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Potential Environmental Hazardous due to Disposal of Ash from Indian Thermal Power Plants

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Abstract

In present study, the leachability of tracing elements of ash collected from three different Indian coal based power plants were investigated. Leaching experiments have been conducted to establish the environmental impact of bottom ash with variation in time duration, pH values and liquid-to-solid (L/S) ratio. During the experimentation liquid-to-solid (L/S) ratio was varied from 20:1 to 60:1. Time duration was taken as 5, 10, 15 and 20 days. The pH value was ordered from 4to7. The leachability of tracing elements Mg, Mn, Cr, Cu, Pb, Zn, Ni, Co, Fe and Mo was investigated to predict the environmental impact disposed bottom ash. Leaching results indicates that the leachate Mn, Mg, Cu, Cr and Zn were present in major proportion while Mo, Fe, Co and Pb appeared in lower proportion. Also, the pH value was found as a highly influencing parameter followed by liquid to solid ratio and time duration.

Keywords: Bottom ash, leaching, toxic element pH.

1. Introduction

The ash generated in coal based Indian thermal power plants is about 350MT during 2015-16 and about 38% coal ash is utilized in various application. However, the huge amount of coal ash (fly and bottom ash) is still disposal in dyke area. These tracing elements may leach out into soil and water during utilization or disposal. The tracing elements present in bottom ash particles causes a potential hazardous to environment and human health (Baba *et al.* 2010, Blissett and Rowson 2012 and Kumar *et al.* 2014). The environmental hazards can be reduces by proper utilization of ash. The extent of tracing elements depends properties of parent coal, melting and formation of new phase materials or oxide (Kim and Lee 2011). Presently, bottom ash is utilizing in civil engineering applications like road construction, concrete, structural fill, embankment and geotechnical applications (Kim and Lee 2011, Kumar *et al.* 2016 and Singh *et al.* 2017). The finer particle of coal ash can be used to improve mechanical properties of geopolymer and other civil engineering application (Cetin *et al.* 2012). But other hand leaching of tracing elements from coal ash causes negative environment impact (Kumar *et al.*2016 and Singh *et al.* 2017). Even through coal ash is not significantly utilized in concrete or geotechnical application which can provide high support to materials. It can also help to provide dense structure with light weight and sound proof. Coal ash can be used as soil amendment to increase nutrient and yield production (Zhang and Solis 2012). The utilization of coal ash residual in fly overs and highway construction has a great potential to reduced solid waste as well as environment risk (Tastan *et al.* 2011). In this article, an attempt has been made to investigate the influence of liquid-to-solid ratio (L/S), time duration and pH on leaching characteristic of bottom ash.

2. Experimental Investigation

Bottom ash samples were collected from Guru Gobind Singh Super Thermal Power Plant, Ropar (India), Guru Nanak Dev Thermal Power Plant, Bathinda (India) and Deenbandhu Chhotu Ram thermal power plant, Yamuna Nagar (India) which are labeled as B.A-I, B.A-II and B.A-III respectively. A number of laboratory tests were conducted to analyze the physio-chemical characteristics of bottom ash samples. Mechanical table top sieve shaker was used to measure the particle size distribution of dry solid bottom ash samples. The specific gravity of ash samples were calculated as per IS: 2386 (Part III) with the help of pycnometer. The gravitational settling method was used to determine the static settled concentration of bottom ash slurries that represents the maximum value of its solid concentration. A digital pH meter was used to determine pH value of the all slurry suspension. Scanning Electron Microscope (Model: JEOL, JSM-6510LV) was used to analyze the surface morphology and chemical composition of solid ash samples. Loss of ignition (LOI) of bottom ash sample was measured by following ASTM C-311 standards.

2.1. Determination of Trace Elements

The tracing metal analysis was performed to investigate the harmful environmental effect produced by the leaching of toxic tracing elements into ground water. The bottom ash samples were completely dried in oven for 6 hour at 120°C to remove moisture. ASTMD-3987 method was used to analyze the presence of tracing elements from all collected bottom ash samples. The leaching experiments were carried out by taking liquid-to-solid ratio (L/S) has been used 20:1, 40:1 and 60:1. Leaching experiments were performed with time duration of 5, 10, 15 and 20 days for 20:1 L/S ratio. The shaking operation was carried out at 100 rpm and 25ºC with Remi orbital shaker. The AAS-4129 (atomic absorption spectrophotometer) was used to analyze the tracing elements by following APHA-1995 standard methods. The water samples were taken from the residential area of thermal power plants for investigation concentration of tracing leached elements present in ground water.

3. Result and Discussion

The scanning electron photograph of ash particles is presented in Figure 1. It is examined that bottom ash is coarser in nature with irregular structure, rough surface texture and dark grey color due unburnt carbon. It is also observed that some of the finer particles like cenosperes were adhered with coarser particles. These cenosperes present in bottom ash samples help as aggregate to develop lightweight concrete and structural materials with sound absorbing tendency (Kim and Lee 2011, Singh *et al*. 2017). From the particle size distribution data, it is noticed that about 62.25, 51.36 and 59.4% particles are coarser than 250 µm whereas only 8.87, 6.52, 7.4% particles are finer than 53 µm for sample B.A-I, B.A-II and B.A-III respectively. The specific gravity of the bottom Samples B.A-I, B.A-II and B.A-III were found as 2.18, 2.25 and 2.15 respectively. EDX Spectroscopy was used to measure the chemical compositions of bottom ash samples which is shown in Figure 2. It is noticed that Al2O3 and SiO_2 are presence in major proportion as compared to FeO, CaO and CO_2 in all samples. The percentage of Al_2O_3, SiO_2, FeO, CaO, and CO_2 are present in bottom ash as 40.29, 52.68, 1.89, 1.27 and 1.56% respectively in sample B.A-I. In samples B.A-II and B.A-III have Al_2O_3 and FeO as 37.46 and 41.54%, 2.05 and 2.22% respectively whereas silica oxide in sample B.A-II and B.A-III is 51.21 and 45.26% respectively. The presence of unburnt carbon content present in ash samples is determined as per standard ASTM C-311. The unburned carbon present on the surface of samples having hydrophobic nature and low density. The value of LOI in bottom ash samples B.A-I, B.A-II and B.A-III were determined as 2.31, 2.95, 3.48 respectively. For measurement of static settled concentration of bottom ash slurries, the initial solid concentration of bottom ash samples were taken as 30% (by weight). The final value of settled concentration was found as 52.89, 51.32 and 53.56% respectively. The pH value of bottom ash sample was measured with help of digital pH meter by taking solid concentration various from 10 to 60% (by weight). The pH value of the all bottom ash suspension lies in the range of 7.28 to 7.54. The pH value of ash suspension shows non-reactive nature. From the pH value data, it is observed that pH of slurry suspension has negligible effect with solid concentration (Zhang and Solis 2008 and Kumar *et al*. 2014).

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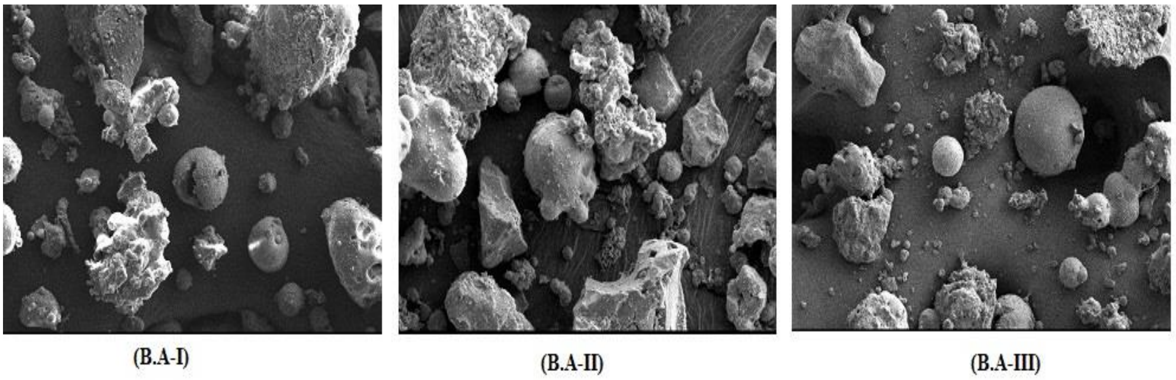
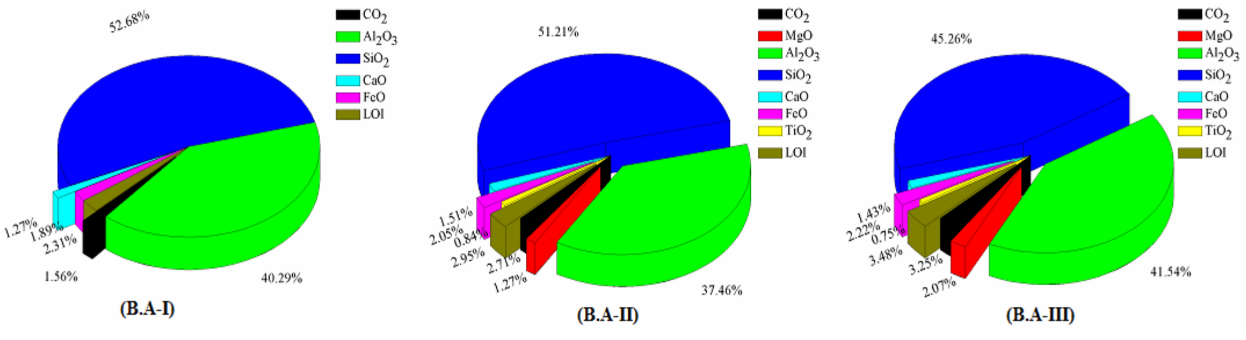

(B.A-I) (B.A-II) (B.A-III)

Figure 1. Morphology of bottom ash particles of sample B.A-I, B.A-II and B.A-III samples



(B.A-I) (B.A-II) (B.A-III)

Figure 2. Chemical composition of bottom ash particles of sample B.A-I, B.A-II and B.A-III samples.

3.1Effect of mixing time duration on pH of slurry suspension

Three bottom ash samples collected from different thermal power plants were used for the investigation. For the preparation of solid suspension of 100 ml capacity measuring cylindrical of 60 mm diameter was employed. The bottom ash slurries of all samples prepared by taking 30% (by weight) intial concentration with water. The variation of pH with time duration of all the slurries samples is presented in Figure 3. The experimental data indicates that as bottom ash is added in water initially for time duration upto 20 minutes for mixing the slurry suspension which cause a sudden increase in pH of slurry suspensions. As the mixing time was increases upto 1 hour, pH value of slurry suspensions gradually increases and almost stabilized afterwards. It was predicted from the experimental data that after two hours of mixing pH of slurry suspension remain unchanged while the equilibrium level was attended after one hours of mixing. This change in pH of suspension may occurred due to the presence of alkaline layer and elements associated with bottom ash particles.

3.2. Tracing element characterization

In the present investigation, leaching of tracing elements like Mg, Mn, Cr, Cu, Pb, Zn, Ni, Co, Fe and Mo from all bottom ash samples were determined. The influence of liquid-to-solid ratio (L/S) on leachate concentration of leaching elements present in the bottom ash is represented in Figure 4. The order of leaching concentration for tracing elements is found as Mg> Mn > Cr > Zn > Cu >Ni > Pb > Fe > Co > Mo, Mg> Mn > Zn > Cr > Cu > Ni > Pb > Fe > Co > Mo and Mn > Mg> Zn > Cr > Cu > Ni > Pb > Fe > Co > Mo for sample B.A-I, B.A-II and B.A-III respectively. The experimental results show that Mg, Mg and Mn has maximum leachability whereas Mo shows minimum leachability for all bottom ash samples in each set of liquid-to-solid ratio (L/S). Similar observation was made by researcher (Baba *et al*. 2010) with coal ash slurry. It is also observed that the leachate concentration of the tracing element increases with increase in liquid-solid (L/S) ratio. The leachate concentration of Mn, Mg, Cr, Zn, Cu, Ni, Pb, Co, Fe and Mo were increases as 41-47, 52-59, 32-39, 27.4-36, 12-19, 12.5-20, 7-11, 1.6-2.4, 6.5-10 and 0.8-1.5 mg/kg respectively with increase in L/S ratio from 20:1 to 60:1 for sample BA-I. The leachate concentration of tracing elements Mn, Mg, Cr, Zn, Cu, Ni, Pb, Co, Fe and Mo in B.A-I, B.A-II and B.A-III bottom ash samples varies from 57-62, 58-66, 31-39, 36-43, 19-24, 13.5-20, 10-12, 2.4-4, 7.5-10, 1.2-1.5 mg/kg respectively at 60:1 liquid to solid ratio

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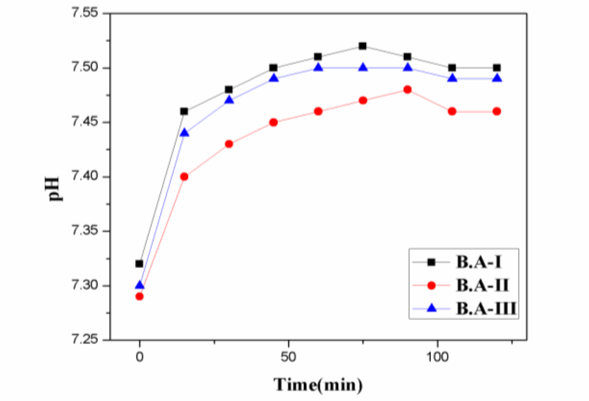

Figure 3. Effect of mixing time on pH of slurry suspension of bottom ash sample B.A-I, B.A-II and B.A-III

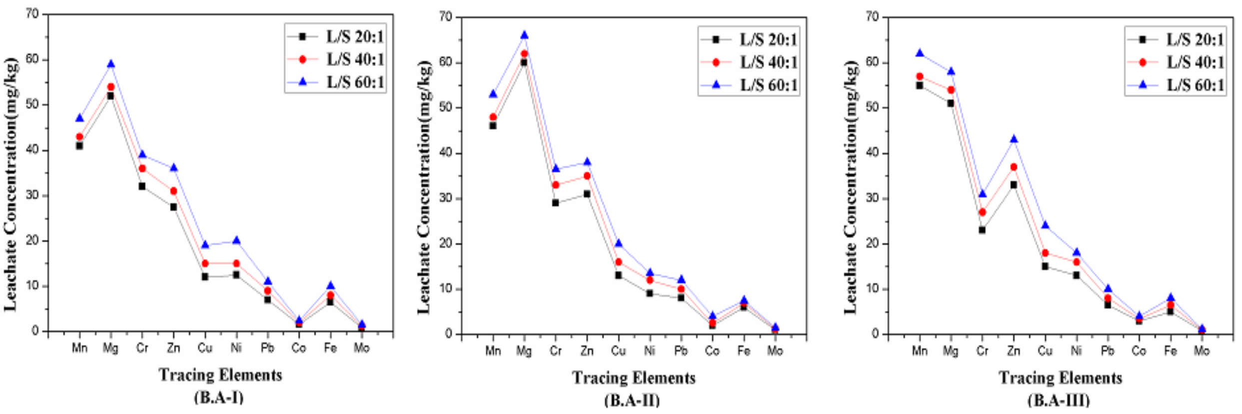

Figure 4. Variation of leachate concentration of tracing element with liquid to solid (L/S) ratio of bottom ash sample B.A-I, B.A-II and B.A-III

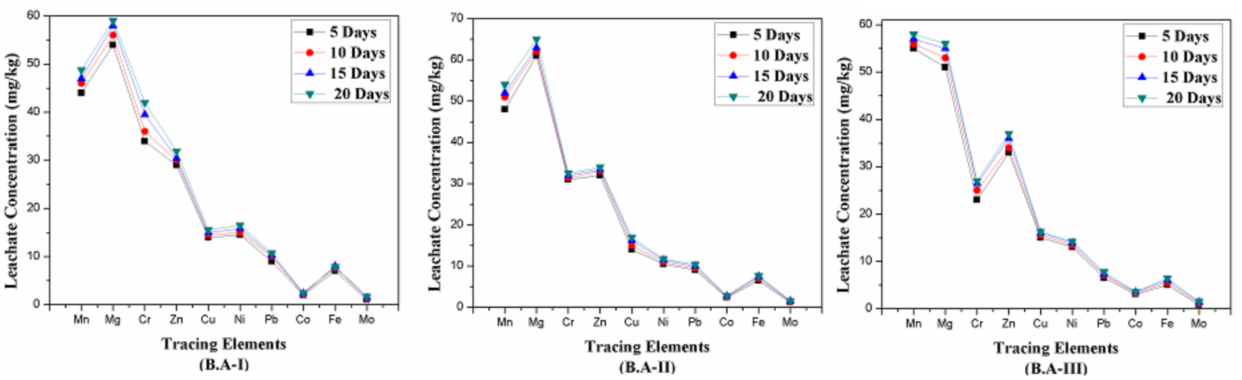

Figure 5. Leaching concentration of tracing elements with change in leaching time of bottom ash sample BA-I, BA-II and BA-III.

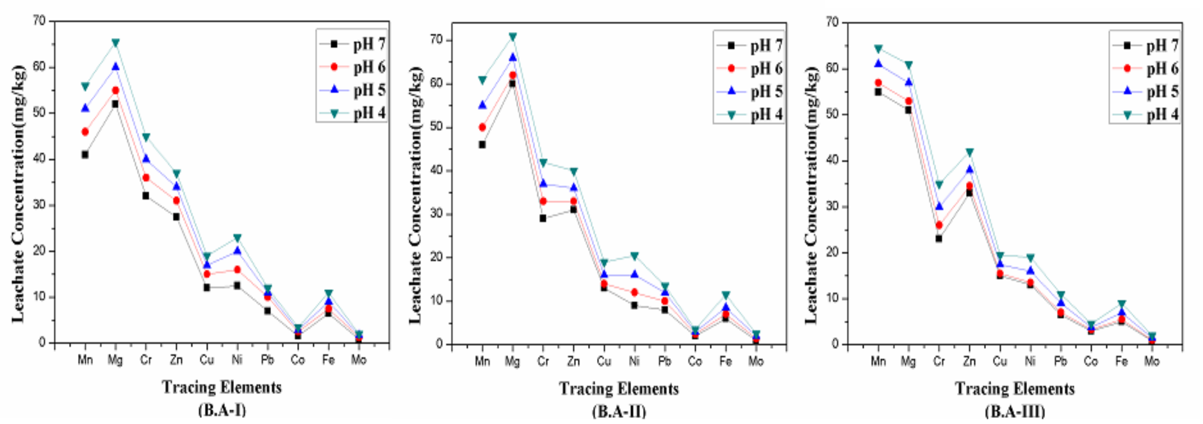

Figure 6. Leaching concentration of tracing elements with variation pH of extraction solution of bottom ash sample B.A-I, B.A-II and B.A-III.

Leaching behavior of bottom ash suspension was investigated with varying time duration of 5, 10, 15 and 20 days. Experimental results show that the leachate concentration of the tracing elements increases with increase in time duration. Moreover, Mn, Mg, Cr, Zn and Cu were leach out with higher proportion as compared to Pb, Fe, Co and Mo. The variation of concentration of tracing elements with time duration in bottom ash B.A-I, B.A-II and B.A-III sample of elements Mn, Mg, Cr, Zn, Cu, Ni, Pb, Co, Fe and Mo as 44-59, 54-65, 24-42, 29-38, 14-17.3, 10.5-16.5, 6.8-10.7, 2-4, 5.5-7.9 and 0.8-1.7 mg/kg respectively as the leaching time duration is increased from 5 to 20 days. The variation leachate concentration of each sample with variation of time by taking 20:1 liquid-to-solid ratio is plotted in Figure 5. The influence of pH on leaching behavior of tracing elements was investigated by taking initial extraction fluid of pH 4, 5, 6 and 7 with 20:1 liquid-to-solid ratio slurry suspensions. The leachate concentration of tracing elements at different pH value is shown in Figure 6. It is noticed that the leachate concentration of tracing element increases with decrease in pH value. Experimental results show that leachate concentration of bottom ash samples B.A-I, B.A-II and B.A-III of elements Mn, Mg, Cr, Zn, Cu, Ni, Pb, Co, Fe and Mo lies in the range of 41-67, 51-73, 23-42, 27.4-43, 12-23, 9-19, 6.5-12, 1.6-5, 5-10 and 0.8-5 mg/kg respectively with change in pH of extraction solution. At pH=4 of extraction solution, the leachate concentration of tracing elements was comparatively high due to release of more heavy metals from bottom ash surface into leachate solution. This also indicates that as the alkaline of extraction solution decreases or its acidic nature increases, the leachate concentration of tracing elements increases. The ground water sample was also collected from residential area of thermal power plants to investigate the harmful effects on human being. The total number of traced elements found from ground water sample are ten. Leaching concentration of tracing elements in ground water sample is represented in Figure7. Result data shows that tracing elements Mg, Cu, Co, Zn and Mo are found lower than the prescribed limits of WHO whereas Mn, Pb Fe, Cr, and Ni cross the limits of drinking water. The tracing elements effects human beings and causes serious health issues such as skin damage, liver failure, heart attack, nervous system damage and lung tumor etc. The leaching of toxic metal elements can be minimize by using better quality of coal and disposal of ash with high concentration (Blissett and Rowson 2012 and Singh *et al*. 2016).

4. Conclusions

In present study, the leaching characteristics of bottom ash was investigated. The disposal of the bottom ash results in higher environmental risk. The elements Pb, Cr, Zn, Ni, Mg, Mn, Fe and Cu are found most abundant elements while Mo and Co are the least abundant elements. In sample B.A-I and B.A-II Mg have maximum leachability where as in B.A-III Mn mi maximum leachability with minimum leachability of Mo in all samples. The tracing

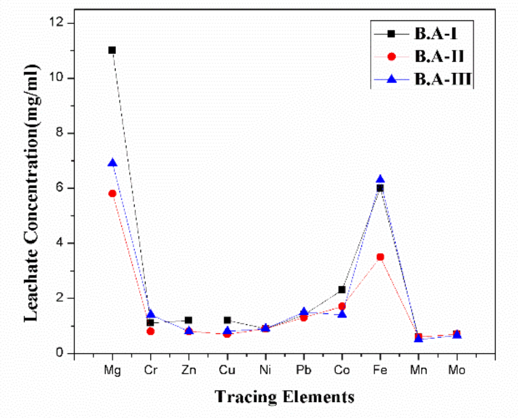

Figure 7. Concentration of various tracing elements in nearby ground water samples B.A-I, B.A-II and B.A-III

elements such as Mg, Cu, Co, Zn and Mo are under the standard permissible limits of WHO whereas Mn, Pb Fe, Cr, and Ni cross these limits. The leachate concentration of tracing element increases with increases in liquid to solid ratio and time duration while decrease with pH value. The pH value found as highly influencing parameter followed by liquid to solid ratio and time duration.

References

Baba A., Gurdal G. and Sengunalp F. (2010), Leaching characteristics of fly ash from fluidized bed combustion thermal power plant: Case study, Çan (Çanakkale-Turkey), *Fuel Processing Technology*, **91**, 1073–1080.

Blissett R. and Rowson N. (2012), A review of the multi-component utilization of coal fly ash, *Fuel*, **97**, 1-23.

Cetin B., Aydilek A.H. and Guney Y. (2012), Leaching of trace metals from high carbon fly ash stabilized highway base layers. *Resources Conservation Recycling*, **58**, 8–17.

Hower J.C., Sakulpitakphon T., Trimble A.S. and Schram W.H. (2006), Major and minor element distribution in fly ash from a coal-fired utility boiler in Kentucky,

Kim H.K. and Lee H.K. (2011), Use of power plant bottom ash as fine and coarse aggregates in high-strength concrete, *Construction and Building Materials*, **25(2)**, 1115–1122.

Kumar S., Gandhi B. K. and Mohapatra S. K. (2016), Leaching characteristics of bottom ash from thermal power plants, *Energy Sources Part A Recovery Utilization and Environmental Effects*, **28**, 79–95.

Kumar S., Gandhi B.K. and Mohapatra S.K. (2014), Performance characteristics of centrifugal slurry pump with multi-sized particulate bottom and fly ash mixtures, *Particulate Science and Technology*, **32**, 466−476.

Mishra U.C. (2004), Environmental impact of coal industry and thermal power plants in India, *Journal of Environmental Radioactivity*, **72**, 35−40.

Singh G., Kumar S., Mohapatra S.K. and Kumar K. (2017) Comprehensive characterization of grounded bottom ash from Indian thermal power plant, *Journal of Residuals Science and Technology*, **14 (1)**, 1-10.

Singh M. K., Kumar S. and Ratha D. (2016) Physiochemical and leaching characteristics of fly and bottom ash, *Energy Sources Part A Recovery Utilization and Environmental Effects*, **38(16),** 2377-2382.

Tastan E.O., Edil T.B., Benson C.H. and Aydilek A.H. (2011), Stabilization of organic soils with fly ash, *Journal of Geotechnical and Geoenvironmental Engineering*, **137–139**, 819–933.

Zhang J. and Solis R. (2008), Fly ash stabilizes gypsiferous soil as embankment material, *Earth and Environmental Science*, **6**, 809–814.