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Bioremediation of Tunisian Textile Sludge by its Co-composting with Green Plant Waste

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Abstract: With the increasingly growing production of textile sludge in Tunisia, evaluation of its use in composting process is essential. The sludge was produced in a textile manufacture in north of Tunisia and the composting system designed involved open piles turned periodically over a period of 3 months proved to be inexpensive and reliable. This experiment examined co-composting of textile sludge with green waste at 1:1 v/v (pile 1) and 1:3 v/v (pile 2) ratios in periodically turned outdoor piles, which were sampled for analysis after the beginning of the composting process. Changes in the composition of the two mixtures were determined by monitoring chemical and microbiological parameters. The produced compost C1 shows a higher C, N, pH and dry matter contents. Organic matter concentration at the end of composting was lower in C1 than C2. The amount of heavy metals and pathogens present in the final product is lower than the amount mentioned for the waste compost use in French norms.

Key words: Composting, textile sludge, heavy metals, *E. coli*

INTRODUCTION

The production of textile sewage sludge has increased sharply in Tunisia due to the expansion of this kind of industrial activities and the imposition of more strict environmental laws. Recently, the accumulation of these wastes poses a growing environmental problem. Land application of this kind of sewage sludge provides a mean for sludge disposal (Jorba and Andres, 2000). The effects of textile sludge on soil quality are dual. On the one hand, sludge application to soil increases the content of organic matter and plant nutrients; on the other hand, the agriculture use of this sewage sludge is limited by the presence of pathogens, heavy metals, detergents and other toxics. To overcome the risks incurred by the land application of this waste, treatment is required to minimize and eliminate the undesirable effects and to optimize the efficiency of the materials once applied to the soil. Composting is considered to be the best pretreatment for overcoming these problems (Sanchez-Monedero *et al*., 2004). 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 (Diaz *et al*., 1993). A decrease in the content of organic pollutants and a reduction in the bio-availability of metal trace elements had also been reported during the composting of sewage sludge (Lau *et al*., 2003). Very little data is available about composting of textile sludge, but with this practice, a potential source of pollution could be reduced in size. The agronomical quality of compost produced from these biosolids is limited mainly by their chemical composition as well as by the stability and maturity of the OM (Marchiol *et al*., 1999).

The main objective of this study is to find the optimal ratio greenwaste /sewage sludge delivered to the composting site. For this purpose, laboratory analysis were designed to examine two mixtures of textile sludge and green wastes at different sludge ratios.

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

Constituent	Content
pH	7.05
DM [a]	30.9
OM [a]	114
COT [a]	18.6
TKN [a, c]	2.89
E. Coli [b]	1.1×10^7

[a]Results expressed g kg^{-1} of dry matter. [b]Results expressed as colony forming units 100 mL fresh material. [c]TKN: total Kjeldahl nitrogen

MATERIALS AND METHODS

A laboratory research was conducted in the laboratory of Tunis International Center for Environmental Technologies from Mai 2006 to January 2007.

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 and greenwaste was composted on a composting platform at 1:1 v/v (pile 1) and 1:3 v/v (pile 2) ratios in periodically turned outdoor piles, which were sampled for analysis after the beginning of the composting process and monitored over 90 days. 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 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 are shown in detail in Table 1.

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 Cr were analyzed by emission spectrometry-ICP (NF EN ISO 11885).

RESULTS AND DISCUSSION

Compost samples used in this study varied in their physical and chemical properties which directly affect compost stability. The mature compost C2 had generally low values for all the parameters determined in this study. These differences were mainly due to the differences in initial source materials of the two composts. The variation in temperature recorded during the process (Fig. 1) was typical of a two-phase composting process (Tomati and Galli, 1995). At the start of the composting process the mean temperature in the core of the two piles was, respectively 22 and 29°C. After pile 1 and 2 formation, temperature increased in both piles with time and was significantly in pile 1 than in pile 2 over the whole incubation period. This temperature rise results from intense microbial activities favoured by the high concentration of easily decomposable organic molecules. Afterwards, during the maturation phase, the temperature decreased steadily to reach the ambient temperature at the end of the process. Physico-chemical features of the two composts at the begening and after composting are shown, respectively in Table 2 and 3.

A comparison of the two produced composts showed that their chemical values fell within the same range in most instances with the exception of the dry matter values owing to the mixture nature

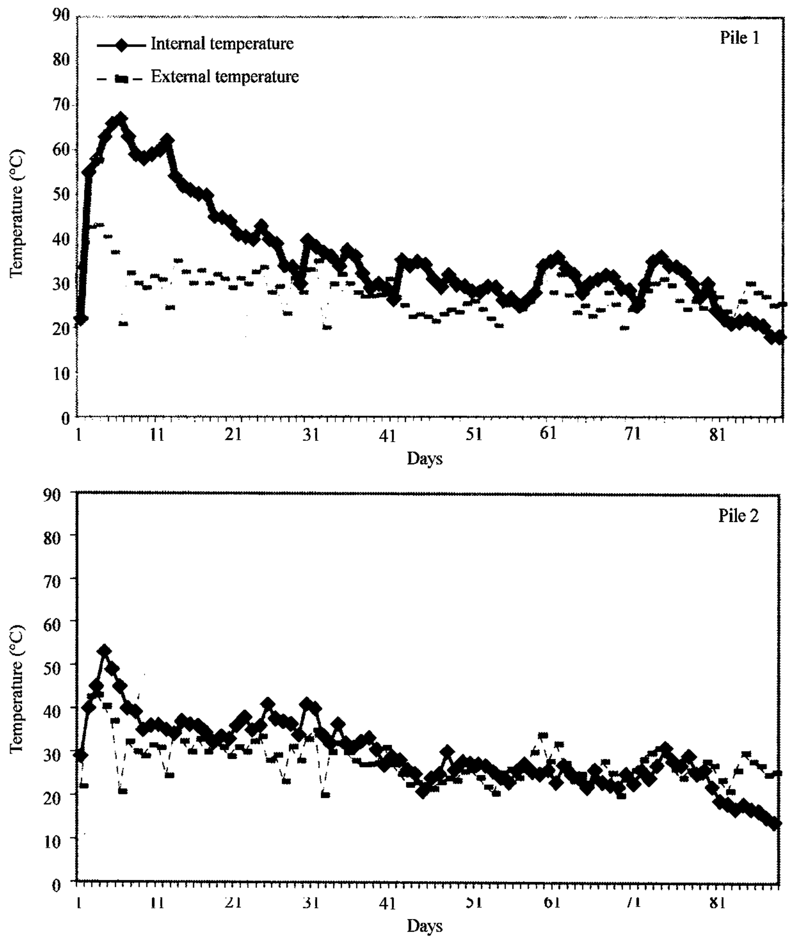

Fig. 1: Changes in ambient air temperatures and pile temperatures during composting

Table 2: Physico-chemical characteristics of the first mixtures (T = 0) (Results expressed in dry basis)

Parameter	C1	C2
pH	8.4	8.1
C org[a]	285	265.8
TKN[ab]	21.8	22.7
DM c	33.8	43.2
OM [a]	599	763
C/N	13.07	11.7
E. coli[d]	$>1.1\times10^6$	2.4×10^5

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

Table 3: Physico-chemical characteristics of the produced composts (Results expressed in dry basis)

Parameter	C1	C2
pH	7.58	7.50
C org[a]	179	166
TKN[ab]	14.2	11.3
DM[c]	80	70.7
OM[a]	344	364
C/N	12.6	14.69
E. coli[d]	7.5×10^3	9.3×10^2

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

Table 4: Amount of heavy metals in the produced composts (Results expressed in dry basis)

Metal (mg kg^{-1} DW)	C1	C2	Limit values (NFU 44095)
Cd	<0.6	<0.6	3
Cu	24.7	21.3	300
Cr	35.6	32	120

of the two piles. The compost obtained just from 1/3 sludge/greenwaste ratio would be more similar to that of vegetal wastes, however the incorporation of sludge allows the elimination of two waste materials and ensures that a better product is obtained. The initial pH of the two mixtures C1 and C2 was adjusted, respectively to about 8.1 and 8.4 by adding textile sludge. It has been noted by (Metcalf and Eddy, 2003) that pH of the composting mixture should generally be in the range of 6-9. The initial pH of about 8.1 for the pile 1 decreased to about 7.58 for the duration of the experiment. This might be contributed by the organic acid formation during the decomposition of organic matter contained in the sludge (Diaz *et al*., 1993). pH decreased to 7.50 in the case of the pile 2 during the composting process It may be considered that the pH value for this pile became lower because of organic acid formation under the composting condition. Moisture content is an important parameter influencing biological activity and biochemical rates. The final moisture content values were 33.1 for C1 and 29.5 for C2. This was due to the water lost with the exhaust gas. Ghaly *et al*. (2006) emphasized the importance of moisture content and stated that the optimum moisture content during composting is in the range of 50-70% depending on the type of composted material. The starting materials C1 and C2 had, respectively a dry mass content of 33.8 and 43.2%. After the whole composting period, the produced compost C2 was characterized by a lower dry mass level than C1 and the dry mass content had increased to 80% and 70.7, respectively in C1 and C2. The final compost C2 had a lower organic matter than the produced material C, probably due to the higher amount of grennwaste added to the compost. (Wu and Ma, 2002). The use of lower sludge ratio in C2 led to a lower decomposition of lignin and cellulose, perhaps because greenwaste might contain a cellulose fraction bonded to lignin which would make it more difficult to degrade (Paredes *et al*., 2002). At the end of the experiments, the C/N ratio was decreased to 12.6 in C1 and increased to 14.69 in C2. The C/N ratio is not constant during composting because of the removal of carbon as CO2 upon microbial respiration. Also, the microbiological degradation leads to excess ammonia formation, which increases the pH and thereby enhances ammonia volatilization (Fogarty and Tuovinen, 1991). The change in the C/N ratio during the composting process is an indicator of the decomposability of the material and the reduction in the total organic carbon indicates rapid biodegradation of carbon. It can be concluded that carbon was not a limiting factor during these composting experiments. The nitrogen losses in the two mixtures C1 and C2 during composting did not exceed 34.86 and 50.22% in either of the two mixtures. The highest N losses in C1 and C2 mixtures was presumably favoured by the pH values in excess of 8 at the begening of the composting prcess. In addition, Composts with a high percentage of green cuttings or garden waste (tree cuttings), under similar conditions for composting, generally give a slightly lower N effect than composts with a high percentage of bio-wastes (Scherer *et al*., 1996). In the present study, the two produced composts showed potentially toxic heavy metal contents (Table 4) lower than the limits established by the French legislation (NF U 44-095). In addition, they were derived from different material ratios and showed many differences between their total analyses, but the composting process seemed to produce materials with similar mineralization behavior.

CONCLUSION

From these data, it can be concluded that composting is a suitable alternative for the recycling of textile sewage sludge. Physico-chemical analysis showed that the composting proceeded properly. The two classic phases of composting resulting from microbiological activity were identified as biodegradation followed by maturation The evolution of the process, the temperatures attained and the analytic values obtained would ensure a proper hygienization and the transformation of all the materials for their further application. Both composts had higher OM and lower potentially toxic heavy metal contents and pathogens than the limits established by the French legislation (NF U 44-095). The optimum ratio for mixing the wastes was 1:2 w/w ratio as this ensured that pile reached higher temperatures, more nitrogen was retained and C:N ratio was similar to that found in soils.

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