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# Production of Biofertilizer from Vermicomposting Process of Municipal Sewage Sludge

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**Abstract:** This study examines the potential of tiger worms (*Eisenia fetida*) in vermiculturing Municipal Sewage Sludge (MSS) into beneficial vermicompost or biofertiliser. Tiger worms weighed 1000 g were cultured in plastic bin (45×30×30 cm) containing 25000 g sewage sludge taken from a selected sewage treatment plant in Malaysia. The daily feeding rate of MSS was made to be equal with the weight of worm biomass. Sludge volume reduction due to vermicomposting process was determined daily. Physical parameters such as temperature, moisture content and pH were recorded. Nutrient contents in vermicompost such as Total Nitrogen (TN), Total Phosphorus (TP) and Total Potassium (TK) were determined for day 1, 7, 14 and day 21. Results showed that vermicomposts produced by tiger worms gradually possessing higher nutrient contents as the composting process progressed. Total nitrogen was found to increase from 19.6 to 35.7 mg $L^{-1}$, total phosphorus from 9.45 to 10.87 mg $L^{-1}$ and total potassium from 3.44 to 4.80 mg $L^{-1}$, respectively. In addition conversion of MSS to vermicompost was found to be 93% by weight and worm biomass showed 30% increment from its initial weight within 21 days. Thus, the present study showed vermicomposting of MSS into organic fertiliser is feasible besides providing a safe and practical disposal method for sewage sludge.

**Key words:** *Eisenia fetida*, vermicomposting, municipal sewage sludge

## INTRODUCTION

Process of sludge disposal from the residual of wastewater treatment plants can pose a serious environmental problem thus stricter environmental regulations need to be imposed. In conjunction, the awareness of environmental problems has forced governments, local authorities and utilities for management to search for new alternative processes or solutions for future waste management strategies (Solisio *et al*., 2002; Moreno *et al*., 2009; Bayat and Sari, 2010; Yadav *et al*., 2010). Effective solid and liquid separation persists to be a major problem in various operation units in waste- water treatment. Among them, sludge dewatering has been pointed out as one of the most expensive and least understood processes. Biosolids are the nutrient rich by-product of wastewater treatment, generated by channeling human waste through treatment plants and collection systems. Although, the terms biosolids and sewage sludge are often used interchangeably, biosolids are the end product after treating sewage sludge with anaerobic digestion in combination with heat (Decaens *et al*., 1999; Elissen *et al*., 2010). The use of biosolids as soil amendments (soil conditioners or fertilizers) or for land reclamation has reduced the volume of biosolids that must be landfilled, incinerated, or disposed of at surface sites. In the last several years, numerous scientific, political and social factors have contributed to a growing public concern over the safety of biosolids which has resulted in strict local ordinances banning. Therefore, the concept of organic matter recovery is becoming more popular to be applied for various purposes. Composting as a resource recovery is becoming a more acceptable alternative for sludge treatment due to potential use for land application as bio fertilizer and soil conditioner (Gupta *et al*., 2005; Suthar *et al*., 2008; Niwagaba *et al*., 2009). The organic portion of solid waste however could be utilized in a very profitable way by composting or by using vermicomposting process (Mainoo *et al*., 2009; Singh *et al*., 2010; Ganesh *et al*., 2009). Vermes is Latin word for worms and vermicomposting is essentially organic composting with worms. In general vermicomposting aids in the disposal by improving the physical quantities of waste (Khwairakpam and Bhargava, 2009; Yadav and Garg, 2009). The use of earthworm in sludge management has been termed as 'vermistabilization'. Vermistablization represents a technology that is environmentally sound and relatively new technology that can be classified as an innovative

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and alternative technology (Follet *et al*., 1981; Hand *et al*., 1988; Surindra, 2009). Earthworms have been used for waste stabilization for many years, especially in Southeast Asia and some third world countries mainly, Canada, United States, Australia and France. Earthworms are one of the major soil macro invertebrates and are known for their contributions to soil formation and turnover with their widespread global distribution. In particular, most of the sewage sludge related to vermicomposting studies employed, activated sludge (a product of biological wastewater treatment) as the raw substrate, however there is a paucity of data on the possibility of vermicomposting the primary sewage sludge which is available in huge quantities (Madan *et al*., 1988; Singh and Sharma, 2002). Thus in the present study, an investigations have been established on the viability of using earthworms as a treatment technique for a selected Malaysian's municipal sewage sludge besides producing beneficial organic fertilizers.

## MATERIALS AND METHODS

**Earthworm collection:** Composting species of tiger worms (*E. fetida*) were chosen as the vermicomposter. Earthworms of *E. fetida* was bought from the earthworm farm at Kuantan, Pahang of Malaysia. About 1000 g of tiger worms were used in this study. Sewage vermicomposting process was done from 18 August 2009 till 9 September 2009.

**Municipal Sewage Sludge (MSS):** Sewage sludge was taken from sewage treatment plant at Indera Mahkota Kuantan, Pahang Malaysia. In this study, 25 kg of dry sewage sludge was used as a feeding substance for the earthworms within 21 days vermicomposting period.

**Experimental set up:** The sewage sludge was introduced in the vermibin without any pretreatment. The average cumulative moisture content of MSS as collected from the site was 60-70% (wet basis). The initial temperature of the sludge was measured as about (27-29)°C and it remained constant for a couple of days. Vermibin by the dimension of 1×0.5×0.5 m (Fig. 1) was used to study the organic degradation of sewage sludge by the earthworm. Therefore a total of 25 kg sewage sludge was fed to the worms. Temperature and moisture content were maintained and the data was recorded thrice a week as shown in Table 1.

On the other hand, the characterization of treated sewage sludge was done before and after it was fed to the worms. Sampling was made every 7 days until day 21 of composting period. Sludge characterization includes physical parameter of pH and chemical properties of Total Nitrogen (TN), Total Phosphorus (TP) and Total Potassium (TK). Besides that the actual mass reduction of sewage sludge during vermicomposting was also recorded.

**Vermicast analysis:** On each day of 1, 7, 14 and 21, vermicast sample was collected and sieved. The vermicast was sieved with hand sorter (net mesh or gauge wire) in order to separate the earthworm and vermicast before its weight was taken. Then, 1 g sample (vermicast) was added into 1 L distilled water for laboratory analyses works. Each dried vermicast sample was analyzed for the following parameters: pH (using standard method, pH meter), total Nitrogen (TN) using hach method (DR2500, method10071), Total Phosphorus (TP) using hach method (DR2500, method8049) and Total Potassium (TK) using a hach method (DR2500, method 8190).

Table 1: Average measured range of parameters

| Parameter | Vermi-bin | Unit | Method |
|---|---|---|---|
| Temperature | 29-31 | Celcius | Thermometer |
| Moisture | 60-70 | % | Standard method |

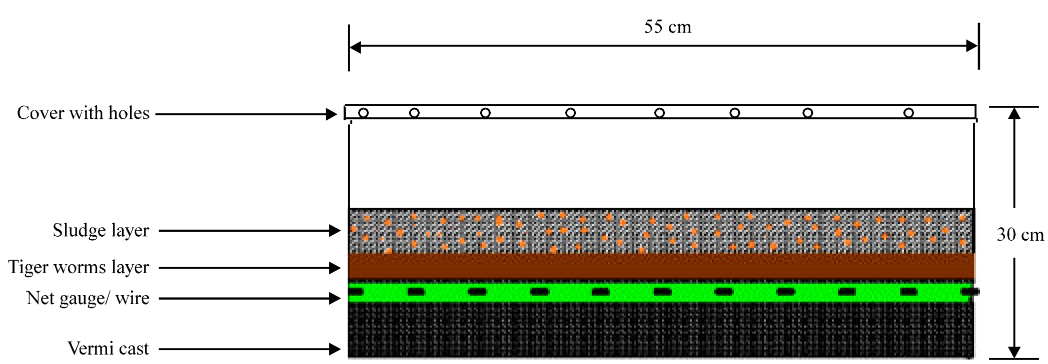


Fig. 1: Schematic design of vermibin

## RESULTS AND DISCUSSION

**Total Nitrogen (TN):** The application of 1 kg earthworm to 25 kg sewage sludge has significantly changed its physical structure and chemical composition whereby the total nitrogen content has been found to increase by 82%. As shown in Table 2, the total nitrogen has increased from 19.6 to 35.7 mg $L^{-1}$ within 21 days of vermicomposting. This result apparently showed that vermicomposting process affects mineralization of nitrogenous organic compounds and the amount of sewage sludge's nitrogen content, thus suggesting that sewage vermicomposting is eminently viable in treating the sewage sludge besides enriching its beneficial nitrogen composition. In particular, the earthworm activity enriches the nitrogen profile of vermicast through microbial mediated nitrogen transformation and addition of mucus and nitrogenous wastes secreted by earthworms. On the other hand, Ruz-Jerez *et al.* (1992) claimed that such condition was attributed to the increased in oxidized carbon due to soil ingestion and not to changes in the soil texture.

Besides releasing N from compost material, earthworms also enhance nitrogen levels by adding their excretory products, mucus, body fluid and enzymes to the substrate. Suthar *et al.* (2008) suggested that the decaying tissues of dead worms also add a significant amount of N to vermicomposting sub-system. In particular the nitrogen enrichment pattern and mineralization activities mainly depend upon the total amount of N in the initial waste material and on the earthworm activity in the waste decomposition sub-system.

**pH:** Changes in pH value during vermicomposting process are shown in Table 2. Vermicast's pH was found to decrease from 6.3 to 5.4 after 21 days. This result showed that vermicomposting produces acidic compound by-product that could be due to microbial decomposition during vermicomposting. In fact this statement is consistent with Elvira *et al.* (1998), who suggested that production of $CO_2$ and organic acids by microbial decomposition during vermicomposting was the underlying factor for the pH decrement.

Table 2: The data obtained from vermicomposting process

| Dates | Compost period (day) | pH | Total nitrogen (mg $L^{-1}$) | Total phosphorus (mg $L^{-1}$) | Total Potassium (mg $L^{-1}$) 38% |
|---|---|---|---|---|---|
| 18/08/2009 | 0-Sludge | 6.30 | 19.6 | 9.46 | 3.47 |
| 20/08/2009 | 1 | 6.05 | 20.0 | 9.43 | 3.53 |
| 26/08/2009 | 7 | 6.02 | 20.6 | 10.1 | 4.16 |
| 02/09/2009 | 14 | 5.92 | 28.3 | 10.6 | 4.63 |
| 09/09/2009 | 21 | 5.40 | 35.7 | 10.87 | 4.80 |

**Total Phosphorus (TP):** As shown in Table 2 vermicomposting has increased the vermicast's phosphorus content up to 14% during the three weeks time. This result apparently showed that vermicomposting can supply biodegradable phosphorus for plantation instead of chemically synthesized phosphorus sources. Similarly, Ghosh *et al.* (1999) have reported that vermicomposting can be an efficient technology for the transformation of unavailable forms of phosphorus to easily available forms for plants. It is hypothesized that vermicomposting process releases TP content from organic waste due to the activity of earthworm's phosphatases. In addition further release of TP is attributed to the phosphorus solubilizing microorganisms that is present in the worm casts (Ghosh *et al.*, 1999; Elvira *et al.*, 1998). In similar statement, Lee (1985) claimed if the organic materials pass through the gut of earthworms, then some of phosphorus being converted to such forms that are available to plants. He further concluded that the availability of TP to plants is mediated by phosphatase produced within the earthworms and further release of TP may be introduced by microorganisms in their casts, after their excretion.

**Total Potassium (TK):** Total potassium content of sewage sludge's vermicast by the end of vermicomposting process is shown in Table 2. An increased in Total Potassium (TK) was recorded in the vermicast than the initial feed mixtures. Total potassium content of vermicast was gradually increased (up to 38%) within the 21 days period. Consistently, our data is supported by Orozco *et al.* (1996), who reported an increased in TK in coffee pulp and textile mill sludge during vermicomposting. This increased maybe due to the microbes present in the gut of earthworms which might have played an important role in this process, in fact Premuzic *et al.* (1998) claimed acid production by the microorganisms is the major mechanism for solubilizing insoluble potassium in the organic waste.

**Earthworm biomass:** The final weight of tiger worms was found to be higher by the end of vermicomposting period. As recorded in the Table 3, the worm's weight has increased by 38% from its initial reading. This finding is consistent with Contreras-Ramos *et al.* (2005) whereby their study showed that earthworms increased their

Table 3: Growth rate of earthworms in vermibin

| Vermibin | Time (days) | Initial weight of worms (g) | Final weight of worms (g) | Weight of sewage sludge/21 days (g) | Weight of vermicompost/21 days (g) |
|---|---|---|---|---|---|
| Tiger worm+ sewage sludge | 21 | 1000 | 1371.64 | 25000 | 23416.10 |

weight by 35% when soil was amended with 5% sewage sludge in spite of contamination with hydrocarbons but lost 77% weight without sewage sludge after 70 days. They concluded that if the weight-increased of worms is accounted for, the nutrient content of ingested organic material largely makes up for the nutrient content of incorporated in the soil. Besides that, Suthar *et al.* (2008) summarized that the factors relating to the growth of earthworms may also be considered in terms of physiochemical and nutrient characteristics of waste feed stocks. Thus, organic waste palatability for earthworms is directly related to the chemical nature of the organic waste that consequently affects the reproduction performance of the earthworm. Therefore, the outcome of this study is not only treating sewage sludge into a vermicast that is rich in nutrients but also production of tiger worm biomass that is of high commercial value.

**Weight of vermicast:** The net weight of harvested vermicast was found to be merely equivalent with the sewage sludge fed to the worms. As shown in Table 3, almost 93% sewage sludge has been converted into vermicast during the 21 days of vermicomposting. It seems that each day every tiger worm eats biomass that equal to their mass body weight. That means, for 1000 g earthworms eat almost about 1000 g feeding material to the bin each day. This conversion rate is significant and roughly can be taken as the projection rate of vermicast for bigger scale vermicast production.

## CONCLUSIONS

Municipal sewage sludge is normally treated in a stabilization pond and will be dumped in a landfill. Such activities require extensive energy and cost of treatment and handling. Instead of being conventionally treated and land filled, this sludge is possible to be converted into vermicompost or biofertilizer which is found to be rich in nutrients for plantation activity. The present study inferred that sewage sludge can be reused and retreated as good quality fertilizer for agricultural purposes. Results of this study indicate vermicomposting is useful for treating the nutrient rich sewage sludge into a high value commodity such as biofertilizer besides producing biomass of tiger worm that is of high commercial value. Vermicomposting has been found capable in enriching the element content of phosphorus, potassium and nitrogen contents of sewage vermicast. Subsequently sewage sludge could be utilized as a biofertilizer which could act as an efficient soil conditioner for sustainable land restoration practices and fertilizer substance that is biodegradable as opposed to chemical synthesized that is obviously harmful to the environment.

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