

Leaching Potential of Fly Ash

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Abstract: The present study has been carried out to assess the leaching potential of fly ash by open column experiment. Fly ash was collected from Parichha thermal power plant, Jhansi. The leachability of fly ash in aqueous environment for the major and trace elements was determined. The concentration of leachable ions was found in the descending order as $\text{Ca} > \text{Mg} > \text{K} > \text{Ni} > \text{Fe} > \text{Al} > \text{Mn} > \text{Cu} > \text{Si} > \text{Pb} > \text{Co} > \text{Zn} > \text{Cr} > \text{Ba}$. During the entire leaching period, the concentration of calcium and potassium did not change significantly into leachate with respect to pH variation and was found to be pH independent. However, the leached out concentration of Mg, Mn, Ni and Co was found to be maximum under slightly acidic condition. The concentration of leached out elements like Zn, Al, Cu, Ba, Pb, Fe and Si was found to be maximum under both acidic and alkaline conditions while chromium was found to be maximum under alkaline condition.

Key words: Fly ash, leaching, trace elements, open column.

Introduction

Disposal of fly ash produced as a waste byproduct obtained from the burning of coal in thermal power plants for generating electricity is a major environmental concern in India (Praharaj et al., 2002; Puvvadi and Baig, 2010). When bulk quantities are involved in order to arrest the fugitive dust, it is stored wet rather than dry (Puvvadi and Baig, 2010). Much of the ash is disposed of in settling ponds with effluent outlets that enter into local water ways (Praharaj et al., 2002). The surface of fly ash particle is only microns (1-200 μ) in thickness and can contain leachable heavy metals (i.e. trace elements) which have condensed on to the surface (Zandi and Russell, 2007).

The ash ponds contain fly ash and water mix in form of a dilute slurry and leaching of metals from this dilute slurry is a function of its pH, which itself is a dynamic

parameter (Goodarzi, 2006). In the initial stage of leaching, the elements adsorbed on the surface of fly ash particles get prominent in leachate. However, as leaching progress further weathering of aluminosilicate glass would release the elements incorporated within the glass particle (Choi et al., 2002).

If the ash pond is unlined, then a significant volume of the ash leachate percolates underground to the underlying water table. The main leachants of the disposed ash are rainwater, locally acidic due to gaseous power plant emission, and the slurry water which carries the ash from the plant to the pond (Praharaj et al., 2002). The mobility of potential pollutants due to ash leaching has been the subject of extensive research (Praharaj et al., 2002). Therefore the present study is conducted to assess the leachability of fly ash produced in Parichha thermal power plant by using open column method.

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Experimental Set up and Methodology

Fly ash sample was collected from dust hopper of electrostatic precipitator of Parichha thermal power plant, Jhansi, India. Sub bituminous type of coal is being burned in thermal power plant for electricity generation.

To study the leaching behaviour of fly ash, open column experiment was conducted for 60 days of time period. A rectangular column was prepared by using perplex sheet of size 40 cm×40 cm×50 cm. Fly ash was mixed with water to make slurry of 1:5 ratio. Column was filled upto a height of 35 cm leaving a 15 cm space at the top as per standard guidelines and procedure adopted for design in the open percolation column experiment (Singh et al., 2007). In order to collect triplicate of leachate sample three different column setup was prepared.

Leachate was collected from three different columns in separate beakers placed below the outlet of columns at 10th day, 20th day, 30th day, 45th and 60th days of experiment. pH of ash slurry into open column was monitored with respect to time by using pH meter.

Leachate collected from open column was digested with nitric acid by using single acid digestion method (APHA, 2005) and analysed for major and trace elements (Ca, Mg, K, Al, Si, Fe, Co, Mn, Ni, Cu, Pb, Zn, Cr and Ba) by using atomic absorption spectrophotometer.

Results and Discussion

Variation of pH into Column

The pH of ash slurry in column experiment was found to be varying from 8.10±0.20 to 5.86±0.05 (alkaline to acidic pH) during the entire study period of 60 days. The initial pH of fly ash slurry was observed as alkaline in nature (8.10±0.20), within the five minutes of fly ash mixing into water. According to data summerised in Table 1, pH was decreasing with increasing number of days and reached to acidic pH at 60th day of experiment (5.86±0.05).

The ash slurry in column showed a decreased value of pH with respect to time. This decline in pH slowly over time is due to the uptake of CO₂ from atmosphere (Lokeshappa and Dikshit, 2012). Schramke (1992) demonstrated that the introduction of CO₂ gas into alkaline fly ash leachate can reduce pH. When CO₂ is absorbed, calcite (CaCO₃) can precipitate, resulting in acidity.

Spears and Lee (2004) generalized that acidic condition of fly ash slurry can be attributed due to the

sorption of SO₂ or the condensation of sulfuric acid from the gas stream on to ash particle surface.

Leaching of Elements from Fly Ash

Perusal of data summarized in Table 1, following concentrations of elements were obtained in leachate collected from open column experiment:

Calcium is present in fly ash in multiple modes of occurrence, primarily lime, anhydrite, calcite and within the glassy matrix. It is the most largely released cation (Kim et al., 2003). In the present column experiment, leached concentration of calcium was recorded as 57.33±7.5 ppm (at 10th day), 119.33±4.04 ppm (at 20th day), 281.66±9.60 ppm (at 30th day), 439±25.35 ppm (at 45th day) and 446±20.66 ppm (at 60th day). Calcium showed a pH independent leaching behavior. Calcium is found to be leached from fly ash throughout the study period.

Magnesium concentration was absent in the leachate collected on 10th day of column experiment. With respect to time and decreasing pH, leaching of magnesium was increased and reached its maximum level at 60th day (150.33±2.08 ppm). The present study revealed that magnesium could not leach in alkaline condition of initial days of experiment. Earlier studies have also reported that magnesium is insoluble in water and alkaline conditions and slightly soluble in acidic condition (Kim et al., 2003). This is due to cationic behaviour of fly ash (Zandi and Russel, 2007).

In the present study, **potassium** concentration in leachate collected from column experiment was recorded as 3.66±2.08 ppm at 10th day, 7.33±2.08 ppm at 20th day, 23.66±3.78 ppm at 30th day, 44.33±3.05 ppm at 45th day and 45.96±3.59 ppm at 60th respectively. It was observed that the leaching of potassium was increased with aging of ash slurry in the column.

Perusal from the data given in Table 1, **aluminium** was found to be leached throughout the study period in both alkaline and acidic condition of ash slurry into the column but the leaching was found to be more with increasing time as the pH was decreased. Aluminium is considered as amphoteric element (Makela, 2012) which can leach in both alkaline and acidic conditions.

At the 10th, 20th, 30th, 45th and 60th days of experiment the **silica** concentration was 0.33±0.04 ppm, 0.55±0.06 ppm, 1.47±0.41 ppm, 2.68±0.34 ppm and 2.73±0.29 ppm respectively. It is observed that very small concentration of silica was leached within initial 20 days of experiment while the concentration was increased with respect to time and decrease in pH of fly ash into column.

Table 1: Composition of leachate collected at different time interval of open column experiment

	Concentration (ppm) in leachate at 10 th day of experiment	Concentration (ppm) in leachate at 20 th day of experiment	Concentration (ppm) in leachate at 30 th day of experiment	Concentration (ppm) in leachate at 45 th day of experiment	Concentration (ppm) in leachate at 60 th day of experiment
pH	7.9±0.04	7.56±0.05	6.18±0.17	5.95±0.12	5.86±0.05
Calcium (Ca)	57.33±7.5	119.33±4.04	281.66±9.60	439±25.35	446±20.66
Magnesium (Mg)	-	7.06±0.85	85.66±13.65	149±6.55	150.33±2.08
Potassium (K)	3.66±2.08	7.33±2.08	23.66±3.78	44.33±3.05	45.96±3.59
Aluminium (Al)	0.74±0.21	1.47±0.20	2.36±0.14	3.74±0.05	3.79±0.05
Silica (Si)	0.33±0.04	0.55±0.06	1.47±0.41	2.68±0.34	2.73±0.29
Iron (Fe)	0.80±0.04	1.7±0.08	3.23±0.07	5.17±0.10	5.19±0.04
Cobalt (Co)	-	-	1.13±0.04	1.73±0.04	1.82±0.02
Manganese (Mn)	-	-	1.61±0.07	3.41±0.35	3.46±0.35
Nickel (Ni)	-	0.54±0.41	3.86±0.20	7.29±0.16	7.34±0.14
Copper (Cu)	0.46±0.05	0.79±0.03	1.56±0.41	2.38±0.16	2.45±0.16
Lead (Pb)	0.37±0.05	0.59±0.06	1.40±0.36	2.30±0.20	2.38±0.25
Zinc (Zinc)	0.27±0.06	0.53±0.06	0.83±0.07	1.36±0.06	1.38±0.05
Chromium (Cr)	0.78±0.07	0.92±0.05	0.63±0.05	0.54±0.02	0.58±0.01
Barium (Ba)	0.04±0.01	0.07±0.01	0.15±0.04	0.16±0.03	0.17±0.02

In most of the leaching studies iron has not found to be leached and observed as below the detection limit. Though, Moreno et al. (2005) has reported that very small amount of **iron** is leachable in near neutral and alkaline solutions. At the 10th, 20th, 30th, 45th and 60th days of experiment the iron concentration was 0.80 ± 0.04 ppm, 1.7 ± 0.08 ppm, 3.23 ± 0.07 ppm, 5.17 ± 0.10 ppm and 5.19 ± 0.04 ppm respectively. It was noticed that the leaching concentration of iron was found to be increasing with respect to time while pH of fly ash slurry was decreasing.

Leaching of **cobalt** increases with decreasing pH (Kim et al., 2003) and at pH above 12, giving rise to amphoteric U-shaped solubility curve (Moreno et al., 2005). Cobalt was not found to be leached from fly ash slurry within 20 days of experiment. At the 30th, 45th and 60th days of experiment its concentration in leachate was recorded as 1.13 ± 0.04 ppm, 1.73 ± 0.04 ppm and 1.82 ± 0.02 ppm respectively.

Leaching of **manganese** was not observed within the initial 20 days of experiment. It was found as 1.61 ± 0.07 ppm, 3.41 ± 0.35 ppm and 3.46 ± 0.35 ppm in leachate collected at 30th, 45th and 60th days respectively. The dissolution of manganese was found to be increasing with increase in time. While manganese was also observed as cationic element which leached only under acidic condition after about 20 days of experiment.

Solubility of **nickel** is markedly sensitive to pH and covers a few orders of magnitude. Ni is found to be removed from fly ash at acidic pH (Kim et al., 2003). Data given in Table 1 reveals that nickel was not found to be leaching within initial days of experiment. Leaching of nickel increased with aging of ash slurry with decreasing pH into column.

Copper was found to be leaching throughout the study period. It was leached in both alkaline and acidic conditions exhibiting amphoteric behaviour. But the leached amount of copper was observed more in acidic conditions of ash slurry at 30th, 45th and 60th days of experiment than alkaline conditions of initial 10-20 days. Sonawane et al. (2016) have also reported the solubility of copper in weakly acidic medium.

Lead is considered as a cationic element and slightly acidic conditions enhance its leachability (Jones, 1995). Lead was found to be leached from fly ash in column study as 0.37 ± 0.05 ppm at 10th day of experiment, 0.59 ± 0.06 ppm at 20th day, at 30th, 45th and 60th days it was 1.40 ± 0.36 ppm, 2.30 ± 0.20 ppm and 2.38 ± 0.25 ppm respectively. In the present study, lead was found to be leached throughout the study period. But the

concentration of lead in leachate was increased with increasing time and decreasing pH of ash slurry into column.

The mobility of **zinc** progressively increases with decreasing pH (Kim and Hesbach, 2009). Acidic conditions of ash slurry into column enhance the solubility of Zn. At the 10th, 20th, 30th, 45th and 60th days of experiment the zinc concentration was 0.27 ± 0.06 ppm, 0.53 ± 0.06 ppm, 0.83 ± 0.07 ppm, 1.36 ± 0.06 ppm and 1.38 ± 0.05 ppm respectively.

Chromium is classified as an oxyanion which tends to be more mobile in neutral to moderately alkaline pH (Hoek et al., 1996). Chromium was found to be leached from fly ash in column study as 0.78 ± 0.07 ppm at 10th day of experiment; however 0.92 ± 0.05 ppm at 20th day, 0.63 ± 0.05 at 30th day, 0.54 ± 0.02 ppm at 45th day and 0.58 ± 0.01 ppm at 60th day of experiment.

The leachability of **barium** does not show any significant dependence on pH but is rather controlled by the ubiquitous Ca against which it competes for sulfate (Fruchter et al., 1990). The presence of large amounts of Ca in solution would promote the precipitation of more insoluble sulfate, more likely coprecipitated as (Ba, Sr)SO₄ than as BaSO₄. At the 10th day of column experiment, barium concentration in leachate was recorded as 0.04 ± 0.01 ppm. However at 20th, 30th, 45th and 60th days it was recorded in leachate as 0.07 ± 0.01 ppm, 0.15 ± 0.04 ppm, 0.16 ± 0.03 ppm and 0.17 ± 0.02 ppm respectively.

Conclusion

The present study concluded that the leachability of calcium and potassium is not dependent on pH change. Calcium and potassium are considered as easily soluble elements in aqueous environment and their dissolution in water is totally pH independent. Whereas, elements like Mg, Mn, Ni, and Co leached in aqueous environment with decrease in pH. This behaviour of element is called as cationic behaviour. On the other hand Zn, Al, Cu, Ba, Pb, Fe and Si showed the minimum leachability at pH 7. Solubility of these elements increases at pH level above and below 7. Elements showing increased mobility at both low and high pH are called as amphoteric. Amphoteric element can react with both acid and bases. Cr showed very low solubility under slightly acidic condition. Its mobility increased with increasing pH. Thus it can be classified as oxyanionic element.

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