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UPSCALING OF COMMUNAL SEWAGE SLUDGE VERMICOMPOSTING TECHNOLOGY

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Abstract

The proper management of communal sewage sludge is a priority of environmental protection. Recently the vermicomposting technology, of using earthworm species in waste management has been increasing. Earthworms are utilizing of the bacterial components of the sludge and during of their metabolic processes, can contribute for the acceleration of full composting processes. In addition, vermicomposting increases the nitrogen (N), phosphorus (P) and potassium (K) content of the treated sludge, and might eliminate of the potential pathogens. We examined the vermicomposting processes both in pilot scale (open- and closed environmental conditions) and among industrial composting conditions, where the compost piles were: 1) uncovered and covered with 2) straw-mulch and 3) with geotextile. Eisenia fetida worms was mixed into the compost-piles. Samples were taken at the beginning, at half time and at the end of the experimental period. Physical and chemical characteristics, such as the pH, dry matter, organic matter, salt, nitrogen (N), phosphorus (P_2O_5), potassium (K_2O), Ca, Mg, humus (H%), H quality and the dehydrogenase enzyme activities (DHA) were determined. Temperature and redox potential were assessed twice a week. Heavy metal concentrations (Pb, Zn, Fe, Cu, Mn) in sludge, in finished vermicompost and in earthworm biomass were analysed. Straw-mulch cover was the best for keeping water balance, improving survival and propagation of worms and increasing phosphorous and potassium availability in the final composts. Earthworms could reduce the amount of heavy-metals by bio-accumulating those toxic elements. Vermicomposting can be a potential tool of the agri/horti-cultural practice for reducing environmental risks and supporting the applicability of nutritive composts, prepared from communal sewage sludge.

Keywords: *communal sewage sludge, vermicomposting, Eisenia fetida*

1. INTRODUCTION

Vermicomposting is an effective and environmental friendly method of organic waste management technologies. During vermicomposting process different worm species are used to transform organic matters. Red worm (*Eisenia fetida*) is one of the most commonly used worm species in vermicomposting of dewatered and putrefied municipal sewage sludge [1]. The worms remove old bacterial cells from the sludge due to their metabolic processes; therefore new bacterial colonization can develop which contribute for the acceleration of composting. In addition, vermicomposting increases the nitrogen (N), phosphorus (P) and potassium (K) content of the treated sludge, and eliminate of the potential pathogens. These parameters are essential for further agricultural use of compost. Maintenance of earthworm culture is relatively simple and inexpensive, and worms can be easily separated from the finished vermicomposts for further use [2, 3]. Vermicomposting technology has some advantages compared to traditional waste composting systems:

- It is one of the most effective way of recycling organic matter and nutrients from wastes
- The compost can be ready for use by 50% faster [1].

- Particle size distribution and texture are more favorable for the agricultural use, since feces of worms improve the aggregate stability of soil particles [4].
- Contains nutrients (N, P, K, Ca and Mg) in higher plant-available forms [5, 6].
- No additives are required for reducing water-content; the sludge can be vermicomposted up to 91% moisture [7].
- Greater microflora, higher microbial and metabolic enzyme-activities [7, 8].
- Increased plant growth by PGA (Plant Growth Activators) and by PGRs (Plant Growth Regulators), synthetized by the gut microflora of earthworms. Other composts does not have this positive effect on plant growth [9-11]
- Contains high amount of humic acids and humates of promoting plant growth [12-14].
- During vermicomposting abundance and risks of potential pathogens might be efficiently reduced [15, 16].

These advantages means that vermicomposting technology can be applied for stabilization and disposal of municipal sewage sludge without any pretreatment and additives. However, vermicomposting can be integrated to traditional composting technology, since it improves the quality of compost as an additive [6, 17, 18].

During traditional composting, concentration of toxic elements are higher in finished compost than in raw material, while at vermicomposting, at the use of suitable earthworms, concentration of toxic elements are decreased in final composts [19-21].

Shahmansouri et al. [22] investigated the heavy metal (Cr, Cd, Pb, Cu and Zn) accumulation with two groups of *Eisenia fetida* in sewage sludge. The results indicated that heavy metal concentrations in the vermicompost decreases with increasing time.

Among two earthworm groups, one of them accumulated significantly higher amounts of micronutrients (Cu, Zn), however the non-essential elements (Cr, Cd, Pb) was significantly greater in the other group. It was concluded that earthworms can accumulate heavy metals at relatively high concentrations in their tissues [22].

2. MATERIALS AND METHODS

Pilot scale experiment

Pilot scale experiment was conducted in Sóskút (at Szigépszerk GmbH.), where the vermicomposting processes were examined both in open- and closed environmental

conditions. Thus, effects of environmental conditions (e.g. temperature, precipitation intensity and moisture of compost) on vermicomposting technology can be studied. The experimental period lasted for 15 weeks. 21 compost prism were examined in the experiment: 4 prisms (2 prisms in open conditions and 2 prisms in closed condition) did not contain worms, and 17 prisms (8 prisms in open conditions and 9 prisms in closed condition) contained them. Each prism contained 3000 worms/m^3. At the beginning of the experiment composite samples were taken from all compost prisms, and the samples were measured by different physical and chemical methods. Next sampling was taken at half time of the experiment, and the last sampling was taken from the finished vermicompost. In the experiment, we did not use any other organic materials or green waste.

Industrial scale experiment

Industrial scale experiment was also carried out in Sóskút. Three different composting technologies were applied: the compost piles were covered with straw-mulch or geotextile or were uncovered. 3 prisms contained worms, and 1 prism did not contain in all three technology. The experimental design is in *Figure 1*. The experimental period, the number of worms and the samplings were the same as in the pilot scale experiment.

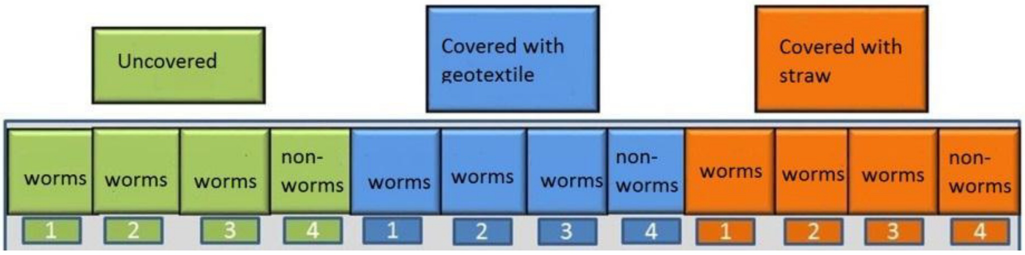

Figure 1. Experimental design of industrial scale experiment

Materials

Municipal sewage sludge used in our experiment originated from Érd (Hungary). According to previous measurements the dry matter content of the sewage sludge was 15-20 %, and half (50%) of the dry matter content was organic matter. Toxic element content of the sewage sludge did not exceed the limit of the permitted toxic elements and harmful substances in sewage sludge for agricultural use according to the Hungarian Government Decree 50/2001. (3. IV.).

The tested species was *Eisenia fetida* (Genus: *Eisenia*, Family: *Lumbricidae*, Order: *Haplotaxida*, Class: *Clitellata*, Phylum: *Annelida*). This worm species is a well-adapted specialist to certain conditions: is an important participator in exploration of degrading organic matter and is a resident of manure or compost which provides nutrients and energy to its organism.

Analytical methods

During samplings and analytical measurements Hungarian regulations were taken into consideration. Samples of sewage sludge, compost and earthworms were dried and sieved (<2 mm) for the measurements. Both pilot scale and industrial scale experiment the following parameters were examined: pH (H_2O), EC (electrical conductivity), from which the total salt content could be calculated, phosphorus content (P_2O_5), potassium content (K_2O), humus content (H%) humus quality and dehydrogenase enzyme activity. Temperature and redox potential were assessed twice a week in order to characterize oxidation-reduction conditions. In this study, only the most important chemical parameters (EC, phosphorus-, potassium- and humus content) will be analyzed, which are essential for the potential agricultural use of vermicompost.

Heavy metal concentration (Pb, Zn, Fe, Cu, Mn) in the starting sludge, in the finished vermicompost and in the earthworms (at the starting and ending of the experiments) were also measured, which means, that bioaccumulation of heavy metals by earthworms can be determined. Samples were examined after nitric acid – hydrogen peroxide digestion with AURORA AI1200 Atomic Absorption Spectrometer (*Figure 2.*), and FP910 (PG Instruments) Flame Photometer (*Figure 3.*).

Figure 2. AURORA AI1200 Atomic Absorption Spectrometer

Figure 3. FP910 (PG Instruments) Flame Photometer

3. RESULTS AND DISCUSSION

According to our results vermicomposting process could be completed and finally ripened compost was developed in all of the treatments, used both in pilot scale and in industrial scale experiments. The finished composting was confirmed by physical and chemical parameters and enzyme activities. The produced vermicompost could be beneficial for agricultural use.

Table 1 shows the results of the pilot scale experiment. Total salt content (mg/kg) reduced more in open environmental condition compared to closed environmental condition.

Phosphorus content was increased during the vermicomposting procedure. In closed condition it increased from 1573±234 mg/kg to 2859±197 mg/kg, while in open condition it changed from 2799±102 to 3289±588.

Potassium content of the vermicompost also increased more in closed environmental condition, where it increased from 2173±546 to 4079±822.

In open condition it raised from 2309±662 only to 3437±444. Humus content increased only slightly in both condition.

Table 1. Measured chemical parameters during pilot scale experiment

		Closed environment		**Open environment**	
		Mean	SD	Mean	SD
Salt content (mg/kg)	starting stage	14706	1772	16645	3231
	middle stage	14025	1389	10327	1075
	final stage	11784	2389	6895	558
P_2O_5 (mg/kg)	starting stage	1573	234	2799	102
	middle stage	2789	222	3153	676
	final stage	2859	197	3289	588
K_2O (mg/kg)	starting stage	2173	546	2309	662
	middle stage	3993	834	2763	540
	final stage	4079	822	3437	444
H (%)	starting stage	27,66	6,18	29,37	4,50
	middle stage	27,35	4,91	30,35	5,14
	final stage	27,72	4,39	31,36	4,96

Table 2. shows the results of the industrial scale experiment. Similar results were observed than in pilot scale experiment. Composting was more effective if the compost prism contained earthworms in all three technologies. Total salt content was decreased in all compost.

In covered compost salt content reduced more than in uncovered compost. Phosphorus content were increased significantly during the experimental period. The highest increase was noticed in uncovered compost, which is followed by the straw covered compost. Potassium content was increased in covered technologies; however, it was reduced in uncovered compost. Increasing of potassium content was higher in straw covered compost than in geotextile covered one. Humus content increased in all three technologies. According to industrial scale experiment straw covered compost was the most effective in terms of agricultural use of vermicompost.

Table 2. Changing of chemical parameters during industrial scale experiment

		Uncovered		**Geotextile covered**		**Straw covered**	
		Mean	SD	Mean	SD	Mean	SD
Salt content (mg/kg)	starting stage	14233	1650	15417	104	16733	333
	middle stage	18150	1150	17017	1115	16633	3177
	final stage	14917	1422	14667	765	11728	2811
P_2O_5 (mg/kg)	starting stage	627	28	991	464	755	88
	middle stage	7076	306	5406	775	5414	393
	final stage	4688	162	4457	199	4649	108
K_2O (mg/kg)	starting stage	1888	436	1312	266	1195	69
	middle stage	1312	67	1118	65	1120	67
	final stage	1466	66	1351	66	1312	66
H (%)	starting stage	20,79	9,44	22,44	5,41	18,59	3,89
	middle stage	19,57	4,51	22,26	8,26	24,83	3,06
	final stage	31,30	10,98	37,24	11,45	35,03	2,00

In pilot scale experiment, both in open and closed environmental condition, worms bio accumulated heavy metals, since higher metal concentrations was observed in worms at final stage compared to starting state. Results shown in *Table 3.* suggests that Cu and Fe accumulated at highest rate in worms. Cu concentration increased by 83.99% in open environment, while only by 69.93% in closed environment.

Table 3. Heavy metal accumulation in earthworms in pilot scale experiment

Open environment					
Heavy metals (mg/kg)	starting stage		final stage		
	Mean	SD	Mean	SD	%
Zn	55,28	4,58	79,12	3,52	43,13
Pb	61,91	4,68	69,76	8,75	12,68
Mn	36,91	2,47	46,21	5,66	25,18
Fe	296,53	47,66	469,74	79,87	58,41
Cu	27,01	1,29	49,69	1,45	83,99
Closed environment					
Heavy metals (mg/kg)	starting stage		final stage		
	Mean	SD	Mean	SD	%
Zn	53,28	4,77	63,18	3,17	18,58
Pb	56,99	4,75	63,26	7,85	10,99
Mn	33,14	2,07	41,10	4,62	24,03
Fe	286,69	42,56	439,70	51,87	53,37
Cu	31,01	1,86	52,69	1,19	69,93

Fe concentration increased by 58.41% in open environment and by 53.37 in closed environment. Other metal concentrations in worms were increased by less than 45% in both environmental conditions.

Bioaccumulation of heavy metals in worms was also observable in industrial scale experiment, since highest concentrations of metals were measured in worms after the experiment than before with the application of all three technologies. The results are shown in *Table 4*. Cu accumulated at the highest rate, its concentration increased by 81.4; 63.7 and 84.2%. The concentration of Fe and Mn increased by 38.7 % to 55.75 %, while Zn and Pb concentrations in worms increased by less than 34.2 % in all three technologies.

Table 4. Heavy metal concentration in earthworms in industrial scale experiment

Uncovered					
Heavy metals (mg/kg)	starting stage		final stage		
	Mean	SD	Mean	SD	%
Zn	40,35	3,78	49,31	3,53	22,20
Pb	62,33	4,68	65,23	6,81	4,65
Mn	30,91	2,14	44,21	3,07	43,01
Fe	242,92	40,66	359,92	76,46	48,16
Cu	29,62	2,96	53,73	1,94	81,44
Geotextile covered					
Heavy metals (mg/kg)	starting stage		final stage		
	Mean	SD	Mean	SD	%
Zn	47,99	3,56	59,77	3,47	24,55
Pb	63,93	4,82	67,23	7,24	5,16
Mn	30,54	2,31	43,39	5,95	42,08
Fe	229,85	475,61	344,74	79,87	49,98
Cu	30,62	1,92	50,12	1,33	63,70
Straw covered					
Heavy metals (mg/kg)	starting stage		final stage		
	Mean	SD	Mean	SD	%
Zn	45,56	4,04	61,12	3,53	34,15
Pb	65,91	4,08	69,69	8,12	5,74
Mn	31,94	2,53	44,29	5,41	38,67
Fe	236,53	47,56	368,39	77,50	55,75
Cu	27,01	1,27	49,73	1,43	84,16

Conclusion

Vermicomposting of municipal sewage sludge were examined in pilot scale and among industrial composting conditions. Vermicomposting were completed successfully in both technological condition. Cooperation between earthworms and microbes resulted more effective conversion of organic matter [1]. It is confirmed by the result of dehydrogenase enzyme activity and humus content and quality from the compost prisms which did not contain worms. It was concluded that salt content decreased, and phosphorus, potassium and humus content increased during the vermicomposting process. The increase of nutrients was also observed in previous studies [5, 6]. These results mean that vermicompost can be an effective soil amendment, since it can decrease the necessary amount of fertilizer and manure applications. Moreover, previous studies show that vermicompost is a PGA (Plant Growth Activators), which is also a great advantage in agricultural use of this type of compost [9-11].

Both in pilot scale and industrial condition earthworms bio accumulated the measured heavy metals (especially Cu and Fe), however the accumulation was higher in open conditions. As the results shows using earthworms for composting can decrease the heavy metal concentration of organic waste, which is confirmed also by other studies [19-22].

In practice, straw covered compost piles could be the best technology for vermicomposting, since it was the best for improving the survival ability of the worms and in increasing the total phosphorous and potassium availability in the final composts.

Based on our results vermicomposting can be a potential tool of the agri/horti-cultural practice for reducing the environmental risks of the increasing amount of communal sewage sludge wastes. Our further assessment is to measuring heavy metal balance, which can contribute to the precise monitoring of heavy metal concentration of communal sewage sludge.

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