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Recycling of Fly Ash Generated from Parichha Thermal Power Plant into Valuable Organic Fertilizer through Vermicomposting Technology Amended with *Eichhornia capsicum* and Cow Dung

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Abstract:
Fly ash is an amorphous ferroalumino silicate, an important solid waste around thermal power plants. In view of the environmental problems generated by the large scale production of fly ash, increasing attention is now being paid to the recycling of fly ash as a good source of nutrients. To reduce the cost of disposal of fly ash and best utilization, it was planned to convert the fly ash in to valuable vermicompost. This study explored the potential role of indigenous earthworm Eisenia foetida to convert the fly ash into best manure. Five combinations of water hyacinth, fly ash and cow dung such as 0%, 5%, 10% 25% and 50% were prepared. In all the vermireactor, there was a significant decrease in pH, TOC and C: N ratio, but increases in TKN, TK and TAP at the end. The heavy metals content in the vermicompost was lower than initial feed mixtures.

Keywords: Fly ash, water hyacinth, cow dung, NPK, heavy metals, C: N ratio

1.0 Introduction:
The Parichha thermal power station (PTPS), located at Jhansi district, Uttar Pradesh India. It is coal fired power station and emitting huge quantity of fly ash particles which are deposited on surrounding agricultural lands. Fly ash is produced as a result of coal combustion in thermal power station and discharged in ash ponds. The emission of fly ash from the stacks into the atmosphere is controlled by particulate devices such as scrubbers, mechanical and electrostatic precipitators (ESP). It uses D, E and F grade coals and the ash content of coal ranges between 35-48%.The chemical composition of fly ash includes major (>1%), minor (1-0.1%) and trace (<0.1%) elements. Presently, Parichha thermal power station has an installed capacity of 640 MW and uses about 10,000 tonnes of coals per day and generating more than 4,000 tonnes of fly ash every day (Vimlesh and Giri, 2009).

Water hyacinth (Eichornia crassipes (Mart) Solms-Laubach; family: Potenderiaceae) has been listed as most troublesome weed in aquatic systems. It is serve environmental and economical problem in many tropical and sub tropical parts of the world. It forms dense mats that prevent river traffic, block irrigation canals, interfere with hydel power projects and destroy rice fields. As water hyacinth decays, there is a sharp increase in nutrient levels in water body, which ultimately creates the problem of eutrophication in aquatic system.
Menon 1993 studies the effect of mixed application fly ash and organic compost on soil and availability and uptake of elements by various plant species. The beneficial effect of earthworm on soil has been attributed to increase microbial population and biologically active metabolites such as plant growth regulators. Recycling of wastes through vermitechnology reduces the problems of non utilization of agro wastes (Kale, R.D., 2000).

2.0 Material and method:
2.1 Experimental design:
As per objective of vermiconversion of fly ash, it is decided that bulky organic waste e.g. water hyacinth (Eichhornia *crassipes*) of higher nitrogen content to be mixed with cow dung for the preparation of bedding materials (BD). Hence, water hyacinth samples were collected from eutrophic pond near to university campus. After collection whole WH samples were washed with running water to remove mud adhered to root and leaves. The samples were cut into pieces (2 to 3 cm) and air dried for five days to remove volatile gases which may be toxic to earthworms. Then air dried WH was mixed with cow dung (1:1 w/w) ratio which was used as bedding material (BM) and

incubated for 21st days. On 22nd days bedding material were weighed into 500 kg (dried weight excluding fly ash weight basis) sample size and put into circular plastic vermireactor (height 12 cm x diameter 15 cm). Then fly ash @ 0, 5, 10, 25 and 50% were mixed with each vermireactor. Subsequently, each vermireactor was inoculated with 20 numbers of *Eisenia foetida* and kept in dark room with a temperature variation 18.5 to 28.0 ^{o}C. Each treatment were maintained WHC at 60-70%. All the treatments studied in triplicates. For carbon and nitrogen analysis samples were taken out at an interval of 0, 15, 30, 45, 60, 90 and 120 days.

The plastic circular containers were covered with iron mesh to protect the earthworms from the predators. Vermicomposting experiment was terminated on 120th day and immediately Earthworm biomass (wet weight) of worms was weighed in an electronic balance and the number of cocoons and hatchlings were counted by hand sorting method. On 120th day representative samples from each vermireactor were collected and put in a refrigerator at 4^{o}C temperature until available nutrient analysis were completed. Each representative samples were also oven dried (105 ^{o} C) and ground into powder and packed into air tight polyethylene. At the stage samples were preserved for further chemical analysis.

2.2 Chemical analysis

The samples were used on dry weight basis for chemical analysis that was obtained by oven drying the known quantities of material at 105^{0} C. The total organic carbon was measured using the method of Walkley and Black 1934. Total Kjeldahl nitrogen (TKN) was determined by following Bermner and Mulvaney (1982) procedure. Total available phosphorus (TAP) was analysed using the colorimetric method (Bansal and Kapoor, 2000). Total potassium (TK) was determined after digesting the sample in diacid mixture [conc. HNO_3: conc. $HClO_4$, 4:1, v/v] (Bansal and Kapoor, 2000) by flame photometer. Total Fe, Cu, Cd, Cr, Pb and Zn were determined by atomic absorption spectrophotometer (AAS) [Perkin Elmer 3500] after digestion of the sample with conc. HNO_3: conc. $HClO_4$, 4:1, v/v (Bansal and Kapoor, 2000).

3.0 Result and discussion:

3.1 Physicochemical Properties of Vermicompost:

Physico chemical properties of fly ash, WH and cow dung are given in Table 1. The major attribute, which makes Fly Ash suitable for agriculture is its texture and the fact that it contains almost all the essential plant nutrients except organic carbon and nitrogen. The main constraint with fly ash using it as a soil supplement is its low availability although it is present in bound form (Bhattacharya and Chattopadhyay, 2002). Vermicomposting has been attempted in this regard, in order to solubilise the unavailable plant nutrients in unavailable form. Nutrient availability was lowest in fly ash. It was found to be highest in cow dung treatments. Incorporating organic matter with fly ash in different combinations resulted in increased nutrient availability. Beneficial aspects of the organic matter on nutrient transformations especially phosphorus transformation through various pathways (Bhattacharya and Chattopadhyay, 2002).It was observed that adopting vermicomposting technology through the use of earthworms (*Eisenia foetida*) helped to increase the available plant macro and micronutrients. Total organic carbon reduction in 0% was significantly higher than vermireactor 25 and 50%. TOC reduction was inversely related to the water hyacianth and fly ash content in the vermireactor. This finding was similar to the found by kaviraj and Sharma 2003, who reported 45% loss of carbon during vermicomposting of municipality, or industrial wastes. Elvira et al., 1996 have attributed this loss to the presence of earthworms in the feed mixtures. Suthar 2006a reported that earthworms promoted such microclimatic condition in the vermireactor that increased the loss of total organic carbon from substrate through microbial respiration. Ash content of the vermicompost from all the reactors was higher than initial bedding material (Table 2) the ash content had decreased in the range of 16 to 45%.

The TOC, ash content, TKN, TK, TAP content of five different dose of FA mixtures in the initial vermibeds were ranged from 449-225 gm/kg, 218-159 gm/kg, 7.5-3.8 gm/kg, 5,4-10.9 gm/kg and 3.6-8.7 gm/kg, respectively (Table 2). The TKN content decreased with increased in FA content in different feed mixture. We also observed differences in C: N ratio and other mineral constituents in different feed mixtures. The data on vermicompost revealed wide variation in TOC, TKN, TK and TAP, in different concentration of fly mixtures, the values ranged from 184–160 gm/kg, 12.1 - 4.7 gm/kg, 13.5- 27.3 gm/kg and 6.0 – 15.0 gm/kg, respectively (Table 3). Irrespective of any initial fly ash concentration in the feed mixtures the vermicompost resulted in substantial increase in the fertilizer value for TKN, TK and TAP. However, TOC content in vermicompost showed a consistent decrease value with respect to their initial feed mixture. TKN content increased in vermicompost in different fly ash based feed mixtures, probably because of mineralization of organic matter (Table 2). Our study highlighted that the TAP content was higher in the vermicompost than their respective initial content. During 120 days vermicomposting 1.6, 2.4, 3.6, 1.7 and 1.6% increase of phosphorus content were observed in control, 5%, 10 %, 25 %, 50% fly ash mixtures respectively. Increase in TAP during vermicomposting is probably due to mineralization and mobilization of fly ash bound phosphorus due to bacterial and faecal phosphates activity of earthworms. Total potassium (TK) content was also higher in the final product than in their initial feed mixtures. No mortality was observed in any feed mixture during the study period. Irrespective to any fly ash content in the vermibeds, the C: N ratios were observed to be decreased with increased of vermicomposting period (Table 4). The control reported maximum reduction for C: N ratio, whereas 50 % FA mixture recorded minimum reduction of C: N ratio after the end of 120 days of vermicomposting. The monthly average reduction in C: N ratio from 60th to 120th day ranged from 3.1 (50 % fly ash mixture) to 9.6 (control) in different fly ash mixtures. It is important to note that the monthly average mineralized nitrogen from 60th to 120th day in 25 % fly ash mixture was lower, that of 50 % was much lower (3.1/month). The lowest rate of reduction in 50 % fly ash mixture indicated adverse impact of high dose FA on microbial activity.

Table 1: Physicochemical properties of fly ash, cow dung and water hyacianth based vermicompost

Parameters	Fly ash	Cow dung	Aquatic weeds (WH)
Moisture content (%)	52.0	74	82.4
pH	6.6	8.3	8.0
Ash contents gm/kg	-	195	417
Organic Carbon (gm/kg)	11.2	452 g/kg	421 g/kg
TKN	113 ppm	7.2 g/kg	10.2 g/kg
TAP	13.8 ppm	3.3 g/kg	5.8 g/kg
TK	16432 ppm	4.9 g/kg	9.8 g/kg
C:N	9.91	62.77	41.27
Zn (ppm)	179.90	308	392
Cu (ppm)	78.6	42.6	280
Fe (ppm)	19876	325	1780
Mn (ppm)	439.6	6.6	10.8
Cd (ppm)	18.9	0.82	1.20
Pb (ppm)	67.46	2.8	78.0
Cr (ppm)	49.46	20.5	62.0
Ni (ppm)	27.5	15.6	44.8

Table 2: Physicochemical characteristics of initial bedding material and vermicompost obtained from different rates of fly ash mixture

Treatment	TOC (gm/kg)	TKN (gm/kg)	TK (gm/kg)	TAP (gm/kg)
0%	449	7.5	5.4	3.6
5%	426	7.1	5.9	4.1
10%	404	6.7	6.5	4.6
25%	337	5.6	8.1	6.2
50%	225	3.8	10.9	8.7

Table 3: Final physicochemical characteristics of bedding material after 120 days vermicompost obtained from different rates of fly ash mixture

Treatment	TOC (gm/kg)	TKN (gm/kg)	TK (gm/kg)	TAP (gm/kg)
0%	184±10	12.1±0.6	13.5±0.3	6.0±0.12
5%	200±30	10.7±0.8	14.75±0.4	7.0±0.5
10%	214±20	9.3±0.4	16.25±0.7	8.0±0.14
25%	199±12	7.3±0.9	20.25±1.1	11.0±0.2

50%	160±15	4.7±1.1	27.25±1.4	17.0±0.4

Note: - Mean ±SE (Standard error)

Table 4: Changes in C: N ratio of CD+WH+FA fed vermireactor during vermicomposting

Treatment	0days	15 days	30 days	45 days	60days	90 days	120 days
0%	59.8	55.5	45.1	40.1	29.0	19.1	9.8
5%	60.0	51.6	34.4	43.0	27.0	11.0	18.0
10%	60.3	49.6	42.4	37.0	32.9	29.0	23.0
25%	60.1	56.9	52.3	48.7	37.3	32.5	27.3
50%	59.2	55	50.9	46.2	40.2	37.9	34.0

Table 5: Heavy metal content (mg/kg) in the initial bedding material (CD+WH+FA)

Treatment	Total Fe (ppm)	Total Cu (ppm)	Total Cd (ppm)	Total Cr (ppm)	Total Pb (ppm)	Total Zn (ppm)
0%	4705	66.3	0.9	24.5	10.3	316.4
5%	5463.5	66.9	1.8	25.8	13.2	309.6
10%	6222.1	67.5	2.7	27.0	16.0	302.8
25%	8497.75	69.4	5.4	30.8	24.6	282.3
50%	12290.5	72.5	9.9	37.0	38.9	248.2

3.2 Status of Heavy Metal in Vermicompost:

The total concentrations of different heavy metals in vermicompost prepared from different combination are increased with increased concentration of fly ash. The mean total metals values ranged from 3716.9 - 8480.4 mg/kg, 39.1 - 51.5 mg/kg, 0.7 - 3.8 mg/kg, 21.8 - 26.0 mg/kg, 5.1 – 12.0 mg/kg and 187.7 – 196.1 mg/kg for Fe, Cu, Cd, Cr, Pb, and Zn, respectively (Table 6). All the metal concentrations were expectedly high in different combination of vermicompost which could be possible due to their high concentration in the feed materials. However, comparison of these values with their respective initial concentrations in bedding materials revealed a substantial reduction of values for all the metals in vermicompost. The total content of heavy elements like Cu, Zn, Cr, Pb and Cd in all the combination of vermicompost in our study were within the safe limits as per guidelines proposed by the pollutant concentration limits. However, bioaccumulation of these toxic metals in earthworm biomass again creates a potential threat to environmental contamination, hence, needed further investigation in this direction.

4.0 Conclusion:

The rate of mineralizable could be decreased due to the increasing concentration of fly ash which had higher proportion of heavy metals which exert toxicity. The higher concentration of fly ash affected the population of microbes and quantity of microbial enzymes. Hence this study on fly ash can be used to enrich the fly ash by vermicomposting to increase the nutrient (NP and K) and reduce pollution. The use of Eisenia foetida to migrate toxicity of metals seemd to be feasible technology and 5% CD+WH+FA mixture can be used for sustainable and efficient for vermicomposting, without showing any toxicity to earthworms. The concentration of macro nutrients were found to increase in the earthworm treated series of cow dung fly ash and water hyacinth combination.

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