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Degradation of sewage sludge from plant wastewater using vermicompost

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ABSTRACT

Organic matter is vital for soil fertility and this may be provided through the humus. Humus liquids are solutions composed of humic and fulvic acids dissolved in water, which provide organic matter to soil through irrigation. In this regard, a study of the degradation of municipal sewage sludge from a wastewater treatment plant using vermicompost, was undertaken. Liquid humus with physicochemical properties that are similar to those presented by the Mexican commercial liquid humus, Hum Ecol® was obtained the waste treatment plant. This similarity was confirmed by conducting a variance analysis of concentrations of important nutrients such as organic matter, carbon, nitrogen, phosphorus and potassium. Statistically, there are no significant differences between the formulated humus and the commercial humus. Also, the test that had the best physicochemical characteristics in terms of nutrients is the formulated humus constituted with a mixture of sludge and equine manure in the ratio of 60:40. It exceeded the content of organic matter and total nitrogen in Hum Ecol® by 31.6 and 2.02%, respectively.

INTRODUCTION

In treating wastewater using a purification process, different sub-products are formed as sewage sludge. These sub-products are the waste generated by the primary and secondary treatments. In Mexico, about 1438 tons/day of sludge is produced from local town activities, and 610 tons/day of sewage sludge from industrial activities (Torres and Zarate, 1997).

For proper disposal of sewage sludge, it is required that it is first stabilised, that is, pathogens and parasites are reduced. In this sense, the biological processes present a viable alternative for stabilisation, because unlike physicochemical processes, the stabilised sewage sludge can be reused.

The process of vermi-stabilisation using worms can be otherwise defined as the digestion of organic material by means of worms. It is a technology based on intensive breeding of worms for the production of humus from an organic substrate. It represents a natural decomposition process that is similar to thermophilic composting, but within this organic material, and digestion of organic matter through ingestion, whereby the worms also help the penetration of air and water, because of their movement through the substrate. This movement enables the movement of particles along different strata. The worms can develop only under aerobic conditions, which are enabled by the porosity of the materials used. The material maintains the same aeration conditions that these animals generate with their displacement as they burrow through the materials and dig a system of internal galleries within the ground. Aerobic conditions allow the

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setting for the flowering of aerobic microorganisms (fungi, bacteria, actinomycetes, and yeasts, that are all coexisting in the natural environment); and this (together with the worms) help to break down the waste.

In the gut of the worm, fractionation processes, cleavage, enzymatic and microbial synthesis and propagation all take place, which result in a significant increase in the rate of degradation and mineralisation of waste, for obtaining a high quality product. This transformation causes loss of nutrients such as nitrogen and potassium that are minimal, compared to traditional composting. The results are two high-quality products: the humus and the earthworms.

MATERIALS AND METHODS

The sewage sludge used was obtained from dehydrated sludge container of a wastewater treatment plant in the town of Tlalnepantla in Mexico. The sludge was analysed according to the norm: NOM-004-SEMARNAT-2002, in order to classify it, check its viability to consider if it is suitable for forestry or agricultural use.

The parameters analysed were fecal coliforms, helminth eggs, total nitrogen, available phosphorus, heavy metals, organic matter, pH, moisture and electrical conductivity. The pilot phase was divided into three stages: the planting of earthworm *Eisenia foetida* and maturation of compost; obtaining of liquid humus and toxicological tests.

Planting of *Eisenia foetida*

The annelid *E. foetida* used was obtained from a farm in the State of Mexico. The annelids were inoculated into organic waste (fruit and vegetables) and were mixed with sewage sludge in different proportions, which involved the adaptation phase of the annelid (Table 1).

Obtaining of liquid humus

The obtained leachate had its electrical conductivity and pH measured weekly. Once the liquid humus was obtained, the physicochemical analyses of concentrations of phosphorus, potassium, carbon and total nitrogen were performed. The analysis methods used are detailed in Table 2.

Once the annelid was adapted to consuming the sewage sludge, four trials based on experimental design were carried out for obtaining the best ratio of sewage sludge and cow manure, using vermicompost, manure and sewage sludge, according to Soriano et al. (2008). Such assays were placed in reactors, adapted to collect the leachate (liquid humus). Weekly pH and electrical conductivity trials were analysed in the formed leachate. Once liquid humus was obtained, the contents of phosphorus, potassium, total nitrogen and total organic carbon were determined.

Toxicological testing

Toxicological assays based on phytotoxicity, to see if growth could be generated in tomato seeds using sewage sludge, were carried out. These were performed using the methodology described by Díaz Báez et al. (2004). The exposure period was terminated after 120 h, and then the effect on germination, and radicle and hypocotyl elongation was quantified. In order to calculate the percentages for comparing with the Germination Index (GI), the following formulas were used:

$$RG = \frac{\text{Number of seeds germinated in the extract} \times 100}{\text{Number of seeds germinated in the control}}$$

$$RE = \frac{\text{Radicles elongation in the extract} \times 100}{\text{Radicles elongation in the intestine}}$$

$$GI = RG \times RE$$

Where RG, relative percent germination; RE, relative growth of radicle; GI, germination index.

Statistical analyses

The statistical data processing using analysis of variance (ANOVA) was performed using XLSTAT 2011, in order to determine significant differences between treatments, and Dunnett's test was used for comparison of means. The probability value regarded as statistically significant was $P<0.05$.

RESULTS AND DISCUSSION

According to the Mexican norm, NOM-004 SEMARNAT-2002, the sewage sludge is classified as excellent, due to the limited presence of heavy metals. For microbiological parameters and parasites the sludge was classified as Class A for *Salmonella* spp. and helminth eggs. For fecal coliforms the sludge was classified as class C. Therefore, this parameter is not a problem for the sludge to be used as a substrate in the vermicompost, as the microbial load benefits the process, being the microorganisms responsible for the degradation of organic matter in the vermicomposting process (Domínguez et al., 2003).

Table 1. Proportions of organic waste and sewage sludge.

	Week				
	1	2	3	4	5
Organic matter (gr)	450	300	200	100	0
Sewage sludge (gr)	50	150	250	350	500

Table 2. Analytical methods.

Parameter	Analytical Method
Total nitrogen	Kjeldahl Method
Available phosphorus	Bray method (Bray and Kurt, 1945) and the Olsen method (Olsen et al., 1965)
Organic matter	Mexican standard NMX-AA-021-1985
pH	Potentiometric analysis
Electrical conductivity	Mexican standard NMX-AA-25-1984

The pH of 6.82 corresponds to a slightly acidic sludge (Ortiz et al., 1993). This value is reported by Reinés (1998) as being suitable for the inoculation of earth worms. Meanwhile, analysis of electrical conductivity indicated an average result of 1439 mS/cm, and according to Sánchez-Salinas (1997), it does not reach values that are considered as slightly saline (2-4 mS/cm).

This value is favourable for the development of annelids that are inoculated into the sludge. The organic matter content was 24.61%, which classifies it as extremely rich (Ortiz et al., 1993). The characterisation of total phosphorus was 3210.52 ppm. This value shows the quality of the sludge as a material that is rich in phosphorus with an optimum development, mainly for plants (Ortiz et al., 1993).

After the first week of adaptation of the annelid, earthworms were harvested using traps, to quantify the reproduction (this operation was performed every week), and also to check their adaptation to the new substrate. In the first three weeks, the adaptation phase was observed, since the reproduction was preserved with a growth of 14 worms on average per week. From week three, it could be seen that the growth phase and reproduction rise to 36 worms per week, on average. Therefore, the annelids were adapted to the new substrate. Growth rates of earthworms in the substrates studied were higher than those observed by other authors in similar laboratory experiments (Elvira et al., 1998).

Liquid humus

Once the devices were installed for the proposed experimental design, and the annelids were sown in the trials, leachate from the vermicompost were then collected. The pH was obtained from the liquid humus.

As shown in Figure 1, the substrate having the better physicochemical characteristics for nutrients is the humus, which was obtained from Test 3, since it exceeded the organic content in Hum Ecol® by 31.6%. On the other hand, the percentage of total nitrogen in this test exceeded Hum Ecol® by 2.02%. The liquid humus obtained in Test 1, which was used as substrate, using 100% sewage sludge exceeded that in Hum Ecol® by 12%, with respect to organic matter. It is noteworthy that an increase in the percentage of sewage sludge in trials, allowed the decrease in the nutrient obtained from liquid humus. The results obtained in this study agreed with those reported by Arteaga and Guridi (2006).

However, the tests were not significantly different ($p<0.05$) from those for Hum Ecol® under the application of an ANOVA. Therefore, there is no significant difference between the assays for the concentration of nutrients.

The toxicity bioassay with tomato seeds (*Lycopersicon esculentum*) is a static-acute multi-concentration toxicity test (of 120 h exposure), in which phytotoxic effects of liquid humus obtained in experimentation are assessed, during the process of seed germination and in the development of seedlings, in the first days of growth.

The results from this investigation exceed the rates of germination obtained by Arteaga and Guridi (2006). The value obtained by the lower GI, was labelled as control (that is, the leached Hum Ecol® with a media of 184.2%). Test 1 obtained 349% of IG, which is the highest value obtained in the experiment. The values obtained show that none of the trials had phytotoxicity. According to Emino and Warman (2004), values below 50% of GI indicate a high phytotoxicity; GI between 50% and 80% indicates moderate phytotoxicity, and values above 80%

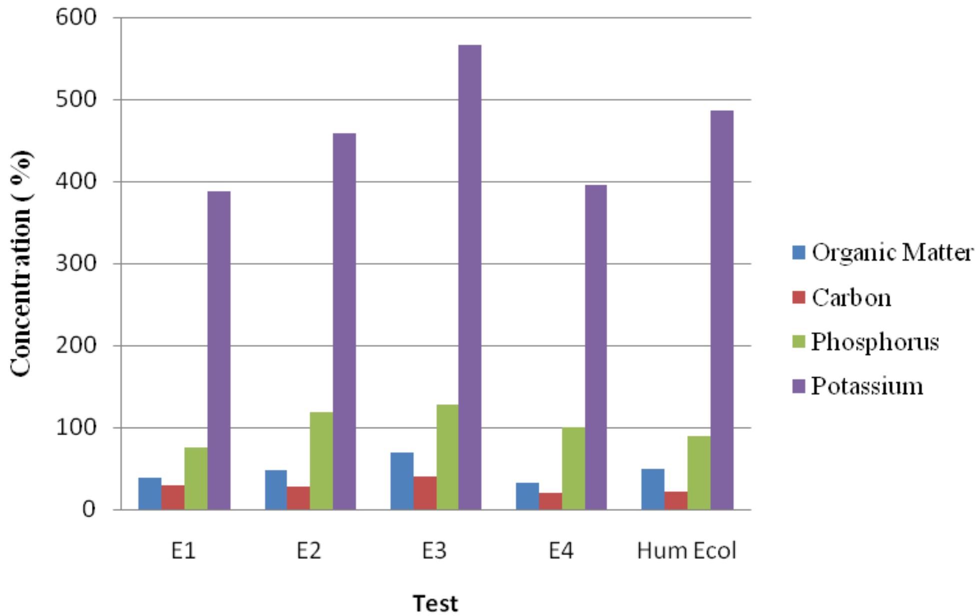

Figure 1. Nutrients of liquid humus.

demonstrate no phytotoxicity.

Conclusion

The physicochemical characteristics of liquid humus obtained proved to be compatible with the commercial liquid humus produced in Mexico (Hum Ecol®) with no existing significant differences between them. The assay using a mixture of sewage sludge and horse manure in proportions 60:40, respectively, proved to be the most appropriate, because the mixture exceeds the concentration of dissolved salts in Hum Ecol®. Likewise, the mixture of sewage sludge and horse manure favoured the nutrient solubility, resulting in higher organic matter content, phosphorus, carbon, nitrogen and potassium, which benefit soil fertilisation and crop development. Due to this, *E. foetida* achieved rapid adaptation to the use of sewage sludge, as it proved to be a rich source of available organic matter. According to toxicological testing, the liquid humus obtained in trials showed no phytotoxicity. Therefore, the sewage sludge can be exploited for use in agriculture, forestry and soil improvement, according to the Mexican norm, NOM-004-SEMARNAT-2002, since it does not present a risk in being used as fertilizer.

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