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REDUCTION OF HEAVY METAL AND MICROBIAL CONTAMINANTS IN SEPTAGE VIA VERMICOMPOSTING

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ABSTRACT

Septage or sludge from septic tank contains heavy metals and pathogens that need to be treated. One treatment option is vermicomposting to convert septage into compost or soil conditioner. In this study, septage underwent vermicomposting process using African night crawler earthworms (Eudrilus eugeniae) for 60 days. Bulking agents, sawdust and cocopeat were added in different proportions to obtain C:N ratio conducive for optimum vermicomposting. The different mixtures (septage, septage+sawdust, and septage+cocopeat) were monitored for temperature, pH, and moisture content. Reduction of heavy metals (Zn, Pb, Cu, Ni, and Hg) was determined in all mixtures while validation was made by measuring the metal accumulation in the earthworms throughout the vermicomposting process. Pathogen removal was determined by regularly conducting coliform, Salmonella sp., and helminth ova analyses. The study showed that a significant decrease in the metals concentration at the mixture indicating that the earthworms can accumulate metals in their body tissues. In addition, the increase in temperature during the vermicomposting process reduced the number of coliform and Salmonella sp.

Keywords: vermicomposting; heavy metals; pathogen, C:N ratio, septage

1. INTRODUCTION

In the Philippines, most of the households use septic tanks for their domestic wastewater disposal [3]. The untreated domestic wastewater sludge or septage, if disposed of to the environment may lead to sanitation problems. The sludge contain pathogens that may contaminate water sources and cause serious water borne diseases such as diarrhea, cholera, typhoid fever and other gastrointestinal disorders.

To prevent the sanitary problems posed by the improper disposal of septic tank sludge, each municipality in the country is encouraged to have its own municipal wastewater treatment plant (MWTP). In this system, domestic wastewater and leachate from solid waste disposal facilities pass through the sewer lines and transported to the MWTP where it is treated to meet the government regulatory standards before the effluent is finally discharged to the receiving water bodies. Sewage sludge or the biosolids are then generated, dewatered and undergo further treatment prior to disposal or for agricultural use [18].

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Biosolids contain nutrients and organic matters that are beneficial to soil and contribute to plant growth. It is also a source of nutrients and act as a soil conditioner [18.19]. But the presence of pathogens and high heavy metal concentrations in the biosolids requires that it must be properly treated to avoid any health risks to the public and contamination in the environment.

Presently, several available septage management and disposal options are practiced worldwide. A life cycle analyses (LCA) of the different options revealed that the ultimate management goal for sewage sludge is through reuse [2]. The United States Environmental Protection Agency (U.S. EPA) issued The Standards for the Use or Disposal of Sewage Sludge (Part 503 designated as Biosolids Rule) in 1999 which regulate and limit the level of pollutants and pathogens in biosolids including septic tank sludges [10]. The rule suggests that the disposal methods of the sludges can be done through landfill, incineration, and agricultural uses. Among these treatment methods, agricultural use is found to be viable and cost-effective where biosolids can be converted into organic fertilizer by composting and vermicomposting [11].

Vermicomposting is basically a composting process with worms [9,11,20]. It is the process by which organic materials such as septage and biosolids are fed to earthworms and undergo physical and chemical changes as it pass through muscular gizzard of the worms where the materials are ground to particle size of 1 to 2 microns [9,12]. In the Philippine condition, the earthworm specie suitable is the African night crawler (*Eudrilus eugeniae*) [5]. These earthworms produce vermicast which are rich in organic matters and nutrients that are readily soluble in water for easy uptake of the plants [9,14,16]. Aside from agricultural uses, vermicast, like compost, serves as media for contaminant sorption, odor filtration, material for soil erosion control and storm-water runoff filtration [15,17].

In this study, the feasibility of septage treatment using vermicomposting process for the reduction of heavy metal concentration and microbial contamination was investigated. Different bulking agent combinations were used and determined in its optimum proportions. Finally, the physic-chemical characteristics of vermicast were compared to the pathogens and heavy metal concentration requirements of U.S. EPA for land applications.

2. MATERIALS AND METHODS

The septage was characterized in order to determine the initial parameters and subsequently compare the same paramaters at the end of the composting process for evaluating process efficiency. Substrates were mixed based on the optimum C:N ratio of 25:1suggested by Ndegwa and Thompson [7]. Earthworms were seeded to the mixtures of substrates with an initial amount calculated based on the optimum feeding rate. The experiment were then undertaken to determine the capability of vermicomposting in producing vermicast that meet the standards and limits for microbiological and heavy metal concentrations stipulated in the U.S. EPA standards for land applications.

2.1 Materials

The vemicomposting process was performed in plastic vermicomposting bins with 0.36 m x 0.52 m with a height of 0.30 m. These plastic bins provide a total exposed surface area of 0.19 m^2 for aeration in each treatment. Two hundred twenty (220) grams of adult African night crawler earthworms (*Eudrilus eugeniae*) were seeded in each bin filled with substrates. Ten (10) kilograms of mixture of substrates were provided to the worms for 60 days vermicomposting time with a calculated feeding rate of 0.75kg feed/kg worms/day.

2.2 Methods

During the vermicomposting, moisture content and pH is read every 3 days, and the temperature tested daily. Moisture content of the compost was determined by oven drying at 110±5°C to constant weight. The MC was maintained at 60 – 80% [5] by adding distilled water every time the MC starts to go down. The pH is tested by adding distilled water in the sample to which a pH probe is immersed. The bin temperature was tested by inserting the soil thermometer into the bin.

2.3 Heavy Metal Analysis

The heavy metal contents of vermicast were measured by total assay method. About two (2) grams of vermicast from different stages of vermicomposting was gathered and analyzed. The samples were ignited at 750°C for 2 hours. The residues of the sample were digested in 15 ml concentrated HCl (Hydrochloric Acid) over a hot plate using low heat. During heating, 10 ml of concentrated HNO_3 (Nitric Acid) were added. Further addition of HNO_3 thereafter was made until a light color is achieved. Heating continues until about 5 ml of liquid remains. To this liquid, distilled water was added to make it a 100 ml solution. The solution was passed through a Whatman GF/C No. 47 filter and the heavy metals were measured from an aspirate of the sample in a Shimadzu AA-6300 Atomic Adsorption Spectrophotometer (AAS). The metals tested are Zn, Pb, Cu, Ni and Hg.

The heavy metal concentration of earthworms was determined using the same protocol for vermicast heavy metal concentration determination. Representative earthworm samples were ignited at 750°C. After the ignition, the residue was digested using the same procedure for the digestion of vermicast. As in the vermicast protocol, heavy metals were also analyzed in an Atomic Absorption Spectrophotometer (AAS). The metals tested are Zn, Pb, Cu, Ni and Hg.

2.4 Pathogen Tests

Four (4) pathogen indicators were tested from the initial mixtures as baseline and after 60 days of vermicomposting as its final test. The total and fecal coliform was determined using multiple-tube fermentation technique (MTFT) for members of the coliform group in accordance with the Part 9221 of the Standards Methods for the Examination of Water and Wastewater [1]. The *Salmonella sp.* was tested using the Tecra Rapid Test Method and verification using Xylose Lysine Deoxycholate (XLD) method. The Helminth ova count was done the sedimentation centrifugation method.

3. DISCUSSION OF RESULTS

Table 1 shows the summary of the heavy metal reduction in the vermicompost from initial mixtures to final vermicast. Consumption of the substrates by the worms caused the decrease in heavy concentrations in the vermicast. The ability of the worms to accumulate the metals in their body tissues was proven in this experiment. No other factors and intervention were added to alter the metal concentrations. Distilled water was used in supplying required minimum moisture to the vermicomposting bins.

The highest reduction rate for zinc (Zn), copper (Cu) and nickel (Ni) is in T_1 (septage+sawdust) at 24.95%, 18.08% and 68.04%, respectively. For lead (Pb) and mercury (Hg), T_2 (septage+cocopeat) got the highest reduction at 53.58% and 57.46%, respectively.

The conversion of septage into vermicast by the worms' action reduces the heavy metal concentration in the vermicompost. The reduction of heavy metals in the vermicompost can be attributed to the accumulation of metals into worms' body tissues. Therefore, it is important to analyze the heavy metal concentrations in the worms before and after vermicomposting for comparison.

Table 1
Concentration of Heavy Metals in the Vermicompost Before and After Vermicomposting (mg/kg).

Parameters	T_0 (Septage)	T_1 (Septage+ Sawdust)	T_2 (Septage+ Cocopeat)
Zinc (Zn)			
Day 0	3,253.21	2,829.34	1,697.77
Day 60	2,688.70	2,123.41	1,395.69
% Reduction	17.35	24.95	17.79
Lead (Pb)			
Day 0	209.89	126.32	159.17
Day 60	157.75	115.69	73.88
% Reduction	24.84	8.42	53.58
Copper (Cu)			
Day 0	335.99	259.79	170.00
Day 60	286.70	212.83	153.04
% Reduction	14.67	18.08	9.98
Nickel (Ni)			
Day 0	248.39	252.28	235.22
Day 60	150.37	80.63	80.93
% Reduction	39.46	68.04	65.59
Mercury (Hg)			
Day 0	0.51	0.51	1.34
Day 60	0.37	0.48	0.57
% Reduction	27.45	5.88	57.46

Table 2 shows the summary of the concentrations of heavy metals in the worms' body tissues from the start of the composting and 60 days thereafter. The concentrations of metals (Zn, Pb, Cu, Ni and Hg) were increased after the vermicomposting indicating that the worms' tissue can accumulate traces of heavy metals from the substrates.

Table 2
Concentration of Heavy Metals in Earthworms Body Tissues (mg/kg)

Parameters	T_0 (Septage)	T_1 (Septage+ Sawdust)	T_2 (Septage+ Cocopeat)
Zinc (Zn)			
Day 0	437.58	437.58	437.58
Day 60	576.11	764.93	494.37
Total Increase	138.53	327.35	56.79
Lead (Pb)			
Day 0	81.46	81.46	81.46
Day 60	85.90	94.73	111.33
Total Increase	4.44	13.27	29.87
Copper (Cu)			
Day 0	46.24	46.24	46.24
Day 60	67.03	89.32	58.14
Total Increase	20.79	43.08	11.90
Nickel (Ni)			
Day 0	176.09	176.09	176.09
Day 60	188.47	197.12	203.61
Total Increase	12.38	21.03	27.52
Mercury (Hg)			
Day 0	0.82	0.82	0.82
Day 60	1.64	1.66	3.56
Total Increase	0.82	0.84	2.74

The high increase of Zn and Cu in the worms' tissue were observed in T_1 (septage+sawdust) with 327.35 mg/kg and 43.08 mg/kg, respectively. The highest total increase of Pb, Ni and Hg concentration is recorded in T_2 (septage+cocopeat) with 29.87 mg/kg, 27.52 mg/kg and 2.74 mg/kg, respectively. It is noticeable that the worms in T_0 (septage) accumulated lesser amount of metal concentration compared to the other two treatments with additional bulking agents. Earthworms reproduced lesser amount in the septage alone, thereby converting lesser amount of vermicast which agreed with the result of Dominguez, et.al [13].

Figure 1 shows the heavy metal concentration of vermicompost products after 60 days of vermicomposting. The limits set by the U.S. EPA for Class A biosolids are shown alongside the parameters for easier reference.

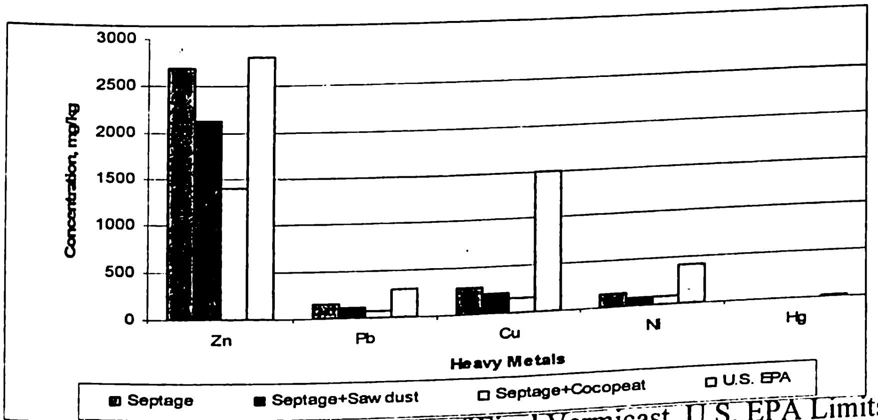

Figure 1. Heavy Metal Concentrations of Final Vermicast, U.S. EPA Limits.

The summary of the comparison of baseline and final values of microbiological analysis on the three (3) treatments are presented in Table 4. It was noticeable that there are reductions in total and fecal coliform. In the total coliform analysis, highest reduction was recorded in T_0 (septage) with 65.36% followed by T_2 (spetage+cocopeat) with 57.69% and T_2(septage+sawdust) with 14.77%.

For the Fecal coliform (*E. coli*) contamination, T_0 (septage) exhibited higher final count of 1.1×10^5 MPN/g compared to the allowed by the U.S. EPA of 1,000 MPN/g to consider the biosolids as Class A for land application. Likewise, T_0 (septage) recorded the lowest reduction rate of 54.17% in Fecal coliform reduction, while T_1 (septage+sawdust) and T_2 (septage+cocopeat) shown high reduction with 99.67% and 98.90%, respectively. This result agrees with the study of Eastman, et al. [4] that vermicompsoting can be used to used as an alternative method for Class A biosolids stabilization. The destruction of *E. coli* in these treatments is due to the addition of substrates to the septage and provided appropriate environmental conditions to the worms for efficient performance.

Table 4
Microbiological Analysis of Vermicompost Products.

Parameters	**T_0 (Septage)**	**T_1 (Septage+ Sawdust)**	**T_2 (Septage+ Cocopeat)**	**US EPA Standard**
Total Coliform, MPN/g				
Baseline	2.8×10^5	8.8×10^5	1.3×10^7	
Final	9.7×10^4	7.5×10^5	5.5×10^6	
% Reduction	65.36	14.77	57.69	
Fecal Coliform, MPN/g				
Baseline	2.4×10^5	2.3×10^5	3.9×10^4	
Final	1.1×10^5	7.5×10^2	4.3×10^2	1,000MPN/g TS
% Reduction	54.17	99.67	98.90	
Salmonella sp. MPN/g				
Baseline	<2	<2	<2	3MPN/10g MS
Final	0	0	0	
Helminth ova				
Baseline	Positive for *Ascaris lumbricoides*	No viable helminth ova found	No viable helminth ova found	
Final	No viable helminth ova found	No viable helminth ova found	No viable helminth ova found	1 viable/10g MS

All treatments in the experiment yielded negative results for *Salmonella sp.* and Helminth ova after 60 days of vermicomposting. Although some of the representative samples used in the experiment did not have *Salmonella sp.* and Helminth ova from the start, still this study showed potential in the reduction of pathogens in biosolids.

4. CONCLUSIONS AND RECOMMENDATIONS

The study showed significant decrease in the metals concentration of the septage mixture indicating that the earthworms can accumulate metals in their body tissues. In addition, the increase in temperature during the vermicomposting process reduced the number of coliform, *Salmonella sp.*, and helminth ova. Final heavy metal concentrations and microbiological contaminant levels of the mixtures all passed the U.S. EPA standards for land applications. These results show that vermicomposting is a viable treatment for septage.

Based on the results of the study, the following are recommended; (a) perform vermicomposting study under controlled conditions, and if possible, with inoculated pathogens, and (b) further studies to look into the flow of metals out of the vermicomposting system.

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