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Vermitechnology for sewage sludge recycling

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ABSTRACT

The present paper is aimed at safe reuse and recycling of sewage sludge (SS) and production of good quality compost using vermicomposting. Three different earthworm species *Eisenia fetida (E. fetida)*, *Eudrilus eugeniae (E. eugeniae)*, *Perionyx excavatus (P. excavatus)* in individual and combinations were utilized to compare the suitability of worm species for composting of sewage sludge as well as the quality of the end product. The sewage sludge without blending can be directly converted into good quality fertilizer (vermicompost). Vermicomposting resulted in reduction in C/N ratio 25.6 to 6–9, TOC (25%) but increase in electrical conductivity (EC) (47–51%), total nitrogen (TN) (2.4–2.8 times), potassium (45–71%), calcium (49–62%), sodium (62–82%) and total phosphorous (TP) (1.5–1.8 times), which indicated that sewage sludge can be recycled as a good quality fertilizer. The present study also inferred that the application of sewage sludge in the agricultural fields after vermicomposting would not have any adverse effect as the heavy metals (Cu, Mn, Pb and Zn) are now within the permissible limits.

1. Introduction

Large scale urbanization, a consequence of economic development is leading to production of huge quantities of waste water in India and posing serious environmental problems for their disposal. The treatment and disposal of sludge produced during waste treatment is one of the most critical environmental issues of today. Sludge produced is large in volume and hazardous. Hence, studies related to its safe handling, disposal and recycling techniques are important. Another issue of concern is that the sewage sludge (SS) and effluents are frequently disposed off on agricultural lands as fertilizer and irrigation purpose, respectively, due to their nutrient contents, especially N and P without any treatments, but they may induce plant and soil toxicity and may have depressive effects on the metabolism of soil microorganisms [1]. But it is advisable for them to undergo an additional stabilization treatment [2]. Therefore, there is a need for ecologically sound technologies which are not only cost-effective, but also sustainable in terms of possible recovery of recyclable constituents from sewage sludges as they are rich in nutrients and have higher organic content.

A sustainable approach to handle this will be to convert it to a useful recyclable product at site by an eco-friendly and economical method. Vermicomposting is a decomposition process involving interactions between earthworms and microorganisms and it is an economical, viable and sustainable option for sewage sludge management. It is easy to operate and can be conducted in contained space to produce a good quality product (fertilizer). Earthworms have been successfully used in the vermicomposting of urban, industrial and agricultural wastes in order to produce organic fertilizers and obtain protein for animal feed. Several epigeics (*Eisenia fetida*, *Eisenia andrei*, *Eudrilus eugeniae*, *Perionyx excavatus* and *Perionyx sansibaricus*) have been identified as potential candidates to decompose organic waste materials [3,4]. Research into the potential use of earthworms to break down and manage sewage sludge began in the late 1970s and the use of earthworms in sludge management has been termed vermicomposting or vermistabilization [5]. In its basic form, this is a low-cost technology system that primarily uses earthworms in the processing or treatment of organic wastes [6]. In nature, several different earthworm species may exist in the same acre of soil, each filling a different niche and using different substrates for food. Therefore, it is possible that a combination of worm species (mixed culture) in a vermicomposting process could accomplish greater stabilization than a single species (pure culture). Literatures on vermicomposting using pure cultures are available but sparse literatures are available on mixed cultures. Other authors [7,8] have reported that polyculture reactor can decompose organic matter more efficiently by accelerating its key microbial properties. But some authors [9] have reported that polyculture did not show any advantage over monoculture in the vermicomposting process. Some authors [10] have also documented that *E. eugeniae* and *P. excavatus* do not coexist comfortably in mixed cultures probably due to competition for food among the earthworm species. *E. fetida* is being used widespread in exist-

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ing vermicomposting systems and also proven of its potential for processing of relatively moist organic materials such as municipal biosolids and animal manure slurries [11]. *E. eugeniae* also reported as a fast-growing and productive earthworm in animal waste that is ideally suited as a source of animal feed protein as well as for rapid organic waste conversion [12]. Literature is available reporting that when tried *P. excavatus* gave excellent changes in organic waste resources and could be used efficiently to combat the problem of waste resources management at low-input basis [13].

Therefore, the objective of the present paper is to try out different earthworm combinations (pure culture or mixed culture) for vermicomposting of sewage sludge. In addition, the paper aims to verify whether different earthworm species can coexist in the same environment and also the safe reuse and recycle of sewage sludge producing a good quality end product.

Table 1
Initial physico-chemical characteristics of SS before composting

S. no.	Parameter	Sewage sludge (SS)
1	pH	6.88 ± 0.1
2	EC (S/m)	0.28 ± 0.08
3	Ash content (%)	42.16 ± 0.5
4	TOC (%)	33.54 ± 0.44
5	TN (%)	1.31 ± 0.1
6	TP (g/kg)	7.97 ± 0.1
7	C/N	25.6 ± 1.5
8	COD (mg/L)	1500 ± 75
9	BOD (mg/L)	580 ± 15
10	Fe (%)	0.63 ± 0.03
11	Cu (mg/kg)	158.2 ± 20
12	Mn (mg/kg)	290.6 ± 30
13	Zn (mg/kg)	612 ± 45
14	Pb (mg/kg)	49.4 ± 6
15	Na (%)	0.5 ± 0.05
16	K (%)	0.86 ± 0.56
17	Ca (%)	5.39 ± 0.68

All data represent average of triplicates.

2. Materials and methods

2.1. Earthworm cultures

Three composting species of earthworms two exotic (*E. fetida* and *E. eugeniae*) and one indigenous (*P. excavatus*) were chosen for the experiment. In the present study exotic earthworms *E. fetida* and *E. eugeniae* were cultured in the laboratory and were randomly picked for experimentation. The indigenous species, *P. excavatus* was collected from the drainage area in Indian Institute of Technology Roorkee campus by hand sorting method. The species were identified at National Zoological Survey of India, Solan, India, before culturing in the field laboratory.

2.2. Sewage sludge (SS)

Sewage sludge was procured from sewage treatment plant at Haridwar, India. The sewage sludge was dried in direct sunlight for 2 weeks with periodic turning to bring its moisture content to 50%. The physico-chemical characteristics of SS are given in Table 1.

2.3. Experimental set up

The experiments were conducted in triplicate, in perforated cylindrical plastic containers of capacity 6 L. The temperature in the experimentation room was maintained at 25 ± 1 °C which is the optimum temperature range for all the three species [14,15]. 10 cm bedding was kept in all the containers using old vermicompost. Approximately 50 g (~100–120 in numbers) of earthworms, having both clitellated and juvenile, were inoculated in the bedding for acclimatization of the earthworms to the new environment then SS was added the next day. The mixed cultures were prepared using the earthworm species in equal proportions and one control was also kept for degradation without any worms. The inoculated earthworms were pure cultures as well as mixed cultures of *E. fetida*, *E. eugeniae*, and *P. excavatus* which are shown in Table 2.

1.2 kg of SS was added to each of the reactors. The quantity of the SS was decided based on the data reported in the literature, that the earthworms can consume the material half their body weight per day under favorable conditions [16]. C/N ratio plays an important role in determining the quality of compost hence, saw dust was added as a bulking agent to increase the C/N ratio to 25.6 as earthworm can grow better when C/N ratio of material is about 25 [17]. The moisture level was maintained about 50–60% through out the study period by periodic sprinkling of adequate quantity of tap (potable) water. To prevent moisture loss, the experimental containers were covered with gunny bags. The measurements for total organic carbon (TOC), total nitrogen (TN), ammonical nitrogen (NH_4^+-N), nitrate nitrogen (NO_3^--N), total phosphorous (TP), exchangeable potassium (K), sodium (Na), calcium (Ca), C/N ratio, electrical conductivity (EC), pH, biological oxygen demand (BOD), chemical oxygen demand (COD) and coliforms were carried out before the introduction of earthworms that is 0 day and on 15th, 30th and 45th day of composting. In addition earthworm growth related parameters like earthworm biomass; and total mortality were measured at the end of the vermicomposting process. These analyses were either carried out on samples immediately after sampling (bacteriological) or within 2 days (the samples were stored at 4 °C until analyzed) for physico-chemical parameters. The values reported are the mean of the triplicates.

2.4. Compost analysis

110 g of homogenized wet samples (free from earthworms, hatchlings and cocoons) were taken out at 0 day and 15 days interval of composting period. The 0 day refers to the substrate taken out before earthworm inoculation. Temperature and moisture content

Table 2
Details of earthworm inoculation in reactors

S. no.	Reactor names	Earthworm combinations (EWs)	Weight of EWs (g)	No. of earthworms
1	R_1	*E. fetida*	50	120
2	R_2	*E. eugeniae*	50	100
3	R_3	*P. excavatus*	50	120
4	R_4	*E. fetida* + *E. eugeniae*	50	110
5	R_5	*E. fetida* + *E. eugeniae* + *P. excavatus*	50	105
6	R_6	*E. eugeniae* + *P. excavatus*	50	115
7	R_7	*E. fetida* + *P. excavatus*	50	120
8	R_8	Control	Nil	Nil

All data represent average of triplicates.