Original Research Article

Impacts of Coal Stockpile on Soil and Water

ABSTRACT

In this study, the soil and water samples were analyzed to evaluate the effects of coal stockpile on soil and water quality at Haluaghat Upazilla, Mymensingh, Bangladesh. As a natural resource, coal has potential contributions to the development of economics of a country but coal storage deteriorates surrounding surface and ground water and soil quality in different ways. Besides, it has significant impacts on the arable lands and water catchments. The analyses of 10 soil and 10 water samples (5 samples from ground water and 5 samples from surface water) were collected at 0 m, 200 m, 500 m and 700 m distance from the coal storage area were carried out using standard methods. The pH, electrical conductivity (EC), organic matter (OM), macronutrients (N, P and K) and heavy metals (Lead and Cadmium) were analysed for soil samples and for water samples pH, EC, macronutrients (P and K), heavy metals (Pb and Cd) were analysed. From the results, it was observed that most of the value of soil and water quality components were higher at close to the coal stockpile area and gradually decreased with distance. Soil pH value showed a decreasing treand (5.2 to 3.2) with increasing distances from the coal storage area; whereas water pH increased gradually with increasing distances from the coal storage area. Soil OM content was found highest at the coal storage area, which decreased gradually with increasing distance. The content of soil N, P, K was also recorded highest at the coal storage area which followed decreasing trend with increasing distance. The content of Pb and Cd in soil adjacent to coal storage area was higher compared to distant areas (500-700 m) in paddy field.

Keywords: Coal, natural resource, coal storage, pH, paddy field

INTRODUCTION

Coal is mostly used fuel in electricity generating sector worldwide. It supplies near about 27% of the primary energy need worldwide. Total global production of bituminous and anthracite (hard coal) was 3837 million tonnes in 2002 and the brown coal production was 877 million tonnes (World Coal Institute 2004, Coalportal 2004 and Australian Coal Association 2004). According to World Coal Institute (2004) and Coalportal (2004), major hard coal producer countries are China (1326 million tonnes), U.S.A. (916.7 million tonnes) and India (333.7 million tonnes) by year 2002. Brown coal is mainly produced by Germany, Greece and North Korea. International trade of coal is dominated by hard coal (mainly bituminous type). Hard coals are used as thermal coal and for the manufacture of steel as coking coal. Coal mining is one of the major industries responsible for different types of environmental pollution. The primary challenge of coal mining to the ecosystem could be harmful impacts to water bodies (Pan *et al*., 2012; Bai *et al*., 2011). A lot of toxic metals, low pH levels, and suspended solids are some other aspects of contaminated water from coal mining or storage site. Coal is the most bountiful fossil fuel in this world (Ramani, 2013) that consists about 75% of the global fuel reserves (Elliott, 1981). It contributes 39% of total electricity generation all over the world (Brown, 2002). Coal is also burnt to produce heat or liquefied to produce gas. Tiwary (2001) reported effects of coal mining on the environment cannot be misjudged though it plays a vital role for economic development of a country. Storing or mining operation in a wrong way is a reason of landscape damage, loss of forestry, surface and ground water pollution that leads to huge loss of ecosystem components (Toren and Unal, 2001). Some components of coal such as polycyclic aromatic hydrocarbons (PAHs) and heavy metals cause adverse biological effects at high concentrations. Coal is formed from organic materials after decomposition undergoing geologic heat and pressure over millions of years. It is considered as nonrenewable resource (EPA, 2000). Carbon dioxide, sulfur dioxide, nitrogen oxides and mercury compounds are released when coal is burnt. For that reason, coal-fired boilers in industries are required to have control devices to mitigate the harmful gas emission. To remove impurities from coal, huge quantities of water are needed at the mine site and coal-fired power plants use considerable amount of water to produce steam and for cooling purpose. When power plants discharge waste water into river, aquatic organisms and water quality can be affected.

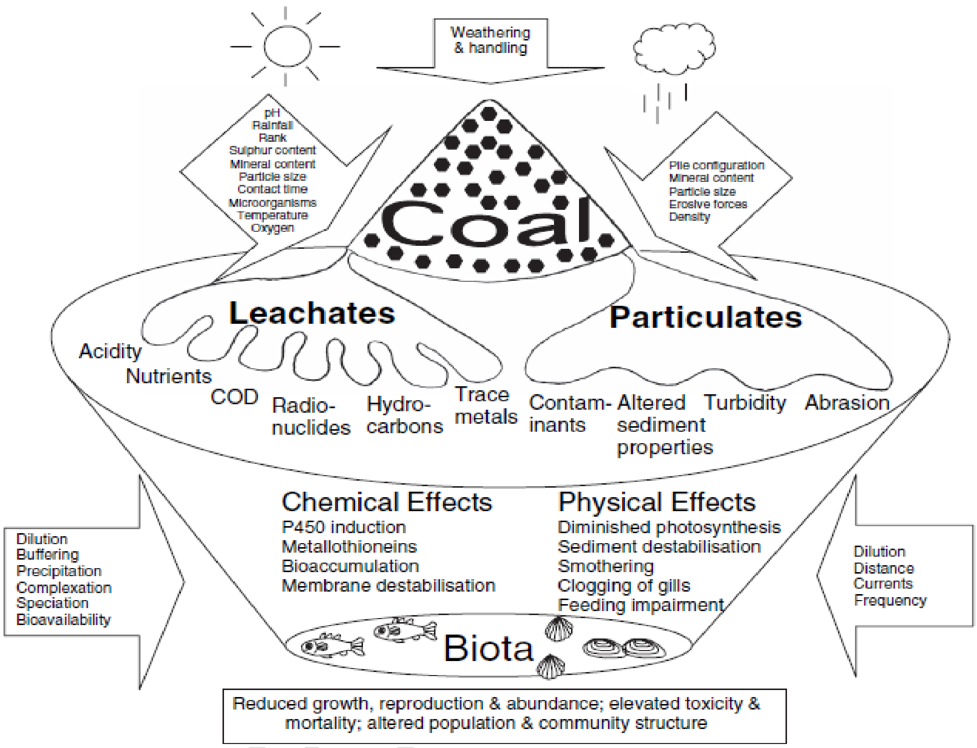

Figure: Impacts of coal in the aquatic environment. Influential factors are in boxed arrows. (Ahrens and Morrisey, 2005)

There are some environmental impacts of coal that occur through its mining, combustion, waste storage, and transport related activities. There are some health effects caused by coal. In 2007, world coal consumption reached at 5,522 million tons, showing about 3.5% increase annually (Pusdatin, 2011). Ghosh (1990) reported that, about 4 ha land is damaged in India, for every million tonnes of coal extracted by surface mining. The coal industry was solely responsible for biologically unproductive area of about 500 ha a year during 1994–95. This increased to 1400 ha by 2000 (Chari *et al.*, 1989). There are some changes in the physical, chemical and microbiological parameters of soils as a result of coal storage. Some are caused by the construction of the storage (Sandlein *et al*., 1983). In abandoned mines, topsoil is very important for the growth of vegetation and has to be conserved for land reclamation after mining (Kundu and Ghose, 1994). The quality of soil will be biologically sterile if it is not properly conserved.

Coal from the mine area is transported by road to the stockpile to further transport by barges. Stockpile is a temporary dump place before the coal is transported through the waterways to be marketed. The coal stockpile in Gubrakura, Haluaghat is one of the few prominent stockpiles in Bangladesh, which is located vicinity to the Bangladesh-India border (near Meghalaya states of India) of an area of about 50 acres. The stockpile location is very strategic because it can be passed by a barge as a transporter of coal to market. Although the location of the stockpile is far from the main road of the Haluaghat and locality, activities in the stockpile generate significant amount of dust, wastes to the surrounding environment. The liquid waste from stockpile can reduce the degree of acidity (pH) and increase the content of total suspended solids (TSS*)*, ferrous (Fe) and manganese (Mn) (Ahrens, 2010). High suspended solids reduce the penetration of sunlight into the water which adversely affects the regeneration of oxygen in the photosynthesis process. On the other hand, excess Fe may affect the lives of aquatic organisms and may cause rust on the metallic equipments. Abnormal pH value of water that is not in the standard range may affect aquatic organisms, such as fish and other animals. Additionally, an abnormal pH is corrosive to metals (Akcil and koldas, 2006). Considering the role of a stockpile to surrounding ecosystem, soil and water quality analysis around coal stockpile at Haluaghat, Mymensingh to justify its fitness for various applications was performed.

MATERIALS AND METHOD

Study area

Samples were collected from different distances of coal storage at Gobrakura, Haluaghat (about 60 km away from Mymensingh sadar upazila). The total area of stockpile is about 50 acre. The area is surrounded with village except north. The storing of coal has been started since 1997. Coal is imported from Meghaloy of India. Many dealers are involved with this business. They store coal for some days or months until selling or transporting to other areas of the country. Coal from this storage is supplied to different brickfields and markets. Photographic view and map of the experimental site are presented below:

Figure 1: Map of the study area (Modified from Banglapedia, 2009)

Figure 2: Coal stockpile

Figure 3: Drain water from coal stockpile area

Sample collection and preservation

A total 20 samples (10 soil samples and 10 water samples) were collected from the selected locations. The samples were collected from 0m, 200m, 500m and 700m distances from storage area. Water samples were collected in 100 ml plastic bottles. The bottles were washed with distilled water prior to collect the samples, 10 samples collected without acid and 10 samples with acid. After collection, plastic bottles were labeled and sealed immediately to avoid direct exposure to air. 10 ml 2M HNO_3 was mixed with 90 ml of sample for heavy metal study. Samples were kept in a cool place until chemical analyses. Soil samples were collected from 0-30 cm depth and kept in polythene bags. After completion of soil sampling, the unwanted materials were discarded from sample. The samples were dried at room temperature, then crushed and mixed thoroughly and sieved with a 20 mesh sieve. Finally, about 200 gm soils were taken for subsequent laboratory analysis.

Soil Quality Assessment

pH, Electrical Conductivity (EC), Organic matter (OM), Nitrogen (N), phosphorus (P), Potassium (K) and Heavy metals (Pb and Cd) of soil samples were analyzed to investigate soil quality. It is important to know the physicochemical properties of soil for successful crop production and other purposes. In this study soil pH were measured by pH meter and EC of soil samples were measured by an EC meter (Model- D.6072 Dreieich, West Germany). Available potassium was extracted by neutral ammonium acetate and determined directly by flame photometer at the wave length of 766.5 to 769.5 nm. Available Phosphorus present in soil was determined by Olsen's method colorimetrically, where $SnCl_2$ was used as reductant. The Kjeldahl method is a method for the quantitative determination of nitrogen in chemical substances developed by Johan Kjeldahl in 1883. Nitrogen was determined by this method in this study. The determination of heavy metal concentration (Pb and Cd) in soil samples was done by using an Atomic Absorption Spectrophotometer (AAS) in AAS laboratory.

Water Quality Assessment

Analysis of different physicochemical properties (pH, EC, concentration of P, K and heavy metals viz. Lead and Cadmium) of the water samples was performed. Water pH was measured by a pH meter. The electrical conductivity of water samples was measured by an EC meter (Model- D.6072 Dreieich, West Germany. Phosphorus of water samples was determined colorimetrically by $SnCl_2$ method according to the procedure outlined by Jackson (1967) and Tandon (1993). In this method, stannous chloride ($SnCl_2.2H_2O$) was used as a reducing agent which formed molybdophosphoric blue complex with sulphomolybdic acid. Exactly, 20 ml water sample was taken in a 100 ml volumetric flask followed by the addition of 4 ml sulphomolybdic acid and 4-6 drops of stannous chloride ($SnCl_2.2H_2O$) solution. The color intensity was measured at 890 nm wavelength with the help of a spectrophotometer (Double Beam Spectrophotometer) within 15 minutes after the addition of stannous chloride. Potassium was determined separately with the help of a Flame photometer (Model Jenway PFP7**.** The determination of heavy metal concentration viz. Lead (Pb) and Cadmium (Cd) in water samples was done by using an Atomic Absorption Spectrophotometer (AAS). Mono element hollow cathode lamp was employed for the determination of each heavy metal. At first, the AAS was calibrated followed by the manufacturer's recommendation. The filtered water sample was run directly for the determination of heavy metal in acidified condition. A standard line was prepared by plotting the absorbance reading on Y-axis versus the concentration of each standard solution of metal on X-axis. Then, the concentration of metal was calculated in the water samples by plotting the AAS reading on the standard line.

RESULTS AND DISCUSSION

The study was carried out to find out the status of soil and water in coal stockpile area. Soil and water samples were collected from ten different locations. The salient features of the study results have been presented and discussed below.

Effect of coal storage on soil quality

Soil pH

Soils can have a pH from 3.5 to 11.0, but plants grow well in the range of 5.0 to 8.5. Brady (2002) reported that a pH range of 6.5 to 7.5 is optimal for necessary plant nutrient availability. If the soil solution is too acidic plants cannot uptake N, P, K and other nutrients. In acidic soils, plants uptake toxic metals and some plants die as a result of toxicity. Therefore, it is important to know the pH level suitable for crop production. The pH rating is shown below:

Soil pH	Ratings
9	Harmful to crops
8-9	Harmful to most of the crops
6-8	Good for all crops
6-5	Slight harmful to the crops
<5	Harmful to crops

The pH values of soil samples around coal storage have been presented in Figure 4. From the Figure it is observed that pH value significantly varied with distances. The values ranged from 3.2 to 5.2 at 0-700m distance. Among the locations, the highest pH value was found at 0 m, which was very close to the pH values of the samples collected from 200 m distance (5.15). The lowest pH value was recorded at 700 m distance. The pH value at the coal storage area and adjacent area was higher compared to distance area, probably due to the effect of liming materials from coal.

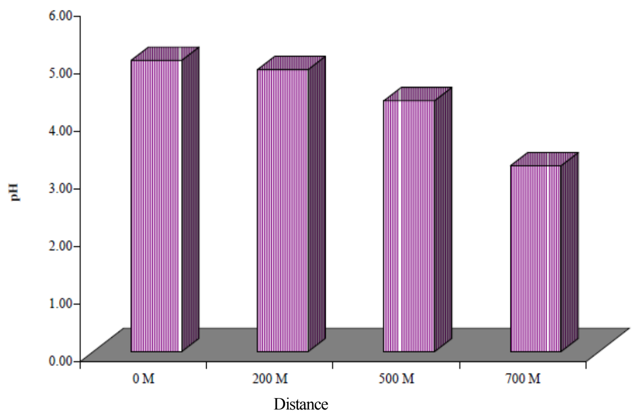

Figure 4: pH values of soil at different distances from coal storage

Soil Electrical conductivity (EC)

The EC values of soil samples significantly varied with distance (Figure 5). It was observed that values ranged from 19.0-61.50 µs/cm. Among different locations, maximum EC value was found 61.50µs/cm at 0 m distance and minimum EC value was found as 19.00µs/cm at 700 m distance. EC is the common measure of dump materials salinity and denotes the ability to carry an electric current. For coal mine soil, Saxena (1989), proposed that while EC < 4 dS/m may be considered to be good for plant productin. EC values within the range of 7-8 dS/m might be acceptable and soil with an EC value 8 dS/m should be considered to be of poor soil quality. The higher EC value was due to upward migration of different type of salts with presence of coal particles and the lower EC value was due to lower amount of salts present in the soil samples.

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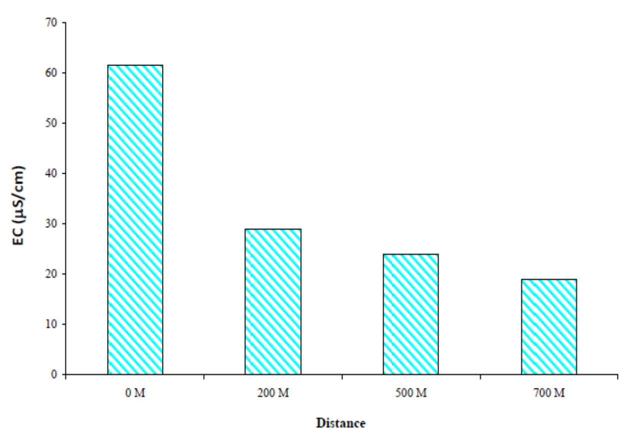

Figure 5: EC values of soil at different distances around coal storage

Soil organic matter content

Soil organic matter content was gradually decreased with the distance from the storage area. The lowest OM content was observed at 700 m and highest at 0 m distance. OM ranged from 0.20 to 1.10%. OM is important for the productivity of arable lands. Production varies with OM content in soil. Presence of organic matter components in storage area define SOM or soil organic matter. It can be divided into three pools: living biomass of microorganisms, fresh and partially decomposed residues, and humus. According to Juma (1999), surface litter is not a part of soil organic matter.

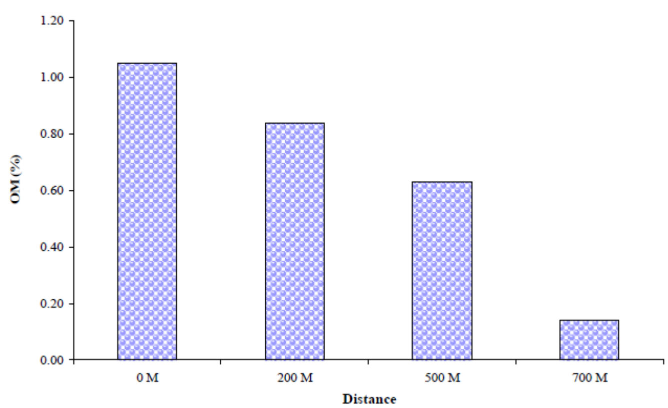

Figure 6: Organic matter of soil collected from different distance around coal storage

Soil nutrient content

From the Figure 7, it is observed that N content was greatly depends on distance from storage area. Maximum content was found at 0 m due to higher amount of mineralizable matter present in soil and lowest was at 700 m due to lower rates of mineralization in soil. N content ranged from 0.02-0.095%. N content is important factor for the productivity of soil. The nitrogen used by plants or crops on dump materials comes from SOM, fertilizers and legumes (Maiti *et al*., 2002).

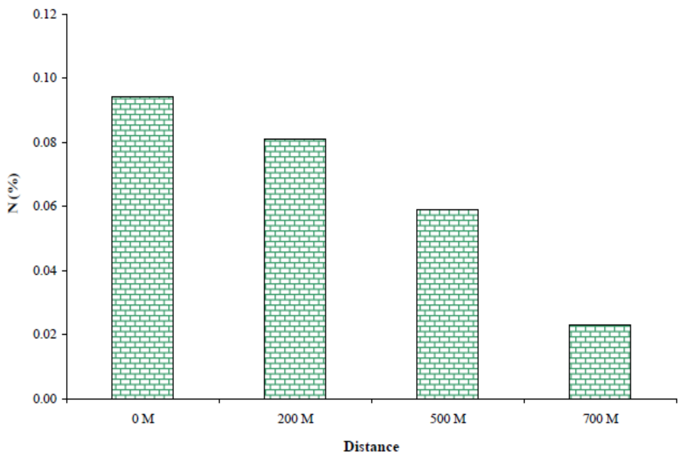

Figure 7: N content of soil collected from different distance around coal storage

The concentrations of P of soil samples have been presented in Figure 8, where it is observed that concentrations of P in soil around coal storage was high and gradually decreased with increase the distance. The standard value of phosphorus in soil should be 22.5 to 56 kg/ha (Gupta *et al*., 2006).The concentrations of P ranged from 11.40 to 16.54 ppm which is agreed with (Tripathy et al., 1998) in soils of Jharia coalfield.

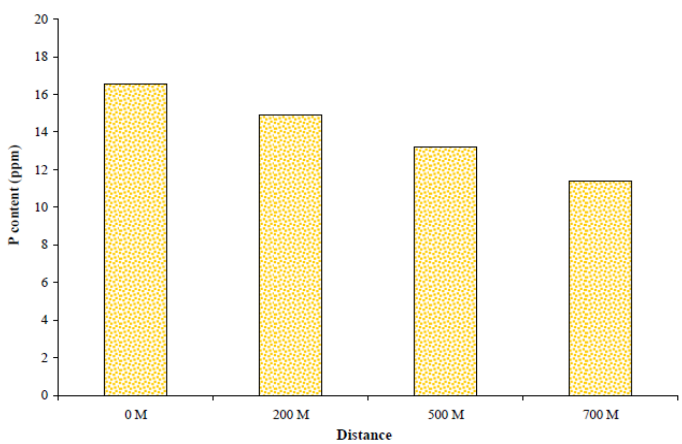

Figure 8: P content of soil collected from different distance around coal storage

The standard potassium content in the alluvial soil should be in between 136-337.5 kg/ha (Gupta *et al*., 2006; Sumner, 1994). The concentrations of K of soil samples have been presented in Figure 9, where it is observed that concentrations of K in soil around coal storage significantly varied with distances. The concentrations of K ranged from 20.37 to 97.77 ppm. The higher K content in 0 m distance indicated that the K in coal was more readily available than the fertilizers K applied to the soil but overall K level is lower than standard value in the study area.

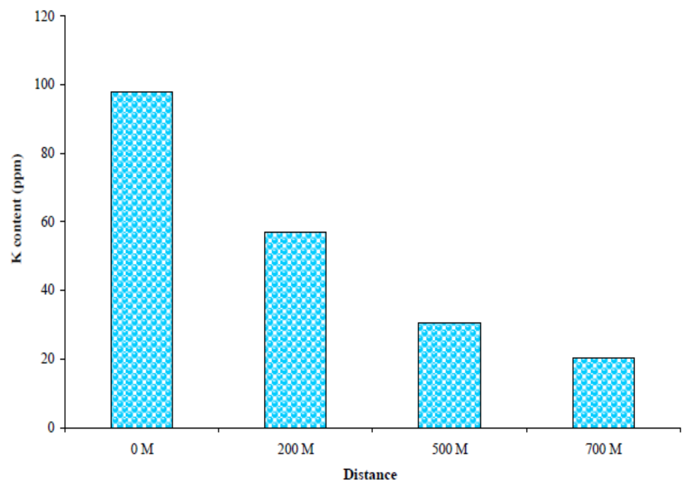

Figure 9: K content in soil collected from different distance around coal storage

Mohapatra (2006) analysed soil arond five opencast coal of a river coal area. The N, P and K content of that study were 2.845, 1.11 and 2.63 kg/ha respectively.

Soil heavy metal content

The concentration of Pb ranged from 0.58 to 0.745 ppm and that of Cd ranged from 0.105 to 0.18 ppm. Both the content of Pd and Cd were higher at storage area and gradually decreased with distance (Figure 10). The permissible limit of Pb and Cd in soil stated by Alloway (1995) is presented in the table below:

Location	Pb (mg/kg)	Cd (mg/kg)
Normal Limit	2-300	0.01-2.0
Critical Limit	100-400	3-8

The content of Pb and Cd of the study area did not exceed the permissible limit. Therefore, it can be said that Pb and Cd content of soil in the study area is not harmful for agricultural uses.

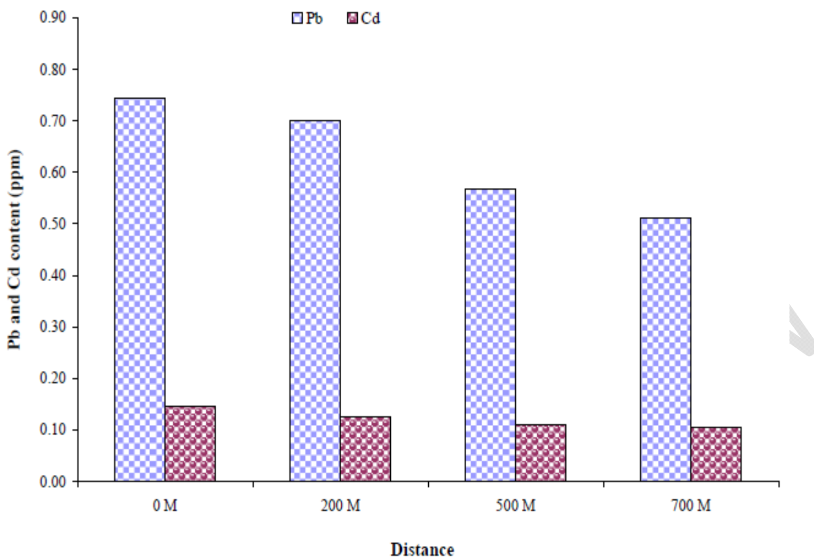

Figure 10: Heavy metals in soil samples collected around coal storage

Effects of coal storage on water quality

Water pH

The pH values of ground water samples around coal storage have been presented in Figure 11. From the result it was observed that pH values of ground water significantly varied with distances. The pH values ranged from 3.2 to 6.5. Among the locations, the highest pH value was found at 700 m, which was very close to the pH values of the samples collected from 500 m (6.44). The lowest pH value was noted at 0 m distance (3.2). The pH values of surface water samples were also significantly varied with distances (Figure 11). Among the locations, the highest pH values (6.5) were recorded at 500 m and 700m distances from the storage area. The lowest pH value was recorded from 0 m distance. It was interesting to note that surface water pH values was significantly higher compared to underground water in all distances from the storage areas.

Coal storage is known to affect both the surface and groundwater. Topography and drainage system of an area of coal storage may influence different types of pollution. The pH of the surface water was comparatively more alkaline in nature than ground water. Coal storage produces acid leachates which lead to acidic groundwater. Water runoff from coal stockpile can be highly acidic leading to low pH in water (Scullion and Edwards 1980, Carlson and Carlson 1994). The acidity of coal leachates is primarily due to the function of coal's sulphur content, such as highly sulphur rich coals normally have low pH values and sulphur-poor coals produce more pH neutral runoff (Tiwary 2001, Cook and Fritz 2002). The strong acid-producing potential of coal stockpile runoff has been confirmed in numerous studies of actual leaching of coal stockpiles (Hall and Burton 1982, Tease and Coler 1984, Cook and Fritz 2002) and has been shown negative effects on groundwater quality (Carlson 1990, Cook and Fritz 2002).

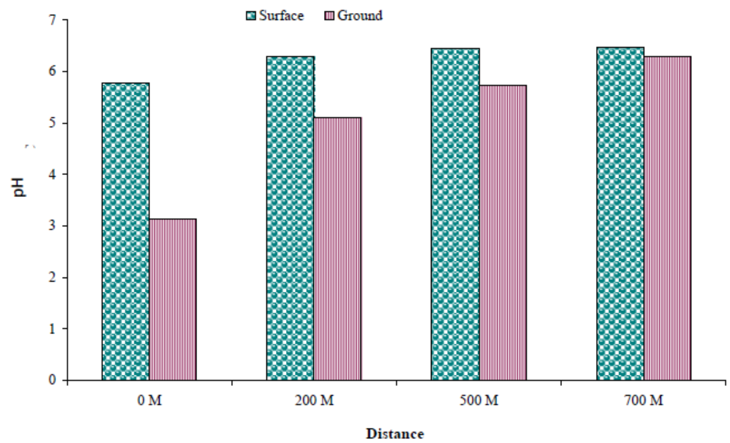

Figure 11: pH of surface and ground water at different distance around coal storage

Water EC

The EC values of surface water samples significantly varied with different distance (Figure 12). From the figure it is observed that values ranged from 88.60 to 136.10µs/cm. Among different locations, maximum EC value was found 136.10µs/cm at 700 m distance. The EC values of ground and surface water samples significantly varied with different distance. It is observed that EC values ranged from 38.20- 125.15µs/cm. Among different locations, maximum EC value was found 125.15µs/cm at 700 m distance and minimum EC value was noted as 38.20µs/cm at 0 m. EC varies with distance and related elements.

Coal pile runoff often leads salinity, due to salts formed from the oxidation and dissolution of mineral components of coals. While coal-generated salinity may not be important for the aquatic environment but the elemental composition of coal pile runoff may differ from surface or ground water. Electrical conductivity (EC) over 8000 µS/cm has been measured in runoff of sulphur-rich coal piles (Nichols 1974, Carlson and Carlson 1994). Coal pile salinity may affect terrestrial and freshwater biota. Rendig and Taylor (1989) reported death of terrestrial vegetation was observed at EC values above 4000 µS/cm for soil solutions.

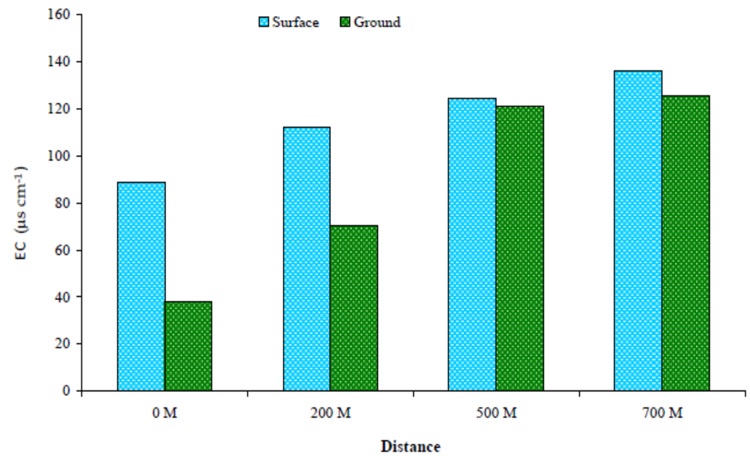

Figure 12: EC values of surface and ground water at different distance around coal storage

Phosphorus and Potassium content in water samples

The concentrations of P of surface water samples have been presented in Figure 13. From the result, it is observed that concentrations of P in water around coal storage significantly varied with distances. The concentrations ranged from 0.27 to 0.85 ppm. The concentrations of P of ground water samples also have been presented in Figure 13. The concentrations of K in surface and ground water samples have been presented in Figure 14. From the result, it is observed that concentrations of K in water around coal storage varied when distances varied. The concentrations ranged from 0.28 to 1.05 ppm. It was higher at 0 m distance and lowest at 700 m distance. Considering ground water, it is observed that concentrations of K in water were higher at 0 m distance and lower at 700m distance.

There are a very few published papers on availability of macronutrients into the aquatic environment from coal storage. Coal does contain nitrogen and phosphorus in considerable quantities and these nutrients can be mixed with water. Most coals contain between 10–2000 ppm phosphorus (Francis 1961, Swaine 1990, Rao and Walsh 1997). Phosphorus content is often correlated with fluorine (Francis 1961). Gerhart *et al*. (1980) reported 0.02–0.12 mg/l of total P in filtered leachates containing 0.8% sub-bituminous coal. Ward (2002) worked with south Australian coals and found up to 60% of P to be leachable by water washings. Querol *et al*. (1996) found between 88–94% of the phosphorus contained in four Spanish coals (P content 68–200 ppm) to be leachable by nitric acid digestion and a little amount of P was mobilised by water of the same coal samples.

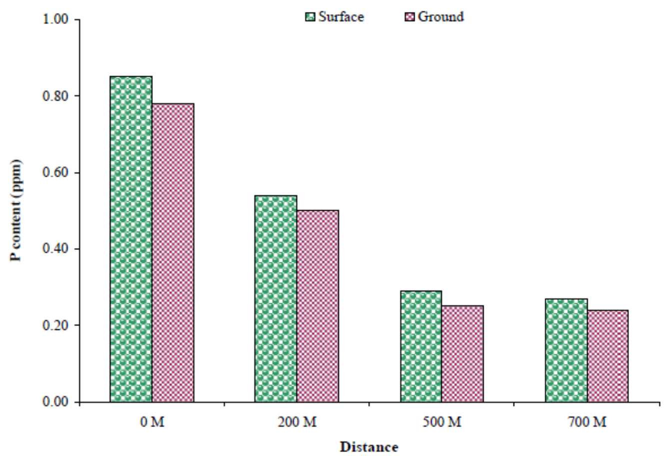

Figure 13: Available P in surface and ground water at different distance around coal storage

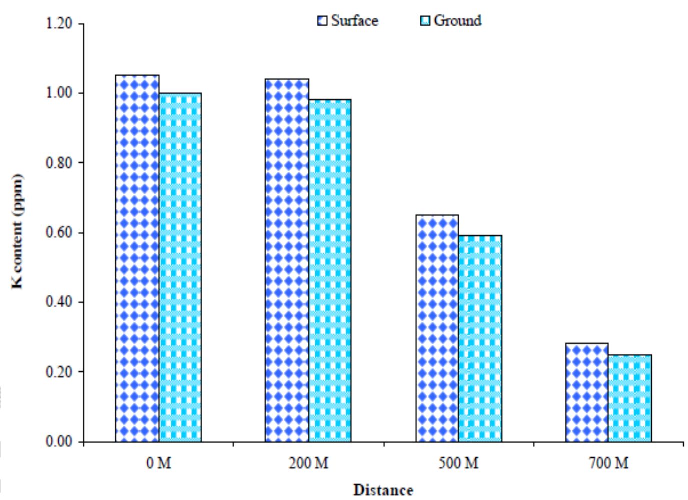

Figure 14: Available K in surface and ground water at different distance around coal storage

Heavy metals content of water

Among heavy metals, the content of Lead (Pb) and Cadmium (Cd) was examined in surface and ground water around coal storage. Concentrations significantly varied with locations and time. The concentrations Pb and Cd of the surface water samples have been shown in Figure 15. It was observed that concentrations of Pb ranged from 0.026 to 0.069 ppm and that of Cd was 0.005 to 0.010 ppm. The concentrations of Pb and Cd in the ground water samples have been shown in Figure 16. It was observed that concentrations of Pb ranged from 0.024 to 0.067 ppm and that of Cd was 0.006 to 0.013 ppm.

Coal contains some trace metals. Metals may be present as dissolved salts in waters as metallo-organic compounds or as mineral impurities. Data on trace metals in coal has been reviewed by Swaine (1990), Swaine and Goodarzi (1995). Every type of coal contains a sizable inorganic fraction which can release trace metals (Ward 2002). The forms in which potentially toxic trace elements are held in coal may vary among coals and greatly depends on the mineral matter present on coal. Many experiments have designed links between the minerals present in coal and the concentration of trace elements (Ward 2002). For example, Cd, Pb, Hg, Sb, Se, Tl and Zn are often associated with sulphides and show strong correlation with minerals present in coal. The sulphur rich coal stockpile leachate helps dissolution of trace metals (Anderson and Youngstrom, 1976). Trace metal concentrations in runoff from coal storage can be so high as to endanger groundwater quality (Cook and Fritz, 2002).

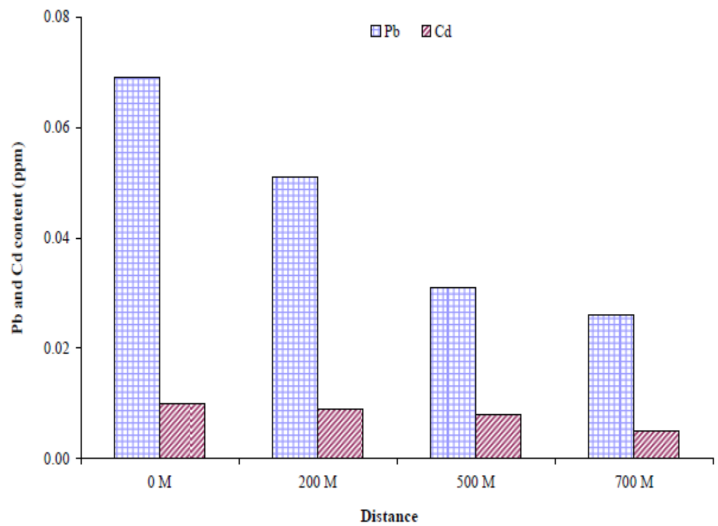

Figure 15: Heavy metals (Pb and Cd) in surface water samples around coal storage

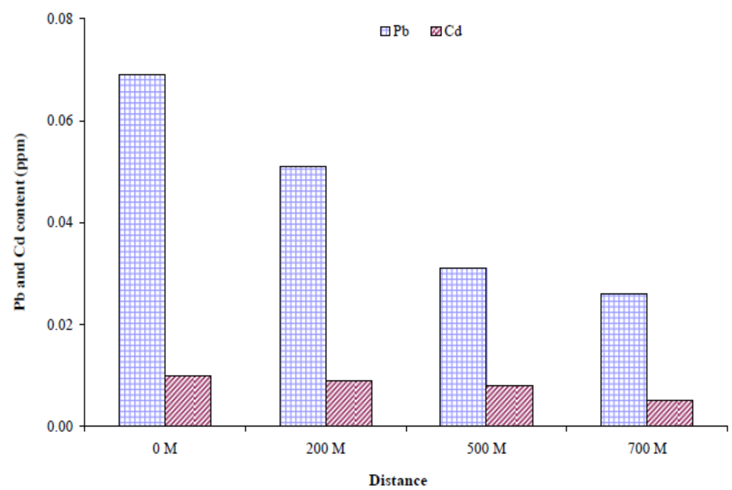

Figure 16: Heavy metals (Pb and Cd) in ground water samples around coal storage

From the results, it is found that all the studied soil and water quality components are higher at coal adjacent area and gradually decreased with distance. The probable reason for that these components may be available in coal which increases the availability of all studied components at 0 m distance. However, to find out the causes of the higher values, it is needed to analyze physical and chemical properties of coal in future researches.

CONCLUSION

Coal is considered as cheap source of energy worldwide but coal and leachate from coal storage has been associated with negative impacts on soil and water quality. Location of stockpile at Gobrakura, Haluaghat, Mymensingh has a significant impact on surface and ground water and soil quality. Loading and unloading coal from this storage also cause noise and influence the air quality at the site of stockpile. Surface and ground water quality is affected by measured pH value, EC, macronutrients level and heavy metal (Pb, Cd) contents. The investigated physicochemical properties of soil might interfere with fertility and productivity of soil in the stockpile area. The effluents from the coal stockpile should be processed before it is discharged to nearest area or water catchments.

Almost all the investigated soil and water quality parameters were higher at coal stockpile adjacent area and were lower in 700 m, 500 m distances. It may be happened due to the availability of these components in coal. However, to find the reasons behind this, it is needed to analyze physical and chemical properties of coal and effluents from coal stockpile should be analyzed comprehensively.

REFERENCES

Anderson WC, Youngstrom MP (1976) Coal pile leachate-quantity and quality characteristics. *Journal of the Environmental Engineering Division*, **102**, 1239–1253.

Ahrens MJ and Morrisey DJ (2005) Biological effects of unburnt coal in the marine environment. *Oceanogr. Mar. Biol.,* 43: 69–122.

Chari KSR, Banerjee SP, Sengupta SR, Luthm KL, Babu CR, Misra BC, Vijaykumar S and Namdeo R (1989) *Report of the Expert Committee on Restoration of Abandoned Coal Mines*, No. J. 11015/13/88–1A (Dept. of Env. Forest and Wildlife, New Delhi).

Sendlein VA, Lyle YH, Carison LC (1983) *Surface Mining Reclamation Handbook* (New York, NY, USA, Elsevier Science).

Kundu NK, Ghose MK (1994) "Studies on the topsoil of an opencast coal mine", *Environmental Conversion* **21**(2), 126–132.

World Coal Institute (2004) *Coal — Power for Progress*. London: World Coal Institute. Online Available HTTP: http://www.wci-coal.com (accessed 30 June 2004).

Australian Coal Association (2004) Black coal exports from Australia. Australian Coal Association. Online Available HTTP: http://www.australiancoal.com.au (accessed 30 June 2004).

Coalportal (2004) *Production and Trade*. Sydney: Barlow Jonkers Pty Ltd. Online. Available HTTP: http://www.coalportal.com (accessed 30 June 2004).

Pusdatin (2011) Coal Statistic Indonesia "The Dirty Truth about Coal: Mining", Sierra Club, June 2007.

Akcil A, Koldas S (2006) Acid Mine Drainage (AMD): causes, treatment and case studies. J Clean Prod 14(12):1139–1145

Ahrens MJ (2010) Biological Effect of Unburnt Coal in the Marine Environment. *An Annual Review* **43** pp 69-122

Tiwary RK (2001) Environmental impact of coal mining on water regime and its management. Water, Air and Soil Pollution, 132(1-2): 185-199.

Brady NC, Well RR (2002) The nature & properties of soils, Pearson Education Ltd, New Delhi.India.

Bai Y, Wang R, Jin J (2011) Water eco-service assessment and compensation in a coal mining region–A case study in the Mentougou District in Beijing. *Ecol Complex* 8(2):144–152

Pan L, Liu P, Ma L, Li Z (2012) A supply chain based assessment of water issues in the coal industry in China. *Energy Pol* 48:93–102

Ramani RV (2013) Coal mining. Retrieved 10 January, 2013, from http://www.britannica.com/EB checked/topic/122975/coal-mining.

Elliott MA (1981) Chemistry of coal utilization: Second supplementary volume. New York, United States: John Wiley and Sons.

Brown CE (2002) World energy resources. Berlin, Heidelberg, New York: Springer Verlag.

Toren T, Unal E (2001) Assessment of open pit coal mining impacts using remote sensing: a case study from Turkey. Paper presented at the Proc 17th Int. Mining Congress Exhibition of Turkey, IMCET2001, ISBN.

Environmental Protection Agency (EPA) (2000) Environmental Impacts of Coal Mining, World Coal Institute, accessed April 2008. "The Dirty Truth about Coal: Mining", Sierra Club, June 2007.

Tandon J (1993) "Modern Irrigated Soils". John Wiley & Sons, New York, pp. 283-250

Jackson ML (1967) *Soil Chemical Analysis*, Prentice Hall of India Pvt. Ltd., New Delhi.

Banglapedia (2009) National Encyclopedia of Bangladesh, Asiatic Society of Bangladesh.

Saxena MM (1989) Environmental analysis: water, soil and air, Agro Botanical Publishers, Bikaner, Rajasthan, pp 121140.

Juma NG (1999) Introduction to soil science and soil resources. Volume I in the series "The Pedosphere and its Dynamics: A Systems Approach to Soil Science." Salman Productions, Sherwood Park. 335.

Maiti SK, Karmakar NC, Sinha IN (2002) Studies on some physical parameters aiding biological reclamation of mine spoil dump a case study from Jharia coalfield, *IME Journal*, 41(6): pp 20 23.

Mohapatra (2006) Environmental cumulative effects of Meghalaya, North East India. *New York Science coal underground mining*. Procedia Earth and Journal **3(9)**:79-85

Ghosh AK (1990) "Mining in 2000 AD – challenges for India", *J. Institution of Engineers (India)* **39**(2), 1-11.

Cook AM, Fritz SJ (2002) Environmental impacts of acid leachate derived from coal-storage piles upon groundwater. *Water Air and Soil Pollution* **135**, 371–388.

Tripathy DP, Singh G, Panigrahi DC (1998) Assessment of soil quality in the Jharia coalfield, Proceedings of the Seventh National Symposium on Environment, ISM, Dhanbad, pp 205.

Gupta S, Mallick T, Datta JK, Saha RN (2006) Impact of Opencast Mining on the soil and plant communities of Sonepur-Bajari Opencast Coal mine area, West Bengal, India, UU Special Publication in Geology, v. 5, pp.194-198.

Sumner, M.: Measurement of soil pH: Problems and solutions. Commun. Soil Sci. Plant Anal., 25, 859-879 (1994).

Alloway BJ (1995) *Heavy Metal in Soils.* Blackie Academic and Profesional.

Scullion J, Edwards RW (1980) The effects of coal industry pollutants on the macro-invertebrate fauna of a small river in the South Wales coalfield. *Freshwater Biology* **10**, 141–162.

Carlson CL. Carlson CA (1994) Impacts of coal pile leachate on a forested wetland in South Carolina.*Water Air and Soil Pollution* **72**, 89–109.

Hall Jr LW, Burton DT (1982) Effects of power plant coal pile and coal waste runoff and leachate on aquatic biota: an overview with research recommendations. *Critical Reviews in Toxicology* **10**, 287–302.

Tease B, Coler RA (1984) The effect of mineral acids and aluminum from coal leachate on substrate periphyton composition and productivity. *Journal of Freshwater Ecology* **2**, 459–467.

Carlson CA (1990) Subsurface leachate migration from a reject coal pile in South Carolina. *Water Air and Soil Pollution* **53**, 345–366.

Nichols CR (1974) Development document for proposed effluent limitations guidelines and new source performance standards for the steam electric power generating point source category. Duluth, U.S.: United States Environmental Protection Agency Report No. EPA 440/1-73-029.

Rendig VV, Taylor HM (1989) *Principles of Soil-Plant Interrelationships*. New York: McGraw-Hill.

Francis W (1961) *Coal — Its Formation and Composition*. London: Edward Arnold.

Swaine DJ (1990) *Trace Elements in Coal*. London: Butterworths.

Rao PD, Walsh DE (1997) Nature and distribution of phosphorus minerals in Cook Inlet coals, Alaska. *International Journal of Coal Geology* **33**, 19–42.

Gerhart DZ, Richter JE, Curran SJ, Robertson TE (1980) Algal bioassays with leachates and distillates from western coal. Duluth, U.S.: United States Environmental Protection Agency, Report No. EPA-600/3-79-093.

Ward CR (2002) Analysis and significance of mineral matter in coal seams. *International Journal of Coal Geology* **50**, 135–168.

Swaine DJ, Goodarzi F (eds) (1995) *Environmental Aspects of Trace Elements in Coal*. Dordrecht: Kluwer.