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Full Length Research Paper

Revaluation of activated sludge and chicken manure through composting by aerobic process

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The activated sludge from the wastewater treatment plant (WWTP) of Tipaza, rich in plant sawdust, and chicken manure from the company Avicola, rich in nitrogenous matter, appears to be perfectly compatible for co-composting. The compost of these two biomasses gives a satisfactory result confirmed by the monitoring of the C/N ratio, a key indicator of the state of composts. Furthermore, the physicochemical parameters and spectral methods are in favor of the development of spreadable compost.

Key words: Wastewater treatment, activated sludge, composting, chicken manure, revaluation, aerobic process.

INTRODUCTION

Two problems are combined in the province of Tipaza. On one hand, the wastewater treatment (WWTP) is generating activated sludge in large quantities. On the other hand, the Avicola company, based in the municipality of Attatba (province of Tipaza) at the heart of the alluvial plain of Mitidja between Nador and Mazafran valleys, produces laying hens. It thus generates a large amount of manure, rich in nitrogen compounds. Currently, the manure was stored in open air on a permeable ground (Rivoirard, 1952). The risk of groundwater pollution by nitrates and phosphates is significant (Bouzid et al., 2013) and solving this problem by transforming the activated sludge and chicken manure into spreadable compost is the objective of this study. A two-step approach was undertaken: An analytical step based on the determination of various physicochemical parameters (temperature, pH and conductivity) and a spectral diagnosis (TFIR, UV-visible and atomic absorption) detailing the state of each component during the transformation process. An identification of the nature of the biomass, as well as the pathogens, was undertaken. The activated sludge from Tipaza WWTP, whose constitution reflects a largely agricultural environment, is rich in plant material. Whereas the manure from the poultry company (Attatba) with a diet-dependent structure, is rich in nitrogen compounds.

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Agricultural use or recycling activated sludge and chicken manure into composting helps restore minerals and organic elements into the soil. However, field application of the obtained compost must not be implemented without confirmed hygienization, stabilization and maturity. In addition, the sludge compost must be free of phytotoxicity, with concentrations of heavy metals (Cu, Zn, Cd, Hg, Cr, etc.) and soil organic micro-pollutants (phthalates, PCBs, PAHs, etc.) in compliance with current international standards. Composting is a process of controlled decomposition and transformation of organic waste under the action of diverse microbial populations (Cheung and Wong, 1983; Inbar et al., 1988; Jimenez and Garcia, 1991; Tuomela et al., 2000; Wei et al., 2000; Wang et al., 2004). It evolves both aerobically and anaerobically (Himanen and Hänninen, 2011; Yazdani et al., 2012; Neumann and Scherer, 2011). This work is based on a simple concept:

A + B = C

Activated sludge + poultry manure = Compost

First, physicochemical analysis (pH, temperature and conductivity), spectral diagnosis (UV-Visible, FTIR) of activated sludge from Tipaza WWTP were done and discussed. The process is repeated for the chicken manure of avicola (Attatba). Second, the process of composting was explored with identification of different parameters by applying spectral methods.

MATERIALS AND METHODS

Configuration of WWTP of Tipaza and Avicola Attatba

The purification station (Tipaza) is geographically located in the region of Chenoua, about 70 km west of Algiers.

In order to produce the compost, analysis and characterization of two products: (A) and (B) separately was performed. A physicochemical characterization of the product (A) (activated sludge) and spectral characterization by UV-Visible and TFIR followed by atomic absorption were carried out to obtain as much information as possible on its chemical composition. A microbiological analysis is indeed required to assess and identify the existing microbial load in the activated sludge. For the compound (B) (chicken manure) from the Avicola Company (Attatba), a physicochemical and spectral characterization by UV-Visible and TFIR facilitates estimating the composition of the manure. The compost is made up by mixing the two compounds in the same proportions, after grinding and homogenization; then degradation and maturation process of the compost was attempted aerobically.

Monitoring the composting process was performed using physicochemical parameters and spectral (UV-Visible and TFIR) and C/N ratio.

Measurements of UV-visible absorption

10 mg of the sample was taken in 100 ml of water under magnetic stirring; after filtration, the measurement were taken by means of a standard spectrophotometer (ZUZI 4201/50 model).

FTIR

Spectrophotometer (Nicolet 5700 series) on pellets made of 1 mg of product was dispersed in 300 mg of KBr.

Atomic absorption

1 g of activated sludge which was incinerated at 550°C for 2 h was taken, the ash was mixed with 5 ml of HCl (0.1 M), and up to 100 ml of distilled water was added. The sample was filtered and then passed through atomic absorption.

RESULTS

Activated sludge

Physicochemical characterization of the activated sludge

For an activated sludge rich in decomposed sawdust, a considerably high C/N ratio (191.17) attracts attention. The neutral pH (6.75) indicates not only a poor organic matter in humic substances but also in free ions with respect to the conductivity (0.3 mS/cm).

The organic matter (14.84%), as well as the mineral (26.16%), remains significant. This result (Table 1) can be explained by the presence of organic molecules of low molecular weight and neutral mineral substance. The physicochemical aspect tends to be a non-spreadable activated sludge due to its poor nitrogen content.

This section focuses on the characterization of heavy metals of crude activated sludge from the purification station (Tipaza). The limit values are also presented (Table 2) according to the NFU 44-095 standard, an important precautionary measure for a potential application of the activated sludge. The analysis by flame atomic absorption of a sample of the raw sludge after incineration at 550 and 750°C for 2 h gives satisfactory results. Indeed, as agriculture is the main activity in the region, the 17 analyzed elements met the standards, some of them are Pb, Cr, Cd, and Co. The amount of these risk elements were acceptable.

Scanning by UV-visible spectroscopy of the untreated raw sludge shows an absorption peak at 210 nm (Figure 1). This reflects an abundance of relatively light molecular weight chromophore; the result is confirmed by the measurements of organic matter.

Microbiological characterization of activated sludge

The microbiological analysis, after sampling and specific identification of pathogenic germs (Figure 2), shows a highly contaminated activated sludge (10^4-10^6) as compared to the standard of the European Commission

Table 1. Physicochemical parameters of the activated sludge and chicken manure.

Parameter	Values	
	Activated sludge	Chicken manure
pH	6.75	7.50
Temperature (°C)	22	20
Conductivity (mS/cm)	0.3	3.50
Water content (%)	59	29
Organic matter (%)	14.84	59.08
Mineral matter (%)	26.16	11.92
Organic carbon (% of MS)	39	18.35
Nitrogen (% of MS)	0.204	1.183
C/N	191.17	15.51

Table 2. Concentrations of metals in the activated sludge.

Elements	Activated sludge at 550 (°C)	Activated sludge at 750 (°C)
K	3.5447	3.7997
Na	2.2355	3.9063
Mg	2.0348	4.1852
Pb	0.0613	0.0150
Zn	0.1196	0.0894
Cu	0.0109	0.0894
Cr	0.6544	0.7965
Sn	Traces	Traces
Cd	Traces	Traces
Ni	Traces	Traces
Al	Traces	Traces
Ag	0.0088	0.0022
Se	2.0612	2.4410
As	0.2873	0.3424
Sb	Traces	Traces
Ca	23.8960	47.1355
Co	0.2961	0.3099

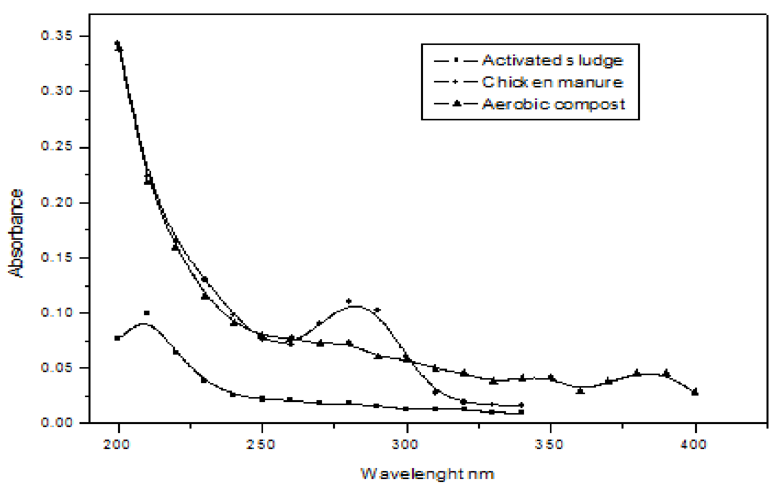

Figure 1. UV-Visible spectrum of product.

Total aerobic mesophilic flora

Yeasts and molds

Staphylococcus aureus

Highlighting of the growth of CSR

Figure 2. Microbiological study of activated sludge.

(EC 2001) which established an update of pathogens in wet activated sludge of the urban sewage sludge with an order of magnitude in the range (10^2-10^4).

The C/N ratio is an indicator for assessing the degree of evolution of the organic matter, that is, its ability to break down more or less easily in the soil. It is commonly accepted that the higher the C/N ratio of a product (C/N = raw sludge, 191.17), the slower it breaks down into the soil, but the more stable is the humus (Inbar et al., 1992). To produce compost in optimal conditions, that is, C/N in the range, 20-30 (Inbar et al., 1992; Chien et al., 2003), the chicken manure from the company Avicola (Tipaza) was introduced.

Chicken manure

Physicochemical characterization of the chicken manure

Carbon, as well as nitrogen, in chicken manure (Table 1) shows richness in organic matter and nitrogen. This implies a suitable C/N ratio (15:51). Moreover, the literature reports 15 <C/N <20: nitrogen cover needed to allow proper decomposition of carbonaceous matter (Jimenez and Garcia, 1991; Bernal et al., 2009). A pH of 7.5 is neutral and a relatively high conductivity clearly demonstrates a lot of free ions. This type of green waste compound is a valuable complement to the development of the activated sludge in question and can give a suitable compost.

The analysis by UV-visible of chicken manure (Figure 1) supports the physicochemical results. Indeed, scanning the manure between 200 and 340 nm shows a characteristic absorption of amino acids and proteins, which involves a significant contribution to nitrogen.

Aerobic compost

The C/N ratio is a key factor in the physicochemical and microbiological soil dynamics. The ideal C/N for spreading lies in the range, 20-30 (Wei et al., 2000; Wang et al., 2004; Himanen and Hänninen, 2011; Inbar et al., 1992; Das et al., 2002), the compost shows a positive trend in this direction. The empirical calculation was done with:

C/N = 191.17 activated sludge gross

C/N = 15.51 poultry manure gross

C/N of the mixture = R_m

$$R_m = (n_1 + n_2 * R_1 * R_2) / (n_1 + n_2)$$

$$R_m = 103.34$$

Where R_m is the C/N average, n_1 and n_2 are the respective quantities of components and R_1 and R_2 the C/N ratio of these components.

The following C/N ratios of the mixture as a function of time (Table 3) shows a C/N of 31 to 28 days, significant value regarding the maturity of compost.

The UV-visible spectrum shows, in terms of appropriate dilution, a characteristic spectrum of composts (Figure 1). Indeed, a shoulder from 260 to 280 nm which corresponds to a rich biodiversity (DNA, RNA, proteins and amino acids) and a series of absorbance 340-390, reveal probably a significant presence of humic substances in small sizes.

The spectroscopic study by FTIR of the compost (Figure 3) shows bands (3300-3400 cm^{-1}) characteristic of OH groups: alcohols, phenols and acids, which may also be associated with the OH group. The 2924 peak (2920-2930 cm^{-1}) indicates the presence of alkyl structures (CH) while the 1647 peak (1630-1650 cm^{-1}) is produced by the aromatic C=C and C=O in amides (ketone and quinone). The absorbance between 1540-1550 cm^{-1} corresponds to the amide II, whereas the peaks in 1385, 1419 and 1456 (1460 to 1380 cm^{-1}) correspond to several chemical groups (CH_3, phenolic OH, COO^-). Furthermore, the peak at 1241 (1265-1223 cm^{-1}) is produced by the amides and ethers whilst the absorption 932, 1021 and 1078 (1120-980 cm^{-1}) characterize the aromatic ethers; It should be noted that carbohydrates and silicates are absorb in this area. In conclusion three intensities remain characteristic: 3400,

Table 3. Physicochemical parameters of compost.

Time (days)	8	12	16	20	24	28
pH	8.9	8.8	8.1	8.1	8.2	8.8
Temperature (°C)	25	20	26	23	24	25
Conductivity (mS/s)	2.9	1.4	2.0	2.6	3.4	3.8
Water content (%)	22.3	19.4	15.2	13.5	12.0	10.9
Organic matter (%)	44.7	41.7	39.8	45.7	48.0	51.3
Mineral matter (%)	32.9	38.8	44.9	40.7	39.8	37.6
Organic carbon	30.7	30.1	29.0	28.7	28.5	28
Nitrogen	0.65	0.71	0.75	0.77	0.80	0.90
C/N	47.24	42.4	38.7	37.3	35.6	31.1

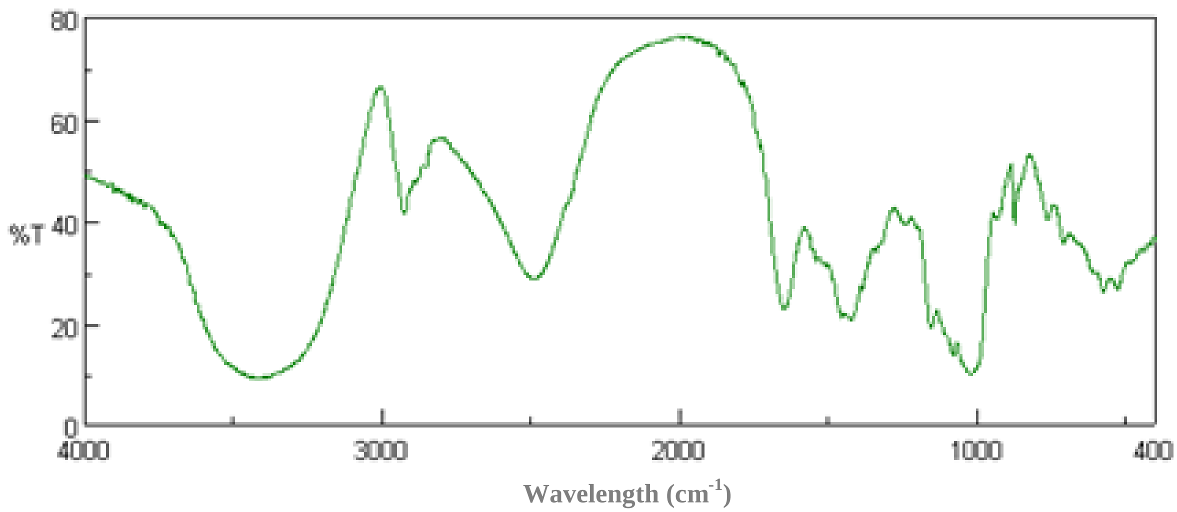

Figure 3. Infrared spectra of aerobic compost.

1620 and 1034 cm^{-1}. The first corresponds to the band OH (OH---OH---OH) and/or NH, the second corresponds to aromatics, and finally the third corresponds to the ether C---O---C. These characteristics confirm the presence of humic substances polymerized by oxidation. The interpretation of the spectrum FTIR is confirmed by NMR study which demonstrated C^{13} aliphatic, aromatic and carboxylic groups in humic substances (Tuomela et al., 2000; Inbar et al., 1992; Chien et al., 2003; Zbytniewski and Buszewski, 2005; Bernal et al., 1998).

DISCUSSION

The reclamation of the activated sludge from Tipaza WWTP as a product with low nitrogen substance is favorable to the nitrogen-rich chicken manure matter. The evolution of composting followed by physicochemical and spectral analysis exhibits enrichment in humic substances, nitrogenous matter and also provides evidence for the maturation of the compost after 28 days. Our analysis is mainly based on the C/N factor. From the literature: C/N <15: with production of nitrogen, the decomposition rate increases; it is at its maximum for a C/N = 10 (15 <C/N <20): Requirement for covered nitrogen to allow proper decomposition of the carbonaceous matter is C/N>20. Insufficient nitrogen allows decomposition of carbon (there is competition between the absorption by plants and the reorganization of the organic matter by soil microorganisms, a phenomenon of "nitrogen starvation") (Jimenez and Garcia, 1991; Laor et al., 2004; Boulter-Bitzer et al., 2006). The nitrogen is then taken from the soil reserves. The mineralization is slow and renders to the soil only a small amount of mineral nitrogen. For the compost to mature in optimal conditions, the carbon/nitrogen ratio (C/N) should be between 15 and 30. Indeed, if the mixture to compost is too low in nitrogen, it will not heat up (no degradation) (Lasaridi et al., 2006; Chikae et al., 2007). Conversely, if the proportion of nitrogen is too high, the compost can overheat and kill microorganisms of the compost (Laor et al., 2004; Deportes et al., 1995) and therefore, efforts should be made to balance the inputs. Spectral methods have been the foundation of our understanding. Indeed, UV-visible of the compost shows specific absorptions not only to organic products (protein and amino acids), but also to nucleic acids, while TFIR reveals humic substances. In addition, physicochemical methods (changes in temperature, pH and conductivity) translate the motion of the biomass and its evolution into quality compost.

Conclusions

The compost made up of activated sludge and chicken manure, and evaluated by physicochemical analysis and spectral parameters, yielded a satisfactory result with an ideal C/N for spreading. Both biomasses appear consistent and confirm an advancement in agreement with reported literature. In addition, our microbiological analysis identified pathogens, which may be neutralized by an increased temperature in the biomass. Moreover, the normalization of heavy metals in the activated sludge and the richness of the chicken manure in nitrogen can bring down the recycling output to acceptable levels. The compost obtained by aerobic process (C/N = 31.1) is hence spreadable.

Conflict of Interests

The authors have not declared any conflict of interests.

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