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WASTE MANAGEMENT OF LIGNITE FLYASH THROUGH VERMICOMPOSTING BY INDIGENOUS EARTHWORMS EISENIA FETIDA.

Dr. Bishnu Charan Pradhan

Dept. of Zoology, Angul Mahila Mahaqvidyalaya, Angul. 759122.

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***Corresponding Author**
Dr. Bishnu Charan Pradhan
Dept. of Zoology, Angul Mahila Mahaqvidyalaya, Angul. 759122

ABSTRACT

Fly ash is an amorphous ferroalumino silicate, an important solid waste around thermal power plants. It creates problems leading to environmental degradation due to improper utilization or disposal. However, fly ash is a useful ameliorant that may improve the physical, chemical and biological properties of soils and is a source of readily available plant macro and micronutrients when it is used with biosolids. In view of the environmental problems generated by the large scale production of flyash, increasing attention is now being paid to the recycling of flyash as a good source of nutrients. To reduce the cost of disposal of flyash and best utilization, it was planned to convert the flyash into a valuable vermicompost. This study explored the potential role of indigenous earthworm *Eisenia fetida* to convert the flyash into best manure. Three combinations of cowdung and flyash such as 1:1 (T_1), 2:1 (T_2) and 3:1 (T_3) were prepared. Among the three T_3 showed the best result in which higher N, P, K and lower OC were observed.

KEYWORDS: *Eisenia fetida*, Vermicomposting , Liginite wastes, Flyash , Macro nutrients and management.

INTRODUCTION

In India and most country major source of electrical energy is coal based thermal power plants, which produce 100 million t per year of coal combustion residues, called as fly ash, as a solid waste. Fly ash, the fine material (60-70%), which has a size below 0.075 mm is a byproduct of pulverized coal fired thermal power station. Its disposal poses a serious problem considering storage space and cost involved in it and dust pollution arising out of its fineness. It has been proved that fly ash can be advantageously used as source of essential plant nutrients like calcium, magnesium, potassium, phosphorus, copper, zinc, manganese and iron in different agro-climatic conditions and soil types in different parts of the country using different doses (10-500 t ha^{-1}) It is also boosting crop growth and yield in wheat, maize, mustard, soybean ground nut etc. Fly ash increases the yield in various crops by 20-25% with high nutritional value.

Fly ash, a resultant of combustion of coal at high temperature, has been regarded as a problematic solid waste all over the world. The conventional disposal method for fly ash leads to degradation of arable land and contamination of ground water[1]. The repeated exposure of fly ash causes irritation in eyes, skin, nose and results in arsenic poisoning.

Coal combustion product generated each year in India is more than 100 mt per annum of which 4 mt is released into the atmosphere. Coal combustion by-products were largely treated as waste materials. In fact, fly ash consists of practically all the elements present in soil except organic carbon and nitrogen. It was found that this material could be used as and additive/amendment material in agriculture applications. A careful assessment of soil and fly ash is required before its application as a soil-ameliorating agent.[1] The present outlets of fly ash disposal are using cement, concrete and grout industries[4] but such use only accounted for 38% of fly ash produced by thermal power stations.[5] The major problem faced by the coal/lignite thermal power stations all over the world is the handling and disposal of ash. In the thermal power station of theNalco ,Angul Odisha., India, ash pond spreads over an area of more than 50 ha and causes serious environmental hazards besides occupying fertile, cultivable land. Mixtures of fly ash with organic waste have been tried by several authors

Menon (36) studied the effect of mixed application fly ash and organic compost on soil and availability and uptake of elements by various plant species. Very little is known regarding the effects of fly ash amendment on soil biological properties. Use of fly ash as a soil-amending agent has been investigated for a variety of crops. Fly ash acts as a potential dust insecticide against various pests infecting rice, vegetables *etc*. And also fly ash as a carrier in pesticide formulation and the role of fly ash in soil properties have been studied by several workers.

The beneficial effect of earthworm on soil has been attributed to increase microbial populations and biologically active metabolites such as plant growth regulators.[16] Recycling of wastes through vermitechnology reduces the problems of non-utilization of agrowastes.[17]The quality and amount of food available influences the size of earthworm populations. The earthworms that are employed in organic wastes mixed with soil, to a certain extent accumulate toxic metals and after vermicomposting they can be re-employed for the same purpose Flyash is the portion of the combustion residue of coal and lignite that enters the flue gas stream in power-generating facilities and consists of many small, glass like particles ranging in size from 0.01 to 100 µm.[10] Flyash is a serious source of air pollution since it remains air borne for a long period of time and causes health hazards.[59] Besides being a health hazard, flyash also degrades the environment, Gupta *et al*.[18] reported that flyash interferes with the photosynthesis of aquatic plants and thus disturbs the food chain. The largest commercial use of flyash currently is in the cement, concrete road fills and grout industries [10]; but such use is only accounted for 38% of the flyash produced by electric power facilities each year.[51] Since flyash is readily available as a disposal material, container substrates could be another avenue of beneficial use in agriculture. However, limited information is available on the use of flyash as amendment to container substrates for biomass production.

Flyash, a solid waste generated from coal-fired thermal power plants, contains both macro and micro-nutrients which can sustain plant growth.[38] It contains several nutrients including S, Ca, Mn and P which are beneficial for plant growth, as well as toxic heavy metals such as Mg,Fe, Cu, Zn, Cr, Pb, Hb, Ni and As.[9]

Menon [36] studied the effect of mixed application of flaysh and organic compost on soil and availability and uptake of elements by various plant species. Sustainable use of flyash to treat agricultural soils tends to conjure concern over long term effects on dynamics and functions of soil biota, such as earthworms, on which there is a dearth of information. Earthworms may also enhance the fertility of soil treated with coal flyash by increasing solubilisation of mineral nutrients such as P and K in the ash.[7]

From the review of literature the flyash has been utilized from long back in the field of agricultural practice such as pesticides.[12,23] But few works are available on coal flyash with earthworms[7] To author's knowledge, no previous studies have been made on vermicomposting of lignite flyash to increase its fertilizer value. The final outcome aids in converting the burden of lignite flyash disposal into an opportunity to produce high-potential organic fertilizers, capable of enhancing soil fertility, bioremediation and improving crop quality, thereby assisting economic growth and protecting the environment. Hence in the present study, efforts have been made to know the potency of *Eisenia fetida* to convert the flyash into vermicompost.

MATERIALS AND METHODS

The *Eisenia fetida* worms were collected from the local agricultural fields around Angul, Odisha, India.

Flyash was obtained from thermal power station, Capptative power plant (CPP) of Nalco, Angul, Odisha, India. The urine free cowdung was collected from the experimental dairy farm in Angul. The collected cowdung was sundried and powdered and used for media preparation.

Preparation of Different Mixtures (Cowdnug and Flyash) and Inoculation of Worms: Combination of cowdung (CD) and flyash (FA) in three proportions viz., 1:1 (T_1), 2:1 (T_2), 3:1 (T_3), (wt/wt) were prepared. The (approx. 40 days old) worms were weighed and inoculated at the rate of 15 g/kg of each mixture.[41,42] Six trails have been maintained in circular troughs for each combination. To each combination 200 g of clay loam soil was added apart from the substrate. A set of control in each combination was also maintained without the earthworms.

Collection of Vermicompost and Compost:

Vermicomposts from all the experimental plastic containers and compost from worm unworked control plastic containers were collected on 10^{th}, 20^{th}, 30^{th}, 40^{th} and 50^{th} day and air dried.

Analysis of Macro Nutrients: The total nitrogen (N), total phosphorus (P), total potassium (K) content of the sample was estimated, by Kjeldhal method as per Tandon[58] for nitrogen, calorimetric method for phosphorus and flame photometric, method for potassium. The organic carbon was determined by the empirical method followed by Walkely and Black.[62]

RESULTS

The performance of vermireactors with cowdung and flyash in terms of macro nutrients during the study period are summarized in Table 1, 2 and 3. Results from chemical analysis of vermicast revealed that considerable amount of macronutrients increased in their quantity.

The organic carbon (OC) decreased in all the treatments including the controls and treatments. The content of organic carbon decreased as the decomposition progress. At the end of the experiment more reduction of organic carbon was observed in the treatments with earthworms than the controls without earthworms. The highest reduction in organic carbon was observed in T_3 (44%), next to that the reduction of organic carbon was observed in T_2 and least reduction of organic carbon was observed in T_1.

The nitrogen (N) content of T_1C (T_1 Control) showed 31% change over the 0 day whereas T_1E (T_1 Experiment) has 63% change over the N content of 0 day. Likewise

Table 1: Pattern of nutrient changes during the vermicomposting of flyash using *Eisenia fetida*

Treatment 1 (T_1) - CD + FA (1:1)

Elements	Control/experiment		Initial	10th day	20th day	30th day	40th day	50th day	% Change from 0 day
OC%	T_1C	Control	17.2± 0.635	16.8± 0.719	16.5± 0.684	16.0± 0.718	15.6± 0.687	15.3± 0.745	12%
	T_1E	Experiment		15.7± 0.791	14.8± 0.929	14.2± 0.835	13.6± 0.635	13.2± 0.925	25%
N%	T_1C	Control	0.35± 0.084	0.37± 0.182	0.38± 0.085	0.40± 0.077	0.42± 0.077	0.45± 0.085	31%
	T_1E	Experiment		0.41± 0.077	0.44± 0.069	0.49± 0.078	0.53± 0.076	0.69± 0.077	63%
P%	T_1C	Control	0.52± 0.077	0.53± 0.067	0.55± 0.087	0.58± 0.079	0.6± 0.168	0.56± 0.099	29%
	T_1E	Experiment		0.54± 0.075	0.59± 0.097	0.65± 0.077	0.69± 0.094	0.78± 0.088	51%
K%	T_1C	Control	0.09± 0.087	0.09± 0.069	0.11± 0.059	0.12± 0.065	0.13± 0.068	0.13± 0.065	45%
	T_1E	Experiment		0.10± 0.066	0.11± 0.065	0.13± 0.064	0.14± 0.083	0.15± 0.069	67%

Mean±SD of six observations, C - Control without earthworm, E - Experiment with earthworm

ANOVA: One way factor				
Analysis of Variation	SS	MS	F	P-value
Between Groups	2.238995	0.447799	0.00955	0.999985
Within Groups	2078.289	49.48355		

Table 2: Pattern of nutrient changes during the vermicomposting of flyash using *Eisenia fetida*

Treatment 2 (T_2) - CD + FA (2:1)

Elements	Control/experiment		Initial	10th day	20th day	30th day	40th day	50th day	% Change from 0 day
OC%	T_2C	Control	33.6± 2.473	32.6± 1.850	32.0± 1.294	31.4± 1.668	30.4± 1.523	29.8± 2.035	12.3%
	T_2E	Experiment		31.8± 1.698	29.02± 1.499	27.8± 2.034	26.2± 1.598	25.7± 2.045	24.5%
N%	T_2C	Control	0.64± 0.173	0.68± 0.169	0.71± 0.160	0.76± 0.171	0.82± 0.203	0.87± 0.233	36.5%
	T_2E	Experiment		0.72± 0.146	0.82± 0.205	0.89± 0.224	0.94± 0.115	1.01± 0.192	58.9%
P%	T_2C	Control	0.90± 0.043	0.93± 0.043	0.96± 0.041	1.04± 0.061	1.11± 0.062	1.2± 0.618	33.1%
	T_2E	Experiment		1.06± 0.068	1.14± 0.041	1.27± 0.057	1.38± 0.063	1.52± 0.069	79.0%
K%	T_2C	Control	0.16± 0.054	0.18± 0.063	0.20± 0.065	0.21± 0.061	0.21± 0.061	0.23± 0.071	44.5%
	T_2E	Experiment		0.19± 0.068	0.21± 0.061	0.23± 0.071	0.25± 0.063	0.27± 0.057	79.0%

Mean±SD of six observations, C - Control without earthworm, E - Experiment with earthworm

ANOVA: One way factor				
Analysis of Variation	SS	MS	F	P-value
Between Groups	9.52631	1.905262	0.010037	0.999968
Within Groups	7972.236	189.8151		

Table 3: Pattern of nutrient changes during the vermicomposting of flyash using *Eisenia fetida* Treatment 3 (T_3) - CD + FA (3:1)

Elements	Control/experiment		Initial	10th day	20th day	30th day	40th day	50th day	% Change from 0 day
OC%	T_3C	Control	49.1± 0.797	45.04± 0.717	44.60± 0.976	42.80± 0.699	41.5± 1.599	39.50± 1.75	64%
	T_3E	Experiment		44.8± 1.379	40.74± 0.65	36.78± 0.746	31.56± 1.680	27.65± 2.045	44%
N%	T_3C	Control	1.01± 0.779	1.06± 0.553	1.12± 0.267	1.16± 0.110	1.28± 0.115	1.39± 0.220	39%
	T_3E	Experiment		1.12± 0.276	1.22± 0.128	1.41± 0.176	1.57± 0.225	1.65± 0.415	65%
P%	T_3C	Control	1.11± 0.078	1.17± 0.168	1.15± 0.128	1.22± 0.173	1.34± 0.343	1.42± 0.495	41%
	T_3E	Experiment		1.22± 0.455	1.35± 0.454	1.48± 0.829	1.70± 0.875	1.81± 1.217	77%
K%	T_3C	Control	0.21± 0.099	0.22± 0.214	0.24± 0.178	0.27± 0.179	0.29± 0.085	0.32± 0.197	53%
	T_3E	Experiment		0.24± 0.177	0.24± 0.077	0.27± 0.085	0.34± 0.157	0.38± 0.125	93%

Mean±SD of six observations, C - Control without earthworm, E - Experiment with earthworm				
ANOVA: One way factor				
Analysis of Variation	SS	MS	F	P-value
Between Groups	68.17727	13.63727	0.038408	0.999135
Within Groups	14921.39	356.0327		

the T_2C showed 36.5% change over the 0 day, while the T_2E showed 58.9% change over the 0 day of the same. In the same way in T_3 also the N change was more in T_3E (65%) than the control (39%). From all the tables it was observed that the vermicomposts in all the samples have more N and lower OC. Higher quantity of N was found in T_3 than the other two treatments.

Phosphorus content of all the treatment increased from the initial content. 29% of change from the initial in control and 51% of change from initial in the experiment was observed in T_1, whereas in T_2 on 50^{th} day 33.1% increase in control and 79% in the compost with earthworms were observed. But, at the same time the highest increase was observed in T_3, i.e, 41% in control and 77% in experiment were noticed. From the tables it is clear that the phosphorus was higher in the compost treated with earthworms.

Among the macro nutrients the quantity of K present was low in all the treatments. Among the three treatments highest mineralization was found in the vermicomposts of T_3 whereas the vermicomposts of all the treatments showed higher mineralization than the respective compost without earthworms.

DISCUSSION

Highest organic carbon reduction was observed in T_3 where highest quantity of OC was available which favours the growth of microbes. The break down of organic matter by earthworm and subsequent microbial degradation takes place in vermicomposting [56,57]. Our finding was supported by Rajesh banu *et al.*[43] where they reported higher microbial population in 50% sago sludge with standard bedding materials during vermicomposting than the 75% and 100% sago sludge. More vermicast recovery and worm zoomass was observed in 20% flyash with cowdung than 40%, 60% and 80% flyash with cowdung [18]. The present findings support the findings of Kaushik and Garg [28] and Suthar.[56,57] where they observed reduction of carbon in the vermicompost. Body fluids and excreta secreted by earthworms (eg. mucus, high concentration of organic matter, ammonium and urea) promote microbial communities in vermicomposting systems. Presence of microbial agents was reported in the earthworm body.[56,57] Earthworm activity significantly decreases organic carbon levels in waste and accelerates waste stabilization process.[56] The reduction in organic carbon during the 50 days study period could be due to the respiratory activity of microorganisms and earthworms.

In general the final content of nitrogen in the vermicompost is dependent on initial nitrogen present in the waste and the extent of decomposition.[29] This finding was supported by the observation of Bhattacharya and Chattopathyay[8] where they have reported N availability was more during vermicomposting in the combination with higher quantity of CD.

The increased N content in vermicompost may be due to the release of nitrogenous products of earthworm metabolism through the urine, excreta (cast) and mucoproteins.[40] The lowest percentage change of N occur in the vermicomposts of T_1, may be due to the presence of more quantity of heavy metals in the flaysh. Highest mineralization was observed in the vermicompost of T_3 and it might be due to the less accumulation of heavy metals in earthworms (3:1) which would reduces the toxicity to the microbes responsible for mineralization.

The highest quantity of P observed on 50th day vermicompost of T_3 which may be due to the multiplication of phosphate solubilizing microbes in casts.[53] which had more cowdung for the multiplication of microbes. More increase of P was observed in the vermicasts.[43] during the vermicomposting of sago waste in lowest percentage of sago sludge. The highest percentage change of P was observed in T_3 and it can be due to the higher percentage of cowdung which was rich in all essential nutrients needed for better vermicomposting.[48]

Mineralization of K was more in vermicompost, which indicates the role of earthworm and microorganisms in mineralization process.[56,57] Kaviraj and Sharma[29] reported 10% increase of total K by *E.fetida* and 5% by *L.mauritii* during the vermicomposting of MSW and it was due to the influence of microflora.

From the data highest mineralization of NPK was observed in T_3 and it might be due to the availability of higher nutrients for earthworms and good medium for the multiplication of microbes.[43,55]

The present investigation is also supported by few findings[4,35], which had reported increased NPK content in the vermicompost than the original feed material.

CONCLUSION

From the results it may be concluded that the rate of mineralization could be decreased due to the increasing concentration of flyash which had higher proportion of heavy metals which exerts toxicity. The higher concentration of flyash affected the population of microbes and quantity of microbial enzymes.

Hence this study on lignite flyash can be used to enrich the flyash by vermicomposting to increase the nutrients (N; P and K) and to reduce pollution. In conclusion , from the current study it is clear that the use of *Eisenia fetida to mitigate toxicity* of metals seems to be feasible technology and 3:1 cowdung-flyash mixture can be used for sustainable and efficient for vermicomposting, without showing any toxicity to earthworms. The concentration of macro nutrients (N, P and K) were found to increase in the earthworm treated series of cowdung and flyash combinations.

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