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Analysing the Top Soil Chemistry for Environments around the Barapukuria Thermal Power Plant, Bangladesh

M. Farhad Howladar, Tanvir Ahmed, Pulok Kanti Deb*, Fazal Md. Mohi Shine, and Md. Abdur Rahman

Abstract – Barapukuria 2x125MW Coal-Fired Thermal Power Plant area is situated under Hamidpur union of Parbatipur Upazila, Dinajpur, Bangladesh where 0.72 million metric tons of coal has been consumed and 0.08 million metric tons of coal ash have been generated every year. This plant generates significantly large quantities of solid byproduct which is disposed of in two designated ponds, but currently a safe management and disposals have become a major challenge to environmentalists and scientists. In this study, the quality of the soil for environment around a thermal station is presented. The samples were taken from different distances from the thermal station. The results of the analysis reflect that the soil is acidic based because of the average pH concentration is 6.92. The average values of organic matter, N, K, Ca, Mg and Na (meq/100g) are 0.87%, 0.04%, 0.27, 5.68, 1.97 and 0.01, respectively whereas the mean concentration of other elements such as P, S, Cu, Fe, Mn, and Zn are 4.94, 51.45, 0.63, 28.62, 16.64 and 0.68 µg/g, respectively. Phosphorus around the power plant soil samples ranges from 2.08 to 9.66 µg/g, which is very low to low compared with the standard. The results of all soil sample analysis also show that all the major chemical parameters such as Na^+, Mg^{2+}, Zn^{2+}, Ca^{2+}, K^+ are slightly varied for different samples but there is a shortage in N, P and S in soil near the thermal plant which might be the indicator of soil consequently the environmental pollution around the area at present and the day coming.

Index Term – Coal, Barapukuria Thermal Power Plant, Soil quality, Soil samples, Pollution, Fly ash, Chemical Analysis, Environmental impact.

1. INTRODUCTION

Each year coal-fired thermal power plant produces a large amount of combustion residues. The solid waste residue of a thermal power plant includes bottom ash, slag and fly ash. Fly ash is the portion of the residue that has sufficiently small enough particle size to be carried away from the boiler in the flue gas [1]. Fly ash accounts for approximately 70% of the solid waste produced from coal combustion [2, 3]. Environmental impacts caused by fly ash disposal and dumping have only recently become identified as an important topic of research. A larger market can be encouraged to productively reuse of fly ash when the environmental impacts can be predicted confidently. In Bangladesh, there is only one coal based thermal power plant named Barapukuria 2x125MW coal-fired thermal power plant (BTPP). Every year a large quantity of fly ash is being produced in this plant and dumped in ash ponds near the power plant, which has some adverse effect on the environment. By the development of BTPP, a new dimension is added to the economy of Bangladesh. From the year of 2006, almost 70% coal extracted from Barapukuria Coal Mine has been used for electrical power generation at this power plant [4]. At BTPP 2x125MW coal-fired plant; it has the capacity to extract 3,333tons of coal per day [5]. From the annual report of BPDB [4], every year, 0.72 million metric tons of coal have been consumed and 0.08 million metric tons of coal ash generates in the BTPP. These coal ashes are dumped with water in two ash ponds near the plant. The discharge water from the power plant is being discharged by an artificial channel in the river Tilai. The chemical analysis of coal ash samples requires a high degree of accuracy because of its adverse effect on the environment. They will provide a better understanding of possible information about the limits of existence in water, soil, and air or can permit planning for appropriate utilization. But there are no detailed researches on the chemistry of the coal ash generated by the BTPP and its impact on soil environment around the power plant area. From this point of view, the principal purposes of this study are to understand the quality of soil, its contamination level for the environment for present and future.

- *M. Farhad Howladar is currently an active Faculty member in Petroleum & Mining Engineering at Shahjalal University of Science and Technology, Bangladesh, PH-+8801731195918. E-mail: farhad-pme@sust.edu; farhadpme@gmail.com*
- *Tanvir Ahmed was an undergraduate student under Petroleum & Mining Engineering Department at Shahjalal University of Science and Technology, Bangladesh.*
- *Pulok Kanti Deb is currently pursuing Master's degree program in Process Engineering at Memorial University of Newfoundland, Canada, E-mail: pulokpme@gmail.com*
- *Fazal Md. Mohi Shine is currently active Faculty member in Geology & Mining at University of Rajshahi, Bangladesh.*
- *Md. Abdur Rahman is currently active Faculty member in Geology & Mining at University of Rajshahi, Bangladesh, E-mail: rahman72ru@yahoo.com; rahman@ru.ac.bd*

2. STUDY AREA, SAMPLING AND METHODS OF ANALYSIS

2.1 Study Area

The study area is located in Hamidpur union of Parbatipur Upazila, Dinajpur District. It is located in flat paddy land on the northwestern corner of Bangladesh at about 45km east of the district headquarters of Dinajpur and 20km east from the

Fig. 1. Location map of the BTPP, Bangladesh.

Table 1. Description of the collected soil samples.

Sample no.	Depth	Longitude	Latitude	Remarks
1	Surface	N 25° 33′ 321′′	E 88° 56′ 774′′	Channel near power plant.
2	Surface	N 25° 33′ 480′′	E 88° 56′ 369′′	Mid channel near power plant.
3	Surface	N 25° 33′ 470′′	E 88° 56′ 972′′	Channel far from power plant.
4	Surface	N 25° 33′ 442′′	E 88° 56′ 920′′	River Tilai far from power plant.
5	Surface	N 25° 33′ 123′′	E 88° 56′ 718′′	Ash pond near power plant.
6	Surface	N 25° 33′ 576′′	E 88° 56′ 804′′	Paddy filed near power plant.

Table 2. Methods Used to Measure the Parameters of Soil Samples.

Parameters and Units	Method of Extraction
Nitrogen, N (%)	Dumas Combustion Method
Phosphorus, P (μg/g)	Modified Olsen Method (Neutral + Calcareous Soil)
Sulfur, S (μg/g)	Calcium Dihydrogen Phosphate Extraction
Potassium, K (meq/100g)	N NH_4OAc Method
Calcium, Ca (meq/100g)	N NH_4OAc Method
Magnesium, Mg (meq/100g)	N NH_4OAc Method
Zinc, Zn (μg/g)	DTPA Extraction Method
Iron, Fe (μg/g)	DTPA Extraction Method
Manganese, Mn (μg/g)	DTPA Extraction Method

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border of India. Bangladesh topographic sheet no. 78C/14 (Scale 1:50,000), which lies between the latitudes 25°33/57// to 25°33/24//N and the longitudes 88°56/71// to 88°56/43//E. (Fig. 1).

2.2 Soil Sample Collection

For assessing the environmental impact, one sack of fly ash and six samples of soil (Table 1) were collected near and far from the study area. The soil samples were collected in plastic bags during the time of sampling. The longitude and latitude of the respective samples were recorded in a GPS.

2.3 Methods of Analysis of collected Soil Samples

Chemical analysis of collecting soil samples was conducted in the laboratory of the Soil Resource Development Institute, Dhaka, Bangladesh. The concentration of 14 parameters was measured which is compared to permissible limits as recommended for Bangladesh by Bangladesh Agricultural Research Council (BARC). All the methods used to measure the concentration of the parameters of soil samples are followed from the fertilizer recommendation guide [6]. The methods used in this study are shown in Table 2.

3. RESULTS AND DISCUSSION

3.1. The Chemical Characteristics of Soil

The soil pH is a measure of the acidity or basicity in soils. pH is defined as the negative logarithm (base 10) of the activity of hydronium ions (H^+) in a solution. It ranges from 0 to 14, with 7 being neutral. A pH below 7 is acidic and above 7 is basic. Acidity in soils comes from H^+ and Al_3^+ ions in the soil solution and sorbed to soil surfaces. While pH is the measure of H^+ in solution, Al^{3+} is important in acid soils because between pH 4 and 6, Al^{3+} reacts with water (H_2O) forming $AlOH_2^+$, and $Al(OH)_2^+$, releasing extra H^+ ions [7]. Basic soils have a high saturation of base cations (K^+, Ca^{2+}, Mg^{2+} and Na^+). This is due to an accumulation of soluble salts which are classified as saline soil, sodic soil, saline-sodic soil or alkaline soil. As a result, the studied soil sample is acidic based because the average pH concentration is 6.92. The organic matter in the soil offers plentiful chemical, physical and biological benefits. Biologically, organic matter serves as a food source for living soil organism and helps to suppress diseases and pests by enhancing soil microbial diversity. Organic matter physically improves the soil by improving water filtration and holding capacity, reducing surface crusting and runoff, making clayey soils easier to work with and improving soil aeration. Chemically, organic matter increases the soil's ability to retain and supply essential nutrients for plants, speeds up the decomposition of soil minerals and buffers the soil against pH changes [8]. Organic matter in soil samples ranges from 0.34% to 1.75%. N cycling in soils is a complex mix of chemical and biological processes. The majority (> 90%) of N in soils is contained in organic matter, with smaller inorganic proportions as ammonium fixed in clay mineral layers, exchangeable ammonium, and nitrate. The N content of soils varies greatly as the organic matter varies, but is within a range of approximately 0.06 to 0.30% (1,200 to 6,000 lb N/acre in the top 6 2/3 inches) for cultivating soil [6]. The percentage of N varies from 0.017 to 0.088 in the studied soils. If finer-grained fly ash, discharged from the ESP, covers the soil around the plant area, then N may not be passed through it. It might be the cause of N deficiency in the study area. If K is deficient in the soil, it may show spots or marginal burn starting from the tips to the older leaves and increase susceptibility to diseases. Drought and cold injury are also the symptoms of potassium deficiency. The concentration of K in around the study area ranges from 0.22 to 0.38 meq/100g. Ca in soil studied samples ranges from 2.60 to 10.08 meq/100g. Becoming white new leaves and died and curled growing points of the plant leaves are the symptoms of Ca deficiency in the soil. The maximum and minimum concentrations of magnesium of the studied samples are 3.88 and 0.96 meq/100g, respectively. Marginal or interveinal chlorosis with the pinkish color of older leaves occurs due to Mg deficiency in the soil. Chlorosis of younger leaves is the symptom of sulfur deficiency in the soil. Sulfur in soil samples ranges from 5.4 to 147.2 μg/g. Rolling, dieback, and chlorosis of younger leaves are the symptoms of Cu deficiency in the soil. The maximum concentration of Cu was 1.02 μg/g, where the minimum concentration was 0.32 μg/g in soil samples. The deficient concentration of Fe in soil samples may cause interveinal chlorosis of younger leaves. The whole leaf may become yellow firstly and finally white in case of severity. The maximum and minimum concentration of Fe was 55.12 and 8.98 μg/g, respectively. Deficient concentration of Mn in soil samples may cause interveinal chlorosis of younger leaves. Whole leaf may become yellow firstly and finally white in case of severity. The maximum concentration of Mn was 25.18 μg/g, where the minimum concentration was 6.28 μg/g in soil samples. Rusting of leaves in rice, uneven crop growth and delay in maturity are the symptoms of Zn deficiency in the soil. The maximum concentration of Zn was 0.22 μg/g, where the minimum concentration was 1.08 μg/g. Arsenic (As) It cannot be destroyed once it has entered the environment so that the amounts that we add can spread and cause health effects to humans and animals [9]. The maximum and minimum concentration of As was 0.05 and 0.00 μg/g, respectively in soil samples. Results are shown in Fig. 2. Comparing with the comparison between the mean value of soil sample test analysis and standard value given by BARC [6] are graphically discussed in Fig. 2.

3.2 Direct Evidence of Soil Pollution

Some direct evidence of environmental degradation had been noticed during the field observation and the sample collection period. A layer of fly ash and bottom ash that covers the soil as

Table 3. Test results of different soil samples collected from BTPP area, Dinajpur.

Parameters & Units	Sample- 1 Channel Face	Sample- 2 Mid Channel	Sample- 3 Channel End	Sample- 4 River Tilai	Sample- 5 Ash Pond	Sample- 6 Paddy Field
pH	7.20	7.00	6.80	6.90	6.70	6.90
Organic matter, %	1.75	0.67	0.40	0.34	1.21	0.87
N, %	0.088	0.034	0.020	0.017	0.061	0.044
K, meq/100g	0.38	0.24	0.22	0.25	0.32	0.22
Ca, meq/100g	3.93	3.20	2.60	6.35	7.90	10.08
Mg, meq/100g	1.17	1.58	0.96	1.29	2.92	3.88
Na, meq/100g	0.01	0.008	0.010	0.019	0.016	0.020
PO_4, µg/g	2.08	1.14	6.50	4.54	9.66	5.74
S, µg/g	13.90	5.40	45.3	49.10	147.20	47.80
Cu, µg/g	1.02	0.32	0.74	0.40	0.96	0.36
Fe, µg/g	54.60	11.56	55.12	19.24	22.22	8.98
Mn, µg/g	25.18	18.76	17.84	20.66	11.14	6.28
Zn, µg/g	0.92	0.22	0.44	0.36	1.08	1.08
As, µg/gm	0.00	0.00	0.00	0.00	0.00	0.05

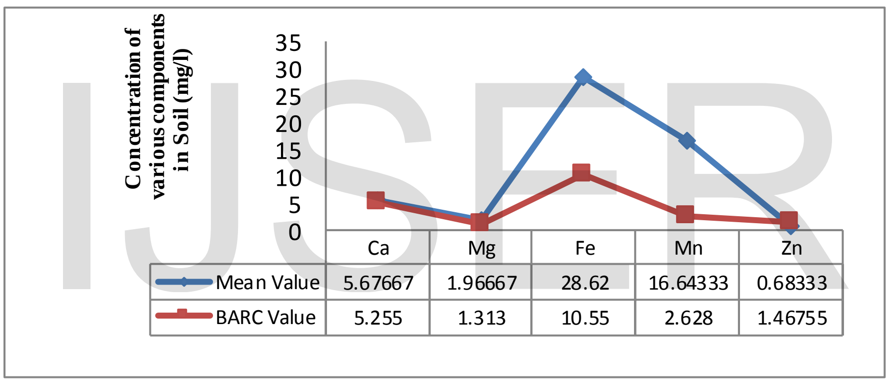

Fig. 2. Two Dimensional Line Chart of mean value of soil sample test analysis vs. BARC (2005) standard value.

well as the root of the plants had been noticed (Fig. 3). Polluted blackish soil layer in the river Tilai was seen at the connection point and its surroundings of the discharge channel and river. Besides, the ash pond is getting dried day by day because of a large amount of fly ash as s a result the fly ash layer is connected with the environment and impacting the environmental parameters like soil.

3.3 Environmental Concerns of Soil Pollution

The metals present in fly ash are in the priority pollutants list as their leaching potentials have been expected to be high. It is recognized that health hazards and environmental impact of thermal power plants result from the mobilization of toxic and radioactive elements from the residues, which in turn mainly depends on meteorological parameters. Contaminated leachates from the acidic fly ash can pose the highest toxicity problem for aquatic environments [10, 11, 12, 13, 14]. Fly ash, which contains heavy metals like lead (Pb), is of large public concern due to toxicity to animals as well as human beings, especially young children. Pb contaminated soils are widespread in the environment because of the extensive use of Pb in industrial wastes [11, 12, 13]. Fly ash contains the high amount of organic and inorganic chemical components such as: As, Cd, Cr, Pb, Hg, Se, Cu, etc. If these enter into their food chain anyhow these chemical components show adverse effects on mankind and animals. Different pathways by which humans can be exposed to metals from contaminated soil and water are discussed here. For the metals like Cd, Cu, Pb and Zn, dermal contact with contaminated soil is not considered to be a significant pathway of exposure. Similarly, exposure through inhalation is also unlikely to be a major exposure route, particularly in the wet tropics, where atmospheric dust levels are expected to be low, though this needs confirmation for the flowing River [12, 15, 16]. However, ingestion of soil does provide a direct exposure pathway, particularly in young children, as a result of frequent hand-to-mouth behavior, can consume relatively large amounts of soil.

4.CONCLUSION

To assess the soil environmental effect of the BTPP, this research focuses on existing soil condition around the area. However, an extensive chemical analysis of soil samples has been done through the determination of different chemical parameters of collected respective samples. The twelve parameters, such as Na^+, Mg^{2+}, Zn^{2+}, Ca^{2+}, K^+, pH, N, Fe, S, Mn, As and organic matter content are determined based on different methods and these results compared with the standard value given by BARC [6].

Fig. 3. Fly ash and bottom ash covering the soil and root of the plants.

Overall Na^+, Mg^{2+}, Zn^{2+}, Ca^{2+} and K^+ are slightly varied from sample to sample besides a comparative deficiency in N, P and S content is yielded. Also, a considerable amount of As concentration which determined in a paddy field near the power plant (sample six) may the evidence of the pollution of soil qualities which would be an indicator for reducing the soil fertility and productivity of the crops in future. On the other hand, the direct evidence of soil contamination is noticed during field observation because of improper dumping of the coal fly ash. Considering these points, it can be concluded that the improper dumping of coal fly or bottom ash from coal based thermal power plant can make a long-term negative impact on the soil environment as well as on the environmental chain as a whole. At the end, this research recommends for a suitable management plan for fly ash dumping as well as the environment, proper implementation and regular monitoring around the studied area.

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