MASS REDUCTION AND RECOVERY OF NUTRIENTS THROUGH VERMICOMPOSTING OF FLY ASH

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(Received 9th January 2007; accepted13th May 2007)

Abstract. In view of the environmental problems generated by large-scale production of fly ash, increasing attention is now being paid to the recycling of fly ash as a good source of nutrients. Because availability of many nutrients is very low in fly ash, available ranges of such nutrients must be improved to increase the effectiveness of fly ash as a soil amendment. In our experiment, we assessed the possibility of increasing total nitrogen, total phosphorus, total potassium and micronutrients in fly ash through vermicomposting. Fly ash was mixed with cow dung at 1:3, 1:1, and 3:1 ratios and incubated with *Eudrilus eugeniae* for 60 days. The concentration of above said macro and micronutrient was found to increase in the earthworm-treated series of fly ash and cow dung combinations compared with the fly ash alone. This helped to transform considerable amounts of total nitrogen, total phosphorus, total potassium and micronutrients from fly ash into more soluble forms and thus resulted in increased bioavailability of the nutrients in the vermicomposted series. Among different combinations of fly ash and cow dung, nutrient availability was significantly higher in the 1:3 fly ash to cow dung treatment compared with the other treatments.
Keywords: *mass reduction, nutrient, fly ash*

Introduction

Fly ash is the fine residue captured from flue exhausts when coal is burnt in power stations. With the consistently increasing number of coal-fired plants, the large-scale generation of fly ash is creating acute waste disposal problems in different parts of the world. The amount of ash produced annually in India was around 90 million tons during 1995 and is likely to exceed 140 million tons in 2020. There are few uses for the tonnages produced and the disposal of fly ash has become a significant problem. The common practice is to dispose these residues to the dumping sites of the power plants, which cover huge areas of otherwise agriculturally productive land. Fly ash is used in civil construction, but it is not very popular because of its cost. It is also used as landfill depending on its pH, for reclaiming acid or sodic soil (Naveen kalra et al., 1997, Gene Stevens and David Dunn, 2004) and to alter the texture and water holding capacity of the sandy soils (Pathan et al*.,* 2003). Co- composting of sewage sludge and coal fly ash has been an effective way to transform the fly ash into nutrient rich product (Fang et al., 1999). However these procedures do not utilize a major portion of the ash and thus thermal power stations have to manage its storage, while keeping the levels of air and water pollution associated with it to a minimum. To overcome this, various possible methods for the safe disposal and reuse of fly ash have been envisaged by different researchers, of which the composting process has received a particular interest (Bhattacharya and Chattopadhyay, 2004).

Composting is one of the most promising ways to recycle the wastes generated from power plants, as the process reduces the volume, and stabilizes the waste. The high organic matter content in the compost product also preserves soil fertility. Composting

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is a widely acceptable alternative for converting waste into a more useful eco-friendly fertilizer to improve soil fertility (Fang et al., 1998, Maleena Imbeah, 1998).

The suitable adjustment of parameters, such as moisture, oxygen level, and temperature during the composting process will determine the proper functioning as well as the characteristics of the final product obtained. Alteration of these parameters may change the quality of the compost. Proper condition should be provided for the growth of microorganisms as well as the earthworm. The addition of fly ash to the composting process has no detrimental effect on either C- to- N ratio or the microbial population (Sunita Gaind and Gaur, 2003).

Although various physical, chemical and microbiological methods of disposal of organic solid wastes are currently in use, these methods are time consuming and expensive. Therefore, there is a pressing need to find cost-effective alternative method of shorter duration. In this regard, vermicomposting has been reported to be a viable, cost effective and rapid technique for the efficient management of the solid wastes. Vermicomposting is a suitable technology for decomposition of different types of organic waste (domestic as well as industrial) into value added material (Payal et al., 2006). Also municipal solid waste can be subjected to vermicompost, which can yield high nutritive value (Kaviraj and Satyawati Sharma, 2003). Earthworms utilize the waste substrate and enhance the rate of decomposition of the organic matter, leading to a composting effect through which unstabilized organic matter becomes stabilized. The biological activity of earthworms provides nutrient rich vermicomposting for plant growth thus facilitating the transfer of nutrients to plants. Another important end product of the vermicompost process is the vermiwash. It is a very good fertilizer, growth promoter and helps inducing flowering and fruit-bearing in higher plants. This can even help plants to get rid of pests and diseases.

The role of earthworms in the process of vermicomposting of waste is a physical and biochemical process. The physical process includes substrate aeration, mixing as well as actual grinding while the biochemical process is influenced by microbial decomposition of substrate in the intestine of earthworms Various studies have shown that vermicomposting of organic waste accelerates organic matter stabilization (James Frederickson et al., 1997) and gives chelating and phytohormonal elements which have a high content of microbial matter (Arancon et al., 2005) and stabilized humic substances.

There has been a growing movement to decrease the rate of inorganic fertilizer applications to soil by using soil nutrients more efficiently and by the increased use of organic matter. Organic manure is an important source for maintaining soil fertility. Maintenance of soil organic matter for sustained soil productivity requires the input of organic manures. Currently there has been more emphasis on use of organic manure all over the world. The use of organic wastes in the application to farmlands has increased over the years, since the use contributes to the disposal of wastes and enhances the preservation of the environment. The high organic matter content in the compost product also preserves soil fertility. Among various sources of organic matter, vermicomposts have been recognized as having considerable potential as soil amendments. So vermicomposting technique has been adopted widely for organic farming.

Keeping the above said problems and ideas in mind, the present study was conducted to assess the potential of *Eudrilus eugeniae* in composting of the cow dung blended fly ash and quality of vermicompost.

Materials and methods

Fly ash for this study was collected from Bharat Heavy Electricals Limited (BHEL) plants located in Tiruchirapalli, Tamil Nadu (India). A bulk sample of fresh fly ash was taken from the hopper of the power plant. After collection the dry ash is thoroughly mixed and stored in plastic lined containers at room temperature before use.

The earthworms (*Eudrilus eugeniae*) and cow dung are collected manually from the vermicompost field which is located in Periyar Maniammai College of Technology for Women, Thanjavur, India. Healthy earthworms of approximately the same size are collected and fresh cow dung is collected from the field for this study.

The study was performed in yards with burnt earthen pots (4.5-L volume), which were inert in nature. Five combinations of fly ash (FA) and cow dung (CD) versus FA alone (T0), CD alone (T1),T2 - FA + CD (1:1),T3 - FA + CD (1:3), and T4 - FA + CD (3:1) were used for the study on a weight basis for each of the materials, at a total weight of 1 kg material in each pot. Each of the treatments was replicated thrice in a completely randomized design (CRD) and incubated (Bhattacharya and Chattopadhyay, 2002) with and without *Eudrilus eugeniae* at 10 worms kg^{-1} material. Earthworms did not survive properly in the treatment with FA alone and periodic additions were made during the sampling dates as necessary. The materials under each treatment were incubated under moist conditions for 60 days at a room temperature range of 28.0 to 33.7°C. Samples were drawn periodically at 15-days interval from each of the incubated materials and were analyzed for pH, Electrical conductivity, Moisture content, Total carbon, Total nitrogen, Total phosphorus, Total potassium, Micronutrients and Heavy metals. Determinations of these parameters were carried out by using the following procedure: pH and Electrical conductivity (EC) were determined using aqueous extract of air dried sample by Systronics Digital pH meter 335 and Systronics Conductivity meter 304. Total organic carbon was estimated by Walkley and Black titration method. Total nitrogen was estimated by Kjeldahl method. Total Phosphorus was estimated by Pemptron method using Systronics Flame Photometer CL 23. Total potassium was estimated by Stanford and English method. Calcium and Magnesium were estimated Versanate titration method. All other micronutrients and heavy metals were analyzed using SOLAR Atomic Absorption Spectrometer (AAS2). For easy composting, 40 to 50% moisture levels were maintained in the samples, moisture content of the samples was determined gravimetrically with the differences between moist and dried samples and necessary corrections were made to get the results on a dry-weight basis. The results were analyzed with CRD.

Result and discussion

Changes in pH, Electrical conductivity, Moisture content, total carbon, total nitrogen, total phosphorus, total potassium, micronutrients in different combinations of fly ash are presented in the table 1 to 14.

The results suggest that earthworms play a significant role in processing fly ash into organic manure. The earthworm activity accelerated the process of decomposition of fly ash and stabilizing the waste. The vermicompost manure was much darker in color and had been processed into a much more homogenous mass after two months of earthworm activity, whereas the material without earthworms remained in compact clumps.

Vermicomposted manure also had a lower Ph *(Table 1),* which may be due to the accumulation of organic acids from microbial metabolism or from the production of fulvic and humic acids during decomposition (Albanell et al., 1988; Chan and Griffiths, 1988). In all treatments, earthworms reduced the pH value, which is in accordance with Atiyeh et al. (2000).

Table 1. *Effect of Vermicomposting on substrate pH*

Treatment	**Days after composting**				
	0	**15**	**30**	**45**	**60**
T_0	8.62	8.62	8.62	8.60	8.60
T_1	7.85	7.80	7.60	7.45	7.45
T_2	8.25	8.30	8.26	8.20	8.22
T_3	8.22	8.24	8.22	8.12	8.10
T_4	8.35	8.32	8.32	8.28	8.26

The EC *(Table 2)* value increased in the beginning of composting up to 30 days in mix 1:3, then steady decrease was observed at the end of composting. The initial increase could be due to the release of mineral salts such as phosphates and ammonia ions through the decomposition of organic substances. The volatilization of ammonia and the precipitation of mineral salts could be the possible reason for the decrease in EC at the later phase of composting (Wong et al., 1995).

Table 2. *Effect of Vermicomposting on substrate EC (Dsm^{-1})*

Treatment	**Days after composting**				
	0	**15**	**30**	**45**	**60**
T_0	0.98	0.98	0.94	0.92	0.90
T_1	1.02	1.00	0.88	0.64	0.64
T_2	0.55	0.43	0.59	0.54	0.42
T_3	0.58	0.61	0.62	0.55	0.36
T_4	0.46	0.30	0.40	0.31	0.29

Total organic carbon *(Table 3)* decreased with time in all treatments. The organic carbon is lost as carbon dioxide and total Nitrogen increase as a result of carbon loss (Crawford, 1983). Microorganism that uses the carbon as a source of energy and Nitrogen for building cell structure brings about decomposition of organic matter. But the reduction was greater in vermicomposting compared to the ordinary composting; this may be due to the fact that earthworms have higher assimilating capacity.

Table 3. *Effect of Vermicomposting on substrate Organic Carbon (%)*

Treatment	**Days after composting**				
	0	**15**	**30**	**45**	**60**
T_0	7.98	7.94	7.92	7.90	7.90
T_1	10.49	10.00	8.32	7.05	7.05
T_2	8.98	8.24	8.10	7.58	6.98
T_3	9.19	8.98	8.26	7.98	7.50
T_4	8.79	8.56	8.10	7.86	7.25

Earthworms also had a great impact on Nitrogen transformation in the compost. Total Nitrogen increased *(Table 4)* in all the treatments but gradually decreased after 45^{th} day of composting. The increase in the Nitrogen value is as result of carbon loss

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and probably because of mineralization of organic matter (Kaushik et al., 2003*)*. The final Nitrogen content of compost is dependent on the initial N present in the waste and the extent of decomposition (Crawford, 1983).

Table 4. *Effect of Vermicomposting on substrate Total Nitrogen (%)*

Treatment	Days after composting				
	0	**15**	**30**	**45**	**60**
T_0	0.19	0.19	0.19	0.20	0.2
T_1	0.68	0.92	1.00	1.40	1.40
T_2	0.19	0.42	0.53	0.92	0.91
T_3	0.22	0.43	0.55	0.78	0.98
T_4	0.19	0.32	0.40	0.65	0.63

Total phosphorus *(Table 5)* also increased with time in all the treatment process and gradually decreased after 45th day. Highest amount of Total phosphorus was recorded in mix 1:3. Normally P is found in unavailable forms like calcium phosphate or potassium phosphate. Our study reveals that worms have the ability to convert insoluble P into soluble forms. Vermicomposting proved to be an efficient technology for providing better P nutrition from organic waste which is accordance with Ghosh et al., (1999).

Table 5. *Effect of Vermicomposting on substrate Total Phosphorous (%)*

Treatment	Days after composting				
	0	**15**	**30**	**45**	**60**
T_0	0.03	0.03	0.03	0.04	0.04
T_1	0.16	0.32	0.52	0.68	0.72
T_2	0.04	0.08	0.09	0.23	0.22
T_3	0.06	0.08	0.09	0.29	0.26
T_4	0.03	0.09	0.09	0.21	0.18

Total potassium initially increased and then decreased gradually after 45th day. Maximum amount was recorded in mix 1:3 *(Table 6).*

Table 6. *Effect of Vermicomposting on substrate Total Potassium (%)*

Treatment	Days after composting				
	0	**15**	**30**	**45**	**60**
T_0	1.15	1.15	1.16	1.18	1.18
T_1	0.98	1.02	1.42	1.68	1.69
T_2	1.20	1.12	1.28	1.68	1.64
T_3	1.18	1.22	1.58	1.98	1.86
T_4	1.22	1.26	1.48	1.89	1.74

In all our treatments, the value of micronutrients increased rapidly with time. Better result was obtained for mix 1:3 ratio in the vermicomposting process. There were no heavy metals at the end of the study which could be related to leaching of these cations by excess water drainage (Kaushik and Garg, 2003).

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Table 7. *Effect of Vermicomposting on substrate Total Calcium (%)*

Treatment	**Days after composting**				
	0	**15**	**30**	**45**	**60**
T_0	0.84	0.84	0.84	0.84	0.84
T_1	0.58	1.21	1.68	2.84	2.85
T_2	0.85	1.41	1.92	2.98	3.25
T_3	0.85	1.58	2.68	3.59	3.59
T_4	0.86	1.32	1.88	3.20	3.19

Table 8. *Effect of Vermicomposting on substrate Total Magnesium (%)*

Treatment	**Days after composting**				
	0	**15**	**30**	**45**	**60**
T_0	0.31	0.31	0.31	0.31	0.31
T_1	0.54	0.88	1.62	2.26	2.24
T_2	0.30	0.72	1.42	2.04	2.01
T_3	0.30	0.98	1.92	2.70	2.69
T_4	0.30	0.89	1.82	2.32	2.31

Table 9. *Effect of Vermicomposting on substrate Total Zinc (ppm)*

Treatment	**Days after composting**				
	0	**15**	**30**	**45**	**60**
T_0	0.78	0.78	0.78	0.78	0.78
T_1	1.28	3.81	5.20	7.46	7.46
T_2	0.72	0.98	1.40	1.35	1.35
T_3	0.86	0.90	1.08	1.40	1.40
T_4	0.79	0.88	1.12	1.39	1.39

Table 10. *Effect of Vermicomposting on substrate Total Copper (ppm)*

Treatment	**Days after composting**				
	0	**15**	**30**	**45**	**60**
T_0	0.06	0.06	0.07	0.09	0.06
T_1	0.78	3.01	4.58	8.22	8.21
T_2	0.05	0.49	0.75	1.15	1.13
T_3	0.12	0.53	0.88	1.20	1.18
T_4	0.09	0.38	0.73	1.18	1.16

Table 11. *Effect of Vermicomposting on substrate Total Manganese (ppm)*

Treatment	**Days after composting**				
	0	**15**	**30**	**45**	**60**
T_0	1.26	1.26	1.27	1.29	1.26
T_1	0.89	1.52	2.00	2.66	2.66
T_2	1.25	1.32	1.58	2.84	2.86
T_3	1.29	1.52	1.92	2.90	2.96
T_4	1.22	1.48	1.88	2.92	2.92

Table 12. *Effect of Vermicomposting on substrate Total Iron (ppm)*

Treatment	Days after composting				
	0	**15**	**30**	**45**	**60**
T_0	2.48	2.48	2.50	2.54	2.48
T_1	2.48	4.27	6.38	9.24	9.24
T_2	2.50	3.88	4.31	6.29	6.29
T_3	2.75	3.92	4.52	6.48	6.49
T_4	2.56	3.88	4.33	6.28	6.27

Table 13. *Effect of Vermicomposting on substrate Total Boron (ppm)*

Treatment	Days after composting				
	0	**15**	**30**	**45**	**60**
T_0	0.04	0.04	0.04	0.04	0.04
T_1	0.12	0.16	0.28	0.44	0.46
T_2	0.03	0.08	0.10	0.12	0.10
T_3	0.04	0.06	0.08	0.12	0.12
T_4	0.04	0.04	0.06	0.09	0.09

Table 14. *Effect of Vermicomposting on substrate Total Molybdenum (ppm)*

Treatment	Days after composting				
	0	**15**	**30**	**45**	**60**
T_0	0.01	0.01	0.01	0.01	0.01
T_1	0.02	0.12	0.22	0.24	0.24
T_2	0.02	0.02	0.02	0.03	0.03
T_3	0.03	0.03	0.03	0.03	0.03
T_4	0.02	0.02	0.02	0.03	0.03

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