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ORIGINAL ARTICLE

INFLUENCE OF VERMICOMPOST ON THE PHYSICO–CHEMICAL ANALYSIS OF FLYASH WITH BEDDING MATERIAL BY EARTHWORM *EISENIA FETIDA*

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ABSTRACT

Flyash is a pulverised product from thermal power plants generated by the burning of coal for several use of flyash have been developed viz. substitute of cement in concrete, land filling, mine filling, agriculture etc. Around 120 million tonnes of flyash (FA) is being produced as a waste every year from different thermal power plants in India. Attempts have been made to use flyash for its chemical composition for upgrading the wasteland or agriculture purposes. Vermicomposting technology which involves rapid decomposition of organic matter with the help of microorganisms present in the gut of earthworm is found to be effective in increasing microbial activity in the soil and to enhance nutrient soil availability. Flyash helped to transform considerable amounts of total nitrogen, total phosphorus, total potassium and micronutrients from flyash into more saoluble forms and thus resulted in increased bioavailability of the nutrients in the vermicomposted material. The present studies have indicated potential role of earthworm like *E. fetida* with various proportions of Bedding material (BM) to convert the flyash into the best manure upto 60% FA and BM was observed to be best for vermicomposting. Among different combinations of FA and BM nutrient availability was significantly higher in the 20% +80% FA+BM treatment compared with the other treatments. Similarly the lower pH and OC content was observed in this treatments. FA based vermicomposting will help in bulk utilization of the FA which is a waste product and otherwise may also cause ground water contamination, mass reduction of FA, nutrients increased by many folds as it increases the porosity is very beneficial. That will ensure sustainable management of bulk waste and environment management.

Keywords: Coal flyash, Earthworms, Vermicompost, *E.fetida*, Macronutrients.

1.INTRODUCTION

Environmental pollution due to release of smoke, gases, effluents and solid wastes from industries is one of the major issues of global concern. Combustion of bituminous and sub-bituminous coal and lignite for generation of electricity in thermal power plants produces solid wastes such as fly ash, bottom ash, boiler slag and flue gas desulphurization (FGD) materials, which are commonly known as coal combustion by- products (CCPS) (Vomberg, 1998). Fly ash is a heterogeneous mixture of amorphous and crystalline phases and is generally considered to be a ferroalumino silicate mineral with Al, Ca, Fe, K, Na and Si as predominant elements (Adriano *et al*., 1980; EI-Mogazi *et al*., 1988; Mattigod *et al*., 1990). Fly ash is a serious source of air pollution. Since it remains air borne for a long period of time and causes health hazards (T.E.R.I., 1998). Besides being a health hazard, fly ash also degrades the environment. According to the data provided by Govt. of India more than 110 mt (million ton) of FA per annum (Kumar *et al.*, 1998; Jamwal, 2003; Yeledhalli *et al*., 2007) is produced, of which, 4 mt is released into the atmosphere. Coal combustion by-products were largely treated as waste materials. Therefore, disposal and utilization of FA need careful assessment to prevent conversion of arable land into landfills and accumulation of toxic metals in soil (Petruzelli, 1989). On the other hand vermicomposting is a cheap and suitable technology for decomposition of different types of organic waste into value added material. Keeping in view of the present, demand and necessity for vermicomposting, it is proposed to utilize lignite FA in the production of vermicompost. FA is disposed of either dry or wet methods. In dry disposal, the FA is dumped in landfills and FA basins.

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In wet method, the FA is washed out with water into artificial lagoons and is called as pond ash. Both methods ultimately lead to dumping the FA on open land, which degrades the soil and endangers human health and the environment. Approximately on an average, 95% of fly ash consists of oxides of Si, Al, Fe and Ca and about 0.5 to 3.5% consists of Na, P, K and S. Pressmud a major by-product from sugar industry. The sugar industries in India are of vital importance to the Indian economy. There are 464 sugar industries in India out of which 36 sugar industries are in Tamil Nadu. Sugarcane is cultivated in 4 million hectares in India with the annual production of 267.5 million tons of cane and 12.9 million tons of sugar. In Tamil Nadu this crop is cultivated in 2.6 lakhs hectares.

As ecosystem engineers, earthworms generate many important physical changes in the soil environment. Use of earthworms for waste management, organic matter stabilization, soil detoxification and vermicompost production have been reported by many authors (Parthasarathi and Ranganathan, 2000; Chaudhuri *et al*., 2002; Manivannan *et al*., 2004; Sarojini *et al.,* 2009; Manimegala *et al.,* 2009; Ananthakrishnasamy *et al.*, 2009; Dharani *et al.,* 2010). The earthworms and/or vermicompost are used to: degrade organic waste, indicate environmentally polluted soil, turnover the soil, prepare protein rich animal feed, produce medicine, improve soil physico-chemical properties, restore soil fertility, induce plant growth, increase plant productivity, reduce pathogenic microbes etc. In nutshell, earthworms may be referred to as waste stabilizers, compost manufacturers, protein producers, pollution preventers and ecosystem engineers. Hence at present, earthworms are aptly called as "nature's miniature factories" and as "Biogold".

Parthasarathi *et al.* (2008) showed variations in the pH and EC in the sandy loam soil after the application of vermicompost for black gram crop. Similarly, Ansari (2007) observed the influence of vermicompost on the pH and EC of soil after the production of spinach, onion and potato. Most of the studies restricted to specific waste and / or specific soil types and / or specific plants. Vermicompost is rich in plant macro nutrients (N, P_2O_5 and K_2O), secondary elements (Ca and Mg) and vital micronutrients like Fe, B, Zn and Mo (Biswas and Mukherjee, 1995; Ramalingam, 1997). Many workers analysed the chemical composition of casts and have reported : a near neutral pH (7) (Haimi and Huhta, 1987); reduction in electrical conductivity (Dusan *et al*., 1991); reduction in organic carbon content (Jambhekar, 1992) and uniform increase in the levels of total nitrogen (Lee, 1985; Orzco *et al*., 1996); total potassium (Tiwari *et al*., 1989) in vermicast. Though plenty of studies are available on waste management/ waste recycling with earthworms, limited studies is available on the utilization of earthworms in the management of fly ash. The available studies are increasing nutrient availability from fly ash (Bhattacharya and Chattpadhyay, 2001), analysis of heavy metal status in vermicomposted fly ash and in earthworm tissue (Gupta *et al.*, 2005), mass recovery of nutrients through vermicomposting of fly ash (Venkatesh and Eevera, 2008), growth and reproduction of earthworms in lignite fly ash (Sarojini *et al.,* 2009) and lignite fly ash management (Ananthakrishnasamy *et al.,* 2009), conversion of lignite fly ash into nutritive compost by earthworm (Dharani *et al.,* 2010).

2.MATERIALS AND METHODS

Eisenia fetida worms were obtained from the stock culture maintained in the Department of Zoology, Annamalai University, India. Fly ash (FA) was collected from thermal power station 1, Neyveli Lignite Corporation (NLC), Neyveli, Tamil Nadu, India. The urine free cow dung was collected from the experimental dairy farm in Annamalai University. The collected cow dung was sun dried and powdered, used as the substrate for the earthworm culture. One month old and cured pressmud was obtained from E.I.D. Parry Sugar Mill at Nellikuppam, Cuddalore District, Tamil Nadu, India.

Bedding material preparation (BM)

The standard bedding material was prepared as per procedure (Kavin *et al*., 1996) and raw materials used were cow dung and pressmud. The bedding material was prepared by taking dry weight of pressmud and cow dung in the ratio of 1:1 (on weight basis).

Preparation of Different mixtures (Bedding material and Flyash) and Inoculation of worms

Combination of Bedding material (BM) and flyash (FA) in five proportions viz.,

Control - 100 %, (cow dung alone); T_{1-} 20% + 80% (FA+BM); T_{2-} 30% + 70% (FA+BM); T_3 - 40% + 60% (FA+BM); T_{4-} 50% + 50% (FA+BM); T_{5-} 60% + 40% (FA+BM) were prepared. The preclitellate worms were weighed and inoculated at the rate of 15g/kg of each mixture. Six replications have been maintained in circular troughs for each combination.

Collection of vermicomposts and compost

Vermicomposts from all the experiments and compost from worm unworked control compost were collected on 0, 30th, 60th and 90th days and air dried.

Analysis of macronutrients

PH and EC were determined by the method described by ISI Bulletin (1982). The total nitrogen (N), total phosphorus (P), total potassium (K) content of the sample was estimated by Kjeldhal method as per Tandon (1993) for nitrogen, colorimetric method for phosphorus and flame photometric method for potassium. Organic carbon content of the sample was determined by empirical method as described by Walkely and Black (1934).

Statistical Analysis

The statistical significance between treatments was analyzed by using two way ANOVA.

3.RESULTS

Physico chemical properties such as PH, EC, OC, N, P and K of FA and BM mixture used in this study of *E. fetida* are depicted in Table 1 to 6**.** The results suggested that earthworm play a significant role in processing flyash into organic manure. The earthworm activity accelerated the process of decomposition of FA and stability the waste. The vermicomposted manure was much darker in colour and had been processed into much more homogenous mass after 90 days of earthworm activity, whereas the material without earthworms remained in compact and clumps.

Vermicomposted manure also had a lower pH (Table1) in all treatments up to end of the experiment. The gradual reduction of pH was noted in T_1 followed by other treatments. The EC (Table2) value increased in the beginning of composting to end of the experiment. The highest EC value was recorded in T_5 followed by others. OC (Table3) decreased with time in all treatments. The OC is lost as CO_2 and total N increase as a result of carbon loss. The maximum reduction of OC was observed in C and T_1 followed by other treatments. Earthworms also had a great impact on nitrogen transformation in the compost. Total N increased (Table4) in all treatments, the maximum TN content was recorded in T_1 followed by other treatments up to 60 days. After that it will gradually decreased at end of the experiment. Total P (Table5) also increased with time in all treatment process and gradually decreased after 60 days of experimental period. The highest amount of TP was recorded in T_1 followed by other treatments. Similarly the total K was initially increased in all treatments up to 60 days and then decreased gradually at 90^{th} day. The highest value of TK was noted in T_1 (Table 6) followed by others.

In all our treatments, the value of macronutrients increased rapidly with time. Better results were obtained for the mixture of T_1 (20%FA+80%BM) combination in the vermicomposting process and 20% to 60% FA combination provide better results of vermicompositng.

Table 1: pH of the vermicomposts of flyash + bedding material mixture by *E.fetida* (p<0.05)

Substrate proportions	Initial (0)	Vermicomposting days 30	60	90
C	4.26±0.51	6.25±0.89 (46.71)	8.83±0.21 (107.27)	6.74±0.30 (58.21)
T_1	4.12±0.68	6.03±0.75 (46.35)	8.48±0.39 (105.82)	6.44±0.56 (56.31)
T_2	3.98±0.34	5.25±0.29 (31.90)	7.73±0.35 (94.22)	6.01±0.79 (51.00)
T_3	3.72±0.73	4.55±0.47 (22.31)	6.72±0.33 (80.64)	5.44±0.32 (46.23)
T_4	3.56±0.72	4.27±0.52 (19.94)	6.24±0.89 (75.28)	5.01±0.29 (40.73)
T_5	3.28±0.26	3.63±0.33 (10.73)	5.25±0.34 (60.06)	4.45±0.30 (35.67)

ANOVA

Analysis of variance	Sum of square	Df	Mean of square	F-value	P-value
Rows	14.9112	23	0.64831341	28.3381584	5.30865E-37
Columns	13.8068	5	2.761365	120.70088	4.61101E-44
Error	2.6309	115	0.02287775		

C – Control, T_1 (20% FA + 80% BM), T_2 (30% FA + 70% BM), T_3 (40% FA + 60% BM), T_4 (50% FA + 50% BM), T_5 (60% FA + 40% BM)
Initial (0) – Worm unworked substrates, Mean± SD of six observations,

Table 2: Electrical Conductivity (dS/m) of the vermicomposts of flyash + bedding material mixture by *E. fetida* (p<0.05)

Substrate Proportions		Vermicomposting days 30	60	90
C	0.76±0.16	0.84±0.10 (10.52)	0.97±0.16 (27.63)	1.07±0.17 (40.78)
T_1	0.79±0.14	0.87±0.10 (10.12)	0.98±0.10 (24.05)	1.10±0.20 (39.24)
T_2	0.85±0.13	0.93±0.08 (9.41)	1.05±0.08 (23.52)	1.15±0.06 (35.29)
T_3	0.89±0.08	0.97±0.16 (8.98)	1.08±0.13 (21.34)	1.20±0.06 (34.88)
T_4	0.93±0.09	1.01±0.06 (8.60)	1.12±0.06 (20.43)	1.24±0.09 (33.40)
T_5	1.01±0.12	1.09±0.08 (7.92)	1.20±0.06 (18.81)	1.31±0.10 (29.70)

ANOVA

Analysis of variance	Sum of square	Df	Mean of square	F-value	P-value
Rows	2.982333	23	0.129667	81.7675	1.99E-60
Columns	1.3214	5	0.26428	166.6544	5.8E-51
Error	0.182367	115	0.001586		

C – Control, T_1 (20% FA + 80% BM), T_2 (30% FA + 70% BM), T_3 (40% FA + 60% BM), T_4 (50% FA + 50% BM), T_5 (60% FA+40% BM) Initial (0) – Worm unworked substrates, Mean± SD of six observations, (+/–) – Percent change of increase or decrease over the initial.

Table 3: Organic Carbon content (%) of the vermicomposts of flyash + bedding material mixture of *E. fetida* (p<0.05)

Substrate proportions	Initial(0)	Vermicomposting days 30	60	90
C	38.89±0.87	31.95±1.71 -(17.84)	27.46±1.53 -(29.39)	22.28±1.35 -(42.71)
T_1	36.28±1.23	30.12±1.42 -(16.97)	25.85±1.82 -(28.74)	21.15±1.34 -(41.70)
T_2	33.44±1.30	28.46±1.49 -(14.89)	24.69±1.67 -(26.16)	20.36±1.13 -(39.11)
T_3	29.74±0.68	25.94±1.79 -(12.77)	22.67±1.48 -(23.77)	19.75±1.11 -(33.59)
T_4	26.63±0.77	24.01±1.07 -(9.83)	20.81±1.43 -(21.85)	19.25±1.42 -(27.71)
T_5	24.42±1.46	22.98±1.08 -(5.89)	19.30±1.17 -(20.96)	18.51±1.24 -(24.20)

ANOVA

Analysis of variance	Sum of square	Df	Mean of square	F-value	P-value
Rows	2795.77	23	121.5552	47.85227	3.16E-48
Columns	1384.564	5	276.9127	109.0114	5.91E-42
Error	292.1251	115	2.540218		

C – Control, T_1 (20% FA + 80% BM), T_2 (30% FA + 70% BM), T_3 (40% FA + 60% BM), T_4 (50% FA + 50% BM), T_5 (60% FA + 40% BM)
Initial (0) – Worm unworked substrates, Mean± SD of six observations, (+/–) – Percent change of increase or decrease over the initial.

Table 4: Nitrogen content (%) of the vermicomposts of flyash + bedding material mixture of *E. fetida* (p<0.05)

Substrate proportions	Initial(0)	Vermicomposting days 30	60	90
C	2.18+0.16	3.68 ±0.22 (68.80)	3.88±0.38 (77.98)	3.58+0.37 (64.22)
T_1	2.09±0.31	3.21±0.25 (53.58)	3.46±0.29 (65.55)	3.34±0.35 (59.80)
T_2	2.08±0.21	3.17+0.19 (52.40)	3.20+0.32 (53.84)	3.18+0.24 (52.88)
T_3	2.03±0.29	3.09+0.17 (52.21)	3.11±0.20 (53.20)	3.07±0.23 (51.23)
T_4	1.99+0.18	2.99±0.25 (50.25)	3.04±0.26 (52.76)	2.98±0.16 (49.74)
T_5	1.94+0.15	2.88+0.12 (48.45)	2.95+0.14 (52.06)	2.86±0.11 (47.42)

ANOVA

Analysis of variance	Sum of square	Df	Mean of square	F-value	P-value
Rows	44.7888	23	1.947339	73.6101	5.46E-58
Columns	6.8642	5	1.37284	51.89383	6.52E-28
Error	3.0423	115	0.026455		

C – Control, T_1 (20% FA + 80% BM), T_2 (30% FA + 70% BM), T_3 (40% FA + 60% BM), T_4 (50% FA + 50% BM), T_5 (60% FA + 40% BM)
Initial (0) – Worm unworked substrates, Mean± SD of six observations, (+/–) – Percent change of increase or decrease over the initial.

Table 5: Phosphorous content (%) of the vermicomposts of flyash + bedding material mixture of *E. fetida* (p<0.05)

Substrate proportions	Initial(0)	Vermicomposting days 30	60	90
C	1.32±0.11	2.07±0.16 (56.81)	2.12±0.14 (60.60)	2.02±0.13 (53.03)
T_1	1.30±0.10	1.86±0.18 (43.07)	1.96±0.15 (50.76)	1.93±0.12 (48.46)
T_2	1.29+0.09	1.84±0.08 (42.63)	1.87±0.22 (44.96)	1.80±0.18 (39.53)
T_3	1.26±0.14	1.79±0.21 (41.26)	1.82±0.30 (44.44)	1.72±0.08 (36.50)
T_4	1.23±0.08	1.72±0.17 (39.83)	1.76±0.11 (43.08)	1.65±0.15 (34.14)
T_5	1.20±0.16	1.65±0.15 (37.50)	1.71±0.10 (42.50)	1.57±0.19 (30.83)

Analysis of variance	Sum of square	Df	Mean of square	F-value	P-value
Rows	10.4881	23	0.456004	98.57301	8.37E-65
Columns	1.805387	5	0.361077	78.05295	2.53E-35
Error	0.531997	115	0.004626		

C – Control, T_1 (20% FA + 80% BM), T_2 (30% FA + 70% BM), T_3 (40% FA + 60% BM), T_4 (50% FA + 50% BM), T_5 (60% FA + 40% BM)
Initial (0) – Worm unworked substrates, Mean± SD of six observations, (+/–) – Percent change of increase or decrease over the initial.

Table 6: Potassium content (%) of the vermicomposts of flyash + bedding material mixture of *E. fetida* (p<0.05)

Substrate proportions	Vermicomposting days			
	Initial(0)	30	60	90
C	0.60±0.13	0.96±0.12 (60.00)	1.05±0.04 (75.0)	0.94±0.13 (56.66)
T_1	0.64±0.12	1.01±0.08 (57.81)	1.10±0.10 (71.87)	0.98±0.09 (53.12)
T_2	0.70±0.05	1.08±0.06 (54.28)	1.17±0.12 (67.14)	1.05±0.08 (50.00)
T_3	0.75±0.15	1.13±0.09 (50.67)	1.21±0.07 (61.33)	1.10±0.04 (46.66)
T_4	0.80±0.03	1.18±0.11 (47.5)	1.27±0.11 (58.75)	1.16±0.12 (45.0)
T_5	0.84±0.13	1.21±0.07 (44.04)	1.30±0.13 (54.76)	1.20±0.08 (42.85)

Analysis of variance	Sum of square	Df	Mean of square	F-value	P-value
Rows	5.772742	23	0.250989	592.9884	2.1E-108
Columns	1.148158	5	0.229632	542.5299	3.44E-78
Error	0.048675	115	0.000423		

C – Control, T_1 (20% FA + 80% BM), T_2 (30% FA + 70% BM), T_3 (40% FA + 60% BM), T_4 (50% FA + 50% BM), T_5 (60% FA + 40% BM)
Initial (0) – Worm unworked substrates, Mean± SD of six observations, (+/–) – Percent change of increase or decrease over the initial.

4.DISCUSSION

Soil pH is one of the important factors as the microorganisms and higher plants respond markedly to their physico–chemical environment. In the present study upward shift in pH with increasing concentrations of fly ash may be attributed to the release of Ca, Na, Mg and OH ions along with other trace elements. They added that the shifting of pH with respect to different days may be due to neutralization of H^+ by the alkali salts present in soil as well as the solubility of more basic metallic oxides of FA with the time. The present findings are supported by Gupta *et al.* (2007) and Hasnah and Hasan (2008) who have reported a decrease in pH from alkaline to acidic or neutral (6.5 ± 0.1 to 7.3 ± 0.2) in all vermireactors of water hyacinth using an epigeic earthworm *E. fetida.* Suthar (2009) results also goes parallel with our results by using *E. fetida*, in which he has reported a decrease in pH during the vermicomposting of biogas slurry, wheat straw and vegetable waste. The reduction in pH in the final products could also have been due to the production of CO_2 and organic acids by microbial activity during the process of bioconversion of the different substrates in the beds (Haimi and Huhta, 1986; Albanell *et al.*, 1988; Chan and Griffiths, 1988; Elvira *et al.*, 1998). Decomposition of organic matter leads to formation of ammonium (NH^{4+}) ions and humic acids (Komlis and Har 2006). These two components have exactly opposite effect on tl pH. Presence of carboxylic and phenol groups in humic aci caused lowering of pH while ammonium ions increased the p of the system. Combined effect of these two oppositely charg ions actually regulates the pH of vermicompost leading to a sh of pH towards neutrality (Pramanik *et al.*, 2007). In the prese study at the end of the vermicomposting process, it was fou that the substrates in all the treatments were near neutral which supporting the above findings.

EC represents the concentration of soluble salts. This increas EC could be due to release of mineral salts such as phosphat and ammonia ions through the decomposition of organ substances, when substrate passes through the gut of earthwori This shows that during vermicomposting process, the soluble sa level increases because of the mineralization activity of earthworms and microorganisms in the organic substance. Joshi and Kelkar (1952) have reported a higher electrical conductivity in casts, which denotes an increase in the level of soluble salts. These findings were supported by the results of the previous work conducted in the laboratory with other earthworm species during the vermicomposting of leaf litter, weeds and agricultural residues (Daniel and Karmegam, 1999; Karmegam and Daniel, 2000 a, b). Gradual increase in EC was recorded in all the feed substrates under decomposition (Table 2). This may be attributed due to freely available ions and minerals that are generated during ingestion and excretion by the earthworms (Garg *et al.*, 2006). The present study is supported by Garg *et al.* (2006) who have reported lower pH and gradual increase in EC in the vermicomposts of all feed mixtures from different types of wastes (Kitchen waste, agro–residues, and Institutional wastes) by *E. fetida.* Karmegam and Daniel (2009) also reported that the reduction of pH and (significant increase in EC) in the final product of vermicomposting of different types of organic substrates by *L.mauritii* and *P.ceylanensis.* On the contrary Venkatesh and Eevera (2008) reported that a decrease in EC during vermicomposting of FA with CD and it might be due to leaching of ammonia.

Suthar (2007a) reported that earthworms fragment and homogenize the ingested material through muscular action of their foregut which results increasing of surface area for microbial action, whereas, microorganisms biochemically degrades and provide some extracellular enzymes required for organic waste decomposition within the worms gut. However, this biological mutualism results in the loss of carbon from substrates in the form of CO_2 due to decomposition and mineralization of organic carbon (Dominguez, 2004). The reduction of organic carbon during 90 days period in the vermicompost could be due to the respiratory activity of earthworms and microorganisms (Curry *et al.*, 1995; Edwards and Bohlen, 1996). In the present study total organic carbon decreased with time in all treatments, falling in line with the observations made by Crawford (1983), where he reported that the organic carbon is lost as carbon–dioxide and total nitrogen increase as a result of carbon loss. Microorganism, that uses the carbon as a source of energy and nitrogen for building cell structure brings about decomposition of organic matter. In the observations of Karmegam and Daniel (2000a) the percentage of OC was reduced day–by–day while that of nitrogen was increased in the worm introduced substrates. Recent studies revealed that vermicomposting process cause significant decline in OC budget of the waste decomposition system and accelerates the waste degradation process (Garg and Kaushik, 2005; Loh *et al.*, 2005; Suthar, 2006, 2007a, 2007b).

Nitrogen is the key–nutrient substance for both plants and animals as well as microorganisms. When soil organic matter is decomposed, nitrogen is released as the usable nutrient ion, ammonium. Originally ammonium was known as the only mineral form of nitrogen, so this conversion of organic nitrogen to the ammonium form was named as mineralization. This release of nitrogen from organic matter decomposition is a major source of usable nitrogen. It is well established that earthworms modify the spatial distribution of soil organic matter in the soil profile, alter its turnover and accelerate nutrient cycling. Earthworms contribute to carbon and nitrogen cycling through the accumulation (consumption), storage (assimilation) and turnover (respiration, excretion, mortality) of nutrients from casts (Whalen *et al.*, 1998). Bhattacharya and Chattopadhyay (2004) have reported nitrogen availability was more during vermicomposting in combination with higher quantity of CD.

Experiments of Kaushik and Garg (2005) demonstrated much rapid decomposition rate of the organic matter, accompanied by increase in N during the first few weeks. Fall in line with above studies in the present study it was observed that N in all the treatments and control increased up to 60^{th} day and a decreasing trend was observed after 60^{th} day. Similar results have been reported by other workers (Bansal and Kapoor, 2000; Atiyeh *et al.,* 2000a).

Phosphorus is the second major key plant nutrient. It is an inorganic nutrient required by both plant and microorganisms. It brings certain essential steps in the accumulation and release of energy during cellular metabolism. It is an essential part of nucleoproteins in the cell nuclei (DNA). Phosphorus has roles in cell division, in stimulation of early root growth, in hastening plant maturity, in energy transformation within the cells and in fruiting and seed production. Bacteria and other organisms continue to hydrolyze organic phosphorus from dead organic residues, making it available for plants. Increase in phosphorus during vermicomposting is probably through mineralization and mobilization of phosphorus by bacterial and faecal phosphatase activity of earthworms (Edwards and Lofty, 1972; Satchel and Martin, 1984; Krishnamoorthy, 1990). Vermicomposting of fly ash was proved to be an efficient method in providing P. This was mainly attributed to the greater phosphatase activity in earthworm casts as reported by Satchell *et al.* (1984). Phosphorus availability was lowest in FA, as discussed earlier (Kumar *et al.*, 1998) and increased when mixed with CD. In the present study incorporating organic wastes with FA in different combinations resulted in increased P availability. The P increases upto a level of 40% (W/W) of fly ash beyond which it declines. The reason may be the concentration of fly ash which remains non toxic for the microbial transformation of inorganic phosphorus to the available form (Mullen *et al.,* 1992). The present study *E. fetida* have clearly established that decreased phosphorus content after 60^{th} day of vermicompost may be due to decreased microbial activity (mineralization) and decreased phosphatase activity.

Potassium is the third most used element by plants. It is one of the elements whose usual chemical compounds are most soluble. It is the most abundant metal cation in plant cells but soil humus furnishes very little potassium during decomposition. Kaviraj and Sharma (2003) reported 10% increase of total K by *E. fetida* and 5% by *L. mauritii* during the vermicomposting of municipal solid waste and it was due to the influence of microflora. In the present investigation mineralization of K was more in vermicomposts, which indicates the role of earthworm and microorganisms in mineralization process as described by Suthar (2007b). Results to Bakthavathsalam and Geetha (2004) revealed that the increased levels of N and K observed in the vermicomposts of paddy chaff and weed plants materials indicated their effective decomposition when they pass through the gut of *L. mauritii*. Suthar (2007b) indicated the presence of highest mineralization of N, P and K in mixed material by *P. excavatus* (mixed crop residue+ cow dung). From the results it may be concluded that the rate of mineralization could be decreased due to the increasing concentration of FA which had higher proportion of heavy metals which exerts toxicity. The higher concentration of FA affected the population of microbes and quantity of microbial enzymes.

Hence this study indicates that considerable amount of lignite FA can be used along with BM to enrich the soil through vermicomposting. From the current study, it is clear that the use of *E. fetida* to mitigate toxicity of FA seems to be feasible technology with upto 40% FA with BM for sustainable and efficient for vermicomposting without showing any toxicity to earthworms. This was supported by Gupta *et al*. (2005), Venkatesh and Eevera (2008), Ananthakrishnasamy *et al*. (2009) and Sarojini *et al*. (2009) where they have reported lower percentage of FA supported the activities of earthworms. The survey of literature indicated that data on vermicomposting and chemical analysis are available plenty on organic wastes but information about vermicomposting of FA and chemical analysis of the vermicompost are scanty. Further, the chemical characterization of vermicompost obtained from the above said experiments is very essential to have an idea about their nutrient status and fertilizing quality. Though few studies have been made on the nutrient changes in fly ash during vermicomposting (Bhattacharya and Chattopadhyay, 2001, 2006; Venkatesh and Eevera, 2008; Ananthakrishnasamy *et al.*, 2009).

5.CONCLUSION

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 20% to 60% of flyash mixture can be used for sustainable and efficient for vermicomposting, without showing any toxicity to earthworms. The concentrations of macronutrients (NPK) were found to increase in the earthworm treated series of BM and FA combinations.

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