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Raw and digested municipal waste compost leachate as potential fertilizer: comparison with a commercial fertilizer

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ABSTRACT

The main pollution issue associated with the compost production in tunnels is the production of a liquid leachate characterized by high levels of salts and NH_4–N as well as high organic load. However, compost leachate may also be considered as a source of nutrients and water and used as fertilizer. Chemical properties and germination index were determined for a raw leachate from a composting facility in order to check if it meets the adequate requirements for using as commercial fertilizer. An anaerobic process was used for biological treatment of leachate in order to reduce the organic load and to improve the fertilizing properties. Results showed for leachates low concentrations of heavy metals, absence of pathogens, suitable amounts of nutrients such as nitrogen, phosphorus and potassium, C/N ratio under 20 and a high germination index. Anaerobic digestion did not improve the fertilizing properties of raw leachate but reduced odour and stabilized residue. This study proves that the raw leachate could be used as potential fertilizer because it meets the requirements usually established for commercial fertilizers. An economic estimation showed that the production cost of leachate as fertilizer is low and that an interesting profit margin could be obtained through the commercialization of the compost leachate as fertilizing liquid. Experimental comparison of raw and digested leachates with a commercial fertilizer shows that the former have better fertilizing qualities than the latter despite this is a marketed product.

1. Introduction

More than 260 million metric tons of municipal solid waste (MSW) are generated in Europe every year with more than 25% of organic matter (EIONET, 2011). In order to avoid the deposition of the organic fraction of municipal solid waste (OFMSW) on landfill, compost production in tunnels is a current method used in the mechanical and biological treatment plants (MBT plants) (Hyde et al., 2001; Henningsson et al., 2004; Aranda et al., 2012). The main pollution issue associated with this compost treatment is the production of a liquid leachate that is characterized by high levels of salts and NH_4–N as well as high organic load (Moreno et al., 2010).

Although municipal waste compost leachate is one of the problems of compost production, it may be considered as a source of nutrients and water. Compost leachate from municipal wastes contains carbon, nitrogen, phosphorus, potassium and trace elements that can be used as nutrients by plants.

The advantages of the use of organic wastes such as compost leachate as fertilizers are evident. Their use would reduce the consumption of commercial fertilizers which need in their production high cost and energy (Hall et al., 1992). Leachate is a waste product, which means that no direct production costs are associated. The use of leachate in agriculture also means that the costs at waste treatment plants can be reduced, since processes for nitrogen and phosphorus removal would not be necessary.

However, due to the nature of the leachates, they may contain, in addition to elements of interest, heavy metals, phytotoxic substances such as ammonia, organic compounds of low molecular weight and/or high salt content (Zhang et al., 2009). From the agricultural point of view, the presence of these substances can mask by negative effects the benefits of leachate (content of organic matter and nutrients).

For an exhaustive analysis about the effects of the incorporation of amendments or products such as leachate to the ground, particularly when products applied are based on the organic matter, content of heavy metals, macro and micronutrients present are needed to be studied, but also their phytotoxicity to predict the behaviour of the organic waste after the application of the amendment.

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Precisely this has been the aim of this preliminary study. Compost leachate has been characterized for use as potential liquid fertilizer checking its composition and phytotoxicity. An anaerobic process has been used for leachate treatment in order to reduce the organic load and to improve the fertilizing properties. Results have been compared with results for a commercial liquid fertilizer.

2. Materials and methods

2.1. Sample collection and analysis

For this investigation raw leachate was collected from the compost leachate pool at the MBT plant of Zamora (Spain) (Fig. 1). The samples were stored in air-tight 25 L polyethylene bottles. They were transported to the laboratory and kept at 4 °C prior to analysis.

Samples of raw and digested leachates and commercial fertilizer were analysed for pH (standard method 4500-H^+, APHA, 1992) and electrical conductivity (standard method 2510 B, APHA, 1992). Chemical oxygen demand (COD) was determined by close reflux colorimetry according to the standard method 5220D (APHA, 1992). Total Kjeldahl nitrogen (TKN) was analysed by a Bloc Digest Analyser after semi-micro-Kjeldahl digestion (standard method 4500-N_{org} C, APHA, 1992). Ammonia nitrogen ($NH_4 - N$) was determined following the standard method 4500-NH_3 (APHA, 1992). Heavy metals, potassium and phosphorous were measured by an inductively coupled plasma atomic emission spectrometry (ICP-AES) after digestion with concentrated nitric acid (standard method EPA 200.7, U.S. Environmental Protection Agency, 1994). The samples were filtered through a 0.45 μm Millipore membrane filter before analysis for total organic carbon (TOC) and total nitrogen (TN) which were measured by the IR-combustion method (standard method 5310 B, APHA, 1992). Coliform organisms were used as indicators of pathogen pollution in leachate (Mor et al., 2006) and analysed according to multitube fermentation technique (standard method 9221 B, APHA, 1992).

2.2. Phytotoxicity assay

Samples of raw and digested leachates and commercial fertilizer were diluted to a concentration series with Milli-Q water. Petri dishes (9 cm diameter) were lined with Whatman No. 1 filter paper which was moistened with 2 mL of sample. Seeds of barley

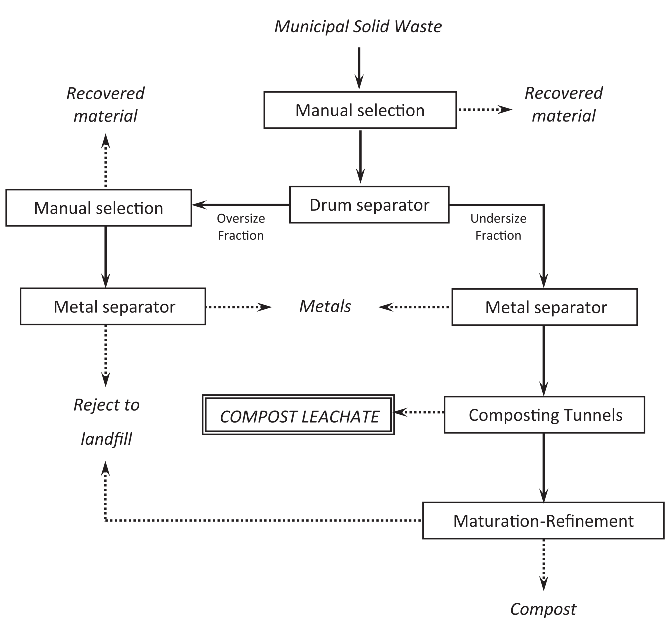

Fig. 1. Operation diagram of Zamora MBT plant.

(*Hordeum vulgare* L.) and grass (*Lolium perenne*) were purchased from local seed suppliers. Ten seeds of each species were placed in a Petri dish, using five replicates for each treatment and five Petri dishes by test. The dishes were arranged in randomized blocks and incubated at 28 °C and 75% moisture in darkness in a culture chamber (*Heraeus*® *Function* Line). Control tests were carried out adding 2 mL of water instead of sample.

Germinated seeds were counted and primary root length was measured after 4 days. Seeds were considered germinated when the radicle penetrates the seed coat (Kapustka, 1997). Germination index (GI) was determined according to Zucconi et al. (1985):

$$GI = [(\text{Seed germination}(\%) \times \text{Root length of treatment}) / \times (\text{Seed germination}(\%) \times \text{Root length of control})] \times 100$$

2.3. Anaerobic treatment

A 5 L BIOSTAT B® Fermenter (B. Braun Biotech) was used for anaerobic treatment of raw leachate. The fermenter consisted of a cylindrical concave-bottom reactor of 5 L equipped with a stirring system and controllers for pH, temperature, agitation and dissolved oxygen (DO) concentration (Fig. 2). The experiment was monitored from a PC using the MFCS/win 2.0 software. Temperature, pH and DO were kept at 35 °C, 7.5 and 0.0 mg O_2 L^{-1}, respectively. Biomass concentration was maintained in values above 650 mg L^{-1} and was obtained by spontaneous inoculation. A settling vessel was placed after anaerobic reactor for effluent clarification. Effluent obtained from settling vessel at steady state is named “digested leachate”.

3. Results and discussion

3.1. Chemical properties

3.1.1. Raw leachate

Chemical properties of compost leachate, summarized in Table 1, show a high organic load in COD of the leachate used. This is a result of the large organic matter content of this liquid which may increase the COD value up to 110,000 mg L^{-1} (Mokhtarani et al., 2012). High content in solids observed is another typical characteristic of compost leachate which presents amounts of solids ranging from 3000 to 50,000 mg L^{-1} (Pitarch et al., 2007).

The major fraction of the TKN was in form of ammonia (NH_4). TKN and $NH_4 - N$ contents were higher than contents usually present in compost leachate (10–500 mg L^{-1} for TKN and 100–400 mg L^{-1} for $NH_4 - N$) (Pitarch et al., 2007) but the strength of the compost leachates varies remarkably with the nature of the feedstock, the maturity of the compost giving rise to the leachate and the composting technology employed (Tyrrel et al., 2008). In fact, we found in literature a composting leachate with a similar concentration in TKN (970–1105 mg L^{-1}) and even higher concentration of $NH_4 - N$ (887–980 mg L^{-1}) (Justin et al., 2010).

Leachate was also rich in phosphorus. With phosphorus content of 1778 mg P L^{-1}, each cubic meter of the raw leachate could provide nearly 2 kg of phosphorous which was readily available for plant uptake.

Leachate pH was almost neutral (6.98) which agree with references where pH values ranged from 5.0 to 7.5 (Pitarch et al., 2007).

Although leachate contained elevated levels of major cations such as K^+ (640 mg L^{-1}), the concentration of heavy metals was low and always below the permissible limits in liquid fertilizers (Table 2).

3.1.2. Digested leachate

Anaerobic treatment of leachate was carried out for five days of hydraulic residence time in order to reduce odour and stabilizes