

## Impact of Fly Ash on Soil from Coal Fired Power Station in West Bengal

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### Abstract

The huge amount of fly ash generated by combustion of coal in thermal power plants is considered as one of the potential source of heavy metal contamination in the surrounding cultivated soils. Crops grown in the soils contaminated with fly ash are rich in heavy metals and consumption of such crops pose hazards to the human health. An attempt was made to study the level of occurrence and mode of distribution of heavy metals like Pb, Cd, Cr, Cu, Zn and Ni in agricultural soils near some ash pond in the periphery of one of the largest thermal power plant of West Bengal. Chemical analysis of the topsoil revealed that the levels and trends of distribution of metals were distinctly different showing normal distribution in essential metals (Cu, Zn and Ni) and abnormal distribution of the toxic metals (Pb, Cd, Cr and As). Besides, the grain size distribution were also studied for investigating the change of textural classes of the soil in this region due to fly ash.

**Key words :** Fly ash, Thermal power plant, Soil, Heavy metals.

Coal fly ash, the principal by-product of coal-fired power stations, is one of the most widely studied pollutants. Fly ash particles, when dumped, cause a serious problem to human and animal health (Page et al. 1979) to the normal functioning of higher plants. In India presently about 70% of the total energy demand is met from coal via combustion in thermal power plant (TPP). In meeting this requirement huge amount (100 million tonnes) of ash is being generated from 85 TPP in the country (Vijayan and Behera 1999). Use of lignite in power generation has led to increasing environmental problems associated not only with gaseous emissions, but also with the disposal of ash residues. In particular, use of low quality coals with high ash content results in huge quantities of fly ash to be disposed of. The main problem related to fly disposal is the heavy metal content of the residue. When low quality lignite and sub-bituminous are burned, its fly ash contains several toxic elements, such as lead (Pb), zinc, (Zn), cadmium (Cd), nickel (Ni) and cobalt (Co), which can leach out and contaminate soils and surface water and ground water. The extent of the heavy metals in fly ash depends on both the mineralogy and particle size distribution of the raw material being burnt and the combustion temperature. Although controlling the particle size and

burning temperature can optimize the extent of the heavy metals, such procedures could be costly. Since the coal mineralogy is generally constant for a given coal deposit, not much can be done to control the heavy metal content in fly ash. However, leaching of heavy metals from fly ash can be prevented by adequate waste disposal techniques. The leached heavy metals from fly ash may become a hazard to the environment because of their contribution to the formation of toxic compounds. The objective of the study was to evaluate the level of occurrence and overall impact of some metals like Pb, Cd, Cr, Cu, Zn, Ni on physico-chemical characteristics of the soil in and around a large coal fired Thermal Power Plant (TPP) at Farakka, west Bengal.

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### Methods

#### *Study Area*

The National Thermal Power Corporation (NTPC) is situated in this area is the largest in eastern India

**Table 1.** Elemental concentrations in fly ash from Indian coals (mg/kg)

Pb	Cd	Cr	Cu	Zn	Ni
35.0	–	120	100	100	150
8.1	–	65.8	–	2027	99.6
53.2	15.7	78.4	58.0	51.5	97.8
46.5	–	–	53.5	115	83.5
17.4	0.6	39.4	28.6	33.9	21.6
12.0	0.4	35.4	19.3	18.2	13.4
45.99	2.4	20.0	24.0	27.6	14.9

and is in operation since 1982. The TPP consumes bituminous and sub-bituminous coal obtained from Ranigunge. The major source of water for use in the TPP is the Ganges River flowing nearby. The fly ash generated from TPP is collected by using electrostatic precipitators (ESP) and both the bottom ash and fly ash of the plant are mixed together and deposited in the three large ash ponds situated near Kendua, Malancha and Nishindra villages around the power plant. The climatic condition of the area is mainly dry in nature and the maximum and minimum temperature is 43 C and 8 C respectively, whereas the average rainfall is 1,400 mm/year. The soil quality of this area is neutral in nature and contains low organic carbon. Cultivation is the main occupation of the villagers of the area. The cultivated crops are mainly paddy, wheat, various pulses and oil seeds. Mango and litchi are the main fruits for export of this area.

#### Collection of Soil and Fly Ash Samples

Six locations were selected : S<sub>1</sub>—Ash pond-1, S<sub>2</sub>—Ash dumping site-1, S<sub>3</sub>—Ash dumping site-2, S<sub>4</sub>—Ash pond-2, S<sub>5</sub>—Ash pond-3 and S<sub>6</sub>—Control (away from TPP). From each location around the ash ponds, ash dumping sites, several numbers of soil samples (0–5 cm) were collected from different agricultural fields in and around 10 km radius of NTPC ash pond or ash dumping sites including one reference sample (S<sub>6</sub>) beyond 10 km by hand operating grab sampler to determine elemental contamination from fly ash dispersal around the power plants and to have a statistical representative soil samples, the six samples were collected by random sampling from each locations were subjected to chemical analysis.

Fly ash sample from three ash ponds of National Thermal Power Corporation was acquired.

**Table 2.** Physical and elemental components in soil in Farakka region around NTPC.

Parameters	S <sub>1</sub>	S <sub>2</sub>	S <sub>3</sub>	S <sub>4</sub>	S <sub>5</sub>	S <sub>6</sub>
pH	7.74	7.78	7.7	7.74	7.96	6.97
Bulk density	1.59	1.52	1.42	1.53	1.54	1.84
OC (%)	1.02	1.07	1.35	1.00	1.14	0.79
WHC (%)	59.4	58.76	62.78	44.93	61.47	50.71
Pb (mg/kg)	61.96	52.57	39.38	51.4	64.89	2.84
Cd (mg/kg)	4.03	3.56	3.94	3.71	4.65	0.57
Cr (mg/kg)	20.19	20.88	15.27	18.47	26.34	7.31
Zn (mg/kg)	75.96	75.49	70.69	77.09	79.30	52.63
Cu (mg/kg)	29.22	31.47	37.01	33.12	28.85	20.47
Ni (mg/kg)	39.19	40.71	34.97	32.06	40.76	32.68

#### Treatment of Samples

The soil samples were air dried in the laboratory and sieved with a 2 mm grade sieve. A standard soil analysis was carried out to determine particle size distribution by international pipette method (Piper 1966) after treatment with 6% hydrogen peroxide (H<sub>2</sub>O<sub>2</sub>) and sodium hexa-metaphosphate. The pH was recorded by potentiometry in soil: water ratio of 1:2.5 (wt/wt) (Jackson 1967) with pH meter (WTW, Model Multi 340i/Set) and the organic carbon content by means of modified Walkly and Black method (Jackson 1967). The water holding capacity was analyzed by keen-box method (Jockson 1967). The results of organic carbon and water holding capacity are expressed as percent and other parameters are expressed as mg/kg (ppm) air-dried soil. Fly ash (undifferentiated) and soil samples (0.25 g) were digested by concentrated nitric acid and perchloric acid (Smith 1987) for determination of trace metals by atomic absorption spectrophotometer (AAS, Model : Varian spectra 55) with graphite furnace atomizer (Thompson and Wood 1982). A sample blank was prepared following the same sequence of digestion procedure and the element analysis was performed against the blank. Validation of the estimation of trace metals was done using standard reference material (SRM No. 1645, NIST, National Institute of standard and Technology former NBS). For the elements tested, the recovery was in good agreement with the certified value. Factor analysis was carried out with component loading.

## Results and Discussion

### Fly Ash

Elemental concentrations in fly ash from the

**Table 3.** Factor analysis of different components in soil.

Variable	Factors				Communality
	1	2	3	4	
Pb	0.95	-0.03	0.09	0.09	0.913
Cd	0.91	0.09	0.20	-0.05	0.871
Cr	0.84	0.36	0.27	-0.10	0.907
Cu	-0.21	-0.04	-0.33	0.76	0.736
Zn	-0.15	0.83	-0.05	0.28	0.790
Ni	0.01	0.84	0.07	0.03	0.702
As	0.91	0.07	0.25	0.10	0.902
Fe	0.50	0.36	-0.69	-0.09	0.861
Na	0.17	-0.45	0.70	0.13	0.744
K	-0.63	0.33	0.44	-0.01	0.703
P	-0.31	0.26	0.06	-0.69	0.635
OC	-0.43	0.31	0.63	0.22	0.727
Eigen values	4.26	2.12	1.86	1.35	—
Percent of variance	35.5	17.70	15.50	11.40	—

present study are compared with results from the literature on Indian fly ash (Table 1). These concentrations are quite variable. These findings are not unexpected, as large variations in concentrations of naturally existing trace elements in coal have been reported from different locations in the same seam bed and from different mining areas (Fuelker and Dave 1986, 1990, Khusek et al. 1983). The chemical properties of fly ash also depend on various parameters such as coal quality, combustion processes and temperature and emission control devices (Kaakinen et al. 1975, Phung et al. 1979, Feulker 1983, Smith 1987).

Generally, lower values found in the present study for NTPC, Farakka fly ash samples as compared to literature values (Table 1) (exceptions being Pb and Cd) reflects differences in the coal being used, these lower values are reassuring with regard to environmental contamination, as coal combustion has been shown to be a substantial anthropogenic emission source for a number of trace elements (Pacyna 1984, Pacyna et al. 1984).

#### *Elemental Concentrations in Soils*

The pH level of the sampling spots from S<sub>1</sub> to S<sub>5</sub> varied from 7.7 to 7.9 and the mean pH of the reference soil i.e. S<sub>6</sub> was 6.97. The pH of the fly ash was 8.12, so it was highly alkaline (Table 2). Thus the pH values of the soils are higher than the reference soil samples. The results showed that organic carbon varied from 1—1.35% which was much higher compared to reference samples (0.79%). For Pb, Cd and Cr

**Table 4.** Grain size distribution of different soil samples.

Sites	Silt (%)	Clay (%)	Sand (%)	Soil texture
S <sub>1</sub>	64.80	10.36	24.84	Silt loam
S <sub>2</sub>	60.00	6.84	33.16	„
S <sub>3</sub>	52.48	7.12	40.40	„
S <sub>4</sub>	36.28	5.92	57.80	Sandy loam
S <sub>5</sub>	41.08	6.44	52.48	„
S <sub>6</sub>	74.76	10.28	14.96	Silt

the soil samples showed higher values in respect to reference soil.

Factor analysis was also employed in the present study to delineate the sources affecting the soil chemistry in regard to analyzed soil components. Basically this analysis is considered as a technique to reduce an original set of variable into a smaller set of uncorrelated components (factors) each resembling a cluster of interrelated variables within the data set and represent together most of the information found in the original variables. It was found that average of 80% of the total ionic variability was accounted for by extracting four composite factors representing higher efficiencies of extraction (Table 3). Moreover, the communalities of each components represented the variability well.

All samples were to some extent loamy soil while the soils far away of the TPP were silty in nature (Table 4). Addition of fly ash alters the texture of sandy or silty or clayey soil to loamy soil (Fail and Wochock 1977).

Kabata Pendisa and Pendias (1984) have reported that the average contents of Cd in soils lie between 0.07 and 1.1 mg/kg. However, the authors add that the background Cd levels in soils should not exceed 0.5 mg/kg, all higher values reflect the anthropogenic input on the Cd status in topsoils. Table 2 shows that Cd levels range between 3.56 and 4.76 mg/kg (whereas in reference soil it is 0.57 mg/kg). It may be due to fly ash because the Cd content in fly ash is 2.4 mg/kg (Table 1).

The increasing toxic metals in the soils may be due to the enrichment of fly ash in these soils. If the presence of higher level of toxic metals in soils is supposed to be originated from ash contamination, the essential metals in ash should also be contributed to the system and this must have also enriched level of essential heavy metals. But this is not found

in the control areas as the sampling sites are basically the agricultural soils where different varieties of plants are cultivated years together. On the other hand, toxic metals are not taken by the plant system due to their lack of biological utilization and hence they are accumulated in the soil. This resulted significant accumulation of toxic metals only in soils around the TPP (Thermal Power Plant) or AP (ash pond) or ADS (ash dumping site), compared to control soils. Study on metal accumulation in soil on various distances away from TPP revealed that the soils collected within the 10 Km radius of TPP were significantly affected as compared to soils beyond this distance. The results showed that the toxic metals affected sampling sites between 1—10 km from TPP or AP or ADS (beyond 10 km, toxic metal levels were low as compared to other locations). It appears that the spreading of ash in agricultural lands are almost restricted within 10 km from TPP or AP or ADS along this direction.

The experimental results show that the toxic trace element concentrations in the soil around thermal power plant are increasing for anthropogenic input in the soil. Heavy metal concentrations are highest in the sites nearer the ash pond or ash dumping sites with respect to the reference soil, which is chosen beyond 10 km radius from thermal power plant or ash pond or ash dumping sites. Most of the soil showed higher level of Pb and Cd load as compared to Cu and Ni loads. The positive impact is established that the soil textural classes of the soil are almost loamy in nature as compared to the reference soil. But if care not taken in the future, subsurface contamination will become an increasing problem. These lands may be used for growing ornamental and timber plants to minimize the transfer of heavy metals from soil to human beings through food chain.

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