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Comparative study on physical and chemical characteristics of sludge vermicomposted by *Eisenia fetida*

Fei Liu[a], Pengfei Zhu[a], Jianping Xue[a,*]

[a]*College of life sciences,Anhui Key Laboratory of Plant Resources and Biology, Huaibei Normal Uni-versity, Huaibei, China, 235000*

Abstract

Prior to vermicompost application to the soils, there is a need to determine the heavy metal concentrations in the final vermicomposts. This study was designed to evaluate the effects of earthworm activity on heavy metals in sewage sludge. Com-pared with before vermicomposting by *Eisenia fetida*, the results are as follows: (1) water content, the pH value and organic matter content decreased, (2) total nitrogen content increased, total phosphorus content, total potassium content decreased, (3) available nitrogen concentration, available phosphorus content increased and, (4) the total content of five metals (Cu, Ni, Cd, Pb and Zn) decreased, and the bioaccumulation factor (BAF) shows that vermicomposting can efficiently remove heavy metals. Therefore, it can be concluded that the soil use of sludge of the Wastewater Treatment Plant in Huaibei is feasible.

Keywords:Eisenia fetida, heavy metals, vermicomposting, wastewater sludge, bioaccumulation factor;

1. Introduction

As of the end of September 2011, urban sewage was processed to 136 million m^3/day, and wet sludge (moisture content 80%) yielded in sewage treatment plants to 34.8 million tons annually in China. Most of them were untreated, and had resulted in a series of problems, e.g. soil pollution. Many other developing countries also. However, wastewater sludges produced by sewage treatment plants are a good source of macroelements and microelements and generally contain a high quantity of organic matter. Their application in agriculture and in silviculture translates into improved soil fertility. Sludges also help maintaining soil structure, soil water-holding ability, soil cation exchange capacity, and soil biological

* Corresponding author. Tel.: +86 15375613892; fax: 86 561 3803237.
E-mail address: liufei888@163.com.

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activity. Although the recycling of sludge is an attractive alternative, its use often brings about certain risks to the environment caused by accumulation of heavy metals and organic compounds and potential contamination from pathogenic organisms[1].The method of sludge disposal included: sludge incineration, common landfill, making brick, vermicomposting and so on. Among the above available alternatives for the disposal of sewage sludge, one of the most attractive is vermicomposting, which is a simple and low-cost technique. This method can be used in the removal of toxic metals and the breakdown of complex chemicals to non-toxic forms[2].After adequate treatment eliminating heavy metals, the sewage sludge has high nutritive value for plants, and its applications as fertilizer are widely used [3]. The transformation of industrial and urban sludge into vermicompost is very important; on the one hand, waste matter is converted into a value-added product, and on the other, it controls pollutants resulting from increasing industrialization or improper treatment of toxic materials. Earthworms, that are large enough to develop mutualistic relationships with microflora inside their gut proper[4], have also been called 'ecosystem engineers' for their ability to profoundly affect the soil structure[5].

Eisenia fetida, which has a short maturity cycle, higher cocoon production rate, and more adaptable to different organic materials[6], was selected for treating the sludge. Vermicompost, which contained a lot of organic matter, humic acid, nitrogen, phosphorus, potassium, and a variety of enzymes, trace elements and amino acids[7], can effectively promote crop growth, and improve product quality[8]. Further, vermicompost can improve low-quality soil, and suppress soil-borne diseases to a certain extent [9]. The goal of this study is to obtain an efficient composting system using a earthworm, *Eisenia fetida*, to remove heavy metals (Cu, Cd, Ni, Pb and Zn) contained in non-stabilized sewage sludge from a wastewater plant located in Huaibei, Anhui province, China. The sludge was vermicomposted for 120 days, and the content of macroelements (N, P, K) and five trace metal elements (Cd, Cu, Ni, Pb, Zn) as measured for the sludge and the *Eisenia fetida* tissues.

2. Materals and methods

Total Kjeldahl nitrogen was measured by the Kjeldahl method. Total P was dissolved by nitric-perchloric acid digestion and determined by spectrophotometry. Total K were determined by flame spectrometry.

A subsample (approximately 10g) of sludge was dried at 105°C and ashed at 550°C to determine moisture and organic matter content, respectively. The pH and conductivity were determined using water diluted samples (1:10), and the content of soil available N, available P and available K were determined by Alkaline hydrolysis diffusion, Mo-Sb Anti spectrophotometric method and flame photometric method, respectively.

The total concentrations of the five metals (Cu, Ni, Cd, Pb and Zn) were measured in three replicates, using 0.5g samples of the sewage sludge collected prior to the laboratory test. These samples were digested in a solution containing 9 mL of nitric acid and 3 mL of chloride acid supra pure grade[10]. On the other hand, for the analyses of earthworm tissue, 0.5g of the samples were also used, although in this case, the solution only contained 10 mL of nitric acid supra pure grade according to the EPA Method 3052.The solutions were analyzed for Cu, Ni, Cd, Pb and Zn by atomic adsorption spectrophotometry (AAS). During all the analyses, appropriate quality controls were analyzed for quality assurance. All the chemicals were analytical reagent or higher grade, and deionized water for laboratory.

All the reported data were analyzed by SPSS17.0 statistical analysis. Comparisons of the means were made by the least significant difference test calculated at *p*-values. Significance was defined as $p \leqslant 0.05$,unless otherwise indicated.

3. Results and discussion

3.1 Physical and chemical properties of sludge

Eisenia fetida survival was very high (98 %) after vermicomposting, and earthworm mortality was very low (< 2%) The pHs of sludge vermicompost were within the optimal range for plant growth. The pHs of sludge vermicompost and than before, has decreased from 7.4 to 6.3. Subler et al. [11] reported that as a class, vermicomposts tended to have lower pH than composts, just as this study did. Haimi and Huhta, [12] during their study on the vermicomposting of some organic residues concluded that the lower pH in the end product (vermicompost) might have been due to the production of CO_2 and organic acids by microbial decomposition during the process of bioconversion of different substrates. Organic matter showed a significant (P<0.01) loss 29.35% by the end of the experiment (Fig.1.a).

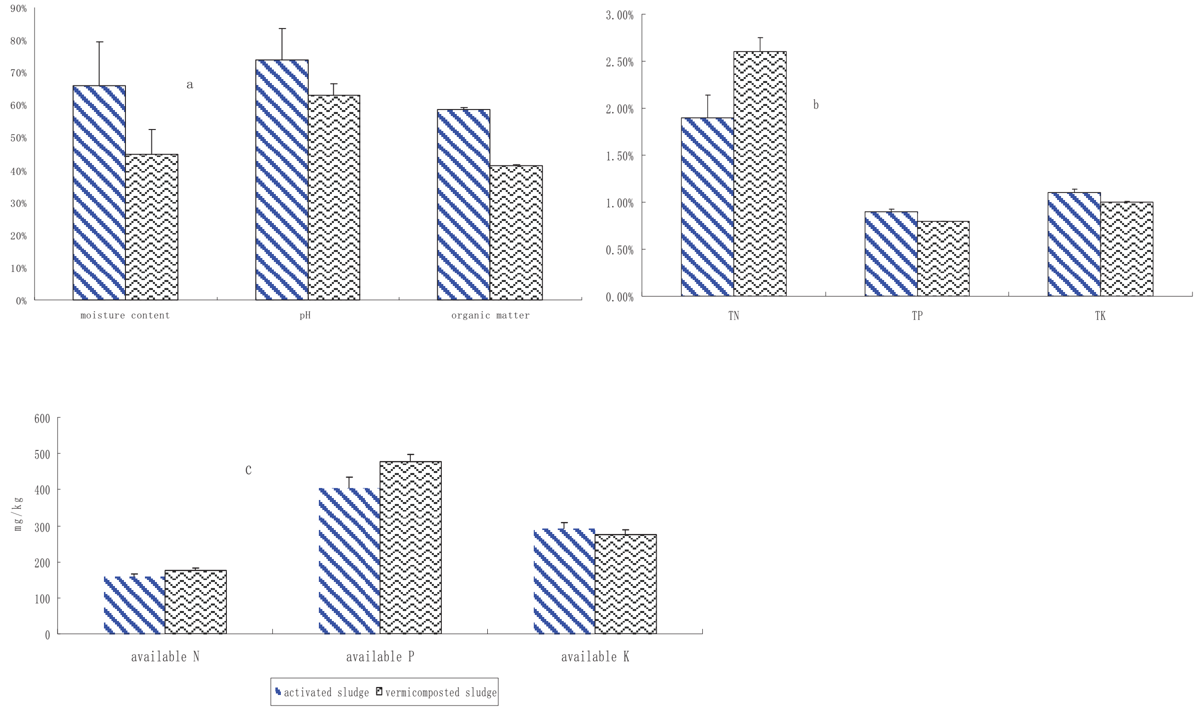

Fig.1.Physical and chemical properties of the sludge tested before and after vermicomposting

Notes:(1) pH/10, dimensionless (2) Available N/10

Elvira, et al.[13] stated that a large fraction of organic matter in the initial substrates was lost as CO_2 (between 20 and 43% as total organic carbon) by the end of the vermicomposting period. Total kjeldahl nitrogen content increased 36.84% in the studied sludge by the end of the experiment (Fig.1.b). The inoculation of *Eisenia fetida* in sludge considerably enhances the nitrogen levels of the substrate by adding their excretory products, mucus, body fluid, enzymes and even through the decaying tissues of dead worms in vermicomposting subsystem[14]. The available N and available P were also higher in the end product (vermicompost) as compared to the initial sludge. Available K was lower in vermicompost than the initial sludge (Fig.1.c)

3.2 Heavy metals

According to table 1, heavy metal concentrations in the vermicompost decreased than initial sludge, and the heavy metal concentrations in earthworm tissues increased. Heavy metals appear in the sludge due to anthropogenic sources. e.g. house dust, paint chip, batteries, etc. Therefore the vermicompost made from sludge may have high heavy metal concentrations. Although many of these elements may be essential for plant growth, the higher metal concentration, the more negative impacts upon plant growth. Heavy metal concentrations (Cu, Ni, Cd, Pb and Zn) in the vermicom-post were much lower than initial sludge due to the adsorption by *Eisenia fetida*. The mean adsorption at the end of the experiments were 68±12.43, 1.89±0.71,155.15±7.49,71±5.822 and 58.69±1.67mg/kg for Cu, Cd, Zn,Pb and Ni, respectively.

Table 1 Concentrations of Cd, Cu, Ni, Pb and Zn in vermicomposted sludge and earthworm body tissues

Selected metals	Initial activated Sludge (mg/kg)	Vermicomposted Sludge (mg/kg)	Earthworm body tissues (mg/kg)	BAF	China limits (mg/kg)	
					Soil pH>6.5	Soil pH<6.5
Cu	105±10.92	37±4.69	89.93±7.82	0.856	500	250
Cd	2.57±0.07	0.68±0.051	7.64±0.35	2.973	20	5
Zn	265±19.22	109.85±7.18	348.75±23.86	1.316	1000	500
Pb	116±8.47	45±2.73	51.33±1.97	0.443	1000	300
Ni	68.73±7.83	10.04±0.51	39.54±1.78	0.575	200	100

An important aspect to be considered is the bioaccumulation factor (BAF) to be used for the identification of environmental pollution. The bioaccumulation of various metals is complex because it involves several processes: absorption, internal distribution, storage and excretion. BAF was used to estimate metal bioavailability in earthworms and as calculated directly by using the equation (1).

$$BAF = C_W(ss) \big/ C_x \qquad (1)$$

Where: C_w(ss) is the earthworm metal concentration at steady state(mg metal/kg earthworm) and C_x is the total metal sludge concentration(mg metal kg^{-1} sludge).BAF refers to the bioavailable concentration reflecting operationally the efficiency of sentinel organisms as bioconcentrators of any given metal. The BAF for the five selected metals ranged from 89.93±7.82,7.64±0.35,348.75±23.86,51.33±1.97 and 39.54±1.78 for Cu, Cd, Zn, Pb and Ni, respectively. As shown in this table 1, the BAFs of Ni, Cu and Pb were lower than 1 in the end of the experiments, and the BAFs of Cd and Zn were greater than 1, on the contrary. The results are in good agreement with the results obtained by other authors[15],who reported that low metal concentrations in soils resulted in high BAF of metals in earthworm.

The observed variations in BAF values for the different metals could be attributed to the earthworms' ability for accumulating heavy metals, which depends strongly on the metal that is bioavailable for uptake rather than the total[16].Bioaccumulation factors for heavy metals may vary over a wide range (from more than 10 to less than 0.1) in relation to the soil metal content and earthworm species. The BAFs of the five heavy metals in *Eisenia fetida* were ranked as: Cd>Zn>Cu>Ni>Pb. Similar results were observed by Dai et al.[15],who found the BAFs of Cu, Zn, Pb and Cd in earthworms(*Aporrectodea caliginosa and Lumbricus rubellus*)inhabiting soil in the order of Cd>Zn>Cu>Pb. Morera et al.[17] showed for various soils that the relative affinity of metals is consistent with the value of the first hydrolysis constant of the cations proposed by Basta and Tabatabai[18] Cu (p*K*=7.7)=Pb (p*K*=7.7)＞＞Zn(p*K* 9.0)＞Cd (p*K* 10.1). These data are also fairly consistent with the BAF values obtained in our study that where: Pb <Cu< Zn< Cd.

As it is well known, the concentration of a compound in an organism is controlled by three factors: absorption, elimination and biotransformation. Uptake can be calculated according to the following equation:[uptake]=[absorption]-[elimination]-[biotransformation][10].The above several factors, it is of great importance that to eliminate the excess of metals for the bioaccumulation of metals[19] showed that for essential metals, such as Cu and Zn, a fast initial uptake was followed by equilibrium after a few days of exposure, highlighting a physiological control and a possible excretion of these elements. For the xenobiotic metals, such as Cd, the excretion was slow or absent. The same bioconcentrations of Cu in earthworms for all our sampling points, leading to the decrease of the BAF for polluted soils, could be attributed to this mechanism. For Zn, even if the concentrations were high, the BAF were also lower in the most contaminated soils. Excretion of a part of Zn could contribute to the regulation of the metal concentrations in earthworms. Data about Ni concentrations are scarce, but Beyer et al.[20] reported that it is not accumulated by earthworms. However, in our study, a fact is that *Eisenia fetida* can accumulate a part of Ni.

4. Conclusion

Results showed the parameters such as pH, water content, organic carbon, and total phosphorous were lower in case of treated sewage sludge than primary sewage sludge. On the contrary, Total Kjeldahl nitrogen, available N, available P were higher. Earthworms could accumulate heavy metals of sewage sludge. This study clearly shows that vermicomposting of municipal sludge might be an effective echnology to convert the negligible resource into some value-added products, e.g. vermicomposts. The bioaccumulation factor (BAF) shows that vermicomposting can efficiently remove heavy metals. The soil use of sludge of the Wastewater Treatment Plant in Huaibei is feasible.

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