Research Journal of Environmental Sciences

ISSN 1819-3412

Academic Journals Inc.

www.academicjournals.com

Research Journal of Environmental Sciences 1 (6): 317-323, 2007
ISSN 1819-3412

Composition of Detergent and Chloride in Tunisian Textile Sludge and Produced Composts as a Function of Sludge Ratio

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Abstract: The present research attempts to ascertain the efficacy of low cost technology (in our case, composting) as a bioremediation technique for reducing detergent and chlore content of textile sludge in semiarid conditions. The sludge was produced in a textile manifacture in the north of Tunisia. The composting system designed involved two parallel open air piles turned periodically over a period of 3-months. Textile sludge was co-composted with greenwaste at (1:1 v/v (compost C1) and 1:3 v/v (compost C2) ratio. In C1, the detregent and chlore contents was reduced respectively by 95,19 and 96.35% in 3 months, compared with the 86.66% efficacy reduction content of chlore in C1 and the increase by 46.34% in C2. The degree of xenobiotics in the first mixture and after composting in C1 was influenced by the introduction of higher sludge ratio. Results from this study demonstrate that co-composting textile sludge with greenwaste may provide an inexpensive and reliable technology for the biodegradation of sludge toxic compounds for further agriculture use.

Key words: Composting, textile sludge, chlore, detergent, biodegradation

INTRODUCTION

Sewage sludges are residues generated at centralized wastewater treatment plants as a result of the treatment of wastes released from a variety of sources including homes, industries, medical facilities, street runoff and businesses. Sewage sludges contain nutrients and organic matter that can provide soil benefits, but they also contain contaminants including metals, pathogens and organic pollutants (Harrison *et al*., 2006). More than 100,000 chemicals substances are in circulation worldwide and only a very few (approximately 5,000) are under regulation (Nordbeck and Faust, 2003). There is a special public concern about organic components, which may have a potential for acute toxicity, mutagenesis, carcinogenesis or teratogenesis or posses estrogenic effects. With land filling being at this time the most widely used method of textile sludge disposal in Tunisia, composting is becoming an acceptable method of recycling organic and reducing land filling. Composting is defined as the aerobic biological decomposition and stabilization of organic substrates, under conditions that allow development of thermophilic temperatures as a result of biologically produced heat, to obtain a final product that is stable, free of pathogens and plant seeds and can be beneficially applied to land (Bertran *et al*., 2004). Detergents contribute to the cleaning process by increasing the water solubility of fat and dirt (Lauridsen and lnge, 2005). Indeed, they have recently been identified as major anthropogenic organic components in sewage sludge because of their physicochemical properties. The properties that make some products desirable as a detergent are precisely the properties that give rise to toxic effects and accumulation in sludge and sediment. The problem is when

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the detergents and cleaning products contained surfactants with a biodegradability of less than 90% (Lauridsen and lnge, 2005). In Europe, criteria for detergents were established and included the requirement of biodegradability under anaerobic conditions. Chloride levels are also of concern, since in high concentrations this ion can be toxic to plant tissues. Previous work of (Garcia and Bernal, 2001) has shown that chloride concentration were the main factor influencing growth. Chloride is the most commonly used disinfecting agent for drinking water and wastewater. Chemically, chloride anions are known to reduce soil sorption of Cd, probably due to the fact that chloride forms relatively strong complexes with Cd. The resulting increase in concentration of Cd in the liquid phase at higher Cl concentrations can enhance Cd mobility in soils. Therefore, High chloride levels in biosolids should be lowered before use on dryland. (Weggler *et al*., 2004). Because of the recent environmental regulations in Tunisia regarding of the treatment of wastewater, it is expected that the volume of sewage sludge produced from wastewater treatment will increase in upcoming years and new alternatives for reducing the risk of some xenobiotics need to be found. In the work reported here, two composts made from textile sludge representing the respective sludge ratios delivered to the initial composting mixtures (50% v/v (pile 1), 25% v/v (pile 2)) were analyzed for detergent and chloride levels to assess variations in their concentrations as a function of the delivery of the initial sludge to the composting site. The knowledge forthcoming from these numerous measurements may allow us to have more consistent evaluation of finished compost qualities.

MATERIALS AND METHODS

Selection of Parameters to Analyse

To determine the range of compounds to analyse, we used two criteria:

- The compound must be listed us high priority contaminant by the health and the environmental authorities.
- Included in other countries sludge or compost regulation guidelines.

Site and Climatic Conditions

The field study was conducted from Mai 2006 to January 2007 in Tunis International Center for Environmental Technologies. The climatic characteristics of the study area are as following: annual precipitation did not vary obviously year by year within the study time. The average mean air temperature was 30°C. The lowest air temperature was 0°C in January and the highest air temperature was 45°C in August.

Composting and Sampling

The physico-chemical sewage sludge came from a textile-wastewater treatment plant in Ras Jebel (in the north of Tunisia). A mixture of sludge, greenwaste and municipal waste was composted on a composting platform and monitored over 90 days. Green wastes were collected selectively from CITET garden. The compost piles were built following the same protocol and comprised a layer of green waste followed by a layer of sludge and according to the design of the experiment. The following graph shows the composition of the piles according to the specific volume of sludge and green matter (Fig. 1). The well progress of composting and microbial activities was followed by measuring with a portable thermometer the pile temperature and external temperature during the composting process. The mixture was turned over periodically to ensure aerobic conditions. Numerous samples from various points of the compost heaps were collected. The two selected times of sampling were T = 0 (initial mixture) and after 90 days.The samples were kept deep frozen until analysis. The typical characteristics of the sludge used in the composting process and are shown in Table 1.

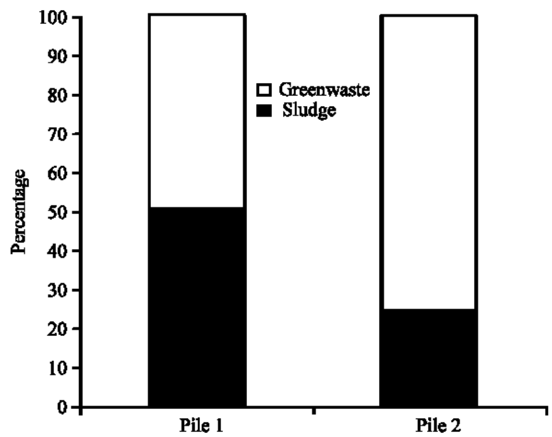

Fig. 1: Composition of the piles according to the specific volume of sludge and green matter

Table 1: Physico-chemical features of the sewage sludge used for composting

Properties	Sludge
pH	7.05
Dm[b]	30.9
OM[a]	114
TKN[a,d]	2.89
TOC[a]	18.6
C/N	6.43
Escherichia coli[c]	1.1×10^7
Mn[e]	2.53
Cd[e]	<0.03
Cu[e]	0.76

[a]Results expressed in g kg^{-1} of dry matter; [b]Results expressed in %; [c]Results expressed as colony forming units 100 mL fresh material; [d]TKN: Total Kjeldahl Nitrogen; [e]Results expressed in mg kg^{-1} of dry matter

Compost Parameters

Nitrogen was determined by the Kjeldahl method (NF ISO 11261), the organic matter by Gravimetry (Rodier 8th Edition). Total organic carbon is measured according to Colorimetry method (ISO 14235). The C/N ratio was calculated from contents of total organic carbon (TOC) and total nitrogen (Kjeldahl) in air-dried samples. The pH was determined with a glass electrode The elements Cd, Cu and Mn were analyzed by emission spectrometry-ICP (NF EN ISO 11885). Mercury was determined by atomic absorption analysis (NF EN 1483). The detergent contents was determined by the colorimetric method. Chloride is measured according to the colorimetric-test method (ISO 7393).

RESULTS AND DISCUSSION

The intense microbial activity induced very significant transformations of the mixture of sewage sludge and green waste, the main characteristics of which are presented in Table 2. The two obtained composts have similar physico-chimical values with the exception of a high dry matter value owing to the mixture nature of the two piles. The enumeration of microbial populations is typically performed to gain information on the biodegradation potential of the of the detergent and chloride contents and/or to test bioremediation efficiency. During composting, the decomposition of organic pollutants is affected by temperature, aeration and the properties of the contained compounds. The data on counts of microorganisms in the composts during composting process are shown in Table 3.

Table 2: Evolution of physico-chemical parameters during composting of a sewage sludge and produced composts

	Pile 1		Pile 2	
Parameters	T = 0	Mature compost	T = 0	Mature compost
pH	8.40	7.58	8.10	7.50
C org[a]	285.00	1790.00	265.80	166.00
TKN[ab]	21.80	14.20	22.70	11.30
DM[c]	33.80	80.00	43.20	70.70
OM[a]	599.00	344.00	763.00	364.00
C/N	13.07	12.70	11.70	14.69

[a]Results expressed g kg^{-1} of dry matter; [b]TKN: Total Kjeldahl Nitrogen; [c]Results expressed in % dry weight

Table 3: Amount of *E. coli* present in the first mixtures and the final composts (Results expressed in fresh basis)

Piles	Final composts	*Escherichia coli* (colony Forming units g^{-1} fresh material)	Limit values (NFU 44095)
1	T = 0	$>1.1\times10^6$	-
	Mature compost	7.5×0^3	10^4 g^{-1} fresh material
	T = 0	2.4×0^5	-
2	Mature compost	9.3×10^2	10^4 g^{-1} fresh material

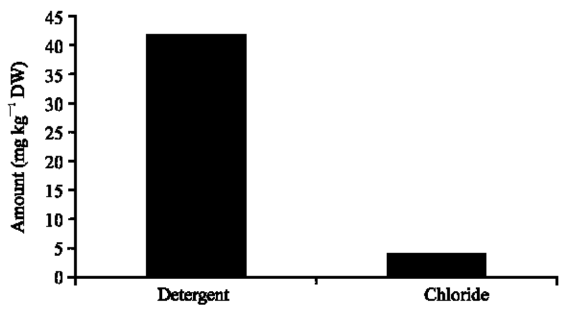

Fig. 2: Amounts of detergent and chloride in the textile sludge (Results expressed in dry basis)

In general, biological parameter tested in this study indicated favourable conditions in the two piles consequences of a moderate frequency of turning. During composting, microbial activities are diverse (Jouraiphy *et al*., 2005). Microbiological analysis of the sewage sludge showed a count of *E. coli* of 1.1 10^7 CFU g^{-1} fresh compost. This could be attributed to rapid proliferation of microorganisms present in the industrial effluent. (Akaninwor *et al*., 2007). It is seen that the *E. coli* counts decreased to 7.5 10^3 CFU g^{-1} fresh compost in C1. The *E. coli* density was significantly reduced also to 9.3 10^2 CFU g^{-1} fresh compost in C2. Thus, the composting process allowed to a decrease in the microbial counts. This drop can be attributed to the exhaustion of nutrients from the medium and/or to the temperature peak during the thermogenic phase in pile 1 and 2 (Jouraiphy *et al*., 2005). At this temperature, only a few days are required to eliminate almost all pathogens and nematodes according to Dumontet *et al*. (1999). The initial levels of chloride and detergents in the sludge are shown in Fig. 2 and their content changes during composting are presented in Fig. 3.

In the first mixtures, chloride contents were very low (0.45 and 0.2 mg kg^{-1} DW respectively). Comparing these values with the first chloride sludge amount (3.78 mg kg^{-1} DW), it was an important decrease of this organic chemical in the two first mixtures by 88.09 and 94.17%. These differences was may be due to mixing and subsequent dilution with greewastes (Harrison *et al*., 2006). Comparing with the results shown in the first mixtures, chloride levels increased slightly in the final compost C2 due to its presence in water used in the maintaining of the moisture of the composts during the composting process (Iiyama *et al*., 1996) and decreased in the mature compost C1 by 86.66% due to more important volatilization and leaching processes (Harrison *et al*., 2006). Comparing to

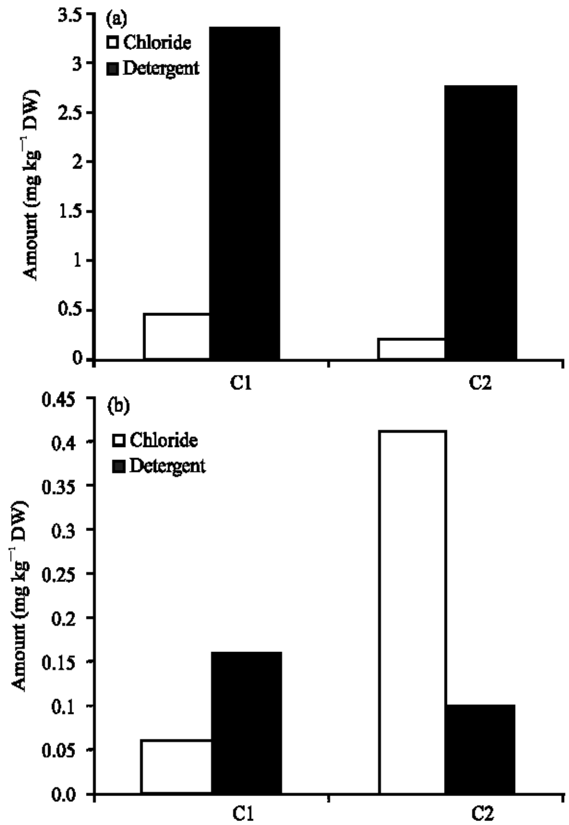

Fig. 3: Amounts of detergent and chloride in the composts C1 and C2 in the first mixtures and after composting (Results expressed in dry basis) a-Amount of detergent and chloride (T = 0) b-Amount of detergent and choloride mature composts

present results, the study of Van *et al.* (2002) showed a higher chloride level in the final compost of 143 mg L^{-1}. Generally, chloride levels are of concern to growers, since in high concentrations this ion can be toxic to plant tissues. Additionally, chloride concentration was one of the main factors influencing vegetable growth (Garcia and Bernal, 2001). The results showed also the degradation of an important masses of the detergent contained in the two composts. The detergent level in the originated sludge was high (41.74 mg kg^{-1} DW) because of their slow and deficient degradation during physico-chimical wastewater treatment. In fact, detergents are affected by two main processes during wastewater treatment: rapid degradation during biological treatment and sorption to solids. Studies have shown that they are >90% and frequently >95% detergent removal from the aquatic phase during wastewater treatment (Bennie, 1999). Many detergent components have been reported to be readily biodegradable by aerobic processes (McAvoy *et al.*, 1998) and some of them escaped aerobic treatment processes. According to Mackay *et al.* (1996), their emission to soil is predominant due to sludge application on agricultural soil and land filling and their presence in sludge may have undesirable environmental effects since the detergent molecules may leach to groundwater contributing to groundwater contamination.

The obtains results in this study demonstrate that aerobic biodegradation has important environmental consequence for detergent contents in the two piles that biodegrade in the presence of air (aerobically) during three months and the degradation rates are similar for the two piles. It could be seen that the level of detergent in pile 1 exceeded 3.33 mg kg^{-1} DW in the first mixture, while that of the pile 2 was lower (2.74 mg kg^{-1} DW). This was simply due to the addition of large amount of greenwaste into the composts. This enlarged the volume and diluted the first detergent content in the sludge. As discussed previously, composted sludge are a mixture of sewage sludge and greenwaste and this mixture lowers the overall percentage of sludge in the product, thus diluting contaminants therein. Also, compost piles are aerated by mixing and these steps may facilitate further aerobic degradation of detergent (Laguardia *et al*., 2001). After composting, the total removal rates of detergent for both of the two piles were beyond 95%. The above data have shown that the degradation rate of detergent during composting was similar for the two piles and that detergent components degrade under aerobic conditions. The composting process is generally marked by a degradation of some detergent componenents during composting of sewage sludge with agricultural waste products i.e., straw, saw dust, tree clippings (Laguardia *et al*., 2001). Similar findings were presented by Solbe (1999) stating a quantitative degradation after composting. Prats *et al*. (1999) reported on a nearly 100% elimination of detergent ingredient (LAS) after 72-day composting of anaerobically digested sludge. Meanwhile, shown by all the indicators, the composts 1 and 2 were mature, stabilized at the end of the experiment and showed pathogenic microorganisms and heavy metals contents lower than the limits established by the French norm on composts made with materials of water treatment (NF U 44-095).

CONCLUSIONS

The findings presented at this study demonstrate that residual levels of detergent and chloride in textle sewage sludge can be efficiently reduced by composting. Levels of detergent and chloride in the final composts are very low and below levels that might pose a risk to sediment organisms but more data is needed particularly on other organic chimicals. The study also documents the high level of detergent biodegradation during the experiment process. The presence of high levels of detergents is to be expected in the textile industries because of their widespread use in this kind of manufacturing activities. This research provides a treatment option that allows textile sewage sludge to be used as a soil fertilizer. Further research on the distribution of detergent degradation products and their cumulative effects on sludge composts are needed along.

ACKNOWLEDGMENTS

We appreciate the effort of all people involved in obtaining the results included in present study. This research was supported by the CITET (Tunis International Center for Environmental Technologies).

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