

# Chemical and spectroscopic analysis of organic matter transformation during composting of sewage sludge and green plant waste

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## Abstract

When a mixture of thick sewage sludge (10 m<sup>3</sup>) and green waste (5 m<sup>3</sup>) was composted, the thermogenic phase (72 °C) improved the hygiene of the final product. After 135 days of composting, overall decomposition reached 60%, with percentage decomposition of hemicellulose, cellulose and lignin 70%, 61% and 37%, respectively. The C/N ratio was 12 and the NH<sub>4</sub><sup>+</sup>/NO<sub>3</sub><sup>-</sup> ratio was 0.24, illustrating the maturity of the final product. During composting, the humification process resulted in an increase in humic acids from 26 to 39.5 mg g<sup>-1</sup>, and a decrease in fulvic acids from 38 to 18 mg g<sup>-1</sup>. The different humification indices and the Fourier transform infra-red (FTIR) spectroscopic analysis revealed an increase in aromaticity and degree of polycondensation, with a decrease in aliphatic groups and a reduction in the easily assimilated peptide and carbohydrate components. The germination index for both lettuce (*Lactuca sativa*) and turnip seed (*Brassica rapa*) was 98% after 135 days of composting, showing that the final compost was not phytotoxic.

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## 1. Introduction

The necessity to preserve natural resources and the optimisation of use of non-renewable energy has encouraged the recycling and recovery of organic waste as an alternative to dumping and incineration (ADEME, 1994). Among the organic waste 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. Nevertheless, direct agricultural use of sewage sludge is limited by the

presence of pathogens, by fermentation of any unstable organic matter and by the organic and inorganic pollutants it contains (Lavoie and Marchand, 1997; Dudka and Muller, 1999). To overcome the risks incurred by the direct use of this waste 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. Composting is considered to be the best pretreatment for overcoming these problems (Ouatmane et al., 2000; Amir and Hafidi, 2001), and the high temperatures reached, 50–70 °C, destroy almost all pathogens (Dumontet et al., 1999). Numerous bacteria degrade the readily available organic components or transform them into stable humic components (Garcia et al., 1992; Diaz-Burgos et al., 1994; Tuomela et al., 2000; Amir et al., 2004).

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A decrease in the content of organic pollutants and a reduction in the bio-availability of metal trace elements has also been reported during the composting of sewage sludge (Kästner and Mahro, 1996; Echab et al., 1998; Lau et al., 2003).

The success of composting is linked to the quality of the final product, especially its stability. Spreading immature or unstable compost can generate serious problems of hygiene and phytotoxicity (Déportes et al., 1995; Pascual et al., 1997). The reliability of individual indicators for the determination of compost maturity is debatable, so several parameters are often considered together. Numerous authors (Mathur et al., 1993; Ouattmane et al., 2000; Tomati et al., 2000) have suggested the use of different maturity indices (C/N ratio, humification indices, and germination indices).

The purpose of this investigation was to follow some of the physico-chemical and microbiological modifications occurring during the composting of activated sludge when mixed with fresh green plants. The evolution of compost maturity was assessed from measurement of various types of humification indices, by comparison with data obtained by Fourier transform infra-red (FTIR) spectroscopy.

## 2. Materials and methods

### 2.1. Composting

The sewage sludge used was taken from the wastewater aerobic treatment plant of Khouribga (Morocco). Thick sludge (10 m<sup>3</sup>) was mixed with fresh green plant waste (5 m<sup>3</sup>) in a pile 8 m long and 1.5 m high on a composting platform. The mixture was prepared so as to optimise the composting parameters, i.e. 60% humidity and a C/N ratio of about 30. Table 1 lists the main physico-chemical characteristics of the raw materials. With the aim of maintaining aerobic conditions during the process, the pile was turned manually every 15 days. Temperature was measured daily at a depth of 50 cm at different positions inside the pile. Samples were taken before composting ( $T_0$ ), after 15 days of composting ( $T_{15}$ ), and at  $T_{60}$ ,  $T_{90}$  and  $T_{135}$ .

### 2.2. Physico-chemical analysis

The pH of a suspension of compost in water (1:2 v:v) was measured. Total organic carbon (TOC) was determined by oxidation with potassium bichromate (Nelson and Sommers, 1982) and total nitrogen by the Kjeldahl method. Ammonium was assayed by distillation in alkaline medium, and nitrates after reduction by Dewarda alloy (Ezelin De Souza, 1998) Ash content was determined after calcination at 550 °C. Decomposition (Dec) was calculated according to the following formula

Table 1  
Physico-chemical features of the sewage sludge and green waste used for composting

Parameters	Sewage sludge	Green waste
Water (%)	55	64
pH	7.2	6
Total Kjeldahl nitrogen (g kg <sup>-1</sup> ) <sup>a</sup>	13	15
Total organic carbon (g kg <sup>-1</sup> ) <sup>a</sup>	367.5	528
C/N ratio	28.3	35.2
Ash (g kg <sup>-1</sup> ) <sup>a</sup>	312	83.3

<sup>a</sup>Results expressed g kg<sup>-1</sup> of dry matter.

(Ezelin De Souza, 1998):

$$\text{Dec}(\%) = 100 \times [(A_f - A_i)/A_f \times (100 - C_i)] \times 100,$$

where  $A_f$  is final ash and  $A_i$  is initial ash.

### 2.3. Extraction and assay of humic substances

Before extracting the humic substances, the samples (15 g fresh weight) were defatted with a chloroform:methanol mixture (2:1). After filtering, the defatted sample was evaporated under nitrogen to eliminate the solvents (Lichtfouse et al., 1998; Amir et al., 2005). The residues were extracted with distilled water three times to eliminate soluble non-humic substances (sugars, proteins) which can interact with humic substances (Amir et al., 2003). Extraction with 0.1 M NaOH (40 ml) was repeated several times until colourless solutions were obtained after centrifugation at 5000 rpm (should be as *g*). The humic substances (HS) obtained were fractionated into humic acids (HA) and fulvic acids (FA) by precipitation of HA by 1.5 M H<sub>2</sub>SO<sub>4</sub> (24 h at 4 °C), which were separated HOW? from the FA solution. Subsequently, the HA were redissolved in NaOH (0.1 M). The HA and FA solutions obtained were dialysed through a Spectra-Por membrane (1000 Da), freeze-dried, and then weighed. Different humification indices were calculated: humification ratio, HS/TOC × 100; humification index, HA/TOC × 100; percentage HA: HA/HS × 100, degree of polymerisation: HA/FA (Sanchez-Monedero et al., 1999).

### 2.4. Fibre assay

The proportion of fibre (cellulose, hemicellulose and lignin) was determined according to the method of Van Soest (1963). The reduction in lignin, cellulose and hemicellulose (organic matter loss) was calculated from the initial and final ash levels,  $A_i$  and  $A_f$  (Paredes et al., 1996)

$$\begin{aligned} \text{OM} - \text{loss} (\text{g Kg}^{-1}) \\ = (100 - 100[(A_i(100 - A_f)]/[A_f(100 - A_i)]) \times 100 \end{aligned}$$

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