Available online at www.sciencedirect.com
ScienceDirect
Environmental Pollution 146 (2007) 463–469
ENVIRONMENTAL POLLUTION
www.elsevier.com/locate/envpol

Ecotoxicological evaluation of the short term effects of fresh and stabilized textile sludges before application in forest soil restoration

Edson V.C. Rosa, Thayse M. Giuradelli[†], Albertina X.R. Corrêa, Leonardo R. Rörig, Paulo R. Schwingel, Charrid Resgalla Jr., Claudemir M. Radetski*

Universidade do Vale do Itajaí, Centro de Ciências Tecnológicas da Terra e do Mar, Rua Uruguai, 458, Itajaí SC 88302-202, Brazil

Received 21 February 2006; received in revised form 18 June 2006; accepted 5 July 2006

Short term ecotoxicity evaluation of textile sludge showed that stabilized sludge can be used in the restoration of a non-productive forest soil.

Abstract

The short term (eco)toxicity potential of fresh and stabilized textile sludges, as well as the short term (eco)toxicity of leachates obtained from both fresh and stabilized textile sludges, was evaluated by a battery of toxicity tests carried out with bacteria, algae, daphnids, fish, earthworms, and higher plants. The (eco)toxicological results showed that, after 120 d of stabilization, the experimental loading ratio of 25% sludge:75% soil (v/v) (equivalent to 64.4 ton/ha) did not significantly increase toxicity effects and increased significantly the biomass yield for earthworms and higher plants. The rank of biological sensitivity endpoints was: Algae ≈ Plant biomass > Plant germination ≈ Daphnids > Bacteria ≈ Fish > Annelids. The lack of short term toxicity effects and the stimulant effect observed with higher plants and earthworms are good indications of the fertilizer/conditioner potential of this industrial waste, which after stabilization can be used in the restoration of a non-productive forest soil.

Keywords: Toxicity tests; Solid waste reuse; Textile sludge; Environmental impact; Soil restoration

1. Introduction

Increasing worldwide production of industrial sludge together with the beneficial characteristics of some of these sludges (e.g., biosolids) motivates alternative disposal options for industrial solid wastes. Land application of biosolids could be an acceptable disposal option, transforming a troublesome waste into a valuable resource (Krogmann et al., 1997). On the other hand, there are some soils with very poor forest productivity due to their natural physico-chemical characteristics. Industrial sludge could be a valuable soil fertilizer/conditioner due to its content of organic matter and nutrients along with its soil ameliorating properties (Khaleel et al., 1981; Phillips et al., 1997). However, uncontrolled disposal of sludge may result in the contamination of land and water resources to such an extent that they become unsuitable from the environmental point of view. Soil and water qualities are fundamental to the diverse communities of microbes, plants, invertebrates and vertebrates that comprise the terrestrial and aquatic ecosystems. Thus careful consideration of the benefits of sludge application and its potential environmental impact is needed before soil application (Saterbak et al., 1999; Obbard, 2001). In this context, most regulations set chemical limit values, predominantly for metals and very few organic compounds, but chemical sludge composition alone cannot provide sufficient information on the potential harmful effects

* Corresponding author. Fax: +55 47 3341 7715.
E-mail address: radetski@univali.br (C.M. Radetski).
[†] In memoriam.

0269-7491/$ - see front matter © 2006 Elsevier Ltd. All rights reserved.
doi:10.1016/j.envpol.2006.07.005

of chemicals on the environment. Furthermore, toxic effects of unknown and often undetermined substances in complex mixtures or with possible synergistic effects of compounds waste products can be detected only by toxicity testing (Sponza, 2003). After sludge application to the soil, the fate of the metals/compounds is controlled by several physical, chemical and (micro)biological processes. For example, soil can adsorb and release ions depending on the types of mineral particles present, the quantity of organic matter, pH, redox potential, moisture status, biotic content, and management. In other words, when sludge is placed in the environment, organic compounds or metals released from the sludge may be further degraded, leached, taken up by biota, or bound to soil particles (Kapanen and Itävaara, 2001). This continuous chemical-sludge evolution in soil after application leads to the formation of mature/stable compost where toxicity is expected to be lower compared to fresh/immature compost. To reduce the toxicity of fresh sludges, interest in composting of industrial sludge before land application is increasing, however, no established methods are available for testing the toxicity of fresh or stabilized sludge (Kapanen and Itävaara, 2001). Thus, the objective of the present study was to evaluate the short term (eco)toxicity potential of fresh and stabilized textile sludges, as well as the short term toxicity of leachates obtained from fresh and stabilized textile sludges in order to investigate safe sludge application to a non-productive red–yellow Podzolic soil. To achieve this objective, a battery of acute (eco)-toxicity tests was carried out with bacteria, algae, daphnids, fish, earthworms, and higher plants according to the ISO methodologies.

2. Materials and methods

2.1. Origin of the soil and textile sludge

The red–yellow Podzolic soil used in this study was collected from the A–C horizons (0–60 cm depth interval) in the rural area of Brusque city (SC State, Brazil). The soil sample was characterized in terms of pH (1:10), texture (pipette method), organic carbon content, cation exchange capacity, N_{total}, organic $matter_{total}$, and C:N mass ratio according to published methodology (EMBRAPA, 1999). The textile sludge samples were collected from a treatment facility in the city of Brusque (SC State, Brazil) where wastewater is treated to the tertiary level by anaerobic digestion. Chemical analysis of the soil and the textile sludge was carried out according to the APHA et al. (1995) methodologies.

2.2. Leachability tests

Leaching test was carried out according to the ABNT, 2004 method, where a solid sample size of 200 g was placed in a 5000 ml bottle, to which 3200 ml of distilled water and a sufficient quantity of acetic acid (0.5 N) to adjust pH to 5.0 were added. The suspension was stirred for 24 h. After filtration, part of the leachate was analyzed according to the APHA et al. (1995) methodologies and part was used to carry out the toxicity tests. The same procedure was carried out with the stabilized textile sludge.

2.3. Stabilization/Maturation

Fresh textile sludge was allowed to repose for 4 months under natural conditions. All 15-d sludge was mixed/homogenized to improve aeration. Accumulated rainwater was naturally evaporated.

2.4. Toxicity tests

2.4.1. Lumistox test

The bacterial *Vibrio fischeri* luminescence inhibition (i.e., Lumistox, Dr. Bruno Lange, Düsseldorf, Germany) test was conducted according to ISO (1996) guidelines at 15 ± 1 °C on leachate samples from fresh and stabilized sludges at pH 7. The exposure time was 30 min. The lyophilized bacterial reagent was obtained from Deutsche Sammlung von Mikroorganismen und Zellkulturen (DSM N# 7151, Braunschweig, Germany). Three different tests (with duplicates) were performed in order to evaluate the reproducibility of the procedure.

2.4.2. Algal growth inhibition test

The algal species used was *Scenedesmus subspicatus* Chodat (strain 86.81 SAG, Göttingen, Germany). Three algal tests for each leachate samples were conducted according to ISO (1990) guidelines with three replicates per concentration (or control). Potassium dichromate was used as a positive control. The cell density of the mixture was adjusted to 10,000 cells/ml by dilution with ISO freshwater algal test medium. The test flasks were incubated on a shaker (100 rpm) with continuous illumination of 70 μE/m^2/s (cool-white fluorescent lamps) at 23 ± 2 °C. After 72 h of incubation, the inhibitory effect based on fluorescent activity was measured at $\lambda = 685$ nm with a Shimadzu RF-551 (Kyoto, Japan) spectrofluorimeter.

Table 1
Physico-chemical and biological composition of soil and fresh textile sludge used in this study (dry weight basis)

Parameter (unit)	Soil	Fresh textile sludge
Al (mg/kg)	734.0	15,639
As (mg/kg)	ND (0.2)	ND (0.2)
Cd (mg/kg)	ND (0.006)	ND (0.006)
Pb (mg/kg)	ND (0.02)	20.96
Cu (mg/kg)	11.99	40.14
Cr_{total} (mg/kg)	13.14	6.01
Fe (mg/kg)	26,646	3942
F^- (mg/kg)	NA	5.84
Mn (mg/kg)	8.61	30.64
Hg (mg/kg)	0.0132	0.082
Mo (mg/kg)	ND (0.04)	ND (0.04)
Ni (mg/kg)	7.33	7.56
Phenol (mg/kg)	NA	25.12
Se (mg/kg)	ND (1.0)	ND (1.0)
Zn (mg/kg)	34.89	937.70
N_{total} (%)	0.16	1.0
$N_{ammoniacal}$ (%)	NA	0.08
P (%)	0.1	1.0
K (mg/kg)	10.0	160.93
OM_{total} (%)[a]	0.3	6.14
Ratio C:N	1:1	6:1
pH (1:10)	4.4	8.2
Humidity (%)	14	93
FC (CFU/ml)[b]	ND	ND
Mould (CFU/L)[c]	NA	8.0×10^6
BOD (mg/L)[c,d]	NA	50
COD (mg/L)[c,e]	NA	252
CEC (meq/100 g)[f]	7.60	NA
Sand (%)	26.0	NA
Silt (%)	14	NA
Clay (%)	60	NA

ND = not detected (quantification limit is in parenthesis); NA = not analyzed.
[a] Organic matter.
[b] Faecal coliforms.
[c] Data from solubility test fraction (250 g/L of dry sludge).
[d] Biochemical oxygen demand.
[e] Chemical oxygen demand.
[f] Cation exchange capacity.