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# Leaching Characteristics of Fluoride from Coal Ash

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**Abstract:** More than 100 million tonnes of coal fly ash is produced annually in India from combustion of coal in power plants. It is expected that up to 2020 AD about 150 million tonnes of coal ash will be produced due to burning of coal in power plants. This will require about 30,000 hectare of land for ash disposal. One of the main problems in disposing of big quantities of coal ash is the possible leaching of different pollutants, including fluoride. A thorough investigation regarding leaching of fluoride from fly ashes is much essential to know the impact of fluoride due to its leaching from fly ash to ground water as well as surface water. In the present paper, short term and long term leaching studies have been carried out on fly ash, bottom ash, pond ash and weathered ash of Chandrapura thermal power station (CTPS), Jharkhand and Ramagundam thermal power station (RTPS), Andhra Pradesh. The amount of fluoride released in different experiments has been evaluated. A field investigation at Damoda abandoned open cast mine of Bharat Coking Coal Limited, filled with pond ash of CTPS has been done. Concentration of fluoride in ground water beneath the ash filled mine has been evaluated on monthly basis. Environmental impact of fluoride and remedial measures for ash disposal has been discussed.

**Key words:** Fluoride leaching, fly ash, ground water.

## Introduction

More than 100 million tonnes of coal ash is produced annually in India from combustion of coal in power plants. At least 95% of this amount is disposed off in the form of slurry in ash disposal ponds, thus contributing to environmental pollution due to leaching of its toxic constituents (Prasad et al., 1996). One of the critical constituents is fluoride, which may be toxic at elevated levels in water. Different researchers (Prasad et al., 1996; Prasad and Jaiprakas, 2000; Prasad et al., 2004; Gregory and Roy, 1985; Wadge and Hutton, 1987; Querol et al., 2001; Theis and Gardner, 1990; Liem et al., 1983; Wasay, 1992; Fleming et al., 1996) have carried out the problem of leaching of heavy metals from disposed fly ash. Non-metals like arsenic, selenium and boron have also been found potentially harmful to both vegetation and animals (Vander Hoek et al., 1996; Cox et al., 1978). The fluoride concentrations in coal ash vary within broad limits of 0.4-610 μg/g and depend on the type of coal being burnt, the particle size of the ash and the efficiency of electrostatic precipitators. The fluoride concentration in leachate water may exceed the standard limits for drinking water (1.0-1.5 mg/l) and may exceed to a high level of 18 mg/l (Piekos and Paslawska, 1998). The knowledge of the leaching behaviour of fly ash is important to know the amount of leachable constituents of environmental importance, as their availability affects the biological system. The first objective of the present study was to investigate the release of fluoride from different ashes obtained from Ramagundam Super Thermal Power Plant and Chandrapura Thermal Power Plant under different laboratory experiments. The second objective was to study the release of fluoride to ground water due to coal ash filled in abandoned open cast mine.

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## Experiment

### Sampling

Different types of ashes were collected from both the power plants. Fly ash was collected directly from electrostatic precipitator. Bottom ash was collected from the bottom of the furnace. Pond ash was collected from the active ash ponds, where the discharge of ash slurry was on progress. Weathered ash of Ramagundam was collected from the old dried up ash pond, where the ash was two years old. Weathered ash of Chandrapura was only six months old. The collected samples were brought to the laboratory and required amount for leaching experiment were obtained by coning and quartering. The major components present in ash, such as $SiO_2$, $Al_2O_3$, $Fe_2O_3$, $TiO_2$, CaO, MgO, $Na_2O$ and $K_2O$ and loss of ignition were determined according to Indian Standard: 1527 for method of chemical analysis of fireclay and silica refractor materials.

### Batch Leaching Experiment

To understand the short-term leaching effect, ASTM standard test method for shake extraction of solid waste with water was adopted (ASTM D 3987). In this method ash of known amount was taken in flasks and distilled water equal to 20 times the weight in grams of the ash was added. Agitation was performed for 18 hours. After agitation samples were filtered and analysis of fluoride was carried out with Orion Specific ionmeter.

### Column Leaching Experiment

To understand the long-term leaching effect of different ashes, open column percolation experiment was performed. The columns prepared for the test were of PVC, approximately of 80 cm. of height with three inches diameter. The columns were open at the one end and closed at other end with a small hole to be used for the collection of leachates. The columns were prepared by gently packing one kg of different ashes. The pore volume of each column was determined and 2.5-pore volume of water passed every week and 10-pore volume of water every month. The experiment was continued for one year. Analysis of fluoride in the collected leachates was carried out on weekly basis with Orion Specific Ionmeter.

### Field Investigation for Groundwater Contamination

In Damoda abandoned open cast mine, coal ash of Chandrapura has been used to fill up the abandoned mine site on the ash filled mine. Five members of boreholes of about 6.5 inches diameter were drilled up to the ground-water level. Four boreholes were on the ash filled zone and one borehole was at the periphery (Figure 1). Groundwater samples were collected on monthly basis

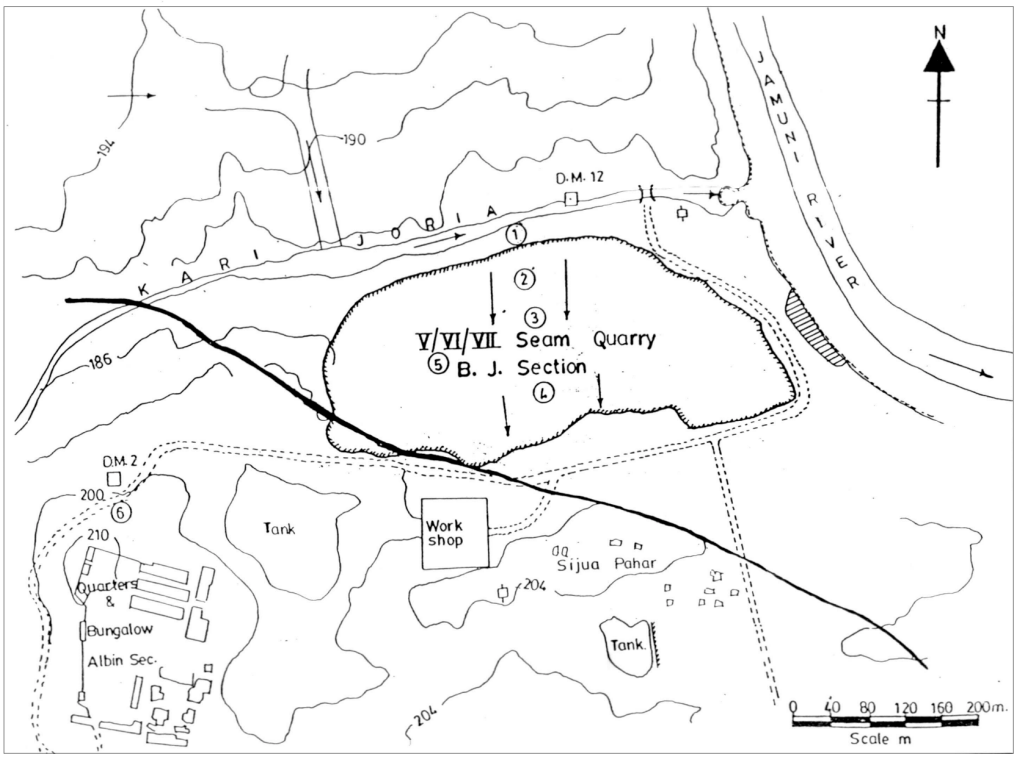


**Figure 1: Damoda abandoned open cast mine of B.C.C.L. filled with coal ash of CTPS.**

from March 2003 to October 2003 with the help of stainless steel bucket of 5-inch diameter. Water from one tube well was also collected on monthly basis, which was located about ½ km away. Analysis of ground water was carried out with Orion Specific Ionmeter.

## Results and Discussion

The results of chemical composition of coal ash of Ramagundam and Chandrapura thermal power plants are given in Table 1. The most abundant component in both the ashes is $SiO_2$ followed by $Al_2O_3$, $Fe_2O_3$ and CaO. The minimum abundant components in both the ashes are $TiO_2$, $Na_2O$, $K_2O$ and $SO_3$. The CaO percentage in both the ashes is less than 10%. This indicates that both the ashes belong to class-F category.

Results of batch leaching experiment conducted on fly ash, bottom ash, pond ash, and weathered ash of Ramagundam and Chandrapura is given in Table 2. From the results it has been seen that the leachate of Chandrapura and Ramagundam, fly ash has maximum

**Table 1*:* Chemical composition of coal ash**

| *Constituents* | *Percentage* | |
|---|---|---|
| | *Ramagundam* | *Chandrapura* |
| Silica as $SiO_2$ | 60.11 | 56.70 |
| Alumina as $Al_2O_3$ | 26.53 | 23.80 |
| Iron as $Fe_2O_3$ | 4.25 | 4.70 |
| Sulphur as $SO_3$ | 0.35 | 0.30 |
| Calcium as CaO | 4.00 | 2.10 |
| Magnesium as MgO | 1.25 | 1.40 |
| Sodium as $Na_2O$ | 0.22 | 0.25 |
| Potasium as $K_2O$ | 0.75 | 0.50 |
| Loss of Ignition | 0.88 | 10.35 |

**Table 2: Fluoride concentration in leachate from batch leaching (mg/l)**

| *Power Plant* | *Fly ash* | *Bottom ash* | *Pond ash* | *Weathered ash* |
|---|---|---|---|---|
| CTPS | 4.6 | 0.275 | 0.992 | 1.08 |
| RSTPP | 0.453 | 0.110 | 0.159 | 0.053 |

concentration of fluoride, compared to bottom ash, pond ash and weathered ash. The fluoride concentration varied from maximum of 4.6 mg/l in Chandrapura fly ash to minimum of 0.053 mg/l in Ramagundam weathered ash leachate. The concentration of fluoride in Chandrapura fly ash leachate has been found more than the Indian drinking water specification (IS: 10500). The changes

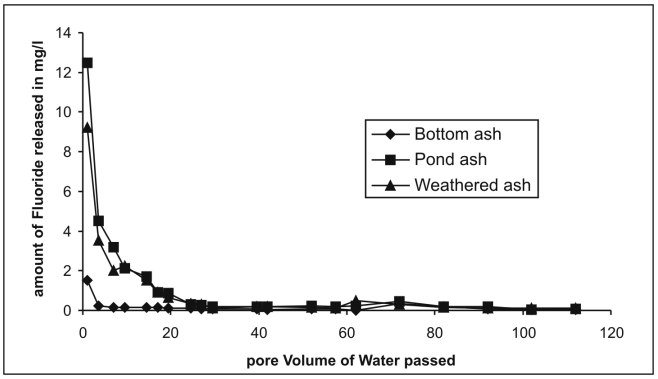


**Figure 2: Release of Fluoride from column leaching of Chandrapura ash.**

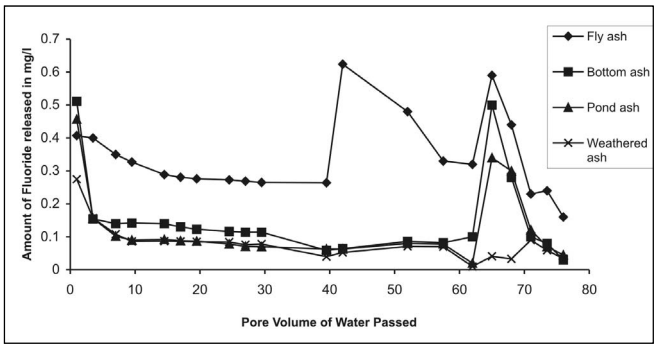


**Figure 3: Release of Fluoride from column leaching of Ramagundam ash.**

of fluoride concentration of leachate samples collected periodically during the one-year column leaching experiment conducted are shown in Figures 2 and 3.

During one-year period 112-pore volume of water was passed through each column except Ramagundam fly ash column, in which 76-pore volume of water could be passed. Initially it has been seen that leachates obtained from first 9.5-pore volumes in Chandrapura pond ash and weathered ash showed quite high concentration of fluoride in it. With continual leaching, the fluoride concentration decreased in somewhat stepwise fashion and by passing 19.5-pore volume of water, the fluoride concentration in leachate decreased to acceptable level. The fluoride concentration in leachate obtained from bottom ash column of Chandrapura in the initial pore volume has been found quite low of 1.53 mg/l. In all the four columns of Ramagundam ashes that include fly ash, bottom ash, pond ash and weathered ash, initial characteristics of leachates of the first pore volume has not shown fluoride in high concentration. In all the columns, the fluoride value decreased gradually up to 112-pore volumes. Fluoride analysis carried out in different groundwater samples collected from the

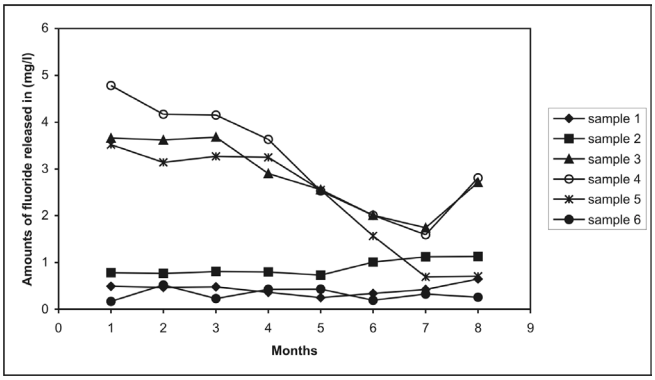


**Figure 4: Fluoride concentration in ground water (mg/l).**

periphery of the ash-filled mine and tube well water ½ km away, is given in Figure 4.

From Figure 4, it has been observed that differences in fluoride concentration in the ground water from different zones have been observed. In initial months fluoride concentration at sampling points 3, 4 and 5 has been found quite high but gradually its concentration showed a decreasing trend in later months. The fluoride concentration in the periphery ground water has been slightly affected by the ash filled zone. The sampling point 2, which is located at the beginning of the ash filled area, showed lesser concentration of fluoride in the initial months and increasing trend in fluoride concentration has been observed in later months. The tubewell water has not shown any sign of contamination with fluoride, indicating the fact that the fluoride in ground water beneath the ash-filled mine has not migrated up to tubewell water.

## Remedial Measures for Ash Disposal

The technology for coal ash disposal should control the migration of leachate from ash to ground water. This technology includes many methods like liner system, leachate collection system, waste cover, etc. Fly ash landfill designed with multiple liner system, a double composite liner, which consists of five feet of Bentonite, clay compact onto naturally occurring clay stone has been proposed (Wasay, 1992). A synthetic liner of 80 mm high-density polythene was placed above compacted clay. Another alternative is to cover the coal ash with a low-permeable membrane, which removes the infiltrated water laterelly, prevents not only groundwater pollution but also the formation of percolates. Migration of fluoride in the ground water from the ash-filled mine to a long distance has not been observed. The abandoned open cast mine, which are located in barren area and where there is no nearby habitats, should be used for disposal of coal ash.

## Conclusion

From the above studies following conclusion has been drawn:

- The percentage determination of major components present in the Chandrapura and Ramagundam ash revealed that both the ashes belong to class-F category.
- Chandrapura fly ash leachate showed high concentration of fluoride in it, more than the drinking water specification (IS: 10500).
- Open column percolation leaching experiment carried out on different ashes of Ramagundam and Chandrapura showed initially higher level of fluoride in leachates but gradually the concentration of fluoride decreased after passing few pore volumes of water.
- Fluoride concentration in ground water evaluated at ash-filled Damoda abandoned open cast mine revealed that fluoride concentration was similar to Chandrapura fly ash leachate obtained from batch leaching. In initial months fluoride concentration has been found to be at a high level but gradually its concentration decreased in later months.
- Groundwater quality beneath the ash-filled zone has little effect on groundwater quality at the periphery of the ash-filled zone but it has no effect on groundwater quality ½ km away from the ash-filled zone.

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