Fly Ash Utilisation for Value Added Products
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Amendment of flyash by vermitechnology for agricultural application

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ABSTRACT

Vermitechnology may be used for amending fly ash for agricultural applications. Applying vermitechnique it is possible to convert fly ash into manure or base soil by properly supplementing it with organic component and making use of the major and micro plant nutrients present in fly ash. The earthworms can survive and multiply in fly ash contaminated medium upto a certain level beyond which their growth and proliferation are impaired. The earthworms can convert soluble lead present in the soil into plant unavailable form within 60 days.

***Key words** : Flyash utilisation, Vermitechnology; Agricultural application*

1.0 INTRODUCTION

Fine particles of inorganic mass resulting from the burning of coal or fossil fuel in thermal power plants or coal based industries are generally known as fly ash. The name underscores the fineness of the particles and their tendency of being air borne easily. Average ash content of Indian coal generally ranges between 30-40%. India has a network of seventy power plants spread all over the country[1-2]. The per anum generation of fly ash is about 60 million tones. Considering 10% annual growth in power generation through thermal power plants, the annual fly ash generation is expected to exceed 100 million tones by 2000 A.D[3].

Fly ash gets air borne very fast and pollutes the environment. Long inhalation of fly ash causes silicosis, fibroses of lungs and bronchitis etc[3]. With changes in the environmental condition, the leaching of the toxic heavy metals present in fly ash eventually contaminate the ground water. Fly ash disposal in the sea or in the river disturbs the aquatic environment. Slurry disposal tanks become the breeding ground of mosquito and bacteria[3].

Fly ash also contains a number of toxic metals like Cr, Pb, Hg, Ni, V, As and Ba[4,5]. These metals when present in the soil hinder the nutrient uptake of the plants[5]. It was observed that with 20% fly ash contamination of the soil, decrease in the bacteria, actinomycetis and fungal population were 57, 80, 87% respectively.

The utilization of flyash in India is 3-5% as compared to 30-80% in developing countries. The applications range from land filling to high value flyash based ceramic products. However, land filling can no more be considered as a flyash disposal scheme as the fine particles of fly ash change the soil texture by reducing the porosity of the soil. Also, it has been argued that the natural weathering causes leaching of the toxic heavy metals from flyash to natural aquifer thereby contaminating the groundwater. In many developing countries landfilling has been restricted because of the unavailability of enough land for filling.

Agricultural application of fly ash has a great potential as it has been contemplated that fly ash can be a substitute for base soil and/or manure. This is even more significant in view of the fact that the agricultural load on the land is continuously increasing with the increase in population. Flyash matrix being essentially inorganic in nature can not be directly put to agricultural use, as it does not possess the necessary carbon and nitrogen required for any soil suitable for cultivation. Also, it has been argued that flyash contains a number of toxic heavy metals, which not only do not have any known nutrient value but also hinder the pick up of other micronutrients by the plants.

However fly ash also contains a number of other elements which are essential major and micronutrients for plants and vegetables. Unfortunately, this virtue of fly ash has not been exploited to the extent it was desirable. Available studies on the agricultural application of flyash either deal with the amendment of soil with flyash or pollution caused by the heavy metals present in fly ash to plants and vegetables. Khan and coworkers studied the effect of varying levels of fly ash on pH, electrical conductivity and available major plant nutrients in an alkaline fine sandy loam soil of Aligarh[3]. Sarkar and coworkers studied the growth of certain tree species in flyash amended soil[6]. The species were, Subabul *(Leucaena leucocephala)*, Chakundi *(Cassia siamea)*, Black siris *(Albezzia lebbek)*, Shisam *(Dalbergia sisoo)* and Gamhar *(Gmelina arobera)*. Mathur and coworkers studied the effect of heavy metals present in flyash on plant species Ipomea carnea, Typha angustata and Calotropis procera.[7]

Vermitechnology has been identified as a convenient option for solid waste management because of its simplicity, user friendly approach and high return on investment. Municipal or paper mill solid wastes have been successfully converted into vermicomposts using certain earthworm species. However, except some sporadic attempts no effort has been made to apply vertmitechnology for treating fly ash. The present work describes the possibility of using vermitechnology for the purpose of amending flyash for agricultural applications. As a feasibility test for applying vermitechnology to fly ash, the same was applied to a number of soil samples synthetically doped with heavy metals, commonly occurring in fly ash, in varying concentrations. The results were encouraging and the technique was extended to flyash amended with organic component. This communication will present the results of vermi experiments carried out at National Metallurgical Laboratory on lead contaminated soil and some preliminary results on actual flyash.

2.0 MATERIALS AND METHODS

2.1 Earthworm species

Earthworm species were collected from a nullah in Jamshedpur through which the industrial effluents were discharged into the river.

2.2 Preparation of earthworm bed and the experiment

For synthetically doped soil samples, dried cowdung and soil were evenly mixed together. For each metal, three beds were prepared in plastic trays of size 2ft.x1ft. In each tray 400 g mixture of soil and cowdung were kept and the trays were watered to maintain the moisture content at 45-50%. This moisture level was preserved during the entire course of the experiment. Aqueous lead nitrate solution was added to each tray in measured quantity so as to make the final concentration of lead in the soil of three trays around 100, 200 and 500 mg/kg respectively. The metal solution was mixed with the soil thoroughly to ensure homogeneity. Each tray was kept for a week before 25 earthworms were released into it. The day of releasing earthworms was marked as d_0. The experiment was continued for a period of 60 days and the last day of the experiment was marked as d_{60}. Soil samples were collected for chemical analyses on d_0 and d_{60}.

Fly ash bed was prepared with soil, cowdung and fly ash. Soil and cowdung were evenly mixed in 5:2 ratio. Six beds were prepared in buckets of 9 inch dia and 10 inch height. The total weight of the fly ash and the soil and cowdung mix was 700 g in all the six beds. However, fly ash was added in measured quantity so as to make the proportion of fly ash in six beds as 5%, 10%, !5%, 25%, 40% and 50% respectively. No external metal was added to the fly ash beds. All the six beds were watered to maintain the moisture content at 40-45%. The beds were kept for a week before 25 earthworms were released into it. The experiment was continued for 60 days. Soil samples were collected on d_0 and d_{60} for chemical analyses.

On d_{60}, a number of earthworms were also collected and analysed for the accumulation of metals in earthworm tissues.

2.3 Chemical analysis

All the soil samples were demoisturised at 110°C before they were analysed. Thus the results presented in this communication are all on dry basis. For total metal concentration HCl-HNO_3-$HClO_4$ tri-acid mixture was used for digesting the soil samples. For the available metal concentration, DTPA extraction scheme was adopted. Reagents used were all of AR grade. 18 M (ASTM Grade 1 Nanopure water was used for making the solutions. All the metals were analysed by GBC 908 AA atomic absorption spectrometer.

3.0 RESULTS AND DISCUSSION

Table 1 lists the trays prepared for the present study and their detailed composition. Table 2 describes the population status of the earthworms released in the trays on d_{60}. It can be seen that in Tray 1, where the lead concentration was about 100 mg/kg, the number of earthworms increased though in subsequent trays where the lead concentration was further increased the number of earthworms dwindled. Expectedly in tray 3, where the lead concentration was about 500 ppm, the number of earthworms on d60 was minimum. This clearly indicates that the earthworms can multiply in the soil contaminated with at least 100 mg/kg of lead. It is however, not possible to comment at this stage about the comfortability level of earthworms in soil contaminated with 100 mg/kg of lead. However, this may be safely inferred that the earthworm species could tolerate soil contaminated with at least 100 mg/kg of lead. In the case of fly ash the earthworms multiplied in trays 4, 5 and 6, though in decreasing order. Thereafter the numbers steadily decreased. Thus it was clear that for the present set of experimental condition, the earthworms could stand maximum 25% of fly ash amendment and beyond which they failed to tolerate. The final weights of the earthworms are in accordance with their numbers for both lead contaminated soil and fly ash.

Table 1 : Detailed composition of trays prepared for vermitreatment

	Soil (g)	*Cowdung (g)*	*Fly ash (g)*	*Total Wt. (g)*	*% Fly ash amendment*
Tray 1	-	400	-	400	-
Tray 2	-	400	-	400	-
Tray 3	-	400	-	400	-
Tray 4	475	190	35	700	5
Tray 5	450	180	70	700	10
Tray 6	425	170	105	700	15
Tray 7	375	150	175	700	25
Tray 8	300	120	280	700	40
Tray 9	250	100	350	700	50

Table 2: Population status of earthworms in different trays on d_{60}

	No. of earthworms in d_0	No. of earthworms in d_{60}	Wt. of earthworms in d_0(g)	Wt. of earthworms d_{60}(g)
Tray 1	25	34	7.1	9.1
Tray 2	25	23	7.9	5.2
Tray 3	25	11	7.1	2.6
Tray 4	25	49	8.4	11
Tray 5	25	37	7.6	8
Tray 6	25	39	9.1	10.5
Tray 7	25	21	9.3	7
Tray 8	25	9	9.3	2.4
Tray 9	25	6	8.7	2.5

Table 3 lists the chemical analyses data for soil samples collected from tray 1,2,3 on d_0 and d_{60}. Total and available lead concentrations have been determined for each of the soil samples. Also given in the Table 3 are the lead accumulation in earthworm's tissues.

Table 3: Total and available lead contents (mg/kg) in different soil samples collected on d_0 and d_{60} and total lead content (mg/kg) in earthworm tissue

	Tray 1	Tray 2	Tray 3
Metal contents in earthworm's body	200	20	100
Total metal in d_0	100	200	511
Total metal in d_{60}	300	309	548
Available metal in d_0	30	40	92
Available metal in d_{60}	10	15	20
% Immobilization	66.6	62.5	76

Table 3 makes a number of interesting observations. It may be seen that in all the three trays consistently total lead concentration is more in d_{60} than in do. Ideally, the total lead concentration should be same in d_0 and d_{60}. However, the data in Table 3 clearly indicates that there is a preconcentration of lead in the earthworm cast. The rate of this preconcentration, however, decreases as the lead contamination increases.

The most interesting and important observation of Table 3 is reflected on comparing the available lead concentration of d_0 and d_{60} soils in all the trays. While one observes steady increase in the total and available lead concentrations in d_0 soil as one moves from tray 1 to tray 3, the corresponding available lead concentrations in d_{60} samples almost constant. This observation has a very far reaching implication. For agricultural soil, the available metal concentration is most important to the plants. That the d_{60} samples show stabilized available lead values even when the total and available lead values in the corresponding d_0 are quite high only convincingly show that the earthworms have the capability to convert the plant available lead to plant unavailable lead. Thus, inspite of the toxic lead being present in the soil in an appreciable amount, it will not be available to the plants and the soil should behave as a safe soil. Based on these data, a new term percent immobilization has been defined which quantifies as to what percentage of the available metal before the vermitreatment has been made unavailable to the plants after vermitreatment. It is also interesting to observe that even under varying experimental conditions, the percent immobilization figure is similar and in fact it is highest in the most polluted environment. It is however felt that before this observation is put to actual agricultural practice further research needs to be carried out to identify the length of the experimental cycle necessary to declare the contaminated soil fit for vegetation.

4.0 CONCLUSION

Present study concludes the following

* Vermitechnology may be used to amend fly ash for agricultural application. The resultant medium may be used as base soil or manure.
* Earthworms can survive and multiply in soil amended with 25% fly ash.
* Earthworms can survive and multiply in soil contaminated with at least 100 ppm of lead
* The earthworms preconcentrate lead in their cast.
* The available lead concentration in the cast is less than the available metal concentration of the untreated soil.

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