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Effect of Stocking Density on Vermistabilization of Waste Activated Sludge

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Abstract: Sludge disposal has always represented a substantial portion of the costs associated with sewage treatment. In addition, the skilled personnel are not easily available to assure sound maintenance and operation of the conventional sludge treatment systems such as aerobic and anaerobic digestion; therefore, it is necessary to employ low cost and low technology practices in sludge management. Using earthworms in stabilization of sewage sludge, which has been approved by considerable work, can be a good alterative. This research was conducted to study the effect of stocking densities on sludge stabilization and sludge characteristics. In this regard, 40, 80 and 120 g earthworm wet weight were introduced into each of the plastic bins sizing 36×25×20 cm (length×width×height) to provide the desired stocking densities of 0.45, 0.90 and 1.35 kg worms m^{-2}. Each bin received 2 kg waste activated sludge. The pilot-scale study showed that the highest VS (24.3%) reduction occurred in a stocking density of 1.35 kg Worm m^{-2} in which TKN and organic to mineral P ratio reduced 58.3 and 93.5 %, respectively.

Key words: Earthworm, eisenia fetida, stabilization, stocking density, waste activated sludge

INTRODUCTION

Research into the potential use of earthworms to break down and manage sewage sludge began in the late 1970s[1] and the use of earthworms in the sludge management has been termed vermicomposting or vermistabilization[2,3]. Considerable work has been done on the use of earthworms in composting various organic materials and it has been established that epigeic forms of earthworms can enhance the composting process to a significant extent, with production of a better quality of final product[4]. Vermicomposting is a bio-oxidation and stabilization of organic material involving the joint action of earthworms and microorganisms. Vermicomposting represents a technology that is environmentally sound, not to be energy, capital or equipment intensive and should not require extensive management.

The objective of this investigation was to determine an appropriate stocking density for enhancing the stabilization of waste activated sludge. Also, the characteristics of the final worm-worked product were determined to study the feasibility of vermistabilized sludge as a soil conditioner due to the increased desire to beneficially reuse practices of waste residuals. Moreover, sludge management imposes high costs on municipal wastewater treatment plants. Vermistabilization process is a low-tech alternative that could be employed in small communities of Iran, which presence of skilled personnel is not readily available.

MATERIALS AND METHODS

This study was carried out at the Department of Environmental Health Engineering, Tehran University of Medical Sciences from July to September of 2003.

According to the results obtained from the lab-scale studies[5] for optimal basic parameters including dry solids (15-20%) and C/N ratio (25), it was tried to determine an appropriate stocking density for sludge vermistabilization process through pilot-scale study. In this regard, experiments were conducted in worm-bins sizing 0.20 m in 0.25 m in 0.36 m (height, width and length). The containers were covered tightly with cotton cloth to prevent escape of worms. The experiments were continued for 40 days in a room having temperature ranging from 18-23°C. Sawdust

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Table 1: Mean characteristics of the fed sewage sludge

Parameter	Unit	Content
Dry Solids (DS)	%	18-20
VS	% in DS	86.00
Ash Content	% in DS	14.00
TOC	% in DS	37.70
Ammonia	% in DS	0.35
TKN	% in DS	1.49
TP	% in DS	2.87
O to In P$		3.31
pH		6.10

$ Organic to Inorganic Phosphorus.

was used to adjust the desired C/N ratio of fed waste activated sludge (WAS). WAS was obtained from a municipal wastewater treatment plant located in the northwest of Tehran. Therefore, studying on the technical and design parameters of this process can help to use it more effectively.

Each container had a surface area of 0.09 m^2 and was inoculated with 40, 80 and 120 g wet weight of *Eisenia fetida* to provide the stocking densities equal to 0.45, 0.90 and 1.35 kg worms m^{-2}, respectively. Two replicates for each stocking density were established. During the first 10 days, the containers were continuously fed until the substrate reached 2 kg and thereafter feeding was ceased. A week after the final feeding, the physicochemical characteristics of the substrate were measured according to Standard Methods[6]. A container without earthworms was chosen as control and consisted of the same amount of waste activated sludge.

In the initial and during the study the following parameters of the substrate were analyzed: pH, Volatile Solids (VS), Total Kjeldahl Nitrogen (TKN), Total Phosphorus (TP), Organic Phosphorus, Inorganic Phosphorus and Total Organic Carbon (TOC). Tables 1 and 2 show characteristics of the fed sewage sludge and worm-worked sludge during the experiment, respectively. All the analyses were carried out according to Standard Methods[6], apart from pH that was determined by the method described in SW-846[7].

RESULTS AND DISCUSSION

Figure 1 shows that the percent reduction in VS increased with stocking densities. The mean VS reduction in stocking densities of 0.45, 0.90 and 1.35 kg worms m^{-2} as 18, 23.8 and 24.3, respectively (Table 3). On the other hand, the reduction of VS in the control was 12.8 %. Fragmentation of organic matter of the substrate significantly increases the percentage of fine particles as a consequence of substrate transit through the earthworms' gut[8]. This mechanical action increased the surface to volume ratio, thus increasing the microbial activity in the substrat[9].

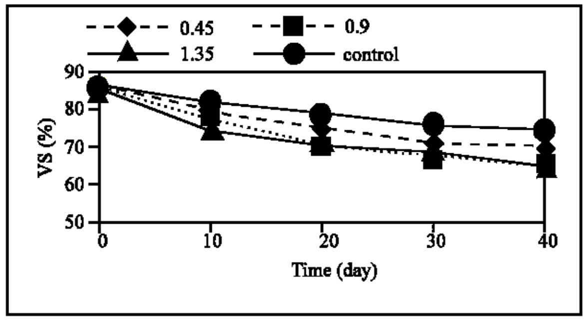

Fig. 1: Percent change of sludge VS in the stocking densities of 0.45, 0.90 and 1.35 kg worms m^{-2}.

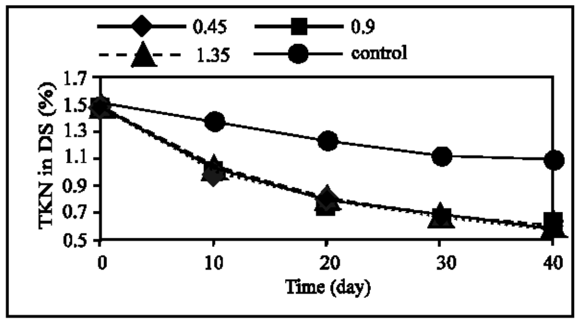

Fig. 2: Percent change of sludge TKN in the stocking densities of 0.45, 0.90 and 1.35 kg worms m^{-2}.

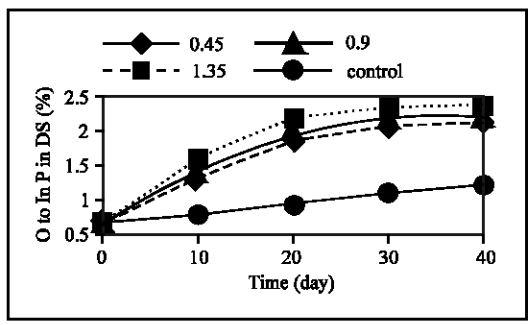

Fig. 3: Percent change of sludge inorganic P in the stocking densities of 0.45, 0.90 and 1.35 kg worms m^{-2}.

Most the reduction occurred during the first 20 days of the experiment and this can be explained by the decomposition of readily biodegradable material. There was not a significant difference in VS reduction between the stocking densities of 0.90 and 1.35 kg worms m^{-2} ($p>0.05$), while the stocking density of 0.45 kg worms m^{-2} showed a significant difference in comparison with two other ones ($p < 0.05$).

Table 2: Change of sludge characteristics in three stock densities during 40-day Vermistabilization*

		Stocking density (kg worms m^{-2})						
		1.35		0.90		0.45		
Parameter	Time (day)	Rep+. 1	Rep. 2	Rep. 1	Rep. 2	Rep. 1	Rep. 2	Control
	10	81.00	80.00	77.00	78.00	74.00	75.00	82.00
	20	76.00	75.00	70.00	71.00	72.00	70.00	79.00
	30	72.00	71.00	67.00	67.00	69.00	68.00	76.00
VS	40	71.00	70.00	66.00	65.00	66.00	64.00	75.00
	10	1.06	1.09	1.04	1.01	0.99	1.02	1.37
	20	0.81	0.82	0.80	0.79	0.72	0.77	1.24
	30	0.70	0.69	0.68	0.67	0.62	0.68	1.12
TKN	40	0.65	0.64	0.62	0.61	0.59	0.65	1.09
	10	1.23	1.34	1.32	1.50	1.52	1.67	0.82
	20	1.83	1.94	1.92	2.10	2.12	2.27	0.97
	30	2.00	2.14	2.11	2.25	2.32	2.40	1.11
In P++	40	2.03	2.18	2.13	2.30	2.34	2.43	1.24
	10	1.35	1.16	1.19	0.93	0.90	0.73	2.52
	20	0.58	0.49	0.51	0.38	0.36	0.27	1.98
	30	0.45	0.35	0.37	0.28	0.25	0.20	1.60
O to In P$	40	0.42	0.33	0.36	0.26	0.24	0.19	1.33
	10	5.90	5.70	5.50	5.70	5.50	5.70	5.80
	20	6.30	6.20	5.90	6.00	5.60	6.10	5.50
	30	6.50	6.60	6.60	6.30	6.10	6.40	5.40
pH	40	6.70	6.60	6.70	6.40	6.40	6.50	5.20

* All parameters except pH and organic to inorganic phosphorus are in percent DS., + Replicate; ++ Inorganic Phosphorus; $ Organic to Inorganic Phosphorus.

Table 3: Percent reduction of sludge VS, TKN and organic to inorganic P in the studied stocking densities

	Stocking Density (kg worm m^{-2})			
Parameter	0.45	0.9	1.35	Control
VS	18	23.8	24.3	12.8
TKN	56.6	58.3	58.3	26
O to In P	88.5	90.5	93.5	60

Changes in TKN content of sludge during the 40-day study are presented in Fig. 2. In general, TKN content of waste activated sludge was decreased in all the stocking densities. TKN reduction in the stocking densities of 0.45, 0.90 and 1.35 kg worms m^{-2} was 56.6, 58.3 and 58.3%, respectively (Table 3), while TKN reduction in the control was 26.8%. TKN reduction can be attributed to the changes in microbial activity caused by the action of the earthworms. This indicates the role of earthworms in the mineralization process during which locked up nutrients changes into plant-available forms. A one-way analysis of variance ANOVA performed on the data showed no significant difference in TKN reduction with the earthworm densities ($p>0.05$), which is in contract with the results founded by Ndegwa *et al.*[10].

Changes in P content of sludge during the 40-day study are presented in Fig. 3. Mean organic to inorganic P reduction of the waste activated sludge in the stocking densities of 0.45, 0.90 and 1.35 kg worms m^{-2} was 88.5, 90.5 and 93.5%, respectively, while organic to inorganic P reduction in the control was 60% (Table 3). The rise in the level of the available P content during vermistabilization is probably due to mineralization of P by the combined action of faecal phosphotases of earthworms and microbial activity of the casts[11]. No significant difference in organic to inorganic P reduction with the earthworm densities was found ($p>0.05$).

CONCLUSIONS

Because sewage sludge disposal practices (e.g., landfilling) are becoming less available and more costly and because of the increasing desire to beneficially reuse of waste residuals, when treated and processed, sewage sludge can be recycled and applied to crop land to improve soil quality and productivity. On the other hand, sludge treatment and disposal are probably the most costly operations in wastewater treatment plants. However, if vermistabilization were to be used as a sewage treatment practice all of the conventional sludge management processes (thickening, digestion and dewatering) would be unnecessary[12]. Thus this process can be a good alternative, especially in developing countries whose economics are labor-intensive.

In this study an appropriate stocking density was 1.35 kg worms m^{-2} which resulted in 24.3% reduction in VS. In the same stocking density, percent change of TKN and Organic P was 58.3% and 74%, respectively.

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