International Journal of

Biological Chemistry

ISSN 1819-155X

Academic
Journals Inc.

www.academicjournals.com

International Journal of Biological Chemistry 5 (1): 46-53, 2011
ISSN 1819-155X / DOI: 10.3923/ijbc.2011.46.53

Composition of Organic and Inorganic Contaminants in Compost Produced from Different Organic Wastes

[1]Mohamed Anis El Hammadi and [1,2]Belgacem Hanchi
[1]Faculté des Sciences, Campus Universitaire, Tunis, 1060, Tunisie
[2]Centre International des Technologies de l'Environnement de Tunis (CITET), Boulevard de, Tunisie

Corresponding Author: Mohamed Anis El Hammadi, Faculté des Sciences, Campus Universitaire, Tunis, 1060, Tunisie Tel: 216 94 86 51 15, 216 77 30 43 46

ABSTRACT
The aim of this study was to evaluate xenobiotics contents (Detergent, heavy metal and chloride) of final compost made from different wastes (Textile sludge, municipal sludge, municipal waste and garden waste). After composting, there was an increase in total heavy metal contents in compost because of loss of mass due to biodegradation of organic matter. In addition, we recorded a slight increase of chloride content. On the other hand, this study demonstrates that aerobic biodegradation has important environmental consequence for detergent contents in the pile that biodegrade in the presence of air during the composting process. However, proper consideration should be given to the compost metal content and further field studies are required to examine the long-term effect of the final product in soils, particularly in relation to biological indicators of soil quality.

Key words: Composting, sludge, heavy metals, chloride, detergent, biodegradation

INTRODUCTION
The presence of organic and inorganic contaminants in the organic wastes pose a grave danger to the environment. To overcome the risks incurred by the direct use of some of these wastes in agriculture, treatment is required to minimise and eliminate the undesirable effects and to optimise the efficiency of the materials once applied to the soil. Among the organic wastes recycled in agriculture, residual sludge generated by wastewater treatment is a source of organic matter rich in both phosphorus and nitrogen. It can contribute to the rehabilitation of degraded soils by its fertilising and other soil-improving qualities (Martinez *et al.*, 2003). Recycling of sludge for agricultural purposes seems to be an appealing solution that enables valuable components to be recycled (Dolgen *et al.*, 2007) and sewage sludge has been used as an amendment to agricultural soils (Kidd *et al.*, 2007) and the application of sludge also increase soil organic matter content that contributing to the structural stability of the soil and to its resistance to erosion (Ortiz and Alcaniz, 2006). Composting is considered to be the best pretreatment for overcoming these problems (Amir and Hafidi, 2001). Composted organic wastes used as substrates could be a feasible option, especially sewage sludge due to its high production (Jouraiphy *et al.*, 2005). Composting is defined as a process of aerobic thermophilic microbial degradation or an exothermic biological oxidation of various wastes by many populations of the indigenous microorganisms which lead to a stabilized, mature, deodorized, hygienic product, free of pathogens and plant seeds, rich in humic substances, easy to store and marketable as organic amendment or fertilizer (Ouatmane *et al.*, 2000). A number

of toxicants discharged through the sewers tend to accumulate in sewage sludge and limits the general use of this waste in agriculture. Besides the necessity to have information about substance groups, which had been characterized as highly toxic, there was a demand for having information about their contents in composts made from materials of water treatment. sources. From these, a vast group of heavy metals is usually the most considered one. Sewage sludge compost is a waste derived material with increased concentrations of heavy metals. Consequently, its use in agriculture and horticulture is problematic with strict regulations determining both the amount and the method of application (Manios *et al*., 2003). Chloride content in sludge compost are also of concern, 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). On the other hand and because of their broad application in households and industry, detergents can be classified as a relevant compound in sewage sludge. The detergent concentration is influenced by the content in the sewage, the treatment process (aerobic, anaerobic), the water hardness, the age of the sludge after storage etc and composting leads generally to a decrease of detergent concentration in the composted sludge (Laguardia *et al*., 2001).

Accordingly, the objective of this study was to examine the levels of total heavy metals (Cr, Cd, Cu, Fe and Mn), detergent and chloride contents in the final compost produced from different wastes.

MATERIALS AND METHODS

Justification of the proposed selection of the wastes for composting: The use in agriculture of good quality compost is an efficient means of re-establishing the balance between the withdrawal and restitution of organic matter in the biosphere. This is particularly important in Tunisian soils, which are generally poor in organic matter. In addition, the return of organic residential waste such as compost to the cycle of nature is one of the most important ecological objectives of recycling and reuse of substances. In this context, the increasingly an growing sewage sludge production in Tunisia justify the choice of a biological treatment for the production of compost as a way of utilizing the waste.

Site and climatic conditions: The field study was conducted from May 2006 to January 2007 in Tunis International Center for Environmental Technologies (CITET). 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 design and sampling: The textile sewage sludge came from a textile-wastewater treatment plant in Ras Jebel (in the north of Tunisia) and the municipal sludge was collected from the wastewater treatment plant of Charguia in Tunis town (Capital of Tunisia). Municipal greenwastes were collected selectively from the central market of Tunis (in Tunis town) and garden greenwastes were taken from the CITET park area. The Typical characteristics of the sludges used in the composting process are shown in Table 1.

A mixture of sludges and greenwastes was composted on a composting platform in periodically turned outdoor piles and the pile comprised a layer of greenwaste followed by a layer of sludge. Composting, on a purpose-built platform, was followed for 120 days and the mixture was turned every 15 days for aeration. The following graph shows the composition of the pile according to the specific volume of sludges and green matter (Fig. 1).

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

Constituent	Textile sludge	Municipal sludge
pH	7.05	-
DM[a]	30.9	-
OM[a]	114	522
COT[a]	18.6	339
TKN[a, b]	2.89	38.3
C/N	6.43	8,85
E. coli[c]	$1.1\ 10^7$	$1.7\ 10^5$
Mn[a]	2.53	63.5
Fe[a]	62.33	7.49
Cd[d]	<0.03	1.95
Cu[d]	0.76	140
Hg[e]	<0.091	<0.091
Cr[d]	5.28	-

[a]Results expressed in g kg^{-1} of dry matter, [b]TKN: Total Kjeldahl nitrogen, [c]Results expressed as colony forming units 100 mL fresh material, [d]Results expressed in mg kg^{-1} of dry matter, [e]Results expressed in µg kg^{-1}DW (dry basis)

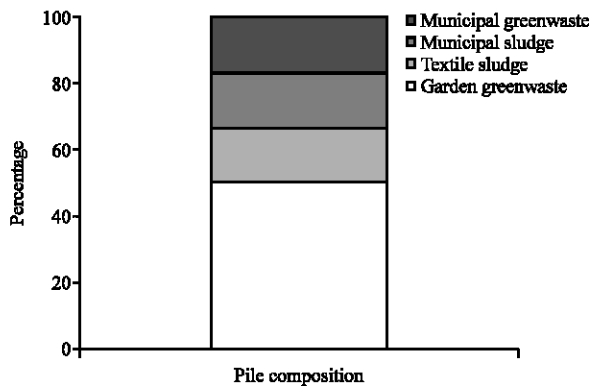

Fig. 1: Composition of the pile according to the specific volume of the wastes

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. Fe was analyzed by emission spectrometry -ICP (NF EN ISO 11885). The elements Cd, Cr, 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).

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 rinsed many times with distilled water and placed on the filter paper. The percentage of germination was measured after incubating

Table 2: Physico-chemical characteristics of the produced compost

Properties	First mixture	Mature compost
pH	7.18	7.63
DM[b]	34.1	71.4
OM[a]	566.0	372
TKN[a]	20.6	18.3
TOC[a]	330.0	233
C/N	16.01	12.73
E. coli[c]	1.1^6	$\approx 10^4$

[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 kjelahl nitrogen, TOC: Total organic carbon

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:

$$GI = (\text{Percentage viable seeds} \times \text{Percentage root length})/100$$

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

$$\text{Percentage root length} = (\text{Root length in the sample/in the control}) \times 100$$

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

Physical and chemical properties of the produced compost are shown in Table 2, compost was near neutral pH (7.63), organic matter content was considerably high (37.2%) and several heavy metals such as Cr, Cd, Cu, Fe and Mn were detected in the compost. The heavy metal concentrations in the final compost deserve consideration since they may affect the final product quality and the change of use and uptake by soil flora will relate to total heavy metal content. The results are presented in Table 3; the results indicate a general increasing trend of compost metal contents in the final compost. Total heavy metal content of Cr, Fe and Cu do not degrade in the composting process and rose above those observed in the first mixture. This is due both to the concentrating effect caused by the weight loss associated with mineralisation of the OM (Sanchez-Monedero *et al.*, 2004) and to phenomena of rapid decomposition of the organic matter, with consequent release of soluble heavy metals (Chaney and Ryan, 1993), although losses through drainage can not be excluded. In addition, Mn is the heavy metal most represented in the final compost and no difference has been detected in the total contents of Cd between the first mixture and the final compost. The content of total Fe ions was 4.63 g kg^{-1} DW in matured compost, which was much lower than its respective initial concentration of 62.33 and 7.49 g kg^{-1} DW in textile sludge and municipal sludge. This was simply due to the addition of large amount of municipal and garden greewaste into the compost. This enlarged the volume and diluted the metal content in compost. Moreover, the reduction in volume of pile after composting also resulted in an increased concentration of heavy metals. In addition, the wide range of biochemical compounds

Table 3: Amount of heavy metals in first mixture and the produced compost (Results expressed in dry basis)

Metal	T = 0	Mature compost	Limit values (NFU 44095)
Mn g (kg^{-1} DW)	-	130	-
Fe g (kg^{-1} DW)	2.7	4.63	-
Cd (mg kg^{-1} DW)	<0.6	<0.6	3
Cu (mg kg^{-1} DW)	11.6	31.3	300
Cr (mg kg^{-1} DW)	4.64	16.8	120

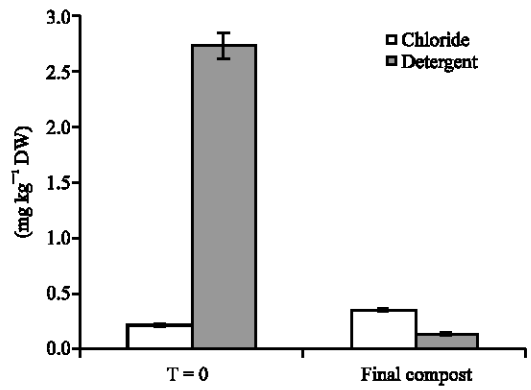

Fig. 2: Amounts of detergent and chloride in the produced compost (Results expressed in dry basis)

dissolved in the wastewater and the industrial processes used yielding the sewage sludge may lead to considerable differences in the heavy metal content of the subsequent composted sewage sludge (Casado-Vela *et al*., 2006). The metal concentrations in this study were below the maximum permissible levels for organic products made with materials of water treatment recommended by the French norm (NF U 44-095). Hence the application of this compost derived from different wastes may be considered as safe and suitable for soil improvement in the agricultural plant production. The initial levels of chloride and detergents in the first mixtures and the produced compost are shown in Fig. 2. In the first mixtures, chloride content was very low (0.2 mg kg^{-1} DW). Comparing this value with the chloride amount in the final compost (0.36 mg kg^{-1} DW), we recorded a slight increase of this organic chemical. This is due to the fact that chloride is present in the water used in the maintaining of the moisture of the composts during the composting process (Iiyama *et al*., 1996). Also, the first mixture contains an average of approximately 56.6% organic matter on a dry weight basis. Following components addition, the first mixture undergoes decomposition to carbon dioxide, water, low molecular weight soluble organic acids, residual organic matter and inorganic constituents. Although most of the organic fraction of the sludge is converted to carbon dioxide and water, some becomes part of the stable soil humus layer (Hernandez *et al*., 1990) and serves to increase the soil's net negative charge. Chloride released from sludge following decomposition may be put into more soluble anions $C1^{-}$. It was observed by Paredes *et al*. (2005) that chloride level in compost can increased the soil salinity after land application and that the levels of $C1^{-}$ were always higher in the soils with compost, particularly with the high dose of $C1^{-}$. The results showed also the degradation of an important masses of the detergent present in the first mixture. The enumeration of microbial populations is typically performed to gain information on the biodegradation potential of the of the detergent and chloride contents. Microbiological analysis of the first mixture showed a count of *E. coli* of 1.1°cfu g^{-1} fresh compost. It is seen that the *E. coli*

Table 4: Evolution of sunflower germination parameters in the sludges and produced composts (All Result expressed in %)

Wastes	% viable seeds	% root length	GI[a]
Control	100	100	100
Municipal sludge	69.92±0.07	92.88±0.2	64.94±0.01
Textile sludge	70.58±0.16	43.55±0.85	30.73±0.13
Produced compost	78.22±0.14	90.43±0.77	70.73±0.20

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

counts decreased to ~10^4 cfu g^{-1} fresh compost in the produced compost. 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 (Jouraiphy *et al*., 2005). The results in this study demonstrate that aerobic biodegradation has important environmental consequence for detergent contents in the pile that biodegrade in the presence of air during the composting process. It could be seen that the level of detergent in the first mixture was 2.74 mg kg^{-1} DW. After composting, the total removal rates of detergent was beyond 94.89%. The composting process is generally marked by a degradation of some detergent components during composting of sewage sludge with agricultural waste products, i.e., straw, saw dust, tree clippings and the pile is aerated by mixing and these steps may facilitate further aerobic degradation of detergent (Laguardia *et al*., 2001). A number of studies have shown that aerobic treatment is a wellsuited solution for reducing the level of detergents (Prats *et al*., 1999; Solbe, 1999) and that composting sludge leads to a decrease of detergent concentration (Elenaa *et al*., 2000). Under aerobic conditions, some detergent compounds will be degradated by ω-oxidation followed by a β-oxidation with subsequent degradation of the alkyl chain. Degradation will be influenced by oxygen availability (Leschber, 2006). Generally, in untreated soils, the detergent content is normally less than 0,2 mg kg^{-1} DW. Although sewage sludge is the main source for detergents in soils, some detergent concentrations in soils may originate from compost application (Carlsen *et al*., 2002). Moreover, the increase of the germination index in the produced product (Table 4) suggested that the composts did not pose any toxicity on the plant growth, that the maturity was sufficient and that composting is an important process that has to eliminate toxic compounds present in sewage sludges (Tiquia *et al*., 1996). Therefore, the produced composts can benefit plant growth and is suitable for agricultural use.

CONCLUSION

From these data, it can be concluded that composting is a suitable alternative for the recycling of different wastes (sludge/municipal sludge/garden greenwaste/municipal greenwaste) and can safely be used to get a good quality of organic fertilizer. The experiment showed a reduction of the levels of detergent and an increase of total heavy metal and chloride contents in the mature compost. This compost met the French norm on composts made with materials of water treatment for heavy metals (NFU 44-095). In addition, the amounts of detergent and chloride in the final product are very low. Furthermore, a greater effort should be made to select wastes for composting to reduce metal content in the final compost, thus minimising the risks of soil pollution.

ACKNOWLEDGMENTS

My thanks go to all of the people involved in obtaining the results included in this study. This work was supported by the CITET (Tunis International Center for Environmental Technologies).

REFERENCES

Amir, S. and M. Hafidi, 2001. Sludge valorization by an aerobic process composting. Mater. Chem. Sci. Ann., 26: 409-414.

Carlsen, L., M.B. Metzon and J. Kjelsmar, 2002. LAS in the terrestrial environment. Sci. Total Environ., 290: 225-230.

Casado-Vela, J., S. Selle, J. Navarro, M.A. Bustamante, J. Mataix, C. Guerrero and I. Gomez, 2006. Evaluation of composted sewage sludge as nutritional source for horticultural soils. Waste Manage., 26: 946-952.

Chaney, R.L. and J.A. Ryan, 1993. Heavy Metals and Toxic Organic Pollutants in MSW-Composts: Research Results on Phytoavailability, Bioavailability, Fate. In: Science and Engineering of Composting: Design, Environmental, Microbiological and Utilization Aspects, Keener, I. (Ed.). Renaissance Publishing, Pittsburgh, PA., pp: 451-506.

Dolgen, D., M.N. Alpaslana and N. Delen, 2007. Agricultural recycling of treatment-plant sludge: A case study for a vegetable-processing factory. J. Environ. Manage., 84: 274-281.

Elenaa, P.P., B.M. Eugeniab, L. Albertob and V.J.N. Jesús, 2000. Agronomic aspects of the sunflower 7-hydroxylated simple coumarines. Helia, 23: 105-112.

Garcia, A. and M.P. Bernal, 2001. Growth of ornamental plants in two composts prepared from agroindustrial wastes. Bioresour. Technol., 83: 81-87.

Hernandez, M.T., J.I. Moreno, F. Costa, F.J. Gonzales-Vila and R. Frund, 1990. Structural features of humic acidlike substances from sewage sludge. Soil Sci., 149: 63-68.

Iiyama, K., B. Stone and J. Macauley, 1996. Changes in the concentration of soluble anions in compost during composting and mushroom (*Agaricus bisporus*) growth. J. Sci. Food Agric., 72: 243-249.

Jouraiphy, A., A. Soumia, M.E. Gharous, J.C. Revelc and M. Hafidi, 2005. Chemical and spectroscopic analysis of organic matter transformation during composting of sewage sludge and green plant waste. Int. Biodeterioration Biodegradation, 56: 101-108.

Kidd, P.S., M.J. Dominguez-Rodriguez, J. Diez and C. Monterroso, 2007. Bioavailability and plant accumulation of heavy metals and phosphorus in agricultural soils amended by long-term application of sewage sludge. Chemosphere, 66: 1458-1467.

Laguardia, M., H. Robert and T. Matteson, 2001. Alkylphenol ethoxylate degradation products in land-applied sewage sludge (Biosolids). Environ. Sci. Technol., 35: 4798-4804.

Leschber, R., 2006. Evaluation of the relevance of organic micropollutants in sewage sludge. Results of a JRC Coordinated Survey on Background Values. Joint Research Centre, EU Commission, ISPRA, Provisional Report.

Manios, T., E.I. Stentiford and P. Millner, 2003. Removal of heavy metals from a metaliferous water solution by Typha latifolia plants and sewage sludge compost. Chemosphere, 53: 487-494.

Martinez, F., G. Cuevas, R. Calvo and I. Watter, 2003. Biowaste effects on soil and native plants in semi arid ecosystem. J. Environ. Qual., 32: 472-479.

Ortiz, O. and J.M. Alcaniz, 2006. Bioaccumulation of heavy metals in *Dactylis glomerata* L. growing in a calcareous soil amended with sewage sludge. Bioresour. Technol., 97: 545-552.

Ouatmane, A., M.R. Provenzano, M. Hafidi and N. Senesi, 2000. Compost maturity assessment using calorimetry, spectroscopy and chemical analysis. Comp. Sci. Util., 8: 124-134.

Paredes, C., J. Cegarra, M.P. Bernal and A. Roig, 2005. Influence of olive mill wastewater in composting and impact of the compost on Swiss chard crop and soil properties. Environ. Int., 31: 305-312.

Prats, D., M. Rodriguez, M. Muela, J.M. Liamas, A. Moreno, J. Ferrer and J.L. Bernal, 1999. Elimination of xenobiotics during composting. Tenside Surf. Det., 35: 294-298.

Sanchez-Monedero, M.A., C. Mondini, M. Nobili, L. Leita and A. Roig, 2004. Land application of biosolids. Soil response to different stabilization degree of treated organic matter. Waste Manage., 24: 325-332.

Solbe, J., 1999. Vipers, humic acids and hurricanes: Some thoughts on environmental risk assessment in Europe. Hum. Ecol. Risk Assess., 5: 1-5.

Tiquia, S.M., N.F.Y. Tam and I.J. Hodgkiss, 1996. Effects of composting on phytotoxicity of spent pig-manure sawdust litter. Environ. Pollut., 93: 249-256.