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Behaviour of Physico-Chemical Parameters and Toxicants in the Composting Site and Relationship Between Them: A Statistical Study

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Abstract: In this study, physico-chemical variables, monitored before and during composting of different mixtures with different ratios were combined to obtain an overall statistical evaluation of the composting process. The study shows that there was statistically a clear positive relationship between Organic Matter (OM) and several parameters such as C and C/N. However, negative but well correlation between detergent and heavy metals as well as negative correlation between OM and heavy metals were also observed suggesting that there is an interaction between them. On the other hand, the data obtained showed important variations of detergent and some heavy metal contents (Fe and Cu) in the composting site. The obtained data provided valuable information concerning changes and relationship between several toxicants and composting parameters. However, further analytical research on the distribution of detergent degradation products and their cumulative effects on sludge composts are needed along.

Key words: Composting, organic matter, heavy metals, detergent, correlation coefficient, index of qualitative variation

INTRODUCTION

Composting is a widely acceptable alternative for converting waste into a more useful eco-friendly fertilizer known to improve soil fertility. Since composting is an inexpensive, simple and environmentally sound process for waste disposal, the composting of thickened and dewatered undigested primary and secondary sludge has been widely applied. Composting results in a decrease in mass and volume of organic wastes (Bertran *et al*., 2004), a reduction in land filling problems and biodegradation of toxic compounds and other organic contaminants. The main types of urban waste that are composted include biowaste, green waste, municipal solid waste and an increasing contribution of sewage sludge from wastewater treatment plants, often co-composted with green waste. The composts prepared from different organic wastes differ in their quality and stability, which further depends upon the composition of raw material used for the compost production (Ranalli *et al*., 2001). Generally, successful composting depends on a number of factors that have both direct and indirect influence on the activities of the microorganisms. They include the type of raw material being composted, its nutrient composition, moisture content, temperature, acidity or alkalinity and aeration. The stabilized compost produced should benefit plant growth and be suitable for agricultural applications (Magdi *et al*., 2003). Furthermore, compost stability relates to the degree to which the Organic Matter (OM) has been stabilized during the composting process (Weppen, 2002). The chemical nature of compost OM changes throughout the composting process and can be a useful

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indication of compost stabilization (Chen, 2002). The extent of OM degradation can be determined by various methods: Mass loss, CO_2 emission and changes in C/N ratio (Eklind and Kirchmann, 2000). Additionally, microbial diversity and activity are indicators of OM decomposition (Magdi *et al*., 2003). On the other hand, the agronomical quality of compost produced from sludges as textile sludge is limited mainly by their chemical composition as well as by the stability and maturity of the OM (Marchiol *et al*., 1999). Dry weight concentrations of pollutants may also be higher in composted material if organic matter is biodegraded without significant degradation of the pollutant. Therefore, the presence of high levels of toxicants as detergents may hinders agricultural land application of the composted textile sludge. In previous studies, composting was suggested to be an inexpensive and technologically straightforward solution for managing biosolid wastes (Elhammadi *et al*., 2007a and b). The main objectives of this research were to investigate the evolution of some principal physico-chemical properties and toxicants before and during composting as well as the relationship between them by using correlation coefficient and Index of Qualitative Variation (IQV) to select suitable parameters which can be used for overall compost evaluation.

MATERIALS AND METHODS

Justification of the Proposed Evaluation Method

Sludges and biowastes are a potential source of harm to humans, animals and water bodies because they may contain potentially toxic elements (heavy metals, organic compounds, weed seeds and pathogens). During their composting process, there is a need for more investigate the evolution of the different composting parameters and toxicants as well as the relationship between them with statistical methods. This would mean that results could be better compared and there would be more consistent evaluation of the composting statement.

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 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 pile 1 comprised a mixture of municipal sludge/textile sludge/municipal greenwaste/garden greenwaste composted at ½:½:1:1 w/w ratios. The piles 2 and 3 comprised a different ratios of textile sludge/greenwaste [(1:1 v/v (Pile 2)) and 1:3 v/v (Pile 3) w/w ratios, respectively]. All 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 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

Table 1: Typical characteristics of the sludges

Properties	Textile sludge	Municipal sludge
pH	7.05	-
DM[b]	30.9	-
OM[a]	114	522
TKN[a]	2.89	38.3
TOC[a]	18.6	339
C/N	6.43	8.85
E. coli[c]	1.1×10^7	1.7×10^5

[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

nitrogen (Kjeldahl) in air-dried samples. The pH was determined with a glass electrode. Cu and Fe were analyzed by emission spectrometry-ICP (NF EN ISO 11885). The detergent contents was determined by the colorimetric method.

Statistical Analysis

In order to better understand the evolution and relationship between the different parameters, the Index of Qualitative Variation (IQV) and correlation coefficients were computed by a Wessa Statistics Software through a Fujitsu computer. Correlation coefficients were obtained to determine the relationship between various chemical, toxicological and biological properties in the composting site (each sample was considered as an individual observation). In the other hand, index of qualitative variation was used to access variation of some parameters in the composting site. IQV is maximized when all values are equally distributed during the composting process.

RESULTS AND DISCUSSION

The sludge features and the composting process had usually been characterized by reference to chemical and physical-chemical parameters (Zbytniewsk and Buszewski, 2005). Therefore, selected chemical properties of the produced composts are given in Table 2. According to the maximum permitted amounts of heavy metals in biosolid composts for their final disposal, as reported by French norm (NFU 44095), the composts obtained in this experiment was classified as excellent amendment for agricultural use because the heavy metal concentrations were lower than the maximum permitted. Mature composts contained less OM than sewage sludge because composting is a biological, aerobic process in which microorganisms utilize OM for their metabolism. During the composting period, carbon (C) compounds are lost, while more complex substances, such as humic acids, are synthesized (Riffaldi *et al*., 1992).

The comparative study of Index of Qualitative Variation (IQV) is of interest to improve understanding of the evolution of some composting parameters as well as the factors affecting them (Table 3). In the case of the OM, High (IQV) was recorded. It is well known that the organic matter decomposition is the reflection of a metabolism of microorganisms in the composting mixture and the process can effectively destroy pathogens and parasites. On the other hand, lower (IQV) was found in the case of *E. coli*. Generally, microorganisms contribute to the mineralization of organic matter compounds, but they only proliferate if water content, air circulation and nutrient availability are appropriate and these parameters changed considerably during composting (Riffaldi *et al*., 1992). Also, this demonstrates the sensitivity of microbial activity during composting (Margesin *et al*., 2006). In addition, total Fe and Cu contents had lower (IQV) (0.65 and 0.79, respectively), perhaps due to the important concentrating effect caused by the greater weight changes associated with mineralisation of the OM during the composting process (Sanchez-Mondero *et al*., 2001). The lowest (IQV) is recorded in the case of the detergent, because of the degradation of an important masses of the detergent contained in the first mixture (McAvoy *et al*., 1998).

Table 2: Typical characteristics of the mature composts

Properties	Compost 1 (pile 1)	Compost 2 (pile 2)	Compost 3 (pile 3)
pH	7.63	8.4	8.1
DM[b]	71.4	33.8	43.2
OM[a]	372	599	763
TKN[a]	18.3	21.8	22.7
TOC[a]	233	285	265.8
C/N	12.73	13.07	11.7
E. coli[c]	$\approx 10^4$	7.5×10^3	9.3×10^2

[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

Table 3: Index of Qualitative Variation (IQV) of the different features in the composting site (Pile 1)

Parameters	Index of qualitative variation
OM	0.96
C/N	0.95
N	0.99
C	0.96
E. coli	0.41
Cu	0.79
Fe	0.65
Detergent	0.24

Table 4: Correlation coefficient of the organic matter (OM) to various parameters in the composting site (Pile 1)

Parameters	Correlation coefficient
C/N	0.90*
N	0.31**
C	0.98*
Cu	-0.87*
Fe	-0.75*

*: Well correlated with the OM, **: Not well correlated with the OM

Correlation test was used to correlate the different parameters in the composting site with the OM (Table 4). With regard to the relationship between OM and C:N ratio, There was statistically positive and high correlation coefficient between them (0.90). When the first mixture is composted, generally there is decrease in C:N ratio with time due to losses of C as CO_2 (Golueke, 1981). The relationship found between OM and C:N is imporatant because there is no single parameter which can be used as a suitable indicator of maturity of a wide range of composts prepared from different materials. In fact, Hirari *et al.* (1983) stated that the C:N ratio cannot be used as an absolute indicator of compost maturity, since the values for well-composted materials present a great maturity variability, due to characteristics of the waste used. Positive low correlation was obtained between total N and OM. This relationship have been widely reported and the decrease of total N during the composting process is due to the mineralization of OM by microorganisms (Grigatti *et al.*, 2004; Laos *et al.*, 2002; Levanon and Pluda, 2002). Generally, an important part of the TN loss is by ammonia volatilization, which is favored by high temperature and pH values. This coefficient is low (0.34) because of the greater N losses during composting. (Bertran *et al.*, 2004). Furthermore, the statistically well correlation found between OM and total C demonstrates that there is a microbial consumption of the available C source (Bernal *et al.*, 1998; Laos *et al.*, 2002) and this indicates that a good degradation rate of total C during composting is of crucial importance for efficient mineralization, which in turn results in reduced C/N values and this is the reason why the determination of carbon in biomass acts as indicator for compost quality (Jedidi *et al.*, 2004). On the other hand, Fe and Cu concentrations in the mixtures were increased during the composting process, there being negative correlations between OM and theese total heavy metal contents. The correlation between the presence of organic matter and the metal contents in the composting site has been supported by a large number of researchers (Eger, 1994; Mitchell and Karathanasis, 1995; Tam and Wong, 1999). The composting process is generally marked by an increase in some metal contents due to the evident reduction of compost mass by decomposition (loss of matter) (Lazzari *et al.*, 2000).

Table 5: Correlation coefficients between detergent and composting parameters (Pile 2 and 3)

Parameters	Compost 2 (pile2)	Compost 3 (pile3)
E. coli	0.99	0.99
OM	0.81	0.76
Cu	-0.97	-0.98
Cr	-0.61	-0.73
Mn	-0.99	-0.92

The comparative study of correlation coefficients is also of interest to improve understanding of the relationship between detergent contents and some of the principal physical and chemical parameters before and during the composting process (Table 5). There was statistically positive and high correlation coefficient between *E. coli* units and detergent in the two piles 2 and 3. It has be shown in many studies that the the composting process is marked by a biodegradation of some detergent componenents during composting, allowed to a decrease in the microbial counts and that microbial activity reflects the quality of the final compost (Ishii *et al*., 2000; Ryckeboer *et al*., 2003). Also, many detergent components have been reported to be readily biodegradable by aerobic processes and the importance of microbial communities for the mineralization of detergent has been investigated in mineralization chambers (Knaebel and Vestal, 1992). With regard to the relationship between OM and detergent contents, there was statistically positive and relatively high correlation coefficient between them in pile 2 and 3 (0.81 and 0.76, respectively), but the relationship is more clear between OM and detergent in pile 1. In another study of (Okolo *et al*., 2005), degradation of OM was reported to be influenced by the incorporation of alternate detergent substrates. Other studies show correlation between the content of organic matter and detergent sorption (Fytianos *et al*., 1998; McAvoy *et al*., 1994; Painter, 1992). In addition, the relationship between detergent and OM can be explained by the sorption of OM to non polar detergent fraction and it is expected that a large fraction of detergent applied to the composting mixture with textile sludge is adsorbed to the organic matter (Schnaak *et al*., 1997). Consequently, under most environmental conditions the detergent molecule has no electrical charge and therefore interacts with compost by hydrophobic sorption to the organic fraction. However, sorption by hydrogen bonding also has been demonstrated (John *et al*., 2000). Furthermore, heavy metals concentrations in the two mixtures were increased during the composting process and the detergent contents decrease in the final compost and therefore, it is a statistically negative but clear correlation found between detergents and heavy metals (Mn and Cu). This demonstrates that there is an interaction between them which may also have influence on fate of other toxicants. DEPA (1995) reports that surfactants may be affected by different chemical and physical processes such as photolysis, hydrolysis, ionisation, oxidation/reduction, ligand exchange, sorption and biodegradation, of which sorption and biodegradation are of practical significance. It have been reported also that detergent can increase the mobility of heavy metals and other persistent organic pollutants and that this ability may be used in bio-remediation of soils polluted with heavy metals (Aronstein and Alexander, 1992). It was suggested that detergents influenced bioavailability of other (unidentified) toxic compounds of the sludge and that interaction of detergent with the toxicity of other contaminants can be therefore investigated (Jensen and Sverdrup, 2002).

CONCLUSIONS

According to the results, the OM varied in the composting site with a clear relationship with several parameters such as C and C/N. Therefore, decrease in OM can be taken in this study as a reliable index when combined with other parameters. With regard to the data obtained from the index of qualitative variation, the results showed important variations of some xenobiotics in the composting site. Furthermore, it is a clear relationship between the detergent contents in the composting site and several parameters such as OM and *E. coli*. With regard to the correlation between detergent and some heavy metals as Mn and Cu, the results showed well relationship between them. Consequently, there is a scientific basis to support the use of detergent concentration as a parameter of quality criteria of final sludge compost. All these analysis serve to highlight the need for further studies of biosolid materials before and after composting, so it will be possible to develop definitive standard procedures which can be used for overall composting evaluation. Also, It is recommended to resolved to what extend the conclusions made in this statement and other organic toxicants could be the target for attention in further statistical studies.

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