1.	BA1	780	33	BDL	2.8	25	19	BDL
2.	BA2	724	29	BDL	2.3	15	20	BDL
3.	BA3	704	27	BDL	7.4	17	26	BDL
4.	BA4	789	34	BDL	5.5	28	30	BDL
5.	BA5	605	27	BDL	4.2	13	29	BDL
	Average	**721**	**30**	**BDL**	**4.4**	**19**	**25**	**BDL**
C.	**Pond Ash**							
1.	PA1	574	23	BDL	0.0	25	33	BDL
2.	PA2	1320	26	BDL	2.3	27	21	BDL
3.	PA3	445	21	BDL	2.8	26	26	BDL
4.	PA4	1006	23	3.6	0.9	20	20	BDL
5.	PA5	332	9	BDL	0.0	0	10	BDL
	Average	**735**	**20**	**0.7**	**1.2**	**20**	**22**	**BDL**

BDL is considered as zero in averaging the value.

Table A.6: Concentration of Trace Elements in Ash Samples of Summer Season

Sr. No.	Sample	Metal Concentration (mg/kg)									F (mg/kg)
		As	Ag	Ba	Be	Cd	Cr	Cu	Co	Hg	
A.	**Fly Ash**										
1.	FA1	**27.6**	**1.0**	**496**	**1.94**	**BDL**	**49.8**	**25.8**	**6.1**	**0.099**	**4.14**
B.	**Bottom Ash**										
1.	BA1	**21.4**	**0.7**	**163**	**1.06**	**BDL**	**52.5**	**15.9**	**6.4**	**0.062**	**5.22**
C.	**Pond Ash**										
1.	PA1	19.9	0.6	860	0.88	BDL	53.7	16.5	5.9	0.113	4.01
2.	PA2	17.0	0.5	469	0.44	BDL	14.2	9.3	3.5	0.095	3.29
3.	PA3	22.6	0.6	505	0.61	BDL	19.9	10.3	3.7	0.067	2.88
4.	PA4	21.7	0.7	525	0.51	BDL	21.3	16.2	7.9	0.131	4.36
5.	PA5	16.5	0.5	564	0.43	BDL	27.6	15.4	6.6	0.054	3.74
	Average	**19.5**	**0.6**	**585**	**0.57**	**BDL**	**27.3**	**13.5**	**5.5**	**0.092**	**3.66**

Table A.6 (Contd…): Concentration of Trace Elements in Ash Samples of Summer Season

Sr. No.	Sample	Metal Concentration (mg/kg)						
		Mn	Ni	Pb	Tl	V	Zn	Se
A.	**Fly Ash**							
1.	FA1	**308**	**6.7**	**34.6**	**16.7**	**0.730**	**59**	**47.0**
B.	**Bottom Ash**							
1.	BA1	**547**	**4.4**	**40.7**	**4.6**	**0.630**	**42**	**16.6**
C.	**Pond Ash**							
1.	PA1	1372	4.9	34.5	5.1	0.360	46	20.6
2.	PA2	596	1.3	3.7	7.9	0.010	35	14.3
3.	PA3	291	2.3	6.9	4.9	0.030	45	15.7
4.	PA4	1711	1.0	12.6	21.1	0.000	57	26.1
5.	PA5	1862	2.2	14.6	3.4	0.000	48	24.3
	Average	**1166**	**2.3**	**14.5**	**8.5**	**0.080**	**46**	**20.2**

Results of Leachate Tests

Table A.7: Concentration of Various Metals in Leachates of TCLP Tests: Winter Season

Sr. No.	Sample	Metal Concentration in Leachates (mg/L)								
		As	Ag	Ba	Cd	Cr	Mn	Ni	Pb	Se
A.	**Fly Ash**									
1.	FA1	0.015	0.002	3.0	0.003	0.026	0.104	0.019	0.003	0.018
2.	FA2	0.006	0.001	3.3	0.002	0.025	0.099	0.018	0.001	0.008
3.	FA3	0.003	BDL	3.2	0.002	0.022	0.111	0.017	0.001	0.005
4.	FA4	0.003	BDL	3.3	0.002	0.026	0.131	0.020	0.001	0.006
5.	FA5	0.003	BDL	3.9	0.002	0.026	0.153	0.024	0.001	0.005
	Average	**0.006**	**0.001**	**3.3**	**0.002**	**0.025**	**0.120**	**0.020**	**0.001**	**0.008**
B.	**Bottom Ash**									
1.	BA1	BDL	BDL	1.3	0.002	0.029	0.174	0.011	0.005	BDL
2.	BA2	BDL	BDL	1.2	0.001	0.030	0.135	0.009	0.005	BDL
3.	BA3	0.007	BDL	1.6	0.001	0.030	0.151	0.013	0.005	BDL
4.	BA4	BDL	BDL	0.7	0.001	0.027	0.114	0.009	0.005	BDL
5.	BA5	BDL	BDL	0.6	0.002	0.027	0.106	0.008	0.004	BDL
	Average	**0.001**	**BDL**	**1.1**	**0.001**	**0.029**	**0.136**	**0.010**	**0.005**	**BDL**
C.	**Pond Ash**									
1.	PA1	0.010	BDL	7.4	0.001	0.035	0.078	0.014	0.006	0.002
2.	PA2	0.011	BDL	8.5	0.001	0.031	0.099	0.011	0.006	0.002
3.	PA3	0.008	BDL	3.4	0.002	0.028	0.049	0.015	0.006	0.001
4.	PA4	0.007	BDL	6.1	0.002	0.032	0.163	0.019	0.009	0.000
5.	PA5	0.012	0.002	7.8	0.004	0.042	0.152	0.029	0.009	0.001
	Average	**0.010**	**0.000**	**6.6**	**0.002**	**0.034**	**0.108**	**0.018**	**0.007**	**0.001**
Threshold Limit		**5**	**5**	**100**	**1.0**	**5**	**10**	**20**	**5**	**1**

BDL: Below Detection Limit.

Table A.8: Concentration of Various Metals in Leachates of TCLP Tests: Summer Season

Sr. No.	Sample	Metal Concentration in Leachates (mg/L)								
		As	Ag	Ba	Cd	Cr	Mn	Ni	Pb	Se
A.	**Fly Ash**									
1.	FA1	**0.011**	**0.002**	**2.4**	**BDL**	**0.022**	**0.136**	**0.018**	**0.002**	**BDL**
B.	**Bottom Ash**									
1.	BA1	**BDL**	**BDL**	**0.6**	**BDL**	**0.021**	**0.047**	**0.008**	**0.002**	**BDL**
C.	**Pond Ash**									
1.	PA1	0.003	BDL	3.2	BDL	0.019	2.630	0.010	0.002	BDL
2.	PA2	0.002	0.001	2.9	BDL	0.019	0.021	0.007	0.002	BDL
3.	PA3	0.004	0.001	2.5	BDL	0.018	0.023	0.004	0.002	BDL
4.	PA4	BDL	0.001	2.1	BDL	0.019	0.022	0.007	0.002	BDL
5.	PA5	0.007	0.002	4.7	BDL	0.023	0.042	0.009	0.002	BDL
	Average	**0.003**	**0.001**	**3.1**	**BDL**	**0.020**	**0.548**	**0.007**	**0.002**	**BDL**
Threshold Limit		**5**	**5**	**100**	**1.0**	**5**	**10**	**20**	**5**	**1**

BDL: Below Detection Limits

Table A.9: Concentration of Various Metals in Leachates of WET: Winter Season

Sr. No.	Sample	Metal Concentration in Leachates (mg/L)								
		Be	Cr	Cu	Co	Mo	Ni	Ti	V	Zn
A.	**Fly Ash**									
1.	FA1	0.018	0.173	0.261	0.049	0.376	0.361	0.002	1.228	8.445
2.	FA2	0.008	0.084	0.180	0.030	0.225	0.235	0.001	0.434	6.011
3.	FA3	0.014	0.100	0.236	0.042	0.302	0.302	0.002	1.095	7.902
4.	FA4	0.014	0.098	0.234	0.040	0.321	0.294	0.002	1.143	7.667
5.	FA5	0.016	0.107	0.263	0.047	0.362	0.340	0.002	1.179	8.156
	Average	**0.014**	**0.112**	**0.235**	**0.042**	**0.317**	**0.306**	**0.002**	**1.016**	**7.636**
B.	**Bottom Ash**									
1.	BA1	BDL	0.034	0.065	0.005	BDL	0.044	BDL	0.050	1.597
2.	BA2	BDL	0.035	0.067	0.005	BDL	0.041	BDL	0.048	1.621
3.	BA3	BDL	0.038	0.053	0.006	BDL	0.045	BDL	0.058	1.565
4.	BA4	BDL	0.034	0.069	0.005	BDL	0.037	BDL	0.053	1.389
5.	BA5	BDL	0.029	0.068	0.004	BDL	0.041	BDL	0.042	1.520
	Average	**BDL**	**0.034**	**0.064**	**0.005**	**BDL**	**0.042**	**BDL**	**0.050**	**1.538**
C.	**Pond Ash**									
1.	PA1	BDL	0.037	0.046	0.006	0.016	0.046	BDL	0.093	2.356
2.	PA2	BDL	0.039	0.052	0.008	0.033	0.057	BDL	0.116	2.457
3.	PA3	BDL	0.044	0.062	0.008	0.053	0.085	BDL	0.122	2.219
4.	PA4	BDL	0.041	0.048	0.008	0.028	0.071	BDL	0.105	1.911
5.	PA5	BDL	BDL	BDL	BDL	BDL	0.001	BDL	0.001	0.019
	Average	**BDL**	**0.032**	**0.042**	**0.008**	**0.026**	**0.052**	**BDL**	**0.087**	**1.792**
Threshold Limit		**0.75**	**5**	**25**	**80**	**350**	**20**	**--**	**24**	**250**

BDL: Below Detection Limits. BDL is considered Zero in averaging values.

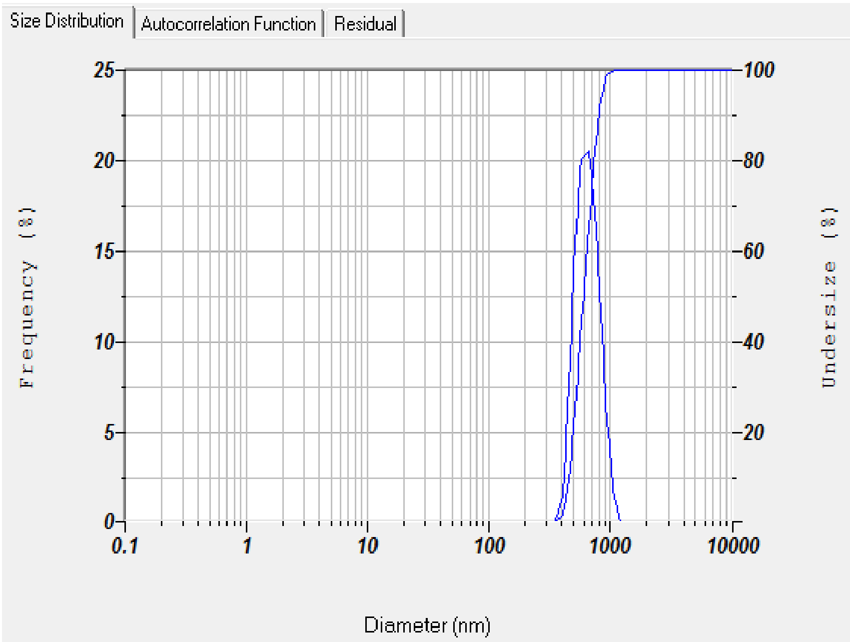
Table A.10: Concentration of Various Metals in Leachates of WET: Summer Season

Sr. No.	Sample	Metal Concentration in Leachates (mg/L)								
		Be	Cr	Cu	Co	Mo	Ni	Ti	V	Zn
A.	**Fly Ash**									
1.	FA1	**0.010**	**0.095**	**0.155**	**0.028**	**0.277**	**0.086**	**0.004**	**0.538**	**0.244**
	Bottom Ash									
1.	BA1	**0.005**	**0.045**	**0.100**	**0.015**	**0.025**	**0.048**	**0.001**	**0.087**	**0.108**
	Pond Ash									
1.	PA1	0.004	0.066	0.094	0.015	0.086	0.067	0.001	0.207	0.105
2.	PA2	0.005	0.070	0.106	0.016	0.096	0.053	0.002	0.324	0.113
3.	PA3	0.005	0.074	0.113	0.013	0.106	0.042	0.002	0.344	0.173
4.	PA4	0.003	0.092	0.075	0.010	0.063	0.102	0.001	0.152	0.102
5.	PA5	0.005	0.168	0.097	0.014	0.136	0.196	0.002	0.261	0.132
	Average	**0.004**	**0.094**	**0.097**	**0.014**	**0.097**	**0.092**	**0.002**	**0.258**	**0.125**
Threshold Limit		**0.75**	**5**	**25**	**80**	**350**	**20**	**--**	**24**	**250**

BDL: Below Detection Limits

Note: Fe is not included in the Schedule II of Hazardous & Other Wastes (Management and Transboundary Movement) Rule 2016.

Particle Size Distribution of Fly Ash, Bottom Ash and Pond Ash Samples



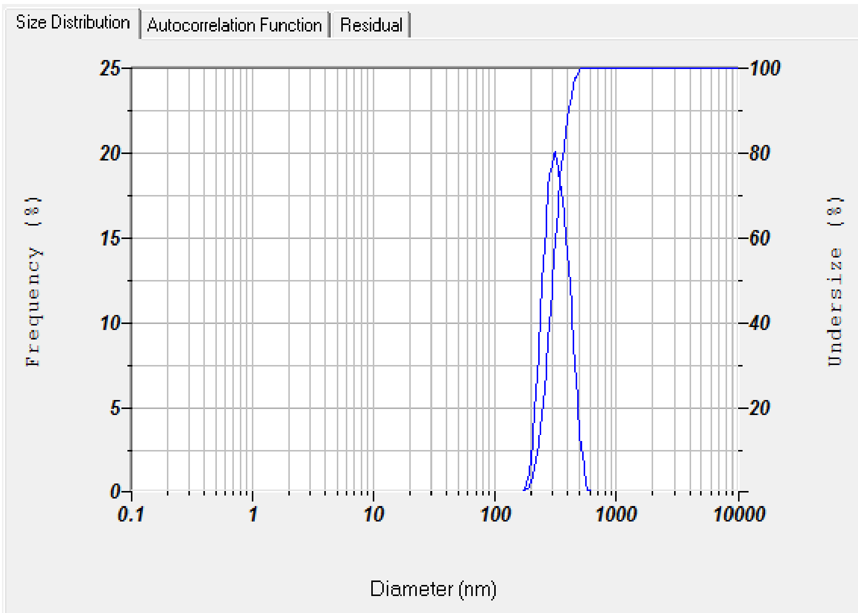


Fig. A.1: Particle Size Distribution of Fly Ash Samples Collected during Winter and Summer

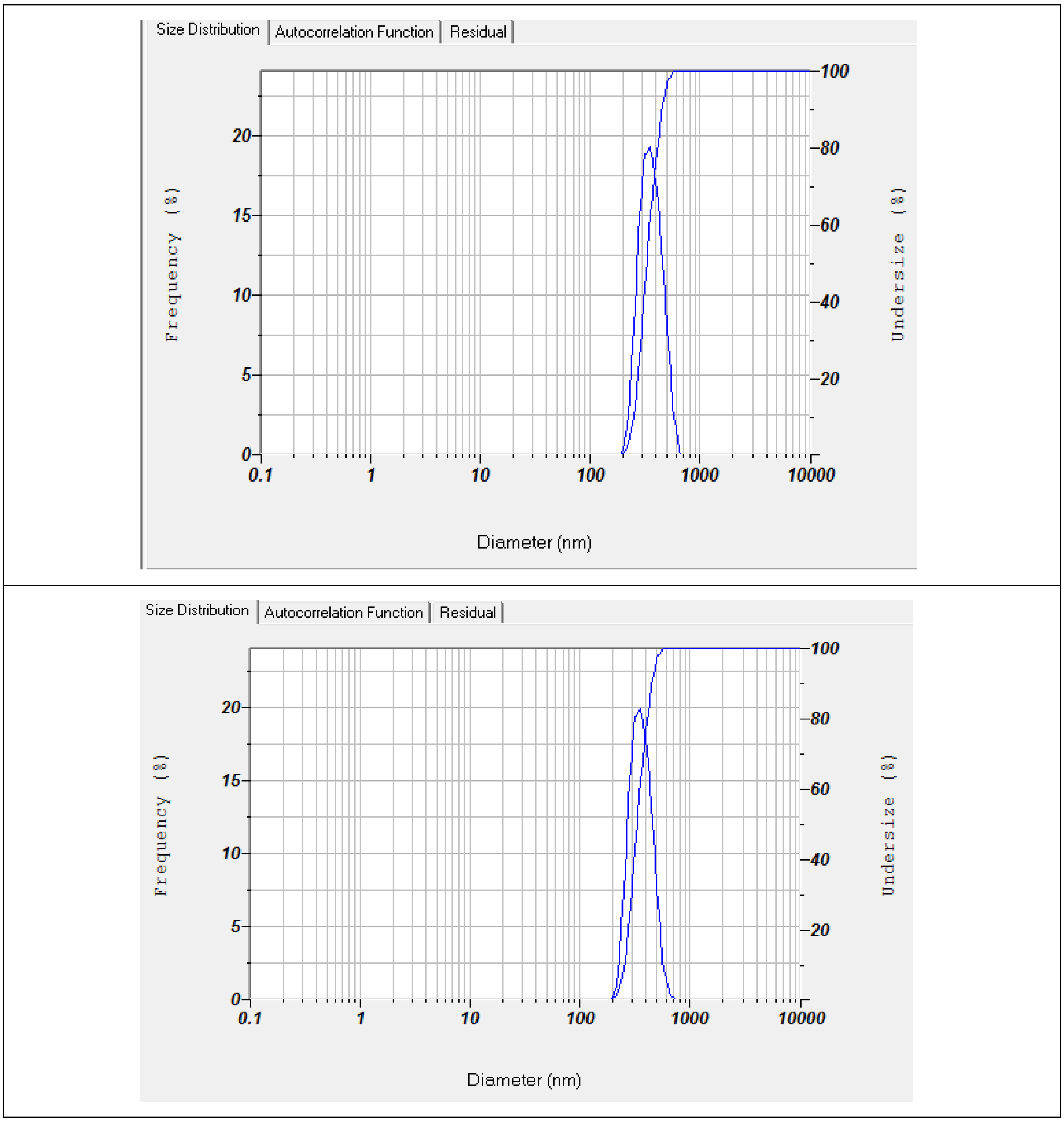


Fig. A.2: Particle Size Distribution of Bottom Ash Samples Collected during Winter and Summer

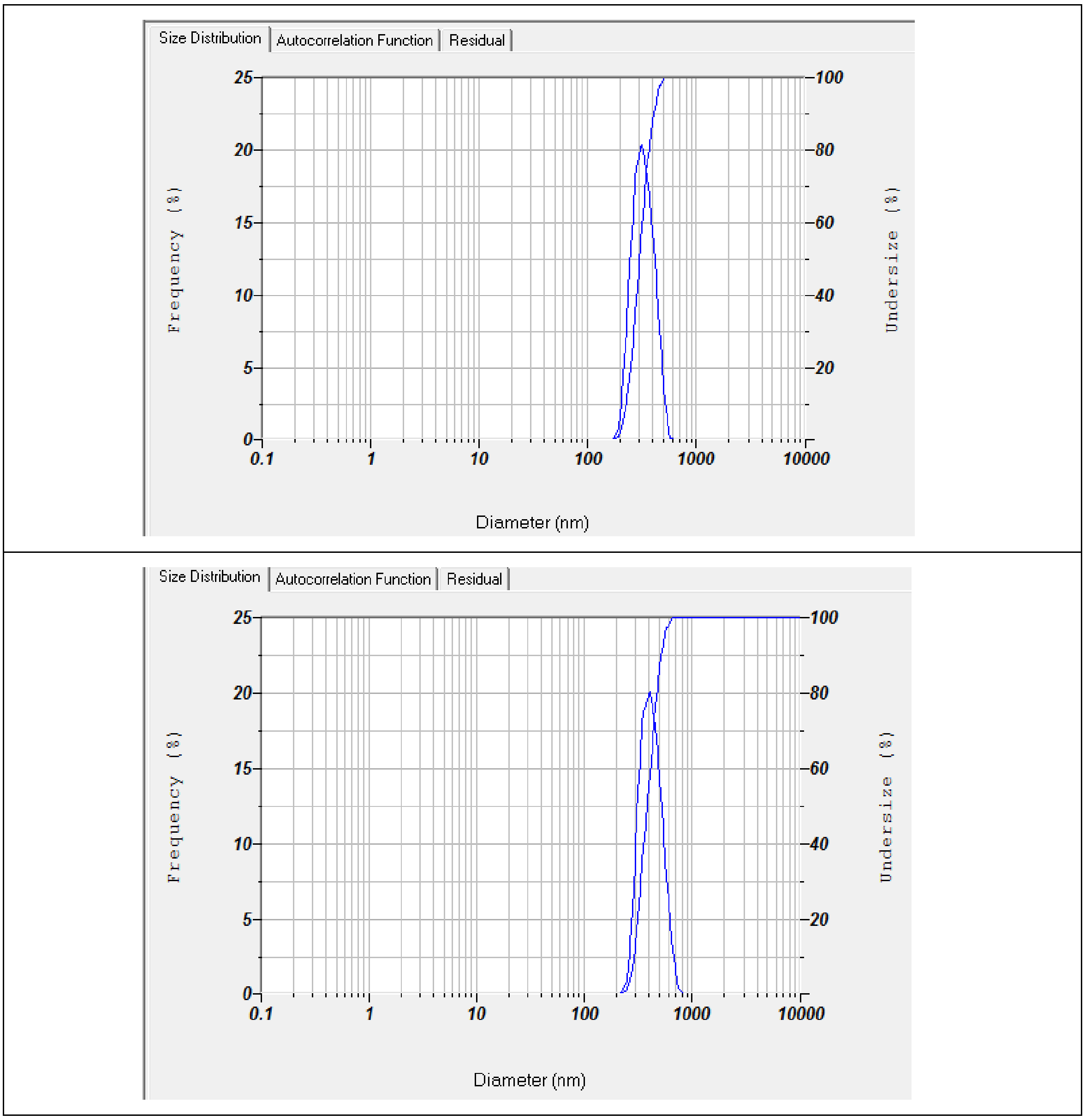


Fig. A.3: Particle Size Distribution of Pond Ash Samples Collected during Winter and Summer

Chapter 5

Ash Transport Impact Study

5.1 Ash Generation

The Vindhyachal Super Thermal Power Project (VSTPP), owned and operated by NTPC Limited, is located on the North West bank of Rihand Reservoir (Gobind Ballabh Pant Sagar) at Vindhyanagar in District Singrauli of Madhya Pradesh. The thermal power plant is operational in different stages as Stage-I (6x210 MW), Stage-II (2x500 MW), Stage-III (2x500 MW), Stage-IV (2x500 MW) and Stage-V (500 MW) with ultimate capacity of 4760 MW.

In order to comply with the requirement of Fly Ash Notification of MoEF&CC dated 03.11.2009, NTPC intends to dispose the ash generated from Stage-II & III (4X500 MW) into the abandoned mine voids of Gorbi mines of M/s Northern Coalfields Ltd. located at an approximate distance of 34.3 kms by Road from the plant. Initially, NTPC proposes to transport ash from VSTPP to the mine voids of Gorbi via road in closed road bulkers of capacity 28 MT capacity (**Fig. 5.1.1**). Approx. 2000 MT per day of ash is proposed to be transported from plant to mine voids. The total number of trips in a day (including back and forth) would be 144 numbers or 6 numbers in an hour as per report prepared by Min Mec Consultancy Pvt. Ltd. Ash transport would be mainly during evening/nighttime for about 12 hours.

Fig. 5.1.1: Road bulker to be used for Ash Transport

5.2 Road Transport Route

The condition of road to be used for transport is mixed type i.e., concrete, black top and haul road. The concrete and black-top road corridor are found both in good as well average/ broken condition, which are further categorized through average silt loading rate as described in **Table 5.2.1**. The road width of different sections is given in **Table 5.2.2.** The whole transport route is shown in **Fig. 5.2.1.**

Table 5.2.1: Details of Ash Transport Road/Route and Silt Loading Rate

Sr. No.	Type of Road	Road Condition	Road Length (Km)	Silt Loading Rate (g/m^2)
1.	Concrete	Good	4.29	1.32
2.	Concrete	Average/Broken partly	3.57	5.2
3.	Black Top	Good	19.21	1.32
4.	Black Top	Average/Broken partly	6.56	5.2
5.	Haul Road	Unpaved/Dust road	0.68	11.4
Total			**34.31**	

Source: Report prepared by Min Mec Consultancy Pvt. Ltd.

Table 5.2.2: Road width at Different Sections of Transport Route

Route Name	VSTPP to Gorbi Mines	
Total Route Length	34.31 km	
Length of Stretch w.r.t. Width	Single Lane (< 5.5 m)	1.15 km
	Inter-mediate (≥ 5.5 m)	0
	Two Lane (≥ 7 m)	20.79 km
	Multi-lane (≥ 10 m)	12.37 km

Source: Report prepared by Min Mec Consultancy Pvt. Ltd.

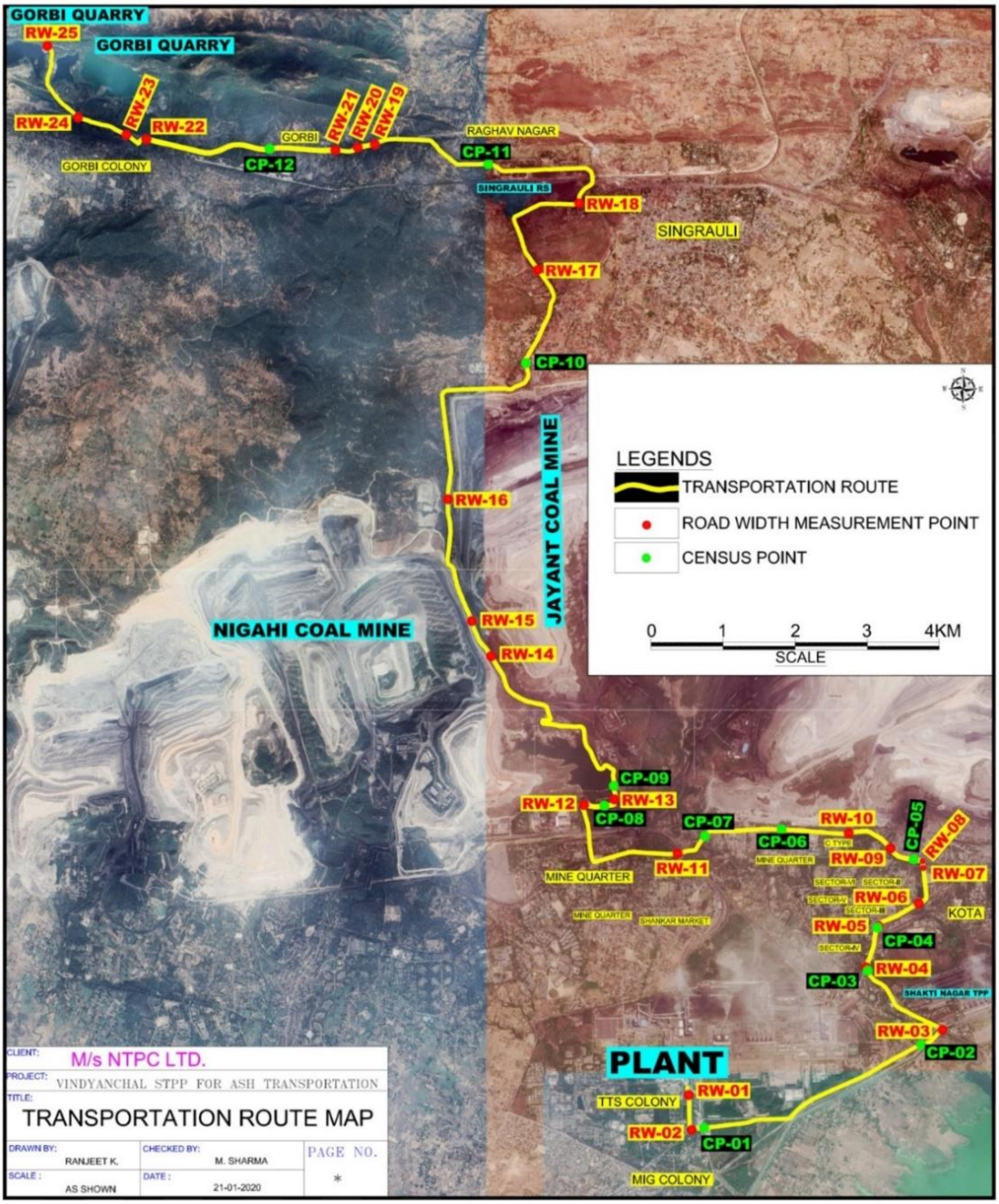


Fig 5.2.1: Proposed Ash Transportation Route on Google Earth Map with Location Codes of Road Measurement & Traffic Census Points

5.3 Emission Load Estimation

The movement of trucks due to transport of ash can generate particulate/dust pollution through two means i.e., emission from exhaust and re-suspension of road dust. Since, the ash will be transported through closed bulkers, therefore, there would not be any dust emission from top of the bulker. The emission generation from exhaust and re-suspension of road dust are estimated as described in **Tables 5.3.1** and **5.3.2**, respectively. The ARAI emission factor of BS-IV for diesel trucks are used to estimate the exhaust emission load for CO, NO_x and $PM_{10.}$ (ARAI, 2018). The emission factor are given in the form of g/kwh and that are converted into g/km by multiplying by 3.0 (factor for diesel trucks). The movement of 144 trucks in a day will generate approx. 22.2 kg/day of CO, 51.5 kg/day for NOx and 0.30 g/day of PM_{10} from the whole road length of 34.3 km.

Table 5.3.1: Estimated Emission load of pollutant from Vehicles exhaust

Parameter	**Unit**	**CO**	**NOx**	**PM_{10}**
Emission Factor	g/kwh*	1.5	3.5	0.02
	g/km#	4.5	10.5	0.06
Emission Load for 34.3 km Transport Route on **24 hours movement**	g/hr	926	2161	12
	kg/day	22.2	51.5	0.30
Emission Load for 34.3 km Transport Route on **12 hours movement** during Evening/night hours	g/hr	1852	4322	25
	kg/day	22.2	51.5	0.30

*ARAI Emission Booklet for vehicles in India, 2018.

#g/kwh = 3.0 g/km for diesel Truck (Source: Internet)

The re-suspension of road dust due to movement of trucks (including Tyre and Brake wear) on road is one of the major sources of PM_{10} emissions. PM_{10} emissions from re-suspension of road dust have been estimated using following empirical equation (USEPA, 2011).

$$E = k\,(sL)^{0.91} \times (W)^{1.02} \qquad \text{(i)}$$

where,

E= particulate emission factor (g/VKT)

k = particle size multiplier (g/VKT), default value of “k” for PM_{10} is 0.62 g/VKT

sL = road surface silt loading (g m^{-2})

W = average weight (tons) of vehicles travelling the road i.e., 39 Tons for loaded trucks/ bulkers and 11 tons for empty trucks.

The PM_{10} emission is estimated to be 195 kg/day from whole transport route of 34.3 km.

Table 5.3.2: Estimated PM_{10} Emission load from re-suspension of road dust due to movement of Trucks

Type of Road	Road Condition	Road Length (Km)	Average Silt Content on Surface (g/m²)	PM_{10} generation from re-suspension of road dust		
				g/km/ vehicle	g/ vehicle	kg/ day
Concrete	Good	4.29	1.32	21	91	13
Concrete	Broken	3.57	5.2	74	265	38
Black Top	Good	19.2	1.32	21	409	59
Black Top	Broken	6.56	5.2	74	486	70
Haul Road	Poor/ dusty road	0.68	11.4	151	103	15
Total		**34.3**				**195**

5.4 Meteorological Parameters

The meteorology plays an important role in dispersion of pollutants from source to receptors. In the absence of primary data, the meteorological parameters are collected from the EIA report of NTPC power plant, 2009, the report prepared by Min Mec Consultancy Pvt. Ltd for a typical May month. The summary of met data in terms of ambient temperature (28-43^{0}C), atmospheric pressure (973-975 mbar), relative humidity (38-50 %) and wind speed (0.5-2.6 m/s) are given in **Table 5.4.1**. **Fig. 5.4.1** shows the windrose plot of the meteorological data for the May month. The dominant direction was observed to be North northeast.

Table 5.4.1: Summary of Meteorological Parameters Used in the Modelling

Parameters	Ambient Temperature (^{0}C)	Atmospheric Pressure (mbar)	Relative Humidity (%)	Wind Speed (m/s)
Minimum	28	973	38	0.50
Maximum	43	975	50	2.60
Average	34	974	44	1.37

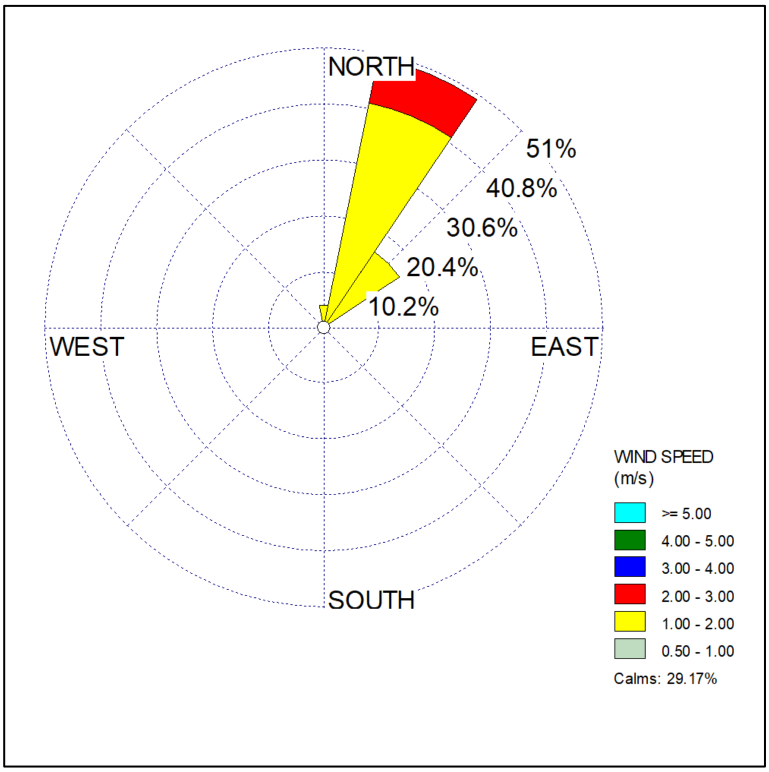


Fig. 5.4.1: Windrose Plot of Meteorological Data for May Month

5.5 Air Quality Dispersion Modelling

Air quality dispersion model i.e., AERMOD is used to predict the incremental concentrations of pollutant based on emission inventory developed in the previous section. Its main objective is the prediction of air pollutant concentration of one and more species in space and time as related to the independent variables such as emission from the vehicles movement, the meteorological variables etc.

The modelling is carried out for 1 km road stretch, considering wind angle (angle between dominant wind and road alignment) of 90 degree so that worst scenario can be simulated. The different scenarios were developed for model analysis based on the road conditions and road width. The scenarios considered are:

- **Scenario 1:** Based on Road Width i.e., 3.5 m, 7 m and 15 m for emissions from vehicles exhaust
- **Scenario 2:** Based on Road Condition i.e. Good (SL - 1.32 g/m^2), Average (SL- 5.2 g/m^2) and Poor/dusty (SL - 11.4 g/m^2) for particulate matter generated from re-suspension of road dust. [SL- silt loading]
- **Simulation 3:** The simulation also carried out for movement of trucks for 24 hour basis (i.e., 6 nos. per hour) and 12 hour basis (i.e., 12 nos. per hour)

5.5.1 Impact due to 24 hours Movement of Trucks for Ash Transportation

The 24 hour and 1 hour average GLCs of CO, NOx and PM_{10} from trucks exhaust emissions for 24 hours trucks movement (06 nos. per hour) are described in **Table 5.5.1.** The 24-hour average incremental GLC of daily average CO conc. is found in the range of 5.16-5.93 µg/m^3 at five meter distance from the edge of different width roads i.e. 3.5 m, 7 m and 15 m in downwind direction. The concentrations reduced to less than 0.5 µg/m^3 at 100 m distance and 0.15 µg/m^3 at 500 m from the road in downwind direction. These values for 1 hour average were 9.6-9.9 µg/m^3 at 5 m and 0.9 µg/m^3 and 0.3 µg/m^3 at 100 m and 500 m, respectively.

Table 5.5.1: Incremental GLCs of CO, NOx and PM_{10} from different Width Road for Trucks Movement of 24 hours

Distance from Road (m)	Incremental Concentration (µg/m^3) wrt distance for different width road for 24 hours trucks movement					
	24 hours Average Conc.			1 hour Average Conc.		
Road width →	**3.5m**	**7 m**	**15 m**	**3.5m**	**7 m**	**15 m**
CO						
5	5.16	5.56	5.93	9.6	9.9	9.9
50	0.80	0.80	0.76	1.5	1.5	1.5
100	0.46	0.46	0.47	0.9	0.9	0.9
300	0.22	0.22	0.22	0.4	0.4	0.4
500	0.15	0.15	0.15	0.3	0.3	0.3
NOx						
5	12.1	13	13.7	21	22	23
50	1.78	1.8	2.02	3.7	4.0	4.6
100	1.10	1.09	1.1	2.1	2.2	2.3
300	0.51	0.51	0.51	1.2	1.3	1.3
500	0.36	0.36	0.36	0.7	0.7	0.7
PM_{10}						
5	0.0680	0.0690	0.0700	0.12	0.12	0.13
50	0.0100	0.0104	0.0109	0.02	0.02	0.02
100	0.0060	0.0063	0.0063	0.01	0.012	0.012
300	0.0029	0.0029	0.0029	0.005	0.005	0.005
500	0.0021	0.0021	0.0021	0.004	0.004	0.004

It is also observed that impact of road width is only on nearest receptors and not on the distant receptors. Similar trend were observed in dispersion of NO_x and PM_{10}. The 24 hour average incremental GLCs of daily average NOx is predicted in the range of

12.1-13.7 µg/m^3 at five meter distance from the edge of different width road. The corresponding values of PM_{10} are 0.068-0.070 µg/m^3 at five meter from the edge of different width road.

Hourly average concentration of NOx is predicted to be 21-23 µg/m^3 at 5 m distance from road, which reduced considerably to 2.1-2.3 µg/m^3 at 100 m distance from the road.

5.5.2 Impact due to 12 hours Movement of Trucks for Ash Transportation

Table 5.5.2 describes the 24 hour and 1 hour average GLCs of CO, NOx and PM_{10} from trucks exhaust emissions for 12 hours trucks movement (12 nos. per hour). The 24-hour average incremental GLC of daily average CO is found in the range of 8.5 µg/m^3 at five meter from the edge of roads in downwind direction. The concentrations reduced to 0.8 µg/m^3 and 0.3 µg/m^3 at 100m and 500 m from the road in downwind direction. These values for 1 hour average are 19.8 µg/m^3 at 5 m and 1.8 µg/m^3 and 0.6 µg/m^3 at 100 m and 500 m, respectively.

24 Hours average NOx levels are predicted to be 19.8 µg/m^3 at 5 m distance, which reduced to 1.8 µg/m^3 at 100 m distance. Similarly, 1 hour average concentration of 43 µg/m^3 at 5 m reduced to 4.3 µg/m^3 at 100 m distance. The impact due to PM_{10} is found to be very less/ negligible.

Table 5.5.2: Incremental GLC of CO, NOx and PM_{10} for Trucks Movement of 12 hours on 7 m Wide Road

Distance from Road	Incremental Concentration (µg/m^3) wrt distance for 7 m wide road for 12 hour trucks movement					
	24 hour average			1 hour average		
	CO	NO_x	PM_{10}	CO	NO_x	PM_{10}
5	8.5	19.8	0.12	19.8	43	0.25
50	1.3	3.3	0.018	3.4	7.1	0.04
100	0.8	1.8	0.011	1.8	4.3	0.03
300	0.4	0.8	0.005	0.8	2.1	0.01
500	0.3	0.6	0.003	0.6	1.5	0.008

5.5.3 Effect of Road Condition on Re-suspension of Road Dust

The road condition plays a very important parameter in terms of air pollution from road transport sector. The clean road generates less particulate pollution than dirty/dusty road. The modelling exercise is carried out using three different types of road sections which are representative of the road to be used by truck for ash transport. It is found that movement of 144 trucks in a day on 1 km road section of good condition (7 m width) will generate daily average incremental PM concentrations of 26 µg/m^3 at 5 m from road, 2.2 µg/m^3 and 0.7 µg/m^3 at 100 and 500 m distance from road, respectively as described in **Table 5.5.3**. These values for typical average road conditions are 82 µg/m^3 at 5 m, 7.7 µg/m^3 at 100 m and 2.5 µg/m^3 at 500 m.

The incremental PM_{10} concentrations from dusty road could be 178 µg/m^3 at 5 m, 16 µg/m^3 at 100 m and 5.2 µg/m^3 at 500 m. The similar pattern is observed for 1-hour average GLCs tas 46 µg/m^3, 159 µg/m^3 and 315 µg/m^3 at five meter distance from road for Good, Average and Dusty road, respectively. The values of PM_{10} will increase by about 1.5 times, when ash transport will be in 12 hours instead of 24 hours as described in **Table 5.5.4.**

Table 5.5.3: Incremental GLC of daily average PM_{10} Concentration from different Types of Roads (24 hours truck movement)

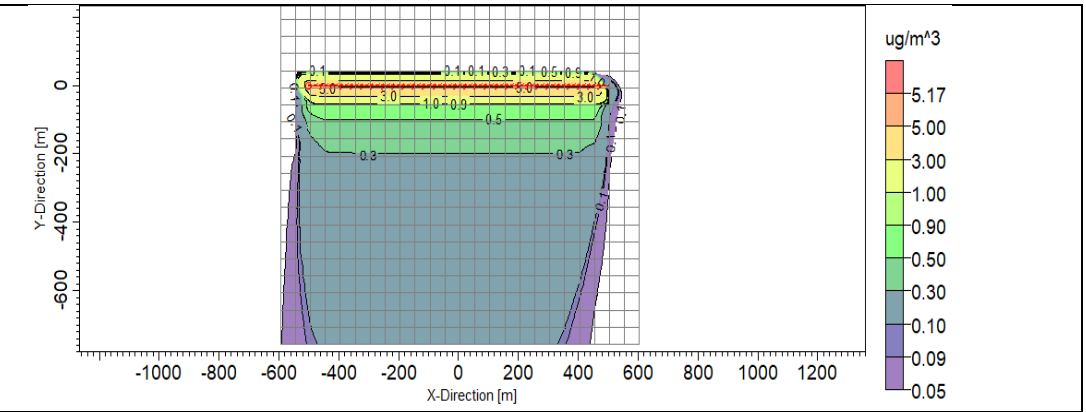
Distance from Road (m)	Incremental GLC (µg/m^3) from different types of Roads during movement of trucks in 24 hours					
	24 hour Average			1 hour Average		
Road Condition→	Good	Average/ Broken	Poor/ Dusty	Good	Average/ Broken	Poor/ Dusty
5	26	82	178	46	159	315
50	3.8	13	26	7.8	25	50
100	2.2	7.7	16	4.4	15	31
300	1.0	3.6	7.1	2.0	7.3	15
500	0.7	2.5	5.2	1.5	5.1	11

Table 5.5.4: Incremental GLC of daily average PM_{10} Concentration from different Type of Roads (12 hours truck movement)

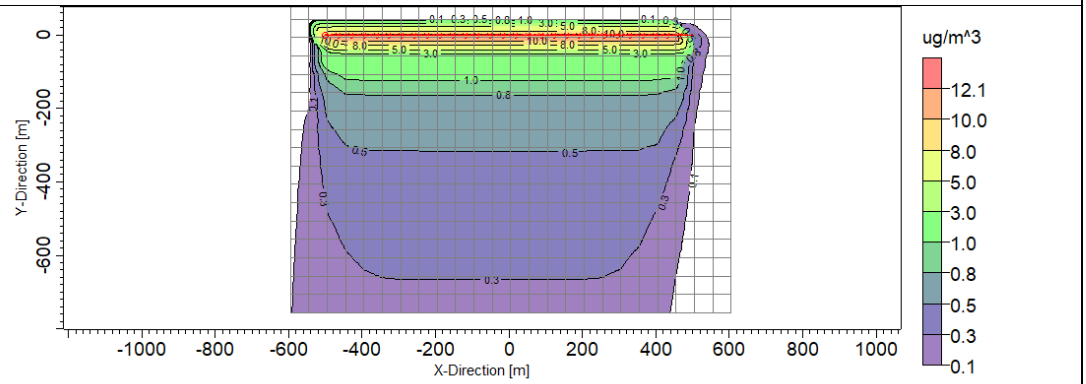
Distance from Road (m)	Incremental GLC (µg/m^3) from different types of Roads during movement of trucks in 12 hours					
	24 hour Average			1 hour Average		
Road Condition→	Good	Average/ Broken	Poor/ Dusty	Good	Average/ Broken	Poor/ Dusty
5	40	133	289	94	296	634
50	6.1	21	46	15	49	100
100	4.2	13	27	9	31	63
300	2.0	6	13	4	14	29
500	1.2	4	9	3	10	21

5.5.4 Pollutant Concentration Isopleths

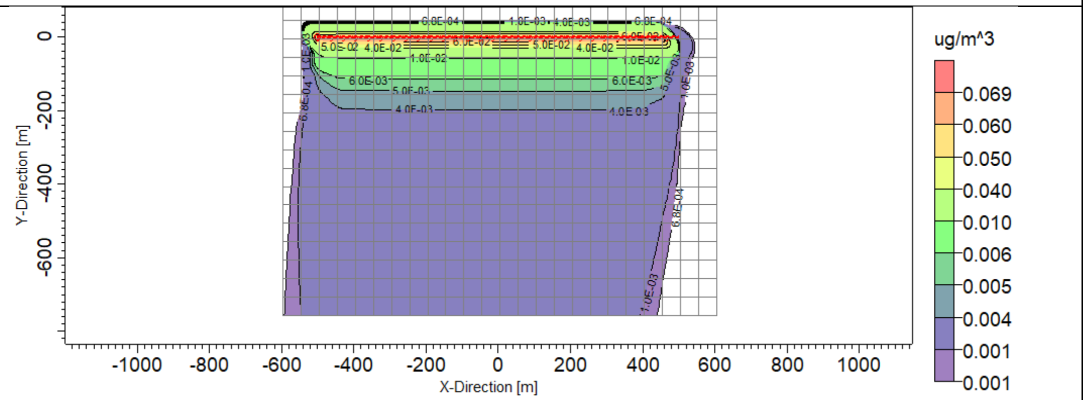
The isopleths of incremental concentrations of CO, NOx and PM_{10} of road section of 3.5 m road width are shown in **Fig. 5.5.1,** however, isopleth of PM_{10} generated from re-suspension of road dust from good, average and dusty roads are shown in **Fig. 5.5.2.**



Isopleth of incremental daily average CO concentrations

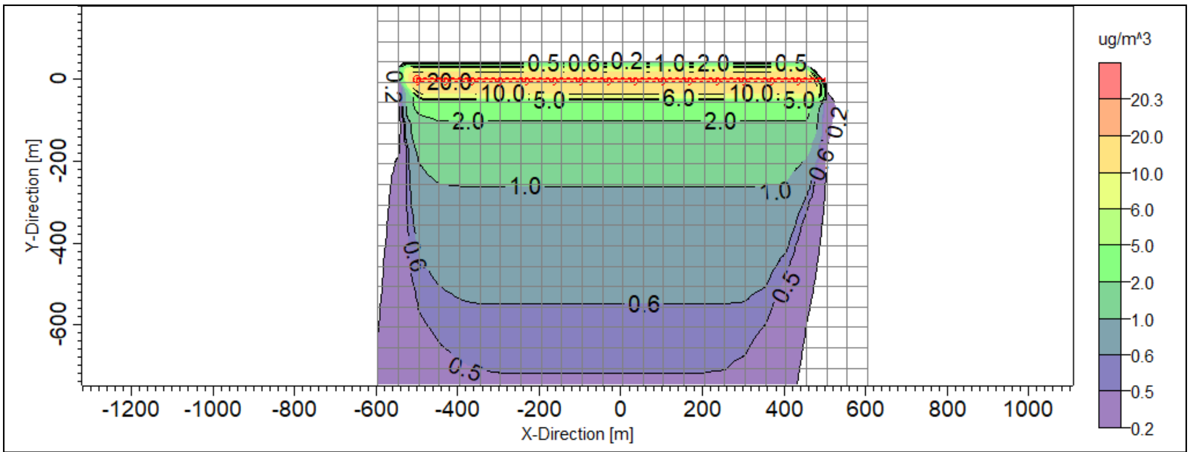


Isopleth of incremental daily average NOx concentrations

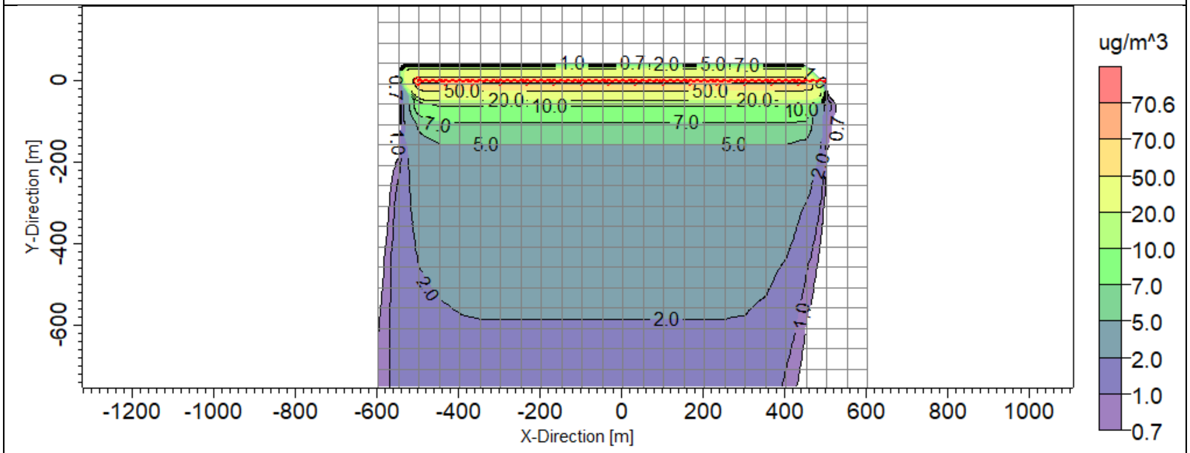


Isopleth of incremental daily average PM_{10} concentrations

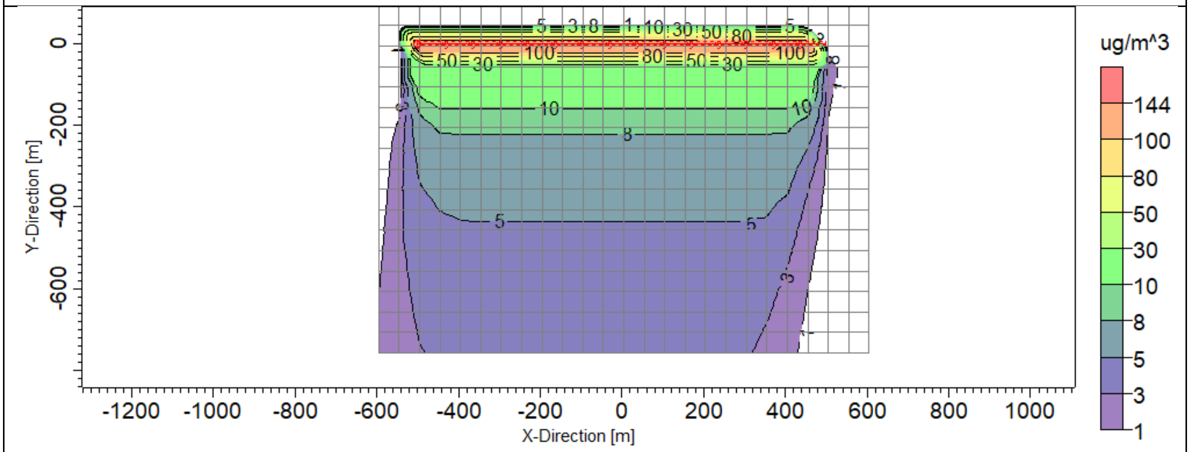
Fig. 5.5.1: Isopleth of Incremental Daily Average Pollutant Concentrations of CO, NOx and PM_{10} for Road Width of 3.5 m along a Stretch of 1 km Road



Road with Good Condition



Road with Average Condition



Road with Poor Condition (Dusty Road)

Fig. 5.5.2: Isopleths of Incremental Daily Average PM_{10} concentrations for Road of Good, Average and Poor Condition (Dusty Road) along a Stretch of 1 km Road

5.6 Summary

The NTPC Vindhayachal proposes to transport ash from VSTPP to the mine voids of Gorbi in closed bulkers via road through a distance of about ~35 kms. About 2000 MT per day ash is proposed to be transported in closed road bulkers of 28 MT capacity. The total number of trips in a day (including back and forth) would be 144 number or 6 numbers in an hour. The condition of road to be used for ash transport is mixed type i.e., concrete, black top and haul road. Some sections of the road are good as well as of average/broken condition. The estimated exhaust emissions due to movement of 144 trucks in a day will generate approx. 22.2 kg/day of CO, 51.5 kg/day for NOx and 0.30 kg/day of PM_{10} from whole road length. However, the re-suspension of road dust may generate approx. 195 kg of PM_{10} in a day from road length of 34.3 km.

Air quality dispersion modelling is carried out for different scenarios considering variations of road width and condition of the road i.e., Good, Average and Poor/dusty. The modelling is carried out for 1 km road stretch considering wind angle (angle between dominant wind and road alignment) of 90 degree so that worst impact can be simulated.

The incremental GLC of daily average CO were found in the range of 5.16 -5.93 µg/m^3 at 5 m from the edge of different width roads i.e. 3.5 m, 7 m and 15 m in downwind direction. The concentrations reduced to less than 0.5 µg/m^3 and 0.15 µg/m^3 at 100 m and 500 m from the road in downwind direction. It is also observed that impact of road width is only on nearest receptors, and not on the distant receptors/locations. Similar trends were observed in dispersion of NOx and PM_{10}. The incremental GLC of daily average NOx were found in the range of 12.1-13.7 µg/m^3 at 5 m distance from the edge of different width road. The values of PM_{10} are insignificant (0.068-0.070 µg/m^3 at 5 m from the edge of different width road).

The incremental PM_{10} concentrations from re-suspension of road dust are predicted to be 26 µg/m^3 at 5 m from road, 2.2 µg/m^3 and 0.7 µg/m^3 at 100 and 500 m distance from road, respectively. These values for typical average road were 82 µg/m^3 at 5 m, 7.7 µg/m^3 at 100 m and 2.5 µg/m^3 at 500 m. The incremental PM_{10} concentrations from dusty road were 178 µg/m^3 at 5 m, 16 µg/m^3 at 100m and 5.2 µg/m^3 at 500 m.

The modeling exercise suggests that re-suspension of road dust due to movement of ash trucks may increase short term PM_{10} levels in the ambient air. Re-supension of road dust needs to be controlled by sprinkling of water, particularly on the roads with average/ broken/poor/dusty condtion. The ash transporting trucks/bulkers should have adequate provision for sprinkling of water as per the condition of road.

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Chapter 6

Overall Summary and Recommendations

NTPC is operating Vindhyachal Super Thermal Power Station (VSTPS) in Singrauli district of Madhya Pradesh located on the North West Bank of Rihand Reservoir (Gobind Ballabh Pant Sagar). The present capacity of VSTPS is 4760 MW. , which has been implemented in five stages.

At present, the unused ash from the power plant is disposed of in the ash dykes located in the peninsular region of Rihand reservoir at about 2.5 km in the South East direction. However, in order to supplement the storage capacity of the ash dykes as well as to reclaim the abandoned mine voids of the de-coaled mines, NTPC proposes to dispose ash from Vindhyachal STPS into abandoned voids of Gorbi mines located at about 15 km in North West direction. For which, permission from MoEF&CC and MP Pollution Control Board shall be required for disposal of ash into Gorbi mine voids.

Detailed terms of reference (ToR) have been prepared for EIA study incorporating baseline data collection, prediction of impacts and suggest appropriate environmental management plan to mitigate the adverse impacts of backfilling of ash into void mines, if any.

NTPC approached CSIR-NEERI to undertake part of the EIA study relating to assessment of flora and fauna, fly ash characterization and assessment of flyash impact of transport from VSTPS to the Gorbi Mines. Keeping in view the scope of work defined NTPC, the studies were conducted by CSIR-NEERI. The details of each component of the study (flora, fauna, ash characterization & ash transport impact) are presented in the previous Chapters, and salient findings of whole study are summarized here alongwith the recommendations.

6.1 Summary of Salient Findings

6.1.1 Water Quality Status

Water samples were collected from three mine voids pond, ash dyke pond and groundwater from 10 km radial of the region for assessment of water quality. Groundwater collected from Handpumps, Borewells and Dug wells which is mainly used for drinking and irrigation purposes. Groundwater quality parameters are compared with respect to drinking water quality standards (BIS 10500-2012) and Irrigation water quailty standard (Ayers & Westcot, 1994). Major observations are as follows.

- **Mine Voids Water:** Water samples were collected from three Mine Voids which were adjacent to each other in Gorbi mines area. Water present in the Mine Voids was found highly acidic in nature (pH range 2.5-3.0). TDS varied in the range of 750-1750 mg/l. Trace metal concentration was found considerably higher with respect to Co, Cr, Fe, Mn, Ni and Zn. In general, trace metal concentration was higher in Mine Void 1 as compared to Mine Voids 2 & 3. At present, the water present in the Mine Voids is not used for any purpose.

- **Ash Dyke Pond Water:** Water sample was collected from existing Ash dyke after treatment. Water was neutral in pH with EC 460 μS/cm (TDS – 240 mg/l) in winter and 550 μS/cm (TDS – 280 mg/l) in summer season. ***All the trace metals were also found within the standard limits of irrigation water quality.***

- **Drinking Water Quality in Villages:** The water samples in both the seasons were found within the permissible limits with respect to pH and TDS. Among the trace metals, the concentration of Cr and Fe was found above the acceptable limits in case of handpump samples of most of the villages in the winter season. Hg concentration was found slightly above the standard limit of 0.001 mg/l in almost all the villages. During summer season, the concentration of Cr and Fe was found higher than the acceptable limits in Handpump of Mahadhaiya, Thurua, Padri, Parsohar, Dadar and Singrauli. However, during summer season, Hg was found within the standards in all the villages, except in Phuljhar, Mahadhaiya and Bastali Abad.

- **Irrigation Water Quality in Villages:** The water samples of both the seasons were assessed on the basis of pH, EC and TDS and it was found that pH of the samples in all the villages were within limits (6.5-8.5), except slighly acidic water (pH 6.2-6.4) in Parsohar, Singraulii and Phuljhar village. On the basis of TDS, the water was found suitable for irrigation purpose. All the trace metals (except Cr) were generally found within the irrigation water standard limits. Zn was found above the limits in village Padri village during both the seasons, whereas Cu was marginally above the limits in Kathas during winter and Mn was marginally above in Gorbi and Kathas villages during summer.

- Fluoride concentration was found to be above the acceptable limit of 1.0 mg/L at the Dadar Village dug well and in the ash dyke pond, whereas it was within limit in rest of the villages including the Mine Voids. The pattern was found similar in both the seasons.

6.1.2 Soil Quality Status

The soil samples were collected from the respective vegetables fields from where the plant samples were collected. After necessary processing, samples were analysed for physical parameters, viz. texture, colour, pH & electrical conductivity (EC) for one winter season only. Soil samples collected from different locations/villages of study area were analyzed for different heavy metals (As, Ba, Cd, Co, Cr, Cu, Fe, Hg, Mn, Ni, Pb and Zn) for both, winter and summer seasons. The results are compared with the available Indian Standards, Awasthi, 2000. Major findings from analysis of soil samples are:

- Soils from the study area were moderate textured with pale brown to brown in color. Texture of soil samples of 12 villages was sandy loam (sand content: 56-70%, silt: 22-38%, clay: 4-16%), whereas 2 samples/ villages (Phuljhar & Baliyari) have loamy sand. Soil near the mine voids was mostly sandy in nature (sand content: 88-90%).

- pH of the soil samples was neutral ranging between 6.5 to 7.7, whereas near mine voids, pH of soil was found in the range of 2.8-3.5. The EC of the soils ranged from 263 µS/cm (Khriwa village) to 1949 µS/cm (Bastali Abad village).

- ***Analysis of results of heavy metals in soil samples indicated that all the metals for which Indian Standards are available, were well below the limits in all the villages soil and near mine voids soil.***

- Cd content was in the range 0.4-5 mg/kg against the limit of 3-6 mg/kg. Cu content was in the range of 9-32 mg/kg against the limit of 135-270 mg/kg. Ni content was in the range of 5-28 mg/kg against the limit of 75-150 mg/kg. Pb content was in the range of 6-24 mg/kg against the limit of 250-500 mg/kg.

- Fluoride content was found to be in the range of 0.53 mg/kg at Thurua to 2.09 mg/kg at Khirwa. Near the Mine Voids 1 & 2, the fluoride content in soil was found to be 0.98 and 1.11 mg/kg respectively. There is no standard limit for fluoride in soil.

6.1.3 Status of Flora in the Study Region

- In the study region total 92 types of different plant species belonging to 40 families were identified. Of the total families, the dominant families of the flora were found belonging to Fabaceae, Malvaceae, Poaceae, and Asteraceae.

- Commonly found tree species in the villages were *Acacia nilotica, Acacia Catechu, Azadirachta indica, Artocarpus heterophyllus, Butea monosperma, Cassia fistula, Ficus religiosa, Gmelina arborea,Madhuca indica, Mangifera indica, Terminalia bellirica,* and *Ziziphus mauritiana.*

- Among the commonly found shrubs were *Ricinus communis, Psidium guajava, Calotropis spp., Lantana camara, Jatrophagossypifolia, Grewia asiatica* and Herbs were *Achyranthes aspera, Alternanthera sessilis, Cassia tora, Desmodium triflorum Euphorbia hirta Scoparia dulcis Sterculia vilosa, Xanthium strumarium.*

- Listing and survey of the plant species carried out was a part of natural vegetation found in the study area. Hence only selective Trees/ shrubs/ herbs were included in the trace metal study which were growing in the vicinity of the inhabited area. They included Bel, Ber (Zizipus), Kathal, Mango, Guvava, Papya, Karonda, Castor (Arand), Neem, Sessile joy weed, Ban-tulsi. A few tree species besides other plants growing in the Mine Void area were also collected viz., Acacia, Babul, Bamboo for metals content analysis.

6.1.4 Status of Metal Content in the Floral Species

Floral species samples of herbs, shrubs and trees were collected from different villages during winter & summer season, depending upon the availability in that particular season. Also few fruit trees and weeds used as fodder were also included in the samples.The collected samples were categorised as Edible portion of Fruit/ vegetables/ grains and non-Edible Portion (biomass samples - leaf & stem). The availability of the edible portion in the plants depended on the stage of plant growth (vegetative/ fruiting) and season. Hence edible portion was collected wherever available in order to assess the bioaccumulation of metals in the edible portion which is consumed by the human beings.

Accordingly, total 225 number of samples (65 samples of edible portion and 160 samples of non-edible portion) were collected during winter season, and 172 number of samples (69 samples of edible portion and 103 samples of non-edible portion) were collected during summer. Samples were also collected from the area near mine voids and existing ash dyke.

All the collected samples were processed as per the standard procedure for determination of metal content in edible and non-edible (biomass) portion of different samples of vegetables, fruits, cereal crops, weeds and tree species. Metals content were determined in terms of As, Ba, Cd, Co, Cr, Cu, Fe, Hg, Mn, Ni, Pb and Zn in all the samples collected from different villages and mine void & ash dyke area.

Level of metals content present in different floral species were compared with the permissible limit suggested by Food Safety and Standards Authority of India (FSSAI, 2011). Among the total 12 metals determined in the present study, FSSAI Standards are available only 7 metals (As, Cd, Cu, Hg, Ni, Pb and Zn). Key findings are as follows:

- Analysis of data indicated that Ni content in edible portion of Arhar exceeded FSSAI limit in 6 villages. Ni levels also exceeded in Karonda, Lakra & Sem, whereas Pb exceeded only in two samples of Lakra and Arhar. Cu exceeded in two samples of Zizipus and Lakra, whereas As exceeded only in one sample of Zizipus. ***During winter, out of 65 samples of edible portion of different species, high levels (exceeding FSSAI limit) of different metals were observed in 15 samples***.

- ***Among the 152 samples of non-edible portion (biomass), high levels of metals were observed in as many as 68 samples during winter.*** Metals like Ni, Cu, Pb, As and Zn exceeded in the different species of vegetables, fruits, cereal crops and weeds.

- Similarly, during summer, 15 samples of edible portion of different floral species exceeded the FSSAI limits in different villages. Metals like Ni, Pb, As, Zn and Hg were found exceeding the permissible limit in different species like, Arhar, Sarson, Bel, Onion, Tomato, Kathal, Mango and Brinjal.

- ***Among the 97 samples of non-edible portion (biomass), high levels of metals were observed in as many as 33 samples during summer.*** Metals like Ni, As, Pb, Cu, Zn and Hg were found exceeding the FSSAI limit in the different species of vegetables, fruits, cereal crops and weeds, almost in all the villages.

6.1.5 Bio-accumulation of Metals in Floral Species

The bio-accumulation factor (BAF) in a floral species is estimated as the ratio of metal concentration in plant species to the concentration of metal in the same soil where the plant is grown. Bioaccumulation factor (BAF) was calculated in both the seasons for the edible portion in different vegetables, fruits and cereals of different villages.

The results showed bioaccumulation factor more than one only for Cu & Hg. Rest all other metals showed BAF less than 1, hence they are categorised as “excluders”.

- **Bio-accumulation of Copper (Cu):** Most of the edible portion of plants viz., Brinjal, Lakra, Sem & Ziziphus in winter season, and Brinjal in summer season showed bio-accumulation factor marginally higher than one. A few species like Brinjal of Bastali Abad, Lakra of Mahadhiya & Baliyari and Ziziphus of Phuljhar and Mahadhiya showed BAF between 2.0 & 2.8, thus can be considered as “metal accumulators”.

- **Bio-accumulation of Mercury (Hg):** Bio-accumulation factor in edible portion of plants was observed in Brinjal, Lakra, Lauki, Sem, Tomato, Amrud, Ziziphus and Arhar in winter, and Bhindi, Brinjal, Mirch, Onion, Sarson, Tomato and Mango in summer season. It has been observed that Lakra of Phuljhar, Mahadhiya & Karaila, Lauki of Phuljhar, Sem of Naudhiya, Tomato of Thurua, Parsohar & Dadar and Ziziphus of Phuljhar, Mahadhiya& Karaila in winter season and Brinjal of Bastali Abad, Mirch of Naudhiya, Onion of Mahadhiya &Thurua, Tomato of Gorbi and Mango of Khirwa in summer season showed BAF more than 2.0, and can be categorised as “metal accumulators”.

6.1.6 Status of Fluoride in edible part of Flora and Bio-accumulation

- The concentration of fluoride in both the seasons was found below the detection limit (BDL) in most of the samples. During Winter, Lakra, Sem and Arhar pods collected in winter season showed fluoride concentration ranging between 0.97 mg/kg - 2.2 mg/kg, whereas during Summer all the samples in different villages showed fluoride concentration below detectable limit.

- Further, bio-accumulation factor (BAF) for Fluoride was estimated and the values for Lakra (Phuljhar village) and Sem (Naudhiya village) showed slight bioaccumulation with BAF value of 1.44 and 1.55 respectively. As the fluoride concentration was found below the detection limit in plants of summer season, hence no bio-accumulation was found in the edible part of different species.

6.1.7 Status of Metal Content in the Fauna and Bioaccumulation

Metal content in different aquatic and terrestrial fauna was assessed. Aquatic species covered were different variety of fishes and benthic invertebrates found in different water bodies. Terrestrial fauna covered different types of invertebrates/ insects. Metal content was also determined in fodder samples, milk, urine and scat of animals, and soil samples. Based on the assessment of metals content in different species/ samples, bioaccumulation in fishes and macro-vertebrates were determined. Samples were collected in winter and summer seasons. Finally, bio-accumulation of metals in different aquatic & terrestrial species has been determined, which is summarised here.

- **Fishes:** In both winter and summer, the BAFs in fishes were found to be below for metals of concern except for Cadmium for which the calculated BAF was exceptionally high and only in Rohu fish collected from Jayant Morwani dam and Kachan river. Hg also has BAF values for Catla above 1 collected from Kachan river.

- **Macro-invertebrates:** No bioaccumulation of Cd, Hg, As and Pb was evident in any of the invertebrate samples such as *Aschena* sp. *Mollusca bengalensis sp.* and Ranatra and the earthworm (*Eisenia sp.*) in both the season 1 and 2 at all sites. All other metals have BAF values below 1 wherein similar patterns of bioaccumulation was observed in both the seasons.

Bioaccumulation of metals such as Mn, Fe, Zn was found high in fishes are not of concern as they are essential metals and are required for various physiological and biochemical functions therefore bioaccumulation of such metals would not be toxic.

The toxic metals analysed here have lower bio-accumulation rates and thus BAF values below 1 possessing no major threat to aquatic species on expect for Cadmium (>4) in one sample that has high accumulation. Elevated concentrations of Cd in Rohu fish can be attributed to depuration process as Cd are non-essential metal ions to the fishes.

6.1.8 Ash Characterization and Leaching Study

The quality of various ash samples (flyash, bottom ash and pond ash) was thoroughly characterized w.r.t various physical, chemical, structural and morphological properties and leaching patterns to assess their hazardous characteristics and potential to leach toxic metals by using TCLP (Toxic Characteristic Leaching Procedure) and WET (Waste Extraction Test) method. The key findings of this study are:

- Particle size analysis was carried out to assess the re-suspension of fly ash in air during handling and transportation. The specific gravity and particle size indicate that the chances of re-suspension of fly ash particles are relatively less during handling and transportation.

- All the ash samples collected from different locations were having similar chemical composition. All the samples from both the sets contain trace quantities of various toxic elements including As, Cr, Se, Pb, Ni etc.

- The morphology of ash particles was determined using Scanning Electron Microscopy which revealed that the particles (fly ash & pond ash) consisted of solid sphere and bottom ash has good porosity.

- The TCLP and WET tests revealed that the toxic metals leached from all the three types of ash samples, however the concentrations of various metals in all the samples were found to be much below the threshold/regulatory limits as per Indian Hazardous Wastes Rules 2016.

- Leaching tests at low pH of 2.9 (in similar range of present mine water) were also conducted. The results were found to be more or less in similar range, and levels were much below the threshold values.

6.1.9 Impact due to Transport of Ash by Road

- The NTPC Vindhayachal proposes to transport ash from VSTPP to the mine voids of Gorbi in closed bulkers via road through a distance of about ~35 kms. About 2000 MT per day ash is proposed to be transported in closed road bulkers of 28 MT capacity. The total number of trips in a day (including back and forth) would be 144 number or 6 numbers in an hour. The condition of road to be used for ash transport is mixed type i.e., concrete, black top and haul road. Some sections of the road are good as well as of average/broken condition.

- The estimated exhaust emissions due to movement of 144 trucks in a day will generate approx. 22.2 kg/day of CO, 51.5 kg/day for NOx and 0.30 g/day of PM_{10}

from whole road length. However, the re-suspension of road dust may generate approx. 195 kg of PM_{10} in a day from road length of 34.3 km.

- Air quality dispersion modelling is carried out for different scenarios considering variations of road width and condition of the road i.e., Good, Average and Poor/dusty. The modelling is carried out for 1 km road stretch considering wind angle (angle between dominant wind and road alignment) of 90 degree so that worst impact can be simulated.

- Analysis of modeling exercise indicates that impact on air quality due to exhaust emissions from ash transport vehicles shall be insignificant, however impact due to re-suspension of road dust due to poor condition of road could be significant. Re-supension of road dust needs to be controlled by sprinkling of water, particularly on the roads with average/ broken/ poor/ dusty condition. The ash transporting trucks/bulkers should have adequate provision for sprinkling of water as per the condition of road.

6.2 Overall Recommendations

Based on the comprehensive study conducted by CSIR-NEERI in the study region, the following recommendations are made:

- Analysis of present environmental situation in the nearby villages of Gorbi Mine Voids and requirement of safe disposal of ash by VSTPS, ***it is concluded that the ash can be disposed of (rather stored) into the Gorbi mine voids of Northern Coalfields.*** However, looking into the elevated levels of certain parameters in the ecosystem, there is a need for monitoring and assessment of key parameters in the nearby villages of Gorbi Mines on a regular basis during the filling of flyash.

- There is a need for more frequent and regular monitoring and assessment of water quality and soil quality parameters in the study region.

- There is need for more frequent monitoring and assessment for metals content in different vegetables, fruits, cereals/crops as well as fodder in different seasons to determine persistent bio-accumulation of metals in different species in the study region.

- Analysis of faunal species indicates that more and frequent studies are needed to ensure safe levels of different metals in different faunal species, particularly, the ones which are consumed by human beings.

- From the study of Ash Characterization and leaching study, it is recommended that detailed geochemical and hydrogeological studies may be undertaken in order to ascertain the long-term impacts of disposal of fly ash/bottom ash. The study may address the determination of quality and location of groundwater, groundwater flow paths, the potential for coal ash to leach toxic elements and to react with minerals or groundwater, etc. It is also recommended that long term monitoring plans including frequent sampling and analysis must be undertaken to check the movement of fly ash particles and leaching of metals and other toxic elements in and around the disposal area.

- The air quallity modeling exercise suggests that re-suspension of road dust due to the movement of ash trucks may increase short term PM_{10} levels in the ambient air. Hence Re-supension of road dust needs to be controlled by timely repair of roads and sprinkling of water, particularly on the roads with average/ broken/poor/dusty condition. The ash transporting trucks/ bulkers should have adequate provision for sprinkling of water as per the condition of road.

- ***The above studies should be conducted by VSTPS on regular basis as part of environmental compliance monitoring in the vicinity of Gorbi Mines, and along the transport route.***

In fact, a large number of industrial, mining and related traffic activities in the Singrauli region generate a huge amount of air pollution, water pollution and industrial wastes, thus affecting the receiving environment of the whole area. Therefore, to ensure the environmental sustainability in the region (which is already identified as critically polluted area), it is recommended that a comprehensive "Carrying Capacity Study" be conducted by the State Pollution Control Board (SPCB) for the Singrauli Region at a regular interval of 5 Years.

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