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Leaching Behaviour of Elements from High Sulphur Fly Ash

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Abstract: Environmental degradation due to leaching of elements from fly ash is of great concern. Leaching result of Cu, Fe, Mn, Pb and Zn from the high sulphur fly ash collected from captive power plant of Nagaon Paper Mill, Assam is reported. The pH of the leachate is weakly alkaline in nature, ranging from 7.39 to 7.90. Fly ash contains very high concentration of elements in comparison with Gondwana counterpart. However, mobilization of elements from the Nagaon fly ash is very less, and is possibly due to the presence of high unburnt carbon.

Key words: Metals, unburnt carbon particle, fly ash.

Introduction

Generation of fly ash has increased from 40 million tonnes in the year of 1994 to 160 million tonnes in 2009-10. Although India is producing huge quantities of fly ash but its utilization is nearly 50% (2009-10), which is very less in comparison to the major fly ash producing countries like China, U.S.A. and Germany (Dhadse and Bhagia, 2008). Therefore, much of the fly ash remains unused and lying in the ash disposal sites. Coal contains various elements, and during its combustion, elements are enriched as a result of loss of carbon as carbon dioxide. Elements are associated with the surface of the ash particle due to evaporation and condensation. Under the natural conditions, the elements are likely to release due to leaching, and contaminate in the vicinity of ash disposal sites.

Contamination of ground water (Hung et al., 2009), surface water (Mills et al., 1999), soil (Praharaj et al., 2003; Agrawal et al., 2010) and stream sediments (Chander et al., 1994) is caused due to the release of potentially toxic elements. Prediction of potential impacts of ash disposal on groundwater quality depends mainly on laboratory leaching studies (Baba and Kaya, 2004; Haynes, 2009). Mobility of elements due to fly ash leaching has been extensively carried out (Praharaj et al., 2002; Ugurlu, 2004; Dutta et al., 2009). Serial leaching studies were carried out throughout the world to investigate the leachability and mobility of metals from fly ash under natural conditions (Praharaj et al., 2002; Spears and Lee, 2004).

Although lots of work on the fly ash leaching has been carried out in recent past in India but all the works focused on the fly ash generated from the Gondwana coal (Praharaj et al., 2002; Ugurlu, 2004) and lignite (Ram et al., 2003). However, no work has ever been attempted to understand the leaching behaviour of elements from the fly ash generated due to the combustion of high sulphur coal which occurs in northeast of India.

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Materials and Methods

Fly ash was collected from the captive power plant of Nagaon Paper Mill located at Jagiroad, Morigaon district, Assam which is nearly 70 km from Guwahati. The fly ash sample was dried and sieved (63 μm) before laboratory analysis and serial batch leaching.

Mineralogy of the fly ash was studied using a Phillips PW-1710 X-ray diffractometer (XRD) employing CuKα radiation at 1.2º/minute scanning rate. Morphology of fly ash was studied using scanning electron microscopy (SEM), JEOL JSM-6480LV, attached with energy dispersive X-ray (EDX). Total concentration of elements in the fly ash was determined using Philips PW 2400 X-ray fluorescence (XRF) from the press pellets. Loss of ignition (LOI) of ash was calculated from the weight loss after heating in muffle furnace at 550 °C for a period of two hours.

To understand the short-term leaching effects, serial batch leaching test was carried out. The leaching test was carried out for different liquid to solid ratios (L/S), 4 and 12, at pH 5.6 following the method of Praharaj et al. (2002). Both the solutions were then stirred constantly and kept for 24 hrs. After 24 hrs, leachate were immediately filtered and added with HNO_3 to bring pH less than 2 for the analysis of metals. The filtrate was stored in tightly capped acid washed polyethylene bottles. For each next step, solution of pH 5.6 was added along with the filter paper from the last step. Each leaching stage was carried out for 24 hrs. Similarly, above mentioned procedure was followed for four days. The pH of the leachate was measured using ORION electrode before acidification. Then the filtrate samples of all days were analyzed using Atomic Absorption Spectrophotometer (PerkinElmer).

Results and Discussion

The XRD pattern of the fly ash sample is shown in Figure 1, and confirms the presence of quartz, hematite, calcite, dolomite, kaolinite and anhydrite. Mullite, which is one of the most common minerals in fly ash generated from the conventional combustion technique, is absent because of the combustion of coal at temperature of nearly 800 °C using fluidized bed combustion method at captive power plant of Nagaon Paper Mill.

The scanning electron photomicrographs of fly ash show the presence of solid spherical cenospheres (Figure 2). The occurrence of rod shaped anhydrite crystal is also confirmed under SEM with the help of EDX. The unburnt carbon particles are clearly distinguishable from their very high porous structure (Figure 2) and their presence indicates low temperature combustion. The EDX spectra (Figure 3) also indicate the presence of high carbon content in the fly ash. LOI, an indirect parameter to indicate the presence of unburnt carbon, is 18.5%, which is very high in comparison to that of Gondwana fly ash.

Concentration of Fe, S, Cu, Pb and Zn in the Nagaon fly ash is much higher than that of Gondwana fly ash (Table 1). Higher concentration of Fe and S is present since the fly ash is generated from Northeastern Tertiary coal, which is highly enriched with pyrite (Chandra et al., 1980). Abnormally high concentration of S and pyrite in Teriary coal of Northeastern India is due to its deposition under the influence of marine environment while Gondwana coal is mostly formed in fresh water environment (Chandra et al., 1984; Ray and Chakraborty, 2002).

The pH of the leachate is weakly alkaline in nature, and ranges from 7.39 to 7.70 and 7.43 to 7.90 for L/S 4 and 12 respectively. Phukan and Bhattacharyya (2003) reported the increase in pH of soil (up to 8) close to the Nagaon paper mill possibly due to the influence of effluent and waste, which is now explained by the leaching test.

The concentrations of elements such as Mn, Fe, Cu, Pb and Zn in the leachate from the ash samples are given

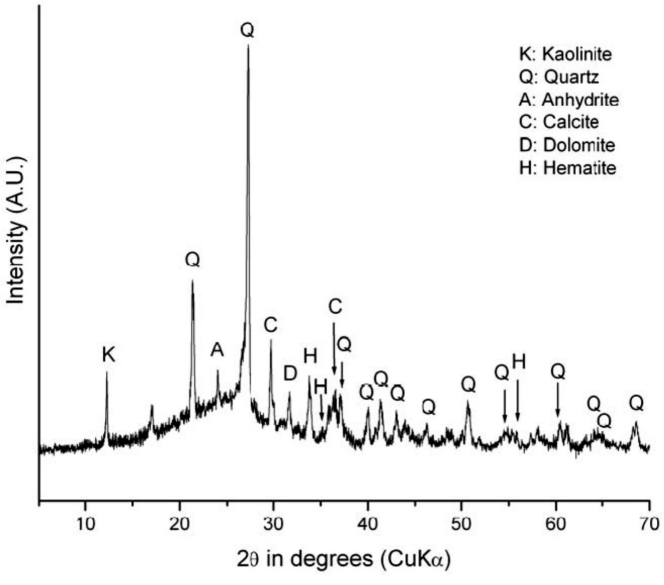

Figure 1: X-ray diffraction pattern of fly ash.

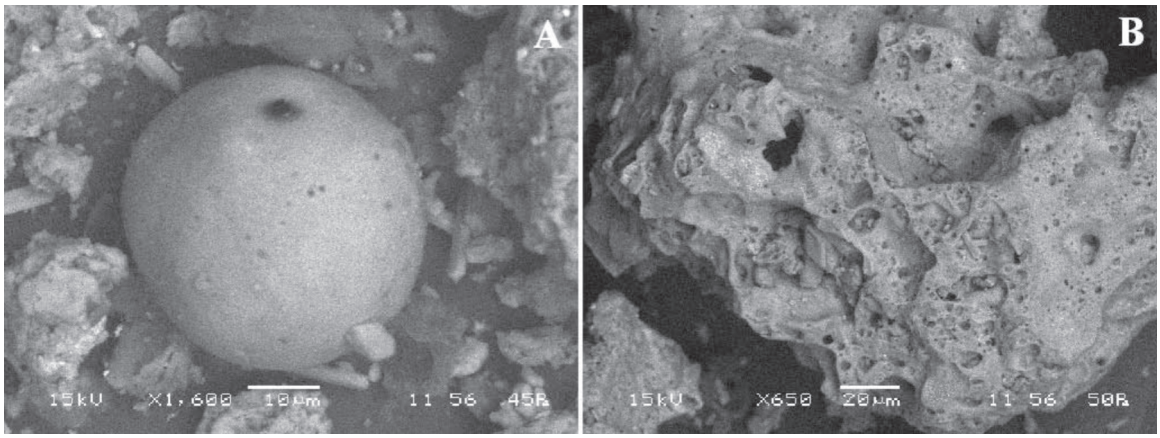

Figure 2: SEM microphotographs of fly ash represent (A) cenosphere and anhydrite crystals, and (B) porous unburnt particles.

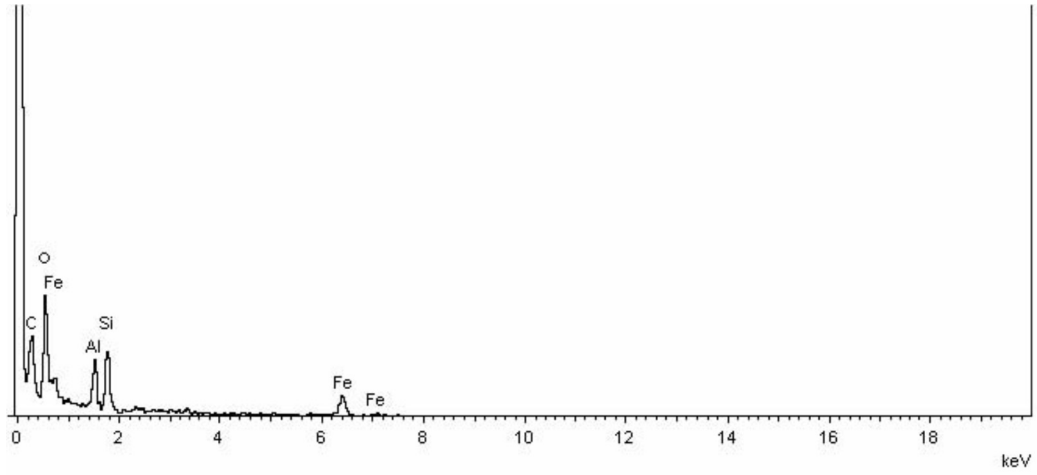

Figure 3: EDX spectra of unburnt particle.

Table 1: Comparison of composition of fly ash (Unit: ppm unless otherwise mentioned)

Elements	*Gondwana fly ash**	*Present study*
Fe	0.80 (%)	6.23 (%)
S	0.03 (%)	0.25 (%)
Cu	15.96	94.00
Mn	109.63	105.00
Zn	10.56	156.00
Pb	6.64	213.00
LOI	0.10 (%)	18.50 (%)

*Praharaj et al. (2002)

in Table 2. Concentration of Mn is above the maximum contaminant level of the drinking water prescribed by United States Environmental Protection Agency (2000) in the all samples while only Fe exceeds in case of Gondwana fly ash at L/S 12. Concentrations of Zn and Cu are within the limits while Pb exceeds only for initial period. Leaching study indicates that elements concentration in leachate from Gondwana fly ash is higher than that of Northeast fly ash. This is possibly attributed to the presence of unburnt carbon, which has the tendency of absorbing the elements' content in latter. As unburnt carbon particles are highly porous in nature and, having very high surface area, therefore, retained the metals (Hequet et al., 2001) without releasing into the aqueous system. Except Fe, there is gradual decrease in the concentration of elements in the leachate with increase in contact time in contrast to that of Gondwana fly ash which indicates that bioavailability of metals is very less from high sulphur Nagaon fly ash, and therefore expect to pose less environmental impact due to fly ash leaching. However, more rigorous column leaching study for longer duration is needed to understand metal mobilization in more appropriate way.

Table 2: Concentration of elements in fly ash leachate at different L/S ratios (all values in ppm)

Present Study						
L/S	*Day*	*Cu*	*Fe*	*Mn*	*Pb*	*Zn*
4	1	0.011	0.022	0.093	0.27	0.012
	2	0.006	0.016	0.049	0.08	0.006
	3	BDL	0.054	0.017	BDL	BDL
	4	0.004	0.43	0.006	BDL	BDL
12	1	0.005	0.021	0.054	0.12	0.008
	2	0.004	0.03	0.029	BDL	BDL
	3	BDL	0.022	0.01	BDL	BDL
	4	BDL	0.035	0.035	BDL	BDL
Gondwana Fly Ash*						
4	1	0.07	0.04	0.28	BDL	0.01
	2	0.02	0.53	0.53	0.55	0.08
	3	0.02	0.06	0.63	BDL	0.25
	4	0.54	0.08	0.75	0.16	0.48
12	1	BDL	0.52	0.02	BDL	0.07
	2	BDL	0.69	0.07	BDL	0.06
	3	0.07	4.24	0.02	BDL	0.09
	4	BDL	1.36	0.02	BDL	0.03
Maximum permissible limit (USEPA, 2000)		1.3	0.3	0.03	0.015	5

BDL: Below Detection Limit; *Praharaj et al. (2002)

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