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DETERMINATION OF TREND OF TOXIC METALS IN LEACHATE SOLUTION OF DIFFERENT MIX PROPORTION OF MINE OVERBURDEN AND FLY ASH

Anupam Kaushik [1], Dr. Sindhu J. Nair [2]

M .Tech. Scholar, Environment Science and Engineering, Department of Civil Engineering, Bhilai Institute of Technology, Durg, Chhattisgarh, India[1]

Professor, Department of Civil Engineering, Bhilai Institute of Technology, Durg, Chhattisgarh, India[2]

Abstract: Global energy demand is set to increase by almost 50% in the period 2016 to 2040. Much of this growth will continue to be concentrated in the developing world, primarily China and India, as industrialization, population growth and the unprecedented expansion of the middle class will propel the need for energy in general and coal, in particular. The Indian coal is of low grade having high ash content of the order of 30-45% producing large quantity of fly ash at coal/lignite based thermal power stations in the country. The management of fly ash has been troublesome in view of its disposal because of its potential of causing pollution of air and water. To minimize such effects Ministry of Environment, Forest and Climate Change (GoI) has given approval to use fly ash for backfilling of opencast mines, stowing of abandoned mines and filling of low laying areas. All the heavy metals found in fly ash—nickel, cadmium, arsenic, chromium, lead, etc—are toxic in nature. They leach into the surrounding soil and can enter food-chains, ground water. Proposed study incorporates ash leachate analysis using laboratory method. This study aims to identify trend of toxic metals in leachate solution of different mix proportion of mine overburden and fly ash.

Keywords: Fly ash, leachate, mine overburden.

1. INTRODUCTION

The generation of fly ash is increasing every year in India as now-a-days a huge quantity of coal is combusted in thermal power plants to produce electricity for fulfilling our increasing energy demands. From a report published by the Ministry of Environment and Forests, Govt. of India, it was found that in the year 2015-2016 the status of fly ash generation from 151 thermal power stations in India is about 176.7441 million tonnes [1]. The Ministry of Power, Government of India estimates that 1800 million tonnes of coal used every year leading to generation of 600 million tonnes of fly ash by 2030-31. This large quantity occupies a vast area for its disposal. It also leads to many health and environmental hazards. Therefore, it is very important to develop some suitable scientific, technical and economic solutions for fly ash utilization. To reduce these fly ash related problems, Ministry of Environment & Forests (MoEF) has issued various notifications on its utilization. They prescribed to achieve 100% fly ash utilization in a phased manner for all Coal/Lignite based Thermal Power Stations in the country. History tells us that the utilization of ash is not a new idea; it was started about 2000 years ago when the Romans built the Colosseum by using volcanic ash in the year 100 A.D which is a very good example of durability. From the report published by the Central Electricity Authority, New Delhi in the year 2015-16 it can be observed that in the Year 2015-16, 60.97 % of the total fly ash were utilized. The State of Delhi has achieved maximum level of fly ash utilization level and the States of Gujarat, Haryana, Jharkhand, Punjab, Rajasthan, Tamil Nadu and West Bengal have also achieved the fly ash utilization level of more than 75% [2]. Now-a-days fly ash has been used for various purposes: for producing 'green building' materials, construction of roads and embankments, for improving the property of the soil and thereby increasing the agricultural yield, as mine back filling material, as a low-cost adsorbent (zeolites) for the removal of organic compounds or heavy metals etc. Arora and Aydilek [3] evaluated the engineering properties of Class F fly ash amended soils as highway base materials. Fly ash is also been used to manufacture different items like doors, flooring tiles, false ceilings, etc. In the present paper, utilization of fly ash in India in the fields of mine back filling is reviewed. Ministry of Environment, Forest and Climate Change (GoI) has given approval to use fly ash for backfilling of opencast mines, stowing of abandoned mines and filling of low laying areas. This idea also attracts our focus towards leachate generation after backfilling and stowing of abandoned mines which can percolate into ground water. Presently mines which are located nearby thermal power plants are using fly ash with their mine overburden to backfill their mine voids. The aim of this study is to find trend of toxic metals in leachate solution in different mix proportion of mine overburden and fly ash.

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2. METHODS AND MATERIALS

2.1 Methods

Laboratory Leaching tests of mine wastes are typically performed using procedures that fall into two basic categories: batch and continuous. These categories are analogous to batch and continuous reactor methods used in metallurgical processing. Batch reactors for leaching tests can be in the form of a closed vessel, a cell, or a column. A continuous reactor for leaching tests usually takes the form of a column. There are many variations on these two types, and what looks like a column leach test apparatus may actually be configured as a batch test, depending on the test design.

The column test is run in up-flow mode. The leachate is de-mineralized water (DMW). The test material should have a particle size < 4 mm. This procedure addresses both inorganic and organic contaminants. Column leaching tests are considered as simulating the flow of percolating groundwater through a porous bed of granular material as shown in figure 1. The flow of the leaching solution may be in either down-flow or up-flow direction and continuous or intermittent. The flow rate is generally accelerated when compared to natural flow conditions. However, it should be slow enough to allow leaching reactions to occur. A basis assumption in column leaching is that the distribution of the leaching solution is uniform and that all particles are exposed equally to the leachate solution. Precipitation or sorption within the column may affect the results. Column experiments more closely approximate the flow conditions, particle size distribution and pore structure, leachate flow, and solute transport found in the field (4). Column experiments can be conducted in both saturated and unsaturated conditions. Unsaturated conditions are usually intended to mimic vadose zone placement. Intermittent addition of a given volume of leachate solution at the top of the column can provide uniform distribution of the fluid and approximate a constant fluid front moving through the unsaturated column. Saturated columns are obtained by a constant fluid flux and allowing the fluid to pond at the top of the column. Variables, such as leachate collection, sampling frequency, leachate flow rate, and duration of the experiment are determined by the experimental objectives (5). In a report to EPRI (3), static (batch) and dynamic (column) methods were compared. Based on a review of the literature, batch systems tend to be inexpensive, simple, and they generate chemical data for mechanistic applications. Column methods are more expensive and more operationally complex, but they generate results that reflect real systems subject to fluid flow and solute transport.

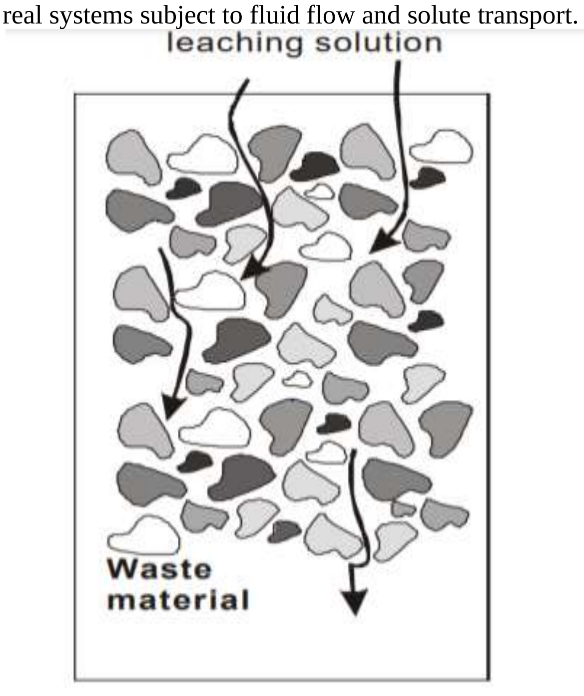

Figure 1: Percolation of water through waste material

Continuous column leach tests are typically conducted by filling a length of pipe or tubing with a solid sample and continuously passing water (or another leachate) through the sample for a specified period. Leachate samples can be collected at any desired frequency and analyzed for any constituent of interest. There are many variables in column leach test design, including:

- Column length and diameter
- Flow type (forced flow from bottom or gravity flow from top)
- Flow rate/residence time
- Sample pretreatment (particle size reduction, oxidation, bacterial inoculation)

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- Leachate composition (water or other reagent to remove O2, etc.)

Column tests are well-suited to determining the concentrations of constituents that can be released over a relatively small number of pore volumes, which corresponds to shorter time periods. The design of a typical column leach test apparatus is depicted in Figure 2.

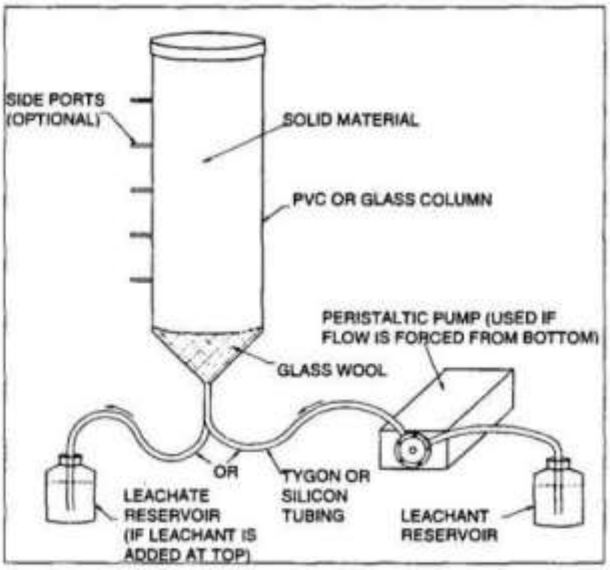

Figure 2: Typical arrangement of column test

Samples of mine overburden were in boulders form which are crushed and sized to suit column test. For this study fly ash and mine overburdens were mixed in different ratio and separate column tests were performed for each mixture. The samples are allowed to mix with demineralized water so that it mix thoroughly and leachate can be produced. For the purpose of the same test duration is kept for approximately 7 days. The setup for column test is shown in figure 3.The leaching effluents coming out from specimens through the outlet of the permeability moulds were collected. The leachate samples were analyzed for the metals Pb, Ni and Cr by an Atomic Absorption Spectrophotometer.

Figure 3: Laboratory setup for column test

2.2 Materials:

The sample of fly ash was collected from nearby local thermal power plant and sample of mine overburden was collected from near by mines area. The samples were collected in a manner that they represent to whole volume. The chemical composition of and physical properties of fly ash and mine overburden are represented in table 1 and table 2 respectively. After observation of chemical composition of fly ash and mine overburden it is found that major chemical

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component are silica, aluminum and iron. However, from physical composition it is found that silt is major component in fly ash and overburden both.

Table 1: Chemical Composition of Mine Overburden and Fly Ash (Weight %)

Constituents	Mine Overburden	Fly Ash
SiO_2	48.2	52.3
Al_2O_3	30.03	33.5
Fe_2O_3	7.8	5.95
CaO	1.05	0.49
K_2O	0.30	1.35
MgO	1.30	0.55
TiO_2	0.65	3.0
Na_2O	0.1	0.16
LOI	10.57	2.7

Table 2: Physical Composition of Mine Overburden and Fly Ash

Property	Mine Overburden	Fly Ash
Specific Gravity	2.4	2.14
Clay (<0.002 mm)	12.8	2.85
Silt (0.075 mm to 0.002 mm)	44.23	76.01
Sand (4.75mm to 0.075 mm)	31.88	21.14
Gravels (>4.75 mm)	11.09	---

3. RESULT AND DISCUSSION

The analysis of leachates from different mixtures gives results as shown in table 3.

Table 3: Leachate Analysis After 7 Days of Flow

Mix Ratio in %		Metal (PPM)		
Overburden	**Fly Ash**	**Pb**	**Ni**	**Cr**
60	40	0.213	0.037	0.610
70	30	0.198	0.028	0.395
80	20	0.115	0.021	0.205
90	10	0.089	0.0068	0.132

Based on above results we can get trend of metals present in different overburden and fly ash mix ratio, which is presented in figure 4.

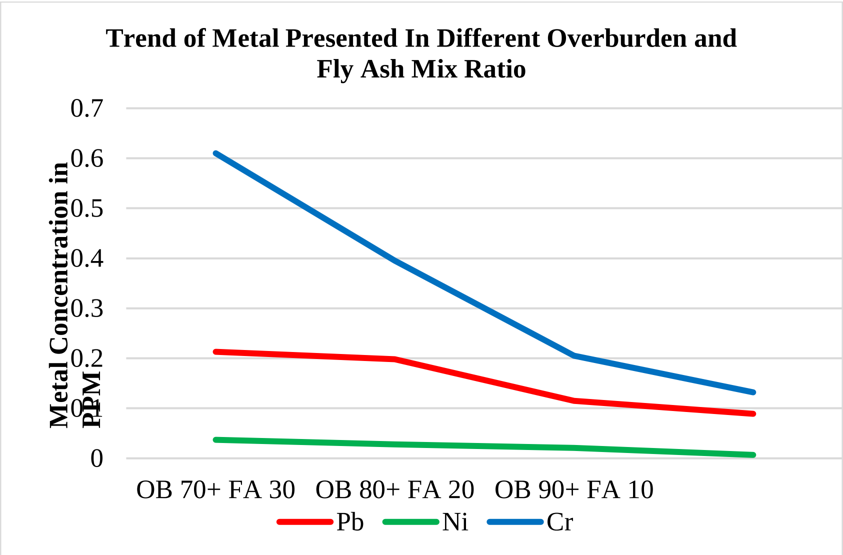

Figure 4: Trend of metal concentration in leachate solution of different mix ratio of mine overburden and fly ash.

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Based on this study and after analyzing of results and trends following points are observed:
1. Toxic metal compounds are decreasing this increase in mine overburden percentage.
2. Nickle is least present toxic metal in leachate.
3. Chromium is most present toxic metal in leachate.
4. All metals presented in leachate are below the threshold limit. Threshold value for maximum contaminant level is considered as 100 times the allowable limit reported elsewhere [6], [7].

4. CONCLUSION

Based on this study and its results it can be concluded that the toxicity of leachate decreases as percentage of mine overburden increase. However, optimum mix ratio depends on ground conditions, availability of mine overburden and fly ash, cost of transportation of fly ash etc. But based on this study it is observed that mix ratio of mine overburden (above 60%) and fly ash can be used for backfilling of mine voids as concentration of Pb, Ni and Cr are well below the threshold limit. In continuation of this study, authors suggest for study of stability of backfill area by investigating physio-mechanical properties of backfill material in different mix ratio of mine overburden and fly ash along with leachate analysis.

5. ACKNOWLEDGEMENT

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