

Physical and Chemical Characterization of Pond Ash

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Abstract

Of the total Solid Waste generated in India, approximately 25% is residue from coal combustion. These residues include fly ash, bottom ash and pond ash. Pond ash is a mixture of dry fly ash and bottom ash. During the years 2010-12, about 408 Million tonnes/year of coal was used and over 130 Million tonnes/year of fly ash was generated by 88 thermal power plants all over India. Pond ash contributes to two major environmental problems: generation of respirable particulate matter (a major air pollutant) and pollution of soil and water due to leaching of heavy metals. The objective of this study was to determine the environmental impacts of open dumping of pond ash around a thermal power plant.

Physico-chemical characterization of three pond ash samples collected from Kolaghat Thermal Power Plant was done. Physical characterization of the samples included determination of Total Solids, Volatile Solids, Fixed Solids, specific gravity, specific surface area, hydraulic conductivity, dry densities, particle size distribution and performing Scanning Electron Microscopy for obtaining morphological characteristics. Surface reactivity and EDS analyses were done to assess different chemical characteristics of the same pond ash samples. Specific surface area gave fineness data and EDS gave elemental composition of the ash samples. Finally, the potential hazards of the samples were assessed depending upon these results.

Keywords: CCR; EDS; SEM; thermal power plant; pond ash; fineness.

1. Introduction

The amount of CCR (coal combustion residue) released by factories and thermal power plants has been increasing throughout the world, and their disposal has become

a serious problem due to the large land requirement. The best way to reduce ever increasing land acquisition problem due to unabated CCR generation is to utilize CCR after converting it into a non-hazardous material. CCR can be used economically as construction materials, structural fill materials, etc. However, due to the presence of different toxic metals (depending on the sources of coal) it cannot be used without pre-treatment. The leachates of toxic metals emanating from ash ponds may contaminate ground water.

CCR characteristics depend on coal type, coal particle fineness, % of ash in coal, combustion technique applied, air/fuel ratio, number of burners used and type of burner. The non-sphericity of ash particles is correlated with coal combustion efficiency and probably with the black carbon to total particle mass ratio. According to Martins et al. (1998) higher coal combustion efficiencies produce high black carbon contents and the particles produced are mostly non-spherical. However, according to Tang et al. (2013) lower or incomplete coal combustion produces ash particles of irregular shapes.

Due to pozzolanic or self-hardening characteristics, CCR can be recycled as construction material (Ghosh and Subbarao, 1998). Pozzolanic characteristics depend on the availability of lime in CCR. If the lime content present in CCRs is very low, then there will be insufficient bonding between the CCR particles due to lack of pozzolanic reaction. So, it may create leaching problems as in that case it will be present in very loose condition during the use of the same as a structural fill material.

The objective of this study was to evaluate the physico-chemical characteristics of pond ash samples for conducting an environmental impact assessment of CCR dumping.

2. Materials and Methods

Three pond ash samples were collected from three different ash ponds situated around the Kolaghat Thermal Power Plant. They were collected in three plastic buckets and were immediately sealed with plastic covers to prevent exposure to sunlight.

TS, VS and FS were determined according to the methods specified in Standard Methods (APHA et al., 2005, page 2-78, method 2540 G.). Specific gravity of ash samples was determined by density bottle following the standard method prescribed in IS 2720 (Part III/Section 1).

Specific surface area of each of the three pond ash samples was determined by Air Permeability Apparatus of Blaine Type by Air Permeability Method (Blaine method; IS: 4031 (Part 3)). It is a measure of the fineness of a sample. Cement was used as the reference material for calibration of the Air Permeability Apparatus.

Hydraulic conductivity was determined by Falling Head Permeability Method for all the three pond ash samples. Particle size distribution curves of all the three pond ash samples were obtained after sieve analysis and hydrometer analysis on the same samples. Different values of % finer and grain size of all three samples were combined to plot particle size distribution graphs.

SEM-EDS study was conducted with JEOL JSM5800 Scanning Electron Microscope with Oxford EDS detector. EDS analysis of the three pond ash samples was done to determine their elemental composition. Oxide components of the samples were determined during performing EDS experiment.

3. Results and Discussion

According to experimental results given in Table 1, water content was almost negligible in all pond ash samples and ash sample 3 had the highest content of volatile solids. Pond ash sample 3 had mostly coarse particles. Ash sample 3 had the highest specific gravity. Pond ash sample 2 had the maximum specific surface area comparable to that of Portland cement (300-500 m²/kg) and sample 3 had the lowest specific surface area. Pond ash sample 2 was also poorly permeable as compared to the other ash samples.

EDS results as shown in Figure 2, provide information about the presence of C, O, Al and Si in significant quantity in all the samples. K, Ca, Ti, Fe, Cu, Zn, As, Se, Cd and Rn were present in trace amounts in the samples and some of those elements were absent in one or more of them.

It is observed from oxide composition of three ash samples given in Table 2, that lime was present to a very small extent (<7%) in pond ash sample 2 only. However, in other samples it was absent. Oxides of Al, Si and Fe were predominantly present (except the absence of oxides of Al in sample 3 and Fe in sample 1).

If specific surface area increases, the sample may be a threat to the environment, as more elements or pollutants get adsorbed on its surface. Further, due to abundance or sequestration of those elements/pollutants, more leaching of the same will occur in aqueous environments.

After observing the SEM images of the pond ash samples (not shown here), it can be concluded that the ash particles were mainly made up of irregular spherical, semi-spherical and sometimes irregular grains and fibrous matrix.

EDS results show presence of toxic elements like As and Cd and radioactive element like Rn in trace amounts.

All the pond ash samples had lime content less than 7%. So the fly ash present in the pond ash samples can be classified as Class-F (Iyer R., 2002).

From Table 3 it can be concluded that pond ash sample 2 had the highest silt/clay component which may be the reason of its poor permeability.

4. Acknowledgement

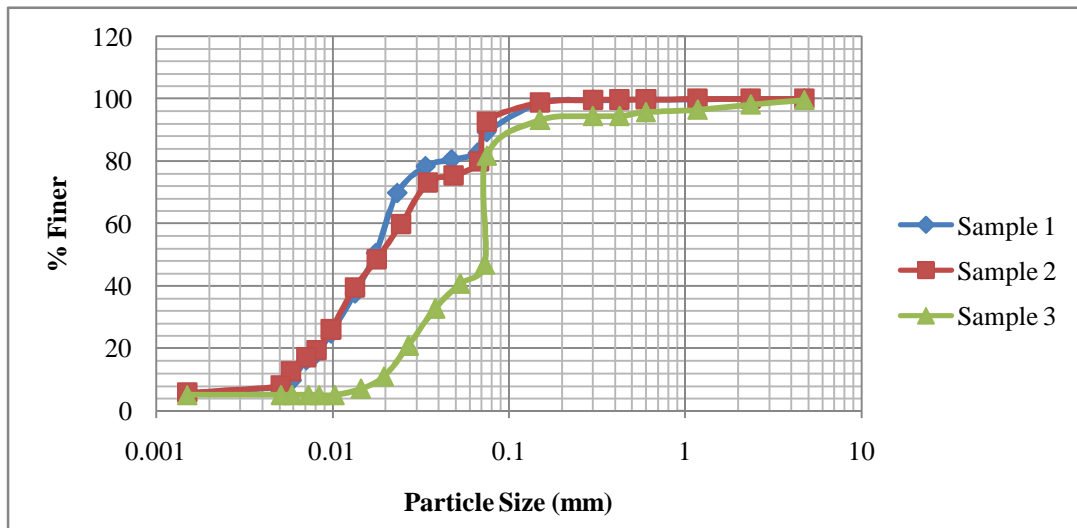
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Table 1: TS, VS, FS, Specific gravity, Fineness, Hydraulic conductivity and Dry Density of Pond Ash Samples.

Parameters	Sample 1	Sample 2	Sample 3
TS (%)	99.91	99.51	99
VS (%)	5.675	7.999	8.949
FS (%)	94.325	92.001	91.051
Specific Gravity at 27 °C	2.065	2.088	2.158
Fineness (m^2/kg)	73.78	254.41	56.62
Hydraulic conductivity at 27 °C	0.992	3.407	2.972
Dry density, γ_d (g/cc)	0.848	0.995	1.221
Void ratio, e	1.435	1.098	0.7674

Table 2: Different Oxide Components of Three Pond Ash Samples.

Different Oxides	% Presence in Different Pond Ash Samples		
	Sample 1	Sample 2	Sample 3
Al ₂ O ₃	37.27	19.67	0
SiO ₂	54.77	59.09	66.17
K ₂ O	7.95	2.39	6.79
CaO	0	2.42	0
TiO ₂	0	4.19	0
FeO	0	12.25	24.66
As ₂ O ₃	0	0	2.38

**Figure 1:** Particle Size distribution Graph of Three Different Pond Ash Samples.

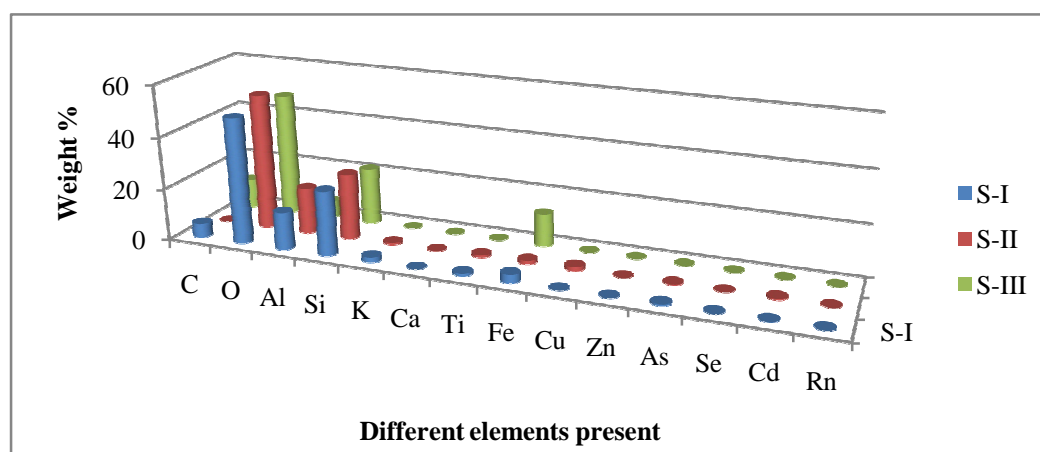


Fig. 2: EDS analysis results of three pond ash samples.

Table 3: Summarisation of Observations Made from Particle Size Distribution Graph.

Parameters	Values of Different Parameters of Pond Ash Samples		
	Sample 1	Sample 2	Sample 3
Gravel % (>4.75 mm)	0.03	0.024	0.436
Sand % (4.75-0.075 mm)	10.698	7.344	17.76
Silt/Clay % (<0.075 mm)	89.272	92.632	81.804
D ₁₀ (mm)	0.005	0.006	0.018
D ₃₀ (mm)	0.012	0.012	0.034
D ₆₀ (mm)	0.02	0.025	0.07
Uniformity Coefficient (C _u)	4	4.17	3.89
Coefficient of Curvature (C _c)	1.44	0.96	0.917

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