LEACHING STUDIES OF INDIAN FLY ASHES FOR EVALUATION OF THEIR SUITABILITY AS MINE FILL MATERIAL

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Abstract

In India approximately 70% of power generation has been through coal fired thermal power plants. About 60% of coal produced, is used for power generation. The low grade quality of coal has an average ash content of 35-40%. It is expected that up to 2020AD, about 150 million tones 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 heavy metals. When looking ways for disposing of coal ash, underground or open cast mine filling with coal ash, is the only answer for solving major disposal problems. Hence a thorough investigation regarding characteristics and suitability of coal ash as mine fill material is very much required to be done, before its disposal. In the present work, leaching studies of fly ashes from two sources: a) Chandrapura Thermal Power Plant Jharkhand (coal ash is being disposed of in damoda abandoned open cast mine of BCCL) and b) Ramagundam Super Thermal Power Plant, Andhra Pradesh (coal ash has been used as stowing material in incline underground mine of SCCL) have been carried out. The samples have been leached with water according to American Society for Testing and Material extraction procedure and the leachates have been analysed to determine TDS, hardness, calcium, magnesium, chloride, sulphate, fluoride and potassium. Heavy metals concentration in leachates have been determined by AAS while total metals in fly ash have been determined by concentrated nitric acid digestion technique followed by AAS analysis.Effect of pH on metal release from fly ash has been studied. A cascade method for investigating the long term leaching of heavy metals from coal ash has been carried out. Suggestion for safe disposal of fly ash as mine fill material has been described. Future trends have also been enumerated.

Introduction

Out society is dependent on a very big production of electricity. Coal is widely used as fuel in electricity production. As a result big quantity of coal ash has become a problem due to disposal difficulties. One of the major difficulties in disposing of big quantities of coal ash is the possible leaching out of pollutants including heavy metals. Heavy metals may pollute surface and underground water and in this way constitute a risk to all life.

When looking for ways of disposing of big quantities of coal ash, the opencast and underground mines left empty from coal extraction, are the only answer for comprehensive utilization of coal ash. In India, so far no concerted efforts have been made to use coal ash as back-fill material in underground and opencast coal mine. To evaluate the suitability of Indian coal ash as mine fill material, it is very much necessary to thoroughly investigate the physico-chemical properties and leaching behaviour of coal ashes . In the present paper, fly ashes from two sources have been investigated according to ASTM extraction procedure and leachates have been analysed. Total metals in fly ash have been determined and effect of different factors like pH, weathering, particle size of fly ash on leaching behaviour have been evaluated. Suggestions for safe disposal and future trends have been enumerated.

Experimental Procedure

American Society of Testing and Materials (ASTM) method-A extraction procedure has been used for batch leaching studies of fly ash, bottom ash, pond ash and weathered ash obtained from Ramagundam super thermal power plant, Andhra Pradesh and Chandrapura thermal power plant, Jharkhand. The weathered ash of Ramagundam was about two years old and Chandrapura was six months old. In the first series of analysis the leachates thus generated have been analysed for total dissolved solids, total hardness, calcium, magnesium, pH, chloride, sulphate, fluoride, potassium and trace elements according to standard methods [6]. To study the effect of pH on metals release, the pond ashes of RSTPS and CTPS have been taken in 1:20 solid:liquid ratio in five different sets and pH have been adjusted to 2,4,6,8 and 10. After the shaking for 18 hours, the samples were filtered and heavy metals like Mn, Cu, Fe, Zn, Cd, Cr, Ni and Pb have been analysed by Atomic Absorption Spectrophotometer.

To study the long term leaching behaviour and determine the maximum quantity of the heavy metals leached out of the fly ash, a cascade method rather than the column leaching test has been used . In the cascade test, the same quantity of solid residue is extracted a number of times with fresh leaching agent. An advantage over the column test is that a high L/S ratios are reached in much shorter times. In the present test a liquid to solid ratio from L/S = 20 to L/S = 100 has been used. For the leaching test distilled water acidified with nitric acid to pH 4 has been used. In all the experiments shaking has been done for 18 hours. The leachates thus obtained have been analysed for Cu, Mn, Zn, Cd, Pb, Fe, Cr, and Ni.Total metal content in pond ash of RSTPS and CTPS has been evaluated by conc. nitric acid digestion followed by AAS analysis.

Table- 1a Batch leaching experiment (fly ash)

(Parameters in mg/l except pH)

TPS	pH	TH	Ca	Mg	TDS	SO_4	Cl	F	K
RSTPP	11.68	320	108	12.15	343	17.72	12.0	0.45	50.1
CTPS	6.66	80	22.4	3.9	90	42.8	4.0	4.6	28.6

Table-1b Batch leaching experiment (bottom ash)

(Parameter in mg/l except pH)

TPS	pH	TH	Ca	Mg	TDS	SO_4	Cl	F	K
RSTPP	9.8	60.0	18.0	3.65	71.0	12.4	8.0	0.11	15.10
CTPS	7.7	25.0	4.8	3.16	40.0	11.13	4.0	0.275	12.1

Table- 1c Batch leaching experiment (pond ash)

(Parameters in mg/l except pH)

TPS	pH	TH	Ca	Mg	TDS	SO_4	Cl	F	K
RSTPP	8.9	120.0	28.0	12.15	137	14.0	8.0	0.159	40.6
CTPS	7.64	40.0	11.2	2.916	57.0	12.10	4.0	0.992	10.2

Table- 1d Batch leaching experiment (weathered ash)

(Parameters in mg/l except pH)

TPS	pH	TH	Ca	Mg	TDS	SO_4	Cl	F	K
RSTPP	8.5	60.0	16.0	4.86	76.0	7.42	12.0	0.053	4.10
CTPS	7.65	35.0	8.0	3.65	45.0	7.0	4.0	1.08	8.45

Table-2 Release of metals from batch leaching in RSTPP ash

(Parameters in mg/l)

Ash type	Mn	Cu	Fe	Zn	Cd	Cr	Ni	Pb
Fly Ash	0.0033	0.006	0.0352	0.1812	0.0013	0.1894	0.0256	0.0035
Bottom Ash	0.0038	0.0119	0.0658	0.050	0.0006	0.0062	0.0048	0.0143
Pond Ash	0.0033	0.0049	0.0525	0.0604	0.0007	0.0047	0.0127	0.003
Weathered Ash	0.005	0.003	.0867	0.014	0.0003	0.0033	0.0061	0.026

Table- 3 Release of metals from batch leaching in CTPS ash
(Parameters in mg/l)

Ash type	Mn	Cu	Fe	Zn	Cd	Cr	Ni	Pb
Fly Ash	0.2001	0.0051	0.0375	1.8637	0.0024	0.0033	0.0491	0.0124
Bottom Ash	0.004	0.0027	0.149	0.0341	0.0006	0.0071	0.0076	0.0157
Pond Ash	0.012	0.0029	0.0681	0.3185	0.0019	0.004	0.0054	0.0062
Weathered Ash	0.003	0.0031	0.1586	0.0095	0.0005	0.004	0.0102	0.0212

Table-4 Total metal concentration in ash, in mg/kg

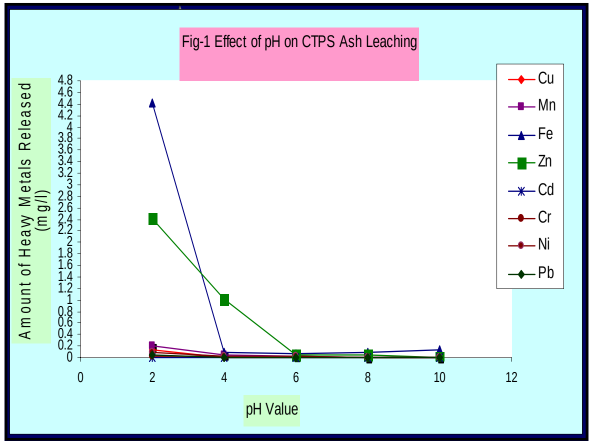
Sample	Cd	Cr	Cu	Fe	Pb	Mn	Ni	Zn
RSTPP	1.0	43.5	27.2	5525	65.3	127	7.6	46.5
CTPS	1.7	16.2	74.7	47750	27.7	1123	21.4	53.3

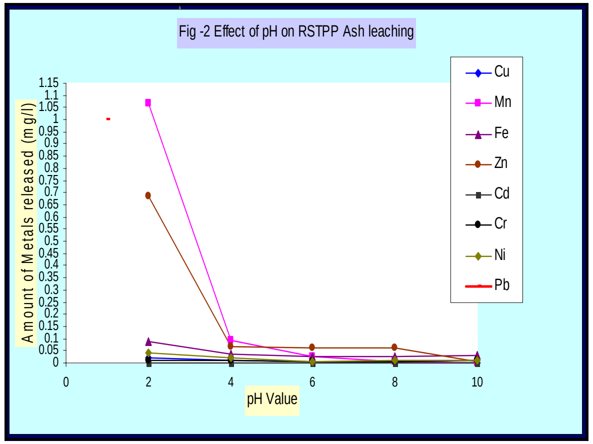
Table-5 Batch leaching experiment (different size fractions) of RSTPP pond ash

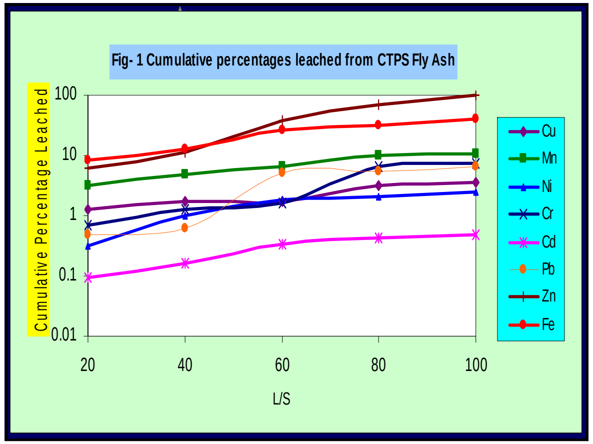
Size Fraction	pH	TH	Ca	Mg	TDS	SO_4	Cl	F	K
+72 (18%)	8.9	65	18	4.86	80	15.014	12	.0865	11.4
-72+100 (25.25%)	8.9	50	12	4.86	95	14.4	6	.0882	6.42
-100 (56.87%)	8.9	45	8.8	4.374	75	12.77	8.8	.115	8.9

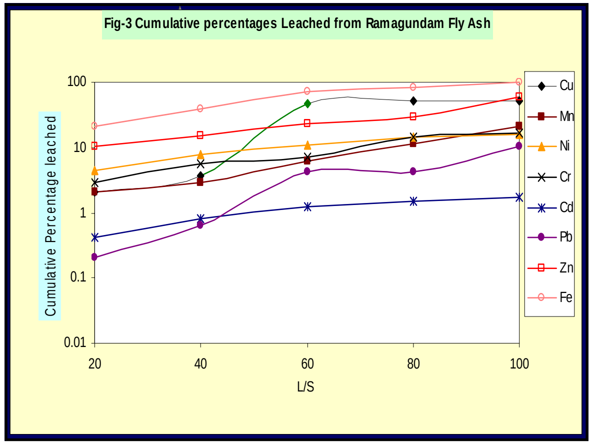
Table-6 Batch leaching experiment (different size fractions) of CTPS pond ash

Size Fraction	pH	T.H	Ca	Mg	TDS	SO_4	Cl	F	K
+72 (33.5%)	7.7	30	6	3.65	40	3.3	8	1.11	7.75
-72+100 (33.87%)	7.6	20	4.8	1.95	30	2.65	4	.996	6.72
-100 (32.62%)	7.6	20	4	2.43	32	1.65	4	.932	5.86









Results and Discussion

Results of batch leaching experiment conducted on fly ash, bottom ash, pond ash and weathered ash of Ramagundam Super Thermal Power Plant and Chandrapura Thermal Power Plant are given in table 1a, 1b, 1c, and 1d. From the results it has been seen that the leachate of NTPC and CTPS fly ashes have maximum amount of all chemical parameters, compare to bottom ash, pond and weathered ash. The weathered ashes showed least amount of chemical parameters in its leachates. Total dissolved solids is an indicator of the total amount of dissolved material in solution. Analysis for Ca using EDTA titration method, specified the amount of calcium in the total hardness. The pH measurements yielded important descriptive information about each leachate, particularly with regard to ability to dissolve metals. The amount of sulphates present in a leachate is an indicator of the trace metals.

The pH range varied from a low of 6.66 for CTPS fly ash to a high of 11.68 for Ramagundam fly ash. The leachates of bottom ash, pond ash and weathered ash of both the places have pH values in between. The total dissolved solids (TDS) values ranged from low of 40 mg/l for Chandrapura pond ash to a high of 343 mg/l for Ramagundam fly ash.

The variations in calcium concentrations for all eight leachates show the same tendencies as the TDS. It has been found minimum of 4.8 mg/l in Chandrapura bottom ash and maximum of 108 mg/l in Ramagundam fly ash.

The sulphates concentrations varied from 7.0 to 42.8 mg/l. Sulphate concentrations show enrichment of acid soluble metal sulphates on the surfaces of ashes. Hence Chandrapura fly ash leachate with maximum of 42.8 mg/l sulphate, exhibits more concentrations of metals than the other ashes leachates. The chloride concentration ranges from low of 4.0 mg/l to high of 12.0 mg/l. Potassium concentration varied from low of 4.20 mg/l in leachate of Ramagundam weathered ash to high of 50.1 mg/l in Ramagundam fly ash. Fluoride concentration varied from low of 0.0537 mg/l in Ramagundam weathered ash to high of 4.6 mg/l in Chandrapura fly ash.

Results of analysis of heavy metals in all leachates are given in tables 2 and 3 for Ramagundam and Chandrapura ashes, respectively. The Chandrapura fly ash leachate contained maximum concentrations of manganese, zinc, nickel and cadmium. The concentrations are 0.2001 mg/l, 1.8637 mg/l, 0.0491 mg/l and 0.002 mg/l, respectively. The Chandrapura weathered ash leachate showed maximum concentration of 0.1586 mg/l of iron. The maximum concentrations of chromium, copper and lead have been found in Ramagundam fly ash, bottom ash and weathered ash leachates as 0.1894 mg/l, 0.0119 mg/l and 0.026 mg/l, respectively. Table 4 indicates the relative distributions of the total metallic components in Ramagundam and Chandrapura pond ashes, studied by complete digestion. High concentrations of iron indicate that it is one of the major components. In general, lower concentrations of heavy metals are present in ashes [8-10].

Trace elements present on the surface of ash particles are the most immediately available for release into aqueous environment. Release of metals from ash surface depend on the pH of the aqueous media. Results of effect of pH on heavy metals released on treatment of Ramagundam and Chandrapura pond ashes are given in Fig.1 and Fig.2, respectively. This reveals that at low pH of 2 maximum metals are released from the surface of the ash into leachate. As the pH increases the dissolution of metals from ash surface decreases. In Ramagundam ash leachates, at pH 2, the order of release of metals is Mn > Zn > Fe > Ni > Cu > Cr > Pb > Cd and in Chandrapura ash, the order of release of metals is Fe > Zn > Mn > Cu >Ni > Pb > Cd > Cr. The variation in order of release of metals may be due to their availability on the ash surface as well as their reactivity at pH 2. Concentration of Cd in leachates of both the places, at all pH were minimum, presumably due to its very low total concentration in ashes.

Cumulative percentages for a number of heavy metals leached out of the two fly ash samples, as a function of the L/S used in the cascade test, have indicated that in Ramagundam fly ash Fe showed the maximum leachability and Cd the lowest. The percentage of leached amounts for the different metals follow the trend Fe> Zn> Cu> Mn> Cr> Ni> Pb> Cd. Similarly in Chandrapura ash Zn showed the highest leachability and Cd the lowest. The percentage of leached amounts for the different metals follow the trend Zn> Fe> Mn> Cr> Pb> Cu> Ni> Cd.

Coal Ash Utilization as Mine Fill

It has been seen that concentrations of chemical parameters in leachates of fresh pond ash and weathered ash showed decreasing tendency. Even fresh pond ash does not contribute alarming concentration of any pollutant in its leachate. The concentrations of heavy metals in all the leachates produced from different ashes, except fresh fly ash, have been found quite low. It seems that the pond ashes from Ramagundam as well as Chandrapura are safe for utilization as mine fill material.

Future Trends

Since a large volume of coal ashes are produced from thermal power plants, the disposal has become very expensive due to strict environmental rules and regulations. The pressure has been increased to find out the ways to safely manage and reuse coal ash, and recover potentially valuable components that it contains. Certain uses of coal ash, where it can be utilized comprehensively, may be as mine fill material and construction material. Other utilization sectors may be recovery of valuable components from it, application in agriculture, preparation of useful materials like zeolites and in roads and embankments. Methods for the mitigation of problems associated with disposal of coal ash may have to be by way of advancement in technology, reducing the dependence on coal, improving the quality of coal by reducing its ash content and finding out ways for the comprehensive utilization of it.

Conclusion

Leachate produced from Ramagundam fly ash showed maximum concentrations of total dissolved solids. Chandrapura fly ash leachate showed high concentration of fluoride in it. Heavy metals like manganese, zinc and nickel are more in fly ash leachate of Chandrapura, whereas chromium is maximum in Ramagundam fly ash leachate. Studies on total metallic components present in the pond ashes indicate that iron is one of the major components and there is variability in heavy metals concentrations. The dissolution of heavy metals from coal ash surfaces in aqueous solution follows a predictable pattern of decreasing release with increasing pH, except chromium. The eight leachates under study further show neutral to alkaline pH and hence metals released from coal ash surfaces have been very less in concentration.

Cascade method give information regarding long term leachability of different metals from fly ash. The laboratory experiment reveals that immediate release of toxic heavy metals from bottom ash, pond ash and weathered ash is not alarming, making them environmentally suitable as mine fill material. Further colum leaching studies are required to be done in all ashes to know their long term leachability characteristics similar to the field conditions. Any coal ash obtained from any thermal power plant must be characterized and leaching studies should be conducted for its suitability evaluation as mine fill material.