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ScienceDirect
Bioresource Technology 99 (2008) 1544–1548
BIORESOURCE TECHNOLOGY

Comparison between pine bark and coconut husk sorption capacity of metals and nitrate when mixed with sewage sludge

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Received 22 September 2006; received in revised form 11 April 2007; accepted 12 April 2007
Available online 6 June 2007

Abstract

Waste products such as biosolids and wood wastes have been frequently used in container production of plants. The use of biosolids in agriculture is a beneficial mean of recycling the by-products of waste-water treatment. However, care must be taken to avoid environmental or human health problems via run-off and leaching.

The objective of this work is to compare the retention capacity of cadmium, lead, zinc and nitrate between pine bark (PB) and coconut fibre (F) when mixed with increasing amounts of composted sewage sludge (CSS) (0%, 15% and 30% (v/v)). Substrates were packed into leaching columns and irrigated with deionised water every 2 days. Leachates were collected during 1 month, and nitrate, Zn, Cd, Pb, EC and pH were monitored along the experiment. PB columns leached lower amount of nitrate than the coconut fibre ones. The same trend was observed for Zn, Cd and Pb. It could be said, that in order to minimize the environmental risks of using sewage sludges our results indicate that it is preferred to mix the sludge with pine bark instead than with coconut husk.

Keywords: Pine bark; Coconut husk; Biosolids; Leaching

1. Introduction

Waste products such as biosolids (Gouin, 1993; Ingelmo et al., 1998; Guerrero et al., 2002) and wood wastes (Hicklenton et al., 2001; Chen et al., 2002) have been frequently used in container production of ornamental trees, shrubs and perennial plants. Nowadays other materials have been used as substrate, for example coconut fibres, because they have many characteristics in common with peat (Lennartsson, 1997). During the past few years this material has become commercially popular, and it is now being successfully used in different parts of the world as peat substitute for container-grown ornamental plants (Handreck, 1993; Stamps and Evans, 1997; Offord et al., 1998; Noguera et al., 2000; Abad et al., 2002).

The use of biosolids in agriculture is a beneficial mean of recycling the by-products of waste-water treatment as they contain plant nutrients and organic matter. However, care must be taken to ensure that use of biosolids in agriculture does not lead to environmental or human health problems via run-off and leaching of nutrients (especially nitrate and phosphate), pathogens, heavy metals and organic contaminants to surface or groundwater (Cooke et al., 2001).

Historically, strategies for application of animal manures have been based on meeting the nitrogen needs of crops to minimise nitrate loss by leaching (Sharpley et al., 1994). Excessive application rates, or inappropriate timing of application, can cause a significant threat to water quality (Shreve et al., 1995; Sharpley and Menzel, 1997). Nitrate is readily soluble and easily leached from soils (Kessavalou et al., 1996).

Concentrations of nutrients in biosolids vary both over time and between treatment plants, depending on the treatment process and the waste-water source (Smith, 1996),

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doi:10.1016/j.biortech.2007.04.032

this fact may influence nutrient loss. For example, the greater the proportion of nitrogen presents as $NH_4^+{-}N$, the greater the potential for nitrate leaching (Shepherd, 1996; Smith et al., 1998a). Composting sewage sludge would also be expected to reduce nitrate leaching because mature composts contain relatively low amounts of mineral nitrogen, and are highly stabilised and resist further mineralisation on application to the soil (Smith et al., 1998b). Hazardous substances may be released from sewage sludge when large quantities are deposited for long periods and may percolate through the soil layers and reach the groundwater (Vanni et al., 1994; Cortés et al., 1992). There is an interest in following the fate of heavy metals in the environment because these elements continue to reach groundwaters (Jorgensen, 1976; Berthet et al., 1989).

In Europe there is an increasing pressure to reduce the leachates from horticultural crops for environmental reasons (Guimera et al., 1995). Therefore, it is necessary to improve commercial nursery practices to control the substrate solution.

Leaching tests are widely used for the assessment of the release of contaminants from different matrices. The release of contaminants from waste is influenced by a large number of physical (e.g. particle size, temperature, mode of contact with water and porosity) and chemical (e.g. pH, redox, sorption properties, complexing agents and reaction kinetics) parameters. A variety of test procedures are available to characterise materials with respect to their leaching behaviour (Quevauviller et al., 1996). Fytianos et al. (1998) by using batch experiments concluded that the leached amounts for the sewage sludge examined metals followed the order: Cd > Zn > Pb > Fe > Mn, and, as expected, when pH decreased, metal concentrations measured in the leachate increased.

The idea of considering the agricultural residues as ion exchangers has been investigated since the beginning of 1970s. Due to their large availability, interesting is growing especially over the last decade (Laszlo, 1996; Manju et al., 1998). Basically, two-thirds of the agricultural residues are composed of polysaccharides (cellulose and hemicelluloses) (Sjöström and Alen, 1999). Cellulose is the most abundant natural polymer and has three reactive hydroxyl groups in every constitutional glucose unit, but no correlation was found by Orlando et al. (2002) between the maximum nitrate adsorption and the cellulose content. The same authors showed the higher nitrate adsorption capacity of pine bark (1.06 mmol/g) in comparison with the coconut husk (0.89 mmol/g).

The objective of this work is to compare the ion adsorption capacity of two different substrates, pine bark and coconut husk, when mixed with composted sewage sludge. The high retention of ions will minimize environmental risk of releasing contaminants to the environment when those residues are use with agricultural purposes.

2. Methods

The substrates tested were pine bark and coconut fibre mixed with increasingly amounts of composted sewage sludge. Biosolid was mixed with both substrates at rates of 0%, 15% and 30% (v/v) of sludge, homogenised and carefully repacked into glass columns (20 × 5 cm). Initial characteristics of the substrates are shown in Tables 1 and 2. The commercially valuable composted sewage sludge (CSS) was produced from a mixture of sawdust and anaerobically digested sewage sludge (volume ratio of 0.2:1) by the aerated-pile method. Three columns per treatment were located in randomized blocks and irrigated with 100 ml of deionised water every two days. Leachates were collected and their volume measured. Nitrate and pH of the leachates were determined with an Orion Research Ion Analyzer 920A by using selective electrodes. Electrical conductivity (EC) was determined with an Orion Conductivimeter and metal content was assessed by voltamperometry, due to their low concentrations in leachates (Metrohm VA 646 y Stand VA 647).

Table 2
Initial characteristics of the substrates tested

Substrate	pH	EC (μS/cm)	OMox (%)	TOM (%)	Nkj (%)
PB	7.0 cb	1937 c	39.3 b	53.3 b	0.43 f
PB + 15%CSS	7.2 b	6157 b	32.6 c	45.2 c	0.89 d
PB + 30%CSS	7.6 a	8237 a	29.3 c	42.5 d	1.25 c
F	6.1 d	1343 c	46.0 a	85.6 a	0.71 e
F + 15%CSS	7.1 cb	5313 b	42.1 ab	53.9 b	1.59 b
F + 30%CSS	7.0 c	9350 a	34.3 c	43.9 cd	2.05 a

Table 1
Main physical characteristics of substrates

Substrate	Particle density (kg/m^3)	Bulk density (kg/m^3)	Porosity$_0$ (%v/v)	Airspace$_{10}$ (%v/v)	μ porosity$_{100}$ (%v/v)	AW$_{10-50}$ (%v/v)	AW$_{50-100}$ (%v/v)
PB	1980 c	290 b	85.4 d	56 a	18 c	9.7 b	3.3 a
PB + 15%CSS	2080 b	410 a	80.3 e	44 b	23 b	9.9 b	4.1 a
PB + 30%CSS	2120 a	426 a	79.9 f	31 c	25 b	19.2 a	4.7 a
F	1580 d	57 e	96.4 a	52 a	21 bc	16.6 a	6.6 a
F + 15%CSS	1980 c	115 d	94.2 b	45 b	24 b	19.5 a	5.7 a
F + 30%CSS	2100 ab	231 c	89.0 c	41 b	32 a	14.4 ab	1.9 a