Iranian J Env Health Sci Eng, 2004,Vol.1, No.2, pp.43-50

Vermistabilization of Municipal Wastewater Sludge with *Eisenia fetida*

***A Parvaresh, H Movahedian, L Hamidian**

Dept. of Environmental Health Engineering, Faculty of Health, Isfahan University of Medical Sciences, Iran

ABSTRACT

Sludges are stabilized to reduce pathogens, eliminate offensive odors and inhibit, reduce or eliminate the potential for putrification. In this study, stabilization of municipal wastewater sludge with and without earthworms (*Eisenia fetida*) was tested in a pilot study. The earthworms were fed at the optimum level of 0.75 kg-feed/kg-worm/day. Decomposition and stabilization of wastewater sludge occurred both in the presence and in the absence of earthworms during 9 weeks but the process was accelerated in their presence. Phosphorus content increased in the sludge with earthworms but decreased in it without them. Nitrogen content in the resulting vermicompost showed no difference with its quantity in the original substrate while it increased in the control treatment.

Keywords: *Sludge stabilization, Vermicompost, Vermistabilization*

INTRODUCTION

Environmental and public health concerns worldwide have led to increasing emphasis on beneficial uses of biosolids as a replacement for incineration or landfill methods. The pertaining regulation and considerations of sludge transportation requires various stages of sludge processing prior to land application (McFarland, 2000).

The most important stage is sludge stabilization. As in the most countries, waste-water treatments facilities in Iran make use anaerobic digesters to stabilize wastewater sludge. However, the digesters used in municipal wastewater treatment plants in Iran have great operational and process deficiencies that lead to partial sludge stabilization. Therefore, the effluent sludge from these digesters must be subjected to complementary stabilization or other supplementary processes with a simple technology, easy operation, and higher efficiency. Vermicomposting has nowadays attracted much attention as a method of sludge stabilization worldwide due to its simple technology and lack of need for expensive equipments (Ndegwa and Thompson, 2000).

In the present study, the efficiency of vermicomposting in stabilizing municipal wastewater was studied as a replacement for the digestion process. The changes in volatile organic material, ash, total carbon, total N, C/N ratio, and the changes in P and K contents were used to determine its efficiency.

MATERIALS AND METHODS

Preparation of substrate and earthworms

The municipal wastewater sludge was taken from effluent sludge of the gravity thickener in Isfahan Southern Wastewater Treatment Plant.

***Corresponding author**: Tel :+98 311 7922662, Fax: +98 311 6682509, *E-mail: pavaresh@hlth.tui.ac.ir*

The sludge was a mixture of primary sludge and waste activated sludge with a moisture content of over 95%. The sludge was initially dewatered by passing through sand beds for 24 h to increase its concentration and reduce its moisture to 80%.

The sludge in the present study was mixed with carbon-rich bulking materials such as straw and decaying leaves in order to accelerate the decomposition process, to improve C/N ratio (through supplying adequate carbon), and to prevent N content less through volatilization (Domiguez et al., 2000). Earthworms (*E.fetida*) were collected from ShirkharKola village in Ghaem Shahr Town, Mazanadaran province, according to recognized identification keys (Pierce and Graff, 1953).

Experimental design A mixture of 85% dewatered sludge and 15% straw and decaying leaves (fig , walnut, spruce and ash tree …) was placed in two containers (0.1 m^2 cross section) to provide a one-month food supply for earthworms assuming optimum feeding rate of 0.75 kg feed/kg-earthworm/day. In order to provide the conditions for microbial inoculation and to prepare a safe environment to enforce earthworms to keep away from the adverse environmental conditions (Benitez et al., 1999), a small container containing mature vermicompost was placed on one of the initial food mixtures. To satisfy the condition of stocking density of 1.6 kg earthworm per square meter (Ndegwa et al., 2000), 161.5 g earthworm was added to the container.

The second container was chosen as control to which no earthworms were added. Both containers were placed in the dark at 14-20 °C. Water was sprayed over the medium to keep moisture constant throughout the study period. Samples were taken from both test and control mixtures after 0, 1, 3, 5, 7, and 9 weeks. Before sampling, the mixture was well stirred and then 200-gram samples were taken from the food mixture from which earthworms were removed. Each sample was again stirred well and immediately tested to determine volatile solids, ash, total nitrogen, moisture, and pH, P and K contents were only measured at the beginning and end of the process.

Analytical methods Mixture contents were measured as follows: moisture by drying samples at 103-105 °C for 18 to 23 h; volatile organics by combusting to ash the dried sample at 550 °C for one hour (APHA, 1992); ash content by combustion of dried samples at 750 °C for two hours (Gotas, 1956) and total N by Kjeldahl method (Theroux et al, 2001). Total carbon was estimated from the relation 1.8c= 100-% Ash. The improved Erhart & Burian method (1997) consisting of potentiometry and a 10 suspension of the sample in deionized water were used to determine pH. Prior to measuring pH, the samples were shaken by a 2000 cina shaker at 350 rpm. To estimate P and K contents, the samples were first dried at a temperature of 80 °C for 48 h, ground fine to a diameter of ≤ 2 mm and then burned dry and digested in chloride acid (Waling et al., 1989). The samples were then analyzed using calorimetry (Tate, 1986) and flame photometry methods (Waling et al., 1989).

RESULTS

The characteristics of the materials used in preparing the substrate for feeding earthworms are presented in Table 1 and the changes in pH and moisture at intervals of 0, 1, 3, 5, 7, and 9 weeks are given in Table 2. Throughout the study period, moisture varied between 59.5-71.9% and pH between 7-8. The temperature of the environment and the beddings as measured daily varied between 14-20 °C as well as between 12-19 °C, respectively.

Table 1: Characteristics of the materials in the substrate prepared for feeding earthworms and container the control

Parameters	Decaying leaves*	Straw	Municipal sludge used in earthworm food	Municipal sludge of control
Total carbon (%)	38.2	46.1	22.6	26.5
Total N (%)	0.87	0.23	3.90	2.98
Volatile solids (%)	91.7	-	44.6	48.9
Ash (%)	26.9	11.7	56.7	49.4
Moisture (%)	6.6	4.6	84.8	88.5
Total solids (%)	93.4	95.4	16.7	11.5
Total K (mg/kg)	24006.5	25061.7	1239.9	1873.1
Total P (mg/kg)	489.9	1674.2	3775.8	4329.3
C/N ratio	42.6	200.0	5.8	8.9

* The decaying leaves used were a combination of fig, walnut, spruce, and ash tree

Table2: Moisture and pH variations in the substrate over the nine weeks of vermicomposting

Time (weeks)	Average moisture,%		pH	
	Reactor with earthworms	Reactor without earthworms	Reactor with earthworms	Reactor without earthworms
0	64.7	71.9	7.0	7.0
1	71.9	66.0	7.4	7.5
3	70.7	75.8	7.5	7.0
5	59.2	70.3	7.0	7.4
7	71.0	68.5	7.7	8.0
9	59.6	70.3	7.5	7.4

Changes in volatile solids content According to Fig.1, the variations in volatile solids content during the study period showed great variations in the presence of earthworms while in their absence and with a delay of one week, volatile solids gradually reduced by the end of the period.

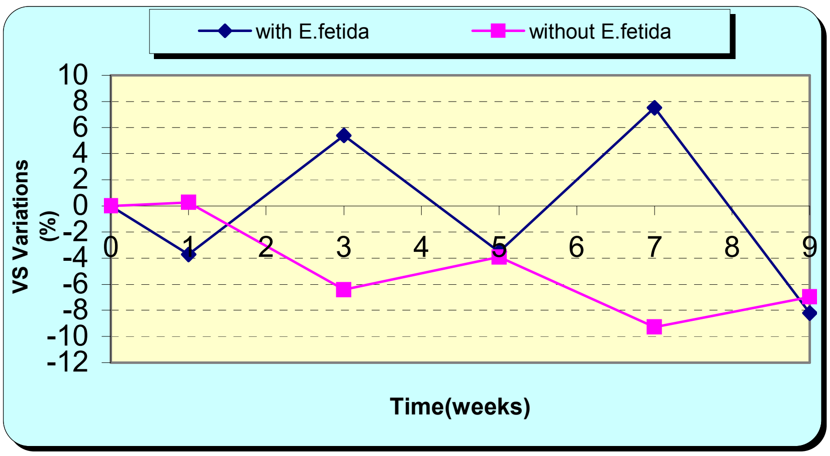

Fig. 1: Comparison of variations in VS over nine weeks of vermicomposting in the two samples with and without *E.fetida*

Changes in ash concentration and total carbon levels The variations in ash concentration and total carbon levels are shown in Figs.2, 3 respectively. As shown in the diagrams, decomposition takes place faster in the presence of earthworms than in their absence.

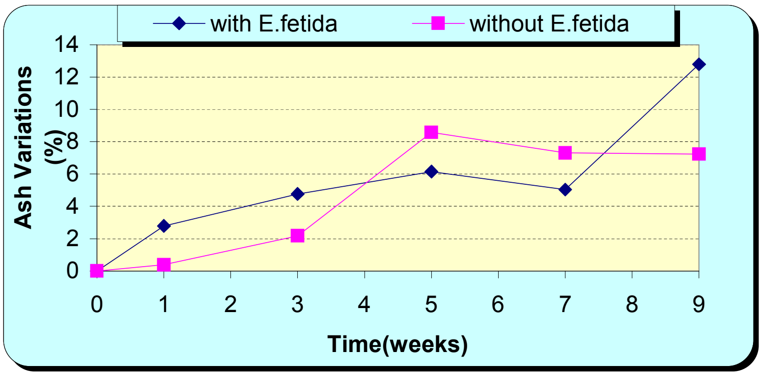

Fig. 2: Comparison of trends in ash variations over the nine-week period of vermicomposting with and without *E.fetida*

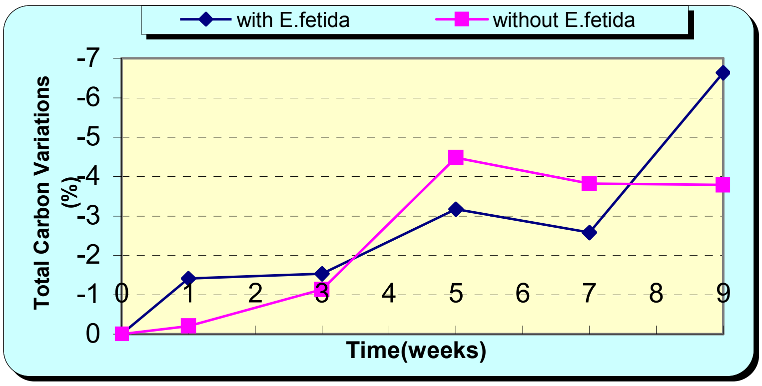

Fig. 3: Comparison of variations in total carbon concentrations over the nine-week period of vermicomposting with and without *E.fetida*

Variations in nitrogen concentration The variations in nitrogen concentration in the presence and absence of earthworms are shown in Fig 4. As with volatile organic solids, nitrogen concentration over the whole process period showed great variations but, in the absence of earthworms, total nitrogen had a generally increasing trend except in the 7th week.

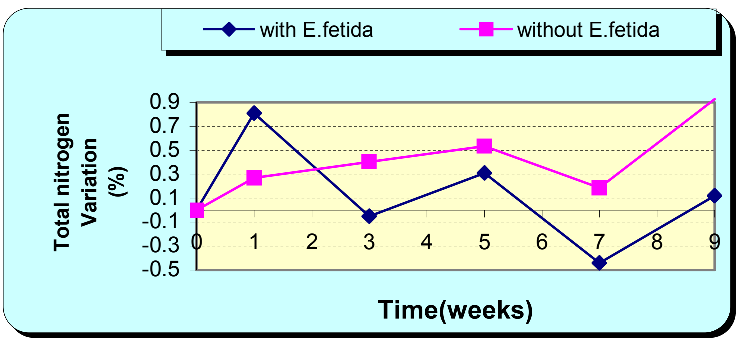

Fig. 4: Comparison of variations in total nitrogen concentrations over the nine-week period of vermicomposting with and without *E.fetida*

Variations in C/N ratios Variations of C/N ratios in the presence and absence of earthworms are shown in Fig. 5. Over the process period, variations in C/N ratios both in the presence and in the absence of earthworms were mostly a function of nitrogen concentration level (Figs.4, 5). At the end of the process, the final control product (compost without the earthworms) with a nitrogen concentration of 2.25% had a lower C/N ratio than the resulting vermicompost (with a nitrogen concentration of 1.04%).

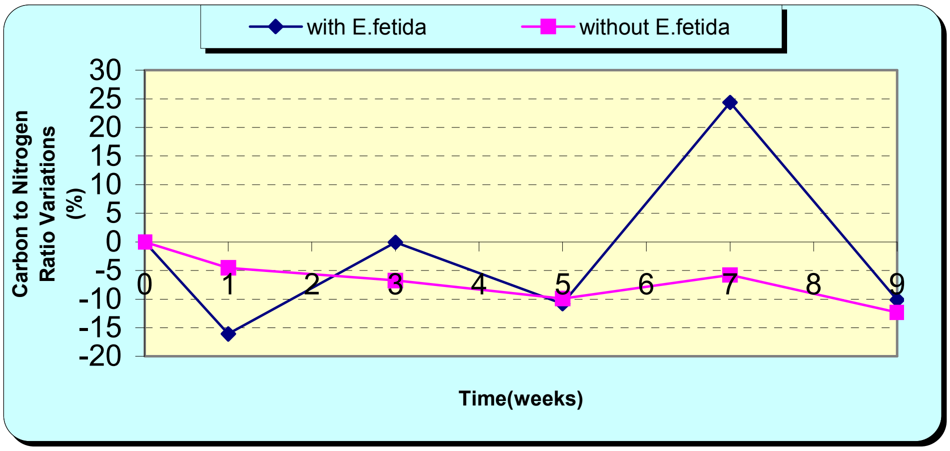

Fig. 5: Comparison of variations in C/N ratios over the nine-week period of vermicomposting with and without *E.fetida*

Variations in P and K concentrations Total P and total k concentration levels in original food mixtures and in the resulting vermicompost and control product after 9 weeks are shown in Table 3. K concentration levels in the control final product and in the resulting vermicompost after nine weeks by 14.34% and 7.55%, respectively.

Table 3: Total P and K concentrations at the process starting and after nine weeks

Medium	Total K (mg/kg)	Variations in K (%)	Total P (mg/kg)	Variation in P (%)
Original food mixture	6647.8	0	3608.0	0
Vermicompost	6145.6	-7.6	3443.0	-4.6
Control initial substrate	6252.1	0	3584.5	0
Control final product	5355.2	-14.3	3802.2	6.1

DISCUSSION

The results of the other investigations have shown that the range of the temperature, moistue and pH were 0-35°C, 60-90% and 5-9, respectively which are suitable condition for earthworms *E.Fetida* growth (Herlihy, 1999). The conditions provided in this study as shown in Table 2 perfectly correspond to the optimum growth conditions. The variations in volatile solids content during the study period showed great variations in the presence of earthworms while in their absence and with a delay of one week, volatile solids gradually reduced by the end of the period (Fig. 1). This bears witness to the difference between vermicomposting and simple composting processes. The cause may be ascribed to the mutual relations between soil

microorganisms and those consumed by earthworms (Vinceslas et al., 1997).
Hartenstein and Hartenstein (1981) reported a 9% reduction in volatile solids over 4 weeks of sludge decomposition by earthworms, which was higher than that of the control by almost one third. Ndegwa and Thompsen (2000) investtigated the stabilization of a mixture of biological solids with paper mulch at C/N ratios of 10, 15, 20, and 25 using *E.fetida*. They obtained a maximum reduction of 9.17% in volatile solids at the C/N ratio of 25. In another study by Ndegwa et al (2000), the reduction was reported as 10.3%. They had obtained end-of-process VS reductions of 8.197% and 6.975% in the presence and absence of earthworms, respectively, concluding that, as in the other studies, earthworms had not adequately reduced sludge VS as an indicator of sludge stabilization.
As shown in the Figs 2 and 3, decomposition takes place faster in the presence of earthworms than in their absence.
This bears witness to the fact that earthworms act as instigators or promoters of microbial decomposition. According to Ndegwa and Thomson (2000), the trend in increasing ash and total carbon contents in the absence of earthworms continues by the fifth week but remains constant afterwards, while in the presence of earthworms, ash and total carbon contents continues to increase throughout the study period to reach its maximum in the last week, i.e. week 9. This difference in trends indicates that the activity of organisms such as earthworms improves soil structure and nutrients, intensifying organic decomposition (Tate, 2000). Mineralization of the organic content, therefore, must be higher in the presence of earthworms as indicated by the results obtained from the present study where at the end of the process, ash content increased by 12.8% in the presence of earthworms but by 7.24% in their absence and total carbon decreased by 6.64% and 3.79% in the presence and absence of earthworms, respectively.
Nitrogen concentration like volatile organic solids over the whole process period showed great variation (Fig 4) but, in the absence of earthwarms, total nitrogen had a generally increasing trend except in the 7th week.
This observation again confirms the difference in decomposition of materials between vermicomposting and composting processes. There are contradictory reports on nitrogen content and its variations in vermicomposting; Hartenstein and Hartenstein (1981) reported nitrogen reduction to be greater in the presence of earthworms by 1.8 times compared to the control. Beitez et al (1999) reported a 36% nitrogen reduction after a 36-week process. Studies by Elvira et al (1996), Bansal and Kapoor (2000), and Atiyeh et al (2000) indicate increasing nitrogen concentration levels in the resulting vermicompost compared to its level in the original substrate. Ndegwa et al (2000) and Mitchell (1997) found no significant differences between total nitrogen concentrations in original substrates and the resulting vermicomposts. The latter reported that despite great variations in total nitrogen concentration during the vermicomposting process, the final concentration levels were not significantly different from that in the initial substrate (1.04% and 0.925%, respectively). The reason for the discrepancies observed in total nitrogen variations in vermicomposting of different wastes lies in the fact that the quality of substrates used in feeding earthworms together with their physical structure and chemical composition affects mineralization of nitrogenous organic compounds and the amount of nitrogen released from these compounds (Bohlen et al., 1999).
As shown in Table 3, K concentration levels in the control final product and in the resulting vermicompost after nine weeks were reduced by 14.3% and 7.55%, respectively. The cause for this reduction may be ascribed to the fact that the excess water passing through the bedding washed this element away. This is also confirmed by Benitz et al (1999). They found that the leachate collected during vermi-

composting had a higher level of K and that it could be used as a K fertilizer (Elvira et al, 1998). The reason for lower concentrations of K in control final product is higher concentration of nitrogen in it as compared to its level in the vermicompost, leading to accelerated K leaching (Manhan, 2000). Total P concentration in the control final product increased by 6.7% compared to its level in the original substrate. This increase indicates the mineralization of phosphorous organic compounds during the process. This also happens in the presence of earthworms, the difference being the absorption of released P by earthworms (Hartenstein and Hartenstein, 1981; Mitchell, 1997). However, as the earthworms were separated from the samples prior to running the tests, P content in the resulting vermicompost showed a P reduction of 4.57%. The presence of earthworms and their activities in sludge accelerates sludge decomposition and increases the mineralization of organic compounds. However, as volatile solids as an indicator of sludge stabilization reduced by only 8.2% by the end of nine weeks, the resulting vermicompost was not yet adequately stabilized after nine weeks, requiring further stabilization or a complementary process to obtain desirable results. Regarding the nitrogen and phosphorus contents, the resulting vermicompost has less adverse and undesirable environmental effects (compared to control final product) with the additional advantage of having higher levels of K.

ACKNOWLEDGEMENTS

The authors are most grateful to the laboratory staff of the Department of Environmental Health Engineering, School of Public Health, Isfahan University of Medical Sciences, Iran.

REFERENCES

APHA, AWWA, WPCF (1992). Standard methods for the examination of water and wastewater, 18th ed. Washington DC, U.S.A.

Atiyeh R M, Dominguez J, Subler S, Edwards C (2000). Changes in biochemical properties of cow manure during processing by earthworms (*Eisenia ander Bauche*) and the effects on seedling growth. *J of Pedobiologia,* 44: 709-24.

Bansal S, Kapoor K K (2000). Vermicomposting of crop residues and cattle dug with *Eisenia fetida. J of Bioresource Technology*, 73: 95-8.

Benitez E et al (1999). Enzyme activities as indicators of the stabilization of sewage sludge composting with *Eisenia fetida*. *J of Bioresource Technolog,* 67: 297-303.

Bohlen P J, Parmelee R W, Allen M F, Ketterings G M (1999). Differential effects of earthworms on nitrogen cycling from various nitrogen 15 labeled substrates. *Am J of Soil Sci Soc,* 63: 882-90.

Dominguez J, Edwards C A, webster M (2000). Vermicomposting of sewage sludge: effect of bulking materials on growth and reproduction of the earthworms *Eisenia anderi*. *J of Pedobiologia*, 44: 24-32.

Elvira C, Goicoechea M, Sampedro L, Mato S, Nogales R (1996). Bioconversion of solid paper-pulp mill sludge by earthworms. *J of Bioresource Technology*, 57: 173-77.

Elvira C, Sampedro L , Benitez E, Nogales R, (1998). Vermicomposting of sludges from paper mill and dairy industries with *Eisenia anderi*: a pilot-scale study. Bioresource. *J of Technology*, 63: 205-11.

Erhart E, Burian K, (1997). Evaluating quality and suppressiveness of Austrian biowaste composts. *J of Compost Sci Utilization,* 5(3): 15-24.

Gotas H B (1956). Composting – sanitary disposal and reclamation of organic waste. WHO, Geneva.

Graff O (1953). Die regeawurmer deutschlands. Schrift. Forsch. Lan. Braunschweig, Volk.

Hartenstein R, Hartenstein F (1981). Physicochemical changes affected in activated sludge by the earthworms *Eisenia foetida*. *J of Environ Quality,* 10(3): 377-82.

Herlihy T E (1999).*Vermicomposting of organic wastes*. 2301W. Medoriew Rd. site 203.

Manhan S E (2000). Fundamentals of environmental chemistry, 2nd ed. Lewis publisher.

Mcfarland M J (2000). *Biosolid Engineering*. Mc Graw- Hill, USA.

Mitchell A (1997). Production of Eisenia fetida and vermicopost from feed-lot cattle manure. *J of Soil Biol Biochem,* 29(3/4): 763-66.

Ndegwa P M, Thompson S A, Das K C (2000). Effects of stocking density and feeding rate on vermicopomsting of biosolids. *J of Bioresource Technology,* 71: 5-12.

Ndegwa P M, Thompson S A (2000). Effects of C to N ratio on vermicomposting of biosolids. *J of Bioresource Techonology*, 75: 7-12.

Ndegwa P M, Thompson S A (2001). Integrating composting and vermicomposting in the treatment and bioconcentration of biosolids. *J of Bioresource Technology,* 76:107-12.

Piearce T (2000). Species identification. http://WWW.nururingnature.Co.Uk/main/education-a.htm)

Tate R l et al (1986). Methods of soil analysis: part II, chemical and microbiological properties. Madison, Viscon- sin, USA, American Society of Agrohomy Inc. *Soil Sic* Soc Am Inc.

Tate R l (2000). *Soil microbiology*. 2nd ed. John wiley & son Inc.

Theroux F r, Eldringe E F, Mallman W L (2001). Laboratory manual for chemical and bacterial analysis of water and sewage. 3rd ed. McGraw-Hill Inc.

Vinceslas-AKPA M, Loquet M (1997). Organic matter transformation in lignocellulosic waste product composted or vermicomposted (*Eisenia fetida anderi*): Chemical analysis and ^{13}c CPMS NMR spectroscopy. *J of Soil Biol Biochem*, 29(3/4): 751-58.

Waling I, Van Vark W, Houba V J G, Van der lee J J (1989). *Soil and plant Analysis, a series of syllabi part7*. Plant Analysis procedures. Wageningen Agriculture University.