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IMPROVING SEWAGE SLUDGE COMPOST QUALITY BY VERMICOMPOSTING

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Abstract

Treatment and disposal of sludge produced during the waste water treatment is one of the most critical environmental issues of today. Therefore, different techniques are used for its disposal and recycling. Vermicomposting is one of the most ecologically and economically sound technologies for handling sewage sludge in order to convert it into a useful recyclable product. The aim of this study was to assess the effectiveness of vermicomposting process applied on three types of dehydrated sewage sludge coming from two different wastewater treatment plants using two earthworm species (Eisenia fetida and Eisenia andrei), as well as the compost quality. Biotic and abiotic parameters were used to assess the vermicomposting process and the quality of the obtained compost. The effect of heavy metal on earthworms was monitored durring the first stages of vermicomposting and at the end of the process. The compost quality was evaluated from an agronomic and ecological point of view through a germination seed test with cress seeds (Lepidium sativum).

***Key words**: earthworms, germination test, phytotoxicity, vermicompost quality, sewage sludge.*

INTRODUCTION

Large scale urbanization is leading to growth of sewage sludge production resulting from wastewater treatment plant in Romania in the last decades, raising serious environmental problems for their disposal. Treatment and disposal of sewage sludge produced during wastewater treatment represent one of the most critical environmental issues of today. The sludge produced is large in volume and hazardous. Numerous studies related to its safe handling, disposal and recycling techniques (Khwairakpam and Bhargava, 2009) have been conducted worldwide.

Sewage sludge can be recycled on agricultural soils because is rich in organic matter and nutrients, but its heavy metal content is a constraint (Khwairakpam and Bhrgawa, 2009; Wu et al., 2018) in the widespread adoption of this disposal method. Sewage sludge is a major contributor of toxic heavy metals such as cadmium (Cd), lead (Pb), copper (Cu), zinc (Zn), chromium (Cr) etc. to soils (Khwairakpam and Bhrgawa, 2009; Lv et al., 2016) due to its direct application as soil amendment. These metals may enter the human and animal body through consumption of the crops. Due to its high organic load, sewage sludge is a suitable waste for treatment through biological techniques such as composting and vermicomposting aimed at obtaining a stable product with a high agronomic value (Villar et al., 2016).

Recent studies have shown that vermicomposting is an efficient and alternative technique for the sewage sludge treatment (Yang et al., 2014; Lv et al., 2016; Malińska et al., 2016). Vermicomposting is a bio-oxidation and stabilization process of organic matter as a result of the interaction between microorganisms and earthworms (Khwairakpam and Bhrgawa, 2009; Villar et al., 2016), and it is a low cost (Nigussie et al., 2016), viable and sustainable option for sewage sludge management. Also, it is easy to operate and can be conducted in contained space to produce a good quality fertilizer (Khwairakpam and Bhrgawa, 2009) for soil. Vermicomposting of sewage sludge has been widely used to stabilize heavy metals in SS (Benitez et al., 1999; Gupta and Garg, 2008; Lv et al., 2016; Suleiman et al., 2017; Wu et al., 2018). Vermicomposting mineralize most of the organic material and transform the residuals into stabilized humic-like materials (Benitez et al., 1999). It is well known that the addition of earthworms can accelerate the bio-stabilization process and the earthworms are considered as the crucial drivers of the vermicomposting process (Yang et al., 2014).

The aim of this study was to assess the effectiveness of vermicomposting process applied on three types of dehydrated sewage sludge, the impact of sewage sludge on earthworm species (*Eisenia fetida* and *Eisenia andrei*), as well as the vermicompost quality.

MATERIALS AND METHODS

These studies used dehydrated sewage sludges from two treatment plants labelled with the P and M initials. Thus, one of the sludges (SS_P) comes from P treatment plant, which serves about 160,000 inhabitants, and two sewage sludges come from M treatment plant (SS_1M; SS_2M), which serves about 32,000 inhabitants.

Physico-chemical analyses of compost were conducted within the soil pollution control laboratory of the Research Institute for Pedology and Agrochemistry in Bucharest.

The initial physico-chemical characteristics of the three types of sewage sludge are presented in Table 1.

Table 1. Initial physico-chemical characteristics of sewage sludge samples

	SS_P	SS_1M	SS_2M
pH	6.52	6.47	6.25
Moisture (%)	67.10	67.69	68.47
C/N	6.59	8.61	8.60
TOC (%)	24.37	22.39	22.70
N (%)	3.70	2.60	2.64
P (%)	1.74	1.73	1.74
K (%)	0.47	0.57	0.61

The contents in heavy metals i.e. cadmium, copper, chromium, nickel, lead, mercury and zinc (Cd, Cu, Cr, Ni, Pb, Hg, Zn) which are presented in Table 2 were also analysed.

The vermicomposting time was 45 days at 25°C. The moisture was maintained in each box at 70-80% (Wu et al., 2018).

After 45 days a product resulted, namely the vermicompost, which was structured, different from the sewage sludge, with a pleasant earthy smell and a dark brown colour.

After this stage, earthworms were separated from vermicompost and then weighed (being left previously for 24 hours in distilled water to empty the digestive tract). Subsequently, the material resulting from earthworms drying was prepared and subject to chemical analyses (Picture 2).

Table 2. Heavy metal contents of sewage sludge samples

	SS_P	SS_1M	SS_2M	WRAP-2011
Cd (mg/kg)	0.340	0.253	0.360	1.5
Cu (mg/kg)	168	167	168	200
Cr (mg/kg)	57	43	50	100
Ni (mg/kg)	41.00	37.00	39.13	50
Pb (mg/kg)	33.00	38.00	34.33	200
Hg (mg/kg)	0.29	0.22	0.24	1
Zn (mg/kg)	751.00	754.00	753.33	400

The earthworms belonging to genus *Eisenia* (*Eisenia fetida* and *Eisenia andrei*), were collected from a pile of plant debris resulting from the green spaces within the University of Agronomic Sciences and Veterinary Medicine of Bucharest campus.

The earthworms with an average length of 5.0 ± 0.2 cm and with a total mass of 100.0 ± 0.42 g were introduced into each box. After balancing, the earthworms were released in each box (Picture 1). No bulking materials have been used.

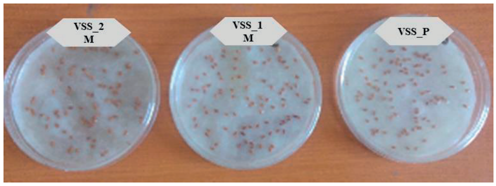
Picture 1. The three boxes with sewage sludge

Picture 2. The three boxes with vermicompost and the resulted earthworms

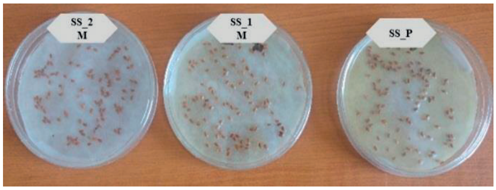
For the germination test, an aqueous extract was produced from both the vermicompost and the initial material (dehydrated sewage sludge). For this, 100 g samples from each of the 3 types of vermicompost as well as 100 g samples from each of the 3 types of dehydrated sludge were taken and mixed with 110 ml distilled water (Picture 3). The extracts obtained were well stirred and left to rest for 24 hours. Subsequently, the extracts were passed through filter paper, thus obtaining the supernatant.

Picture 3. Vermicompost and dehydrated sewage sludge extracts

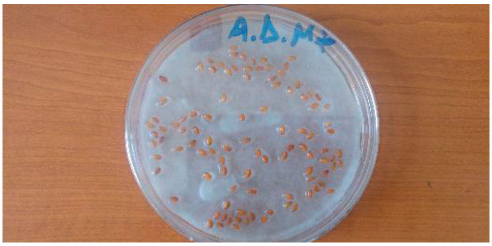
In order to evaluate the quality of the vermicomposts (VSS_P, VSS_1M and VSS_2M), a germination test was performed in Petri dishes (Picture 4) where those vermicomposts were compared to the three types of dehydrated sludge, SS_1P, SS_1M and SS_2M (Picture 5). A control variant with distilled water (ADM) was also performed (Picture 6). A filter paper was inserted in each Petri dish and 100 cress (*Lepidium sativum*) seeds were placed on it. Then, 5 ml of supernatant was added over the seeds and in the control variants, only distilled water was added. The Petri dishes were inserted in the incubator at 25ºC for 48 hours and then the germinated plants were counted for each variant and the evolution of the seedlings was observed. The seeds were sprayed daily with vermicompost extract, compost extract and distilled water, respectively. The initial number of germs was recorded, and their evolution was monitored. All tests were made in triplicates.



Picture 4. Germination test with vermicompost extract after sowing



Picture 5. Germination test with dehydrated sewage sludge extract after sowing



Picture 6. Germination test with distilled water (control) after sowing

RESULTS AND DISCUSSIONS

The physico-chemical characteristics of the vermicompost are presented in Table 3. In the initial stage, the moisture of the 3 types of dehydrated sewage sludge had very close values, 67.10% (SS_P), 67.69% (SS_1M) and 68.47% (SS_2M), and after vermicomposting it decreased to approx. 50%. The lowest moisture was registered at VSS_2M (48.45%), and the highest, at VSS_P (54.86%). Thus, compared to the initial status, the moisture differences were of 12.24% (VSS_P), 16.23% (VSS_1M) and 20.02% (VSS_2M).

Table 3. Physico-chemical characteristics of sewage sludge vermicompost

	VSS_P	VSS_1M	VSS_2M
Moisture (%)	54.86	51.46	48.45
PC (%)	63.81	66.47	68.37
OM (%)	35.54	36.91	28.01
pH	5.52	6.25	8.34
TOC (%)	17.38	18.10	13.93
N (%)	2.06	1.70	0.91
C/N	8.43	10.65	15.31
P (%)	1.03	0.77	0.21
K (%)	1.44	1.62	1.48
Ca (%)	3.17	3.34	2.38
Mg (%)	1.08	1.10	1.05

The vermicompost had an organic matter content (OM) between 28.01% (VSS_2M) and 36.91% (VSS_1M), and the total organic carbon content (TOC) had values between 13.93% (VSS_2M) and 18.10% (VSS_1M), generally lower than the initial content (24.37% at SS_P, and the other two types of sludge, SS_1M and SS_2M, had values just over 22%).
The decrease of TOC due to vermicomposting was also reported by other authors (Hait and Tare, 2011) and could be caused by carbon loss in the form of CO_2 as a result of the respiration of microorganisms (Nigussie et al., 2016; Suleiman et al., 2017).
At the same time, total N content also decreased and had values between 0.91 and 2.06% compared to the status before vermicomposting.
Other studies have reported an increase in total N content due to vermicomposting associated with a decrease in the amount of dry matter that could be due to the consumption of the substrate by earthworms and microorganisms and their metabolic activity (Suleiman et al., 2017).
The decrease in N content can be associated with the absence of food resources given the low values of C/N ratio in the initial stage (Wu et al., 2018). The C/N ratio at the end of vermicomposting had higher values, the highest value being registered at VSS_2M (15.31). The total P content decreased compared to the content of the initial material.
Regarding the pH values, they were decreasing by a pH unit at VSS_P compared to the initial value, and at VS_2M, there was an increase by two units compared to the initial value.
The pH value decrease in case of sewage sludge vermicomposting was also reported in other scientific papers (Yang et al., 2014; Lv et al., 2016), and it could be due to nitrogen and phosphorus mineralization (Suleiman et al., 2017).

Table 4. Heavy metal content of sewage sludge vermicompost

	VSS_P	VSS_1M	VSS_2M	Upper limits (WRAP, - 2011)
Cd (mg/kg)	1.187	1.091	0.881	1.5
Cu (mg/kg)	197	79	49	200
Cr (mg/kg)	65.87	41.41	28.8	100
Ni (mg/kg)	83.0	28.8	29.5	50
Pb (mg/kg)	67.08	18.96	22.29	200
Zn (mg/kg)	1232	627	233	400

The heavy metal contents of vermicomposts (Table 4) were compared with the initial values of the dehydrated sewage sludge content and with the upper limits for minimum compost quality for general use in United Kingdom (WRAP, 2011) in the absence of some recommended values for Romania. Increases of contents in all heavy metals analysed (Cd, Cu, Cr, Ni, Pb, Zn) were registered, in general, at VSS_P. However, regarding Cd, it registered increases of the content in all three vermicomposts compared with the initial values of dehydrated sewage sludge. The highest content was registered at VSS_P, and the lowest at VSS_2M. However, the Cd content did not exceed the limit value of 1.5 mg/kg (WRAP, 2011). The Zn content of VSS_P registered a large increase amounting to 1232 mg/kg compared to 751 mg/kg in the initial stage. The Zn content of the other two types of vermicompost decreased slightly but remained above the upper limit recommended by WRAP (2011). High values of Zn content have also been reported in previous studies (Suleiman et al., 2017).
The chemical analyses performed at the end of vermicomposting on earthworm samples revealed a high Cd content of those in case of VSS_P and VSS_1M. In case of VSS_P, a high Cu and Zn content was also highlighted. Previous studies have shown that earthworms are heavy metals accumulators and *Eisenia andrei* species has the highest accumulation capacity. Therefore, attention must be paid on the risk of introducing heavy metals into the food chain (Suleiman et al., 2017).

Table 5. Heavy metal content of earthworms at the end of vermicomposting

	VSS_P	VSS_1M	VSS_2M
Cd (mg/kg)	4.4	5.2	1.8
Cu (mg/kg)	55	23	34
Ni (mg/kg)	23.6	6.98	19.5
Pb (mg/kg)	16.2	5.3	10.8
Zn (mg/kg)	329	194	214

For the vermicompost quality evaluation, a germination test with cress (*Lepidium sativum* L.) was performed in three replicates. The seeds were germinated in an incubator, and after 48 hours from introduction into the incubator, the number of cress germs was counted. At this stage, the highest number of germs (the average of the three replicates) was registered in VSS_2M (92) vermicompost variant and the lowest number in SS_P (69) variant, compared to the control variant with distilled water, which had an average number of 96 germs (Figure 1, Picture 7). At 5 days after introduction into the incubator, the maximum number of seedlings (100) was registered in all variants with vermicompost, as well as in those with dehydrated sewage sludge, except for SS_2M.

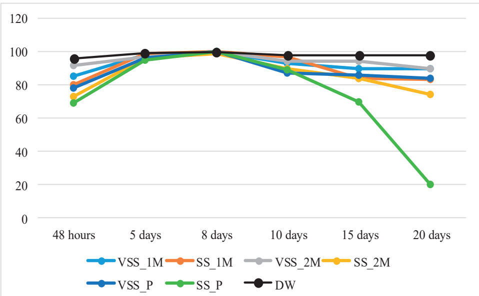
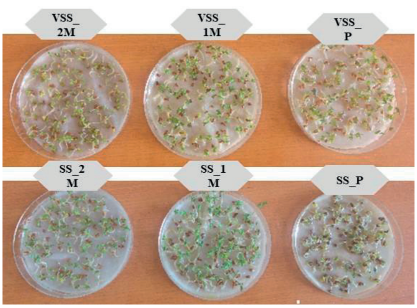
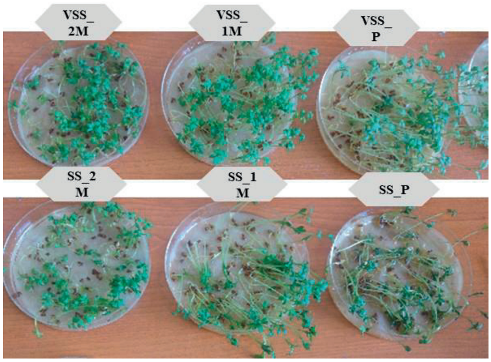


Figure 1. The evolution of the cress plants number under the influence of vermicompost extracts



Picture 7. Cress seed germination in vermicompost and dehydrated sewage sludge extract after 5 days

The evolution of seedlings and plants was monitored for 20 days. 10 days after the experiment establishment it was observed that the seedlings began to die, the most affected being those from the VSS_P and SS_P variants where the highest number of dead seedlings was registered, i.e 13 and 11 (Picture 8, Picture 9).



Picture 8. Cress seed germination in vermicompost and dehydrated sewage sludge extract after 10 days


Picture 9. Cress seed germination in distilled water after 5 and 10 days

After 20 days, the highest number of dead plants was registered in SS_P (80) variant, and in the vermicompost variants, most of the dead plants being recorded in VSS_P (16). In the vermicompost variants, on the 20th day, the highest number of viable plants was in average of 90 in VSS_1M and in VSS_2M followed by VSS_P (86). The plants may have been affected by the presence of heavy metals in the dehydrated sewage sludge variants. Previous studies have shown that sewage sludge cannot be independently used in vermicomposting process (Lim et al., 2016), and bulking materials is needed for enrichment of the diversity of microbial population and enzymatic activity (Hait and tare, 2011), and also to alleviate heavy metals phytotoxicity (Wu et al., 2018).

CONCLUSIONS

Vermicomposting is emerging as a most appropriate alternative to conventional aerobic composting (Hait and Tare, 2011), and vermicompost is a more advanced stage of raw materials decomposition than thermophilic compost (Nigussie et al., 2016). But, in order to ensure successful vermicomposting of sewage sludge, several suitable external materials should be applied to mitigate the toxicity of sewage sludge (Wu et al., 2018). The feed quality is of primary importance for the growth and reproduction of worms (Molina et al., 2013). However, further studies regarding heavy metal phytotoxicity, and their bioaccumulation by the earthworms are required.

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