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Phytotoxicity of Tunisian Municipal and Textile Sludges Compared to the Produced Composts

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Abstract: In this study objective was to determine the phytotoxicity of textile sludge, municipal sludge and their produced composts made from a mixture of sludge and greenwaste (1:1 ratio w/w). The toxicity of the different materials was investigated using sunflower germination bioassays. After the incubation period, percentage of viable seeds and root length as well as germination index were determined. The germination index varied from 30.73 to 95.05% and both textile and municipal sludges presented higher phytotoxicity level than their produced composts. An important observation was that the inhibition of root growth appeared as more sensitive phytotoxicity indicator than the percentage of viable seeds. The germination index indicated the reduction of sludge phytotoxicity with composting. This research provides a basis for the further improvement of composting and for future risk assessments of compost application.

Key words: Composting, toxicity, seed germination test, germination index, percentage of viable seeds, percentage of root length

INTRODUCTION

The volume of urban and industrial biosolids has increased in recent decades in most Mediterranean countries, which makes it difficult to manage them. Land application of composted biosolids is a promising alternative of their disposal as the composting process reduces the volume and stabilizes the wastes. In another context, the growing scarcity of organic matter in the agricultural soils of Mediterranean regions, as a result of adverse climatic conditions (warm and dry summers with a prolonged drought and heavy rainfall during autumn) and inadequate soil management practices, has led to the search for new sources of organic matter to increase its level in these soils and to replace the losses caused by mineralization (Marche *et al*., 2003). 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). Composting can also decrease or eliminate the toxicity of sewage sludge (Araujo and Monteiro, 2005). Chemical parameters (pH, electrical conductivity, carbon forms, inorganic nitrogen forms and cation exchange capacity) and biological parameters (germination index), have been used successfully as indicators of compost stability and maturity from different sources (Butler *et al*., 2001; Iannotti *et al*., 1994). Sludge compost stability and maturity are comprehensive properties indicating the degree of organic matter decomposition and potential of phytotoxicity caused by insufficient composting. (Wu and Ma, 2001). The one of the most widely parameters accepted to evaluate compost maturity is the Germination index, which is a measure of phytotoxicity, has been considered as a reliable indirect quantification of compost maturity (Cunha Queda *et al*., 2002). Sludge composting could bring

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environmental benefits, but it could also ceate environmental risks, as there is a possibility that pathogens, heavy metals and other phytotoxic contaminants may remain at high levels in the composted product. Therefore, use of plant seeds to indicate compost maturity is seen as a protective approach, since respiration or stability testing does not directly indicate potential plant problems.

The purpose of this investigation was to assess the toxicity of municipal and textile sludge as well as their produced composts following a germination test performed with Sunflower seeds (*Helianthus annuus* L.).

MATERIALS AND METHODS

Site and Climatic Conditions

The field study was conducted from May 2006 to January 2007 in Tunis International Center for Environmental Technologies. The climatic characteristics of the study area are as: 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 textile sewage sludge was collected from a textile-wastewater treatment plant in Ras Jebel (in the north of Tunisia). The municipal sludge was collected from the wastewater treatment plant of Charguia in Tunis town (Capital of Tunisia) and this sludge is used in the north of Tunisia as organic amendment to increase soil fertility. Preservation of the sludge was conducted prior to experimental run. Garden greenwastes were taken from the CITET park area. A mixture of sludges and greenwastes were composted on a composting platform at 1:1 v/v and the pile comprised a layer of greenwaste followed by a layer of sludge and according to the design of the experiment.

In a previous studies (El Hammadi *et al*., 2007a and b), we have concluded that both mature composts met the French norm on composts made with materials of water treatment for pathogenic microorganisms and heavy metals (NF U 44-095). Characteristics of sludges and composts are shown in detail in Table 1.

Compost Parameters

Nitrogen was determined by the Kjeldahl method (NF ISO 11261) and the organic matter by Gravimetry. 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).

Germination Test

Germination tests were performed with (*Helianthus annuus* L.). The germination index was determined by placing a layer of compost or sludge sample in a Petri dish covered with a filter paper and water was subsequently added until the filter paper was completely submerged. Seeds of sunflower (*Helianthus annuus* L.) were then rinced many times with distilled water and placed on the filter paper. The percentage of germination was measured after incubating the covered Petri dishes (three replicates for each sample of the compost) in the dark at 25°C for 96 h (Table 2). The Germination Index (GI) was computed by the formula:

$$\text{GI} = (\text{Percentage viable seeds} \times \text{percentage root length})/100$$
$$\text{Percentage viable seeds} = (\text{No. of viable seeds in the sample/in the control}) \times 100$$
$$\text{Percentage root length} = (\text{Root length in the sample/in the control}) \times 100.$$

Table 1: Typical characteristics of the sludges and the produced composts

Properties	Textile sludge	Municipal sludge	Textile compost	Municipal compost
OM[a]	114	522	344	251
TKN[a]	2.89	38.3	14.2	14.8
TOC[a]	18.6	339	179	198
C/N	6.43	8.85	12.7	13.37
E.Coli[c]	1.1×10^7	1.7×10^5	7.5×10^3	<30
Na	6.32	-	3.58	-
Cd	<0.03	1.95	<0.6	<0.6
Cu	0.76	140	24.7	23.1
Hg	<0.91	<0.091	-	<0.091

[a]Results expressed in g kg^{-1} DW dry basis, [b]Results expressed in %, [c]Results expressed as colony forming units 100 mL fresh material, OM: Organic Matter, TKN: Total Kjeldah Nitrogen, TOC: Total Organic Carbon

Table 2: Principal conditions and material used during the seed germination test

Conditions	Seed germination test
Temperature	25°C
Light	No
Test duration	96 h
Control	Distillate water
No. of replicates	3
Material	Compost Filter paper Plastic dish Distillate water

Statistical Analysis

In order to calculate the sample means and standard deviations between the different parameters, all data were statistically analysed using a Wessa System Software through a Fujitsu computer and each sample was considered as an individual observation. Values are mean of three independent replicates ±SE (n = 3).

RESULTS AND DISCUSSION

There are a variety of compost phytotoxicity tests which have been proposed and published (Mathur *et al*., 1993). The Germination GI is a factor of relative seed germination and relative root elongation. Additionally, this germination bioassay was included since it is used to determine the maturity and phytotoxicity of composts and other biowaste materials (Roe *et al*., 1997). The obtained germination bioassay results are showed in Table 3. In general, Sunflower germination was inhibited by textile sludge more than municipal sludge, while no significant adverse effects were observed with the two produced composts. In addition, there was a reduction in percentage of viable seeds and germination index in all assays involving sludge materials and the seed germination index are 30.73 and 64.94% in textile sludge and municipal sludge, respectively. Compared to the results found by Fuentes *et al*. (2004), the germination index in their study was more than 70% for both barley and cress seeds in the presence of sewage sludge. Textile sludge had a stronger inhibitory effect on viable seed percentage and root length indicating that it may induce more adverse effects than municipal sludge. Generally, germination index values below 50% indicate that phytotoxic compounds might have not been metabolised inhibiting germination (Epstein, 1997). In the case of textile sludge, the salt concentrations (especially Na), might have inhibited Sunflower development and thus reduced the germination index. The large salt concentration might thus limit the use of this kind of sludge (Contreras-Ramos *et al*., 2004). The percentage of root length was determined as 92.88 and 43.55% for the municipal sludge and textile sludge, respectively. The respective % viable seeds of the above sludges were 69.92 and 70.58%, respectively. It was suggested in the study of (Wong *et al*., 1983) that toxic compounds may have suppressed the percentage of viable seed but the toxic effects of sludges

Table 3: Evolution of sunflower germination parameters in the sludges and produced composts (all result expressed in %)

Biowaste materials	Viable seeds (%)	Root length (%)	Gi[a]
Control	100.00	100.00	100.00
Municipal sludge	69.92±0.07	92.88±0.2	64.94±0.01
Produced compost	86.23±0.66	110.23±0.60	95.05±0.03
Textile sludge	70.58±0.16	43.55±0.85	30.73±0.13
Produced compost	82.35±1.08	91.55±1.02	75.39±1.10

All values are reported as mean±standard deviation between three replicates, [a]Germination index

can decline with time and seeds can adjust to the more adverse conditions (Wong *et al*., 1983). Therefore, the inhibition of root growth appeared as more sensitive phytotoxicity indicator than the percentage of viable seeds. In fact, the roots are the responsible for absorption and accumulation of metals and metal concentrations affect more the roots than the aerial parts of the plant (Oncel *et al*., 2000). Generally, the major problem is the potentially phytotoxic nature of the sludges mainly as a result of a combination of several factors, such as their high salinity and of any excess of ammonium ions, organic compounds, or any low molecular weight fatty acids they might carry. All these can also inhibit root growth (Hoekstra *et al*., 2002). The germination index of Sunflower reached 95.05 and 75.39%, respectively in municipal compost and textile compost after the composting process, revealing loss of phytotoxicity and achievement of compost maturity. In the two composts, percentages of seed germination were greater than 80%. Also, Significant differences were noted in the root lengths achieved by Sunflower seeds incubated in textile and municipal composts. The seeds incubated in textile compost had lowest germination index than the others developed in municipal compost. Also, the Increases in GI values corresponded with decreases in concentrations of heavy metals and *E. coli* in the matured composts (both mature composts had total heavy metal lower than the French limit values of composts to be used as soil fertilizer). The results imply that the elimination of phytotoxicity and the composting rate in the case of textile sludge was slower than that of municipal sludge. In fact, the matured composts used finished their curing stage and were stable after the end of the composting process. Also, there appeared to be a clear relationship between Sunflower germination and compost maturity. Moreover, the increase of the germination index in the produced products suggested that the composts did not pose any toxicity on the plant growth (Tiquia *et al*., 1996), that the maturity was sufficient (Zucconi *et al*., 1981) and that composting is an important process that have to eliminate toxic compounds present in sewage sludges. Therefore, the produced composts can benefit plant growth and is suitable for agricultural application (Campbell *et al*., 1995). However, compared with the control seeds with 100% germination index, the composts appeared to contain some phytotoxicity inhibitors. Alvarez *et al*. (1995) mentioned that the formation of an excess of acetic indol acid, a phytotoxic compound, during composting inhibited plant growth and absorption of nutrients.

CONCLUSIONS

Based on these findings, germination index varied greatly among the sludge and compost samples. On the other hand, Sunflower germination appeared to be inhibited by the presence of textile sludge more than municipal sludge and the results suggest that phytotoxic compounds are involved. Furthermore, both obtained composts had acceptable germination index and their use in agriculture could be used without problems as soil amendment at proper rates. The present study demonstrates that the composting process can decrease the biological toxicity of municipal and textile sludge and this may contribute to the prevention of serious environmental negative impacts. Compost hygiene is of ever increasing concern and it must be one of the most important focus in the future since compost marketing is growing.

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