ISSN 2229-5518

Coal Fly Ash of Barapukuria Thermal Power Plant, Bangladesh: Physico Chemical Properties Assessment and Utilization

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Abstract: Proper utilization of fly ash could be minimized the surrounding environmental pollution of coal fired power plant and therefore some physico-chemical properties such as pH, conductivity, moisture content, bulk density, unburned carbon content, specific gravity, water holding capacity, liquid limit, plastic limit, grain size distribution along with X-ray Fluorescence (XRF), X-ray Diffraction (XRD) analysis were investigated on coal fly ash of Barapukuria Thermal Power Plant, Bangladesh. Resulting data showed that the analyzed fly ash are of useful component for recovery of alumina, opencast mine filling, road reclamation, cement and concrete production, waste water treatment and various agricultural applications.

Key Words: Coal, Coal Fly ash, Thermal power plant, Physico-chemical properties, Particle size distribution, XRF, XRD analysis.

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1. INTRODUCTION

Coal is the energy resource for electricity generation and it contributes 27% energy consumption in the world [1]. After burning of coal, a vitrified light, hollow and spherical shaped waste materials is collected from the chimney of the burning plant is called fly ash (FA).

The major constituents of most of the FA are silica (SiO_2), alumina (Al_2O_3), ferric oxide (Fe_2O_3), ferrous oxide (FeO) and calcium oxide (CaO). The other minor constituents are Na_2O, K_2O, MgO, TiO_2, SO_3, MnO, P_2O_5 and unburned carbon.

When coal is burned at high temperature, it produces hazardous gases as SOx, NOx, COx, and NH_3 together with FA waste materials which create several pollution problems in air, soil surface and in ground water around the power plant area. In presence of rain water, absorbed gases of FA produce toxic substances as H_2SO_4, HNO_3, H_2CO_3, NH_4OH etc., which are discharged to nearby lands and increase the acidity to soil and water and devastate the crops of the surrounding agricultural fields. Worldwide coal based power stations are producing a huge amount of fly-ash and facing that serious environmental pollution with disposal problem [2-3].

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Proper utilization of FA can be solved such problems. Various applications of FA have been reported such as recovery of alumina [4-5], waste water treatment [6], cement and concrete production [7-8], the production of fly ash based geopolymers [9-11], the filler in FA polymer composites [12], road construction [13] etc. However, that utilization depends on the characterization of the respective FA. Physico-chemical characteristics of FA vary depending on the type of coal used, particle size, boiler type and the combustion efficiency of the thermal power plant [14]. So, the evaluation of physico-chemical as well as mineralogical characterization of FA is important before its proper utilization in different fields. With the rapid growth of industrialization, the demand of energy is increasing day by day, as a result the demand of coal is increasing other than oil and gas to establish coal based new power plants.

Barapukuria thermal power plant (BTPP) is the only coal based power plant in Bangladesh established beside Barapukuria Coal Mine Co. Ltd., as in view that the mining coal could be supplied easily to the power plant. It consists of two 125 MW units with an installed capacity of 250 MW. Barapukuria coal mainly bituminous, ash contain 10.19%-14.01%, calorific value around 12,000 Btu/lb with containing less amount of sulpher 0.63%-0.71% and comparatively it is of good quality and less toxic than Indian coal [15]. BTPP produces 300 metric ton coal combustion FA per day by burning 2,400 metric ton of coal to generate 250MW electricity. This huge amount of FA dumped in open disposal sites without economic utilization, causes serious pollution to the surrounding environment. Very little is known about the FA of BTPP. No characterization even though utilization research has yet been conducted on FA of BTPP.

The present research work deals with the physico-chemical characterization on FA of BTPP as it can be used for several fields under the local condition and demand to reduce the environmental pollution.

2. MATERIALS AND METHODS

FA samples were collected from BTPP. Sample was prepared by proper mixing and characterized by standard method. pH was determined by using digital Jenway pH/mV/Temperature meter (model 3510). Conductivity was measured by Hanna Conductivity Meter (model HI2315). Moisture content was measured by gravimetric method. Unburned carbon content was calculated by loss of ignition procedure. Bulk density was determined through the calculation of a weight of known volume of air-dried sample and it's mass per unit volume. Specific gravity of the FA sample was determined followed by the procedure of ASTM D 854-00. Water holding capacity was measured by following the method of Arpita Das et. al. 2011 [16]. Liquid limit and plastic limit was determined by following ASTM D 4318. Particle size of the FA was measured by using a laser based particle size analyzer (model microtrac-S3500). Chemical composition of FA was examined by using XRF (model Rigaku ZSX Primus, equipped with an end window 4.0 Kw Rh-anode X-ray tube) instrument. Chemical phases were identified by XRD (model- Bruker D8 Advance, $Cu_{K\alpha}$= 1.5406 ^{0}A).

3. RESULTS AND DISCUSSION

3.1. Physico-Chemical Characteristics of Coal Fly Ash:

Physico-chemical characteristics are important phenomena for economic utilization of FA, which were analyzed and summarized in Table 1. The pH of Barapukuria FA was found 6.2 which were almost neutral and/or weakly acidic. Less content of alkaline elements and absorbed gases (SO_X, NO_X, CO_X, NH_3) of FA decreased the pH to made weakly acidic. Electric conductivity showed high value as 0.4 mS/cm which indicates that the samples are abundant in various ions. These ash samples could be used as an additive material in agriculture purposes [17]. Moisture content is an important parameter for FA characterization. Because it helps to find the quality of compaction when it is used as a backfilling material. High amount of moisture achieve good compaction whereas less amount of moisture compact weakly and creates fugitive dust problem. Moisture content of FA sample was found 1.08%, which is less than soil, indicating that it may create dust problem around the dumping area. Specific gravity of FA sample was less than that of natural soils and it was found 2.12 which indicate that the experimental samples are lighter than soil. So it can be used for underground mine filling materials [18-19]. Carbon present in FA is called unburned carbon. Generally, the lower the carbon content and the finer the ash particle used in cement formulations whereas, higher carbon content of FA can be used as a fuel in brick manufacturing since the carbon in the ash could be burnt during the calcinations process, thereby saving electricity. The unburned carbon in FA was found 2%.

Table 1

Physico-chemical characteristics of fly ash sample of BTPP.

Sl No.	Parameters	Average ± SD
1.	pH	6.20 ± 0
2.	Conductivity (mS/cm)	0.40 ± 0
3.	Moisture content (%)	1.08 ± 0.106
4.	Unburned carbon content (%)	2.00 ± 0.101
5.	Bulk density (g/cm)	0.90 ± 0.014
6.	Specific gravity	2.12 ± 0.007
7.	Water holding capacity (%)	78.76 ± 0.647
8.	Liquid limit (%)	47.00 ± 1.414
9.	Plastic limit (%)	Nil

This result is favorable for cement production. Bulk density is an important parameter for agricultural application. Because low bulk density of ash samples are very much suitable for agriculture purposes. In the present study, bulk density of the experimental sample was measured at 0.9 g/cm^3, which is less than normal soil indicating that the experimental sample can be used as an additive and backfilling materials for road reclamation. Water holding capacity was found 78.76%, which is very high as the moisture content was found less. It can be enhanced the mobility of nutrients in soils [20]. Liquid limit is an important parameter for structural and geotechnical application. It depends on silt content in FA sample. Liquid limit of FA sample was found 47% which is high. So, the resulting data indicates that the experimental FA is suitable for construction uses, it makes the structure stable by the behave as viscous fluid. Plastic limit depends on clay content in the FA sample. In this study, it was not found because of less amount of clay present in there.

3.2. Particle Size Distribution:

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ISSN 2229-5518

Particle size distribution of FA is important to understand its physical properties. Fig. 1. illustrated the distribution pattern of FA particle. The grain size was observed in between 497.8 µm to 2.750 µm and the maximum yield was found 6.88% at 44µm in size. The mineralogical size distribution parameter sand, silt and clay were also calculated through this curve and which is shown in Table 2.

Table 2.

Grain size distributions of fly ash sample of BTPP.

Sl No.	Grain Size	Grain Size Distribution (%)
1.	Sand size particle (>62.5 µm)	31.65 ± 0.353
2.	Silt size particle (62.5 µm-3.9 µm)	66.59 ± 0.127

Sand mainly naturally occurring granular material and found 31.9% in the ash. Silt is granular material of a grain size between sand and clay and observed 66.68%. Clay is a fine grained aluminium silicate particle and found 1.42% in the FA sample. Less amount of clay exhibit non-plastic limits and exhibits plasticity when it is mixed with water.

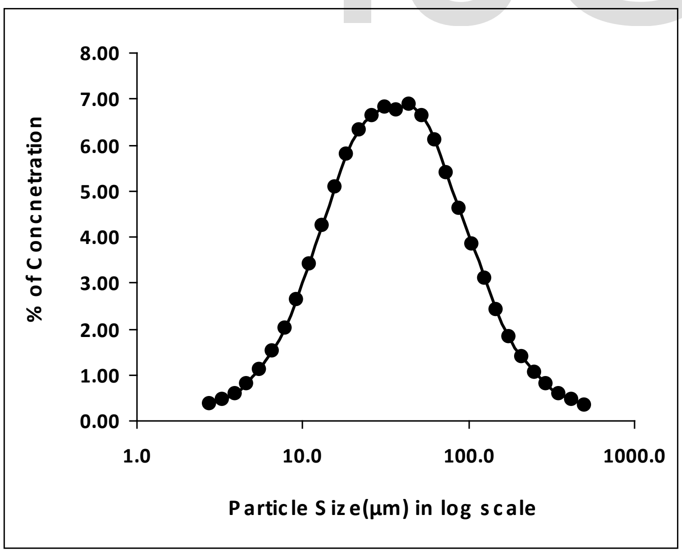

Fig. 1. Particle size distribution of fly ash sample of BTPP

3.3. X-Ray Florescence Analysis:

XRF analysis was used to determine the actual chemical composition of research materials. Table 3 shows the results of XRF test carried out on the FA as received from the BTPP. According to Table 2. The major component of FA of BTPP was alumina (Al_2O_3) and silica (SiO_2) and found 40.12% and 50.20% respectively. This result indicates that the analyzed FA is useful component for alumina, aluminium recovery. It is also useful to produce aluminium based agrochemicals, construction materials, carbothermal reduction process etc. Iron oxide (Fe_2O_3/FeO) and titanium dioxide (TiO_2) concentration is little bit higher

Table 3

Chemical composition of fly ash sample of BTPP determined by X-RF analysis.

Composition	%
SiO_2	50.20
Al_2O_3	40.10
Fe_2O_3	3.32
TiO_2	2.38
CaO	1.29
MgO	0.20
Na_2O	0.06
K_2O	0.93
P_2O_5	0.66
SO_3	0.45
MnO	0.05
NiO	0.01
CuO	0.0158
ZnO	0.0068
PbO	0.0073
Loss on Ignition	2.00

3.32% and 2.38% respectively than other elements. Alkali metal such as sodium oxide (Na_2O), potassium oxide (K_2O), calcium oxide (CaO), Magnesium oxide (MgO) content in the FA is less and found 0.06%, 0.93%, 1.29% and 0.20% respectively. On the basis of chemical composition, total amount of alkali oxide (Na_2O, K_2O, CaO, MgO etc) is lesser than 10% and the sum of Al_2O_3, SiO_2 and Fe_2O_3 present in FA is greater than 70% indicates that the analyzed FA was class F type and which follows ASTM C-618-03. This type of FA is pozzolanic in nature and therefore pozzolanic behavior of this type could be utilized to manufacture of cement and concrete. Because the active constituent of class F fly ash is siliceous or alumina-silicate glass. Various trace elements found in the FA as Manganese oxide (MnO) 0.05%, Cupric oxide (CuO) 0.015%, Nikel oxide (NiO) 0.010%, Lead oxide (PbO) 0.007% and Zinc oxide (ZnO) 0.006% indicating that this material is useful for plant growth in agriculture fields. Phosphorous pentaoxide (P_2O_5) was found 0.66% which is less however it could be amending the less fertile soil. Sulpher trioxide (SO_3) content of analyzed fly-ash sample was less and found 0.45%. So, this FA is not so much environmentally hazardous which may cause acid rain.

3.4. X-Ray Diffraction Analysis:

The XRD pattern in Fig. 2. Shows that the main crystalline phases of fly-ash are mullite, quartz and magnetite. The intensity of quartz is very strong, with mullite forming a chemically stable and dense glassy surface layer. The hematite peak was not found it might be the cause of magnetite concentration are abundant than hematite and the low amount of calcium oxide decreased it intensity to be appeared.

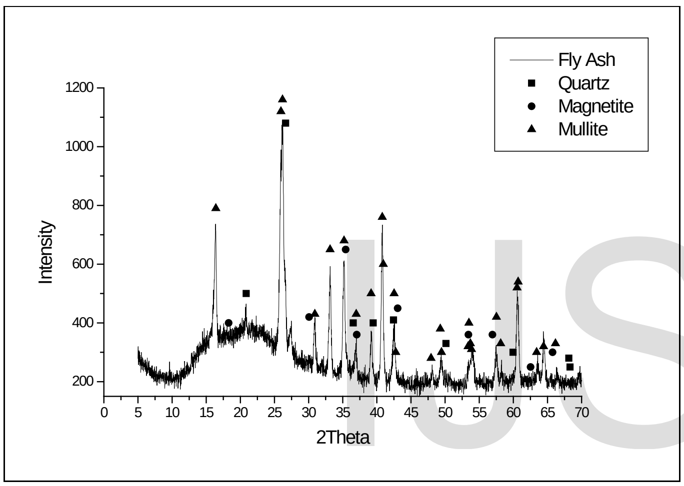

Fig. 2. XRD pattern of fly ash sample of BTPP

4. CONCLUSION

Based on the above results it can be concluded that the FA of BTPP are class F-type FA and almost neutral and/or weak acidic. It is lightly responsible for plant growth as nutrient quality is much better than soil. Presence of high content alumina (40%) and pozzolanic characteristics of high content silica (55%) suggest that it is applicable for recycling of alumina, as well as production cement and concrete. It can also be used for open cast mine filling and waste land reclamation. Thus the beneficial utilization of the FA of BTPP could be solved the hazardous effects and develop the surrounding environment safe and clean.

ACKNOWLEDGEMENTS

This work is supported by the grant in aid by Bangladesh Council of Scientific and Industrial Research (BCSIR), Ministry of Science and Technology, Govt. of Bangladesh. The authors would like to thanks Md. Aminur Rahman, SSO for his technical assistance.

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