Available online at www.sciencedirect.com
ScienceDirect
Bioresource Technology 99 (2008) 7545–7552
BIORESOURCE TECHNOLOGY

Sawdust and natural zeolite as a bulking agent for improving quality of a composting product from anaerobically stabilized sewage sludge

Antonis A. Zorpas [a,*], Maria Loizidou [b]

[a] ENVITECH Ltd., Laboratory of Environmental Technology (Research Institute), Griva Digeni 37, P.O. Box 34073, 5309 Paralimni, Cyprus
[b] National Technical University of Athens, Department of Chemical Engineering, Laboratory of Environmental Science 9, Heroon Polytechniou Street, Zographou 157 00, Greece

Received 29 November 2007; received in revised form 5 February 2008; accepted 10 February 2008
Available online 24 April 2008

Abstract

This study has dealt with the production of compost from dewatered anaerobically stabilized primary sewage sludge (DASPSS) and sawdust (SWD). SWD is added in order to increase the humic substances in the final product. The DASPSS is mixed with clinoptilolite (Cli), which is used as a bulking agent at 20% w/w, and the mixture is amended with sawdust at 10%, 30% and 40% (w/w). The final results have indicated that by increasing the sawdust concentration in the initial mixture, the humic substances in the final product increase too. The natural zeolite that was added in the initial mixture takes up a significant amount of heavy metals. In order to observe the maturity of the final product, the germination index is used in oat cultivation. The results indicate that the substrate appears to be non-phytotoxic after 75 d of maturity. Also, in order to estimate the metal leachability of the final compost product, the generalized acid neutralization capacity procedure is applied, and it is found that by increasing the pH values, the heavy metal concentrations decrease.

Keywords: Composting; Zeolite; Leach ability; Partitioning; Phytotoxic

1. Introduction

The mineralization of biogenic substances is a part of the natural recycling process, which occurs at any place where organic material is synthesized by plants and degraded by animals and by microflora. This mechanism keeps the global balance upright. Environmental problems associated with sewage sludge disposal have prompted strict legislative actions over the last years. At the same time, the upgrading and expansion of wastewater treatment plants have greatly increased the volume of produced sludge. The sludge is classified as solid waste that requires special methods of disposal, because of its noxious properties. However, much of the sludge originating from urban wastewater treatment is contaminated with heavy metals (Wozniak and Huang, 1982; Hasit and Christensen, 1987; Sims and Skline, 1991; Langenbach et al., 1994; Karvelas et al., 2003; Wei and Liu, 2005). These metals may leach from sludge and enter the ecosystem, the food chain and finally the human body. Also, the total concentration of heavy metals cannot provide useful information about the risk of bioavailability, toxicity and capacity for remobilization of heavy metals in environment (Fernandez et al., 2000; Kunito et al., 2001; Liu et al., 2007).

The most common treatment methods of sludge is landfill, composting, incineration and the agricultural use. All these methods present tend to have some potential environmental impacts. Landfill presents to have emissions of CH_4, CO_2, odours and also produces leaching of salts, heavy metals and persistent organics to ground water. Also landfill and the uncontrolled use of sludge in agriculture accumulate the hazardous substances in soil and the toxic substances in food chain. Incineration is a very promising treatment method due to that fact that the volume of the

* Corresponding author. Tel.: +357 23743440; fax: +357 23743441.
E-mail address: antoniszorpas@yahoo.com (A.A. Zorpas).

0960-8524/$ - see front matter © 2008 Elsevier Ltd. All rights reserved.
doi:10.1016/j.biortech.2008.02.014

raw material is limited, however, it presents with environmental impacts like emission of SO_2, NO_x, CO_x, dioxins, and heavy metals if the incineration is not controlled.

In the greater region of Athens, with almost 4,500,000 citizens, the main wastewater treatment plant is located at the rock-island of Psittalia. At this plant, $\sim$750,000 $m^3\,d^{-1}$ of mainly municipal wastewater along with industrial wastes is subjected to biological treatment, producing approximately 250 ton d^{-1} of dewatered anaerobically stabilized primary sewage sludge (DASPSS) (Zorpas et al., 1998). Landfill is the main practice for the management of the sewage sludge, and this fact generates potential environmental risks such as the production of odors and methane gas, and the contamination of groundwater by the leachate produced in landfill site (Zorpas et al., 1997). Composting provides a simple and cost-effective alternative treatment method for sewage sludge by decomposing organic matter, producing a stabilized residue and disinfecting pathogens (Fang et al., 1999). The composting method is parallel with the landfill directive (1999/31/EC), which requires the minimization of biodegradable waste in landfills. The composted product can also be used as a fertilizer or soil conditioner because of its large content of stabilized organic matter. However, the high content of heavy metals in sewage sludge compost has proven to be a limiting factor in the land application of sewage sludge compost (Wong et al., 1997). The addition of natural zeolite, clinoptilolite, during sewage sludge composting has been proven to be a promising way to reduce the heavy metals content (Zorpas et al., 2000), since zeolite (clinoptilolite) has the ability to take up heavy metals. Zeolite utilization had become popular in the last decade, due to its cation exchange and molecular sieving properties (Ouiki and Kavannagh, 1997; Zorpas, 1999).

According to European Union the use of sewage sludge in agriculture should be in such a way as to prevent harmful effects on soil, vegetation, animals and man, thereby encouraging the correct use of such sewage sludge (directive 86/278). According to the directive 86/278 the member States shall prohibit the use of sludge where the concentration of one or more heavy metals in the soil exceeds the limit values which they lay down in accordance with Annex IA and shall take the necessary steps to ensure that those limit values are not exceeded as a result of the use of sludge.

The aim of this work is to present the effect of natural zeolite and sawdust (SWD) in the maturity of the co-composting product with DASPSS and the phytotoxicity of the final product in oat cultivation.

2. Methods

The DASPSS samples were collected for a period of six months (April–September: 200–250 kg every two days from the Psittalia wastewater treatment plant. Then the samples were dried, homogenized and stored. Natural zeolite, clinoptilolite (Cli), used as a bulking agent, was collected from Evros (Region in North Greece). Selected composition characteristics of the materials used (Zorpas, 1999) are given in Table 1.

Table 1
Composition characteristics of DASPSS, Cli and SWD

Parameters	Mean value of 20 samples		
	DASPSS	SWD	Cli
Moisture %	70.10 ± 2.01	12.00 ± 2.15	7.15 ± 0.50
pH	7.05	8.00	7.85
Conductivity mS cm^{-1}	1.005 ± 0.005	1.101 ± 0.010	0.155 ± 0.002
Organic matter %	45.05 ± 1.05	90.15 ± 2.21	Not detected
Ash %	27.23 ± 1.10	5.03 ± 1.25	80.65 ± 1.50
TOC %	26.10 ± 0.50	55.05 ± 2.35	not detected
TKN %	1.90 ± 0.20	1.80 ± 0.20	0.032 ± 0.002
$N\text{-}NH_4$ mg g^{-1} dry samples	9.57 ± 0.50	19.73 ± 0.70	1.40 ± 0.15
$P\text{-}PO_4$ %	2.45 ± 0.25	2.60 ± 0.25	Not detected
Humic substances %	1.80 ± 0.05	9.50 ± 0.50	Not detected
E4/E6	1.25 ± 0.01	1.38 ± 0.01	Not detected
Lignin %	4.50 ± 0.50	30.50 ± 0.50	Not detected
Cellulose %	2.06 ± 0.05	52.10 ± 1.00	Not detected
C/N	13.73 ± 0.50	30.55 ± 1.00	Not detected
C/P	10.65 ± 0.50	21.15 ± 1.00	Not detected
Germination index	17 ± 2	63 ± 2	75 ± 5

Significant difference at $p < 0.05$.

The composting process was carried out in the laboratory using an in-vessel reactor of 1 m^3 active volume (Finstein et al., 1992). The thermophilic phase in the reactor lasted for 15 d. The temperature in the center of the reactor was about 60–65 °C and the moisture percentage was between 40 and 50%. The samples were aerated using an aerated air force (oxygen concentration range in the reactor was between 5 and 8%). A temperature indicator controller was controlling the operation of the fan in order to maintain the temperature at about 60 °C, according to the following principle: minimum air flow (2.3 m^3 per m^3 active volume) was provided at low temperature (<30 °C) and maximum air flow (28 m^3 per m^3 active volume) was provided at high temperature (>60 °C). The minimum airflow corresponds to the minimum oxygen demand for the microorganisms and the maximum airflow corresponds to the necessary air for cooling. After the thermophilic period, in which the organic material was biodegraded, the compost was piled to an enclosed package where it remained for about four months to mature (periodically this was stirred). Also it is very important to know that there was not any leachate during the composting processes. The reason is that the reactors at the first step of composting were closed and during the thermophilic phase the contents were evaporated.

The ratio of the materials used for the preparation of the samples for co-composting is

SSC1: 80% w/w (70% w/w DASPSS + 10% w/w SWD) plus 20% w/w Cli.
SSC2: 80% w/w (50% w/w DASPSS + 30% w/w SWD) plus 20% w/w Cli.