The Agronomic Value of The Sewage Sludge of Tenerife. Composting

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ABSTRACT

One of the most effective ways of recycling the organic and mineral fractions of sludge from the treatment of domestic wastewater is to compost the sludge with the organic fraction of domestic refuse. In the present study, a compost on a semi-industrial scale was obtained from a mixture of domestic refuse and sewage sludge. The evolution of the different parameters throughout the process was noted and the most interesting physico-chemical characteristics from an agricultural point of view determined. The compost, because of its high percentage of total organic matter (43.62%), its relatively high N, P, K, Ca and Mg contents (2.82%, 1.25%, 1.63%, 5.16%, and 1.07%, respectively), its balanced oligoelement levels and low content of non-essential heavy metals, can be considered, in principle, a good organic fertilizer with possibilities for use in the agriculture of the island of Tenerife.

INTRODUCTION

At present, the three most important systems of utilizing sewage sludge from the sewage stations are direct use in agriculture after sterilization, incineration with recovery of energy and composting. There are other systems in the investigative stage such as gasification, pyrolysis, production of combustible briquettes, production of proteins for animal feed, etc.
One of the most effective ways of recycling the organic and mineral contents of this sludge is to compost it with the organic fraction of solid domestic waste (Paris, 1977). Composting dilutes the concentration of heavy metals (usually high in sludge) (Wiley & Spinalle, 1962) and the serious dangers of biological contamination in applying ineffectively sterilized sewage to agricultural land are avoided (Maistre, 1964).

The aim of the present study was to obtain a compost on a semi-industrial scale from a mixture of domestic refuse and sewage sludge, following the evolution of the different parameters throughout the aerobic thermophilic composting process, and to determine the most interesting physico-chemical characteristics from the agricultural point of view.

METHODS

Composting system

The composting procedure followed was similar to that used by Kehren (1967), the simplest and least expensive system, adapted to warm countries such as the Canary Islands. This trial was carried out between February and August with 75 days of fermentation and 90 days of complementary maturation.

The inert (metals, glass, etc.) and combustible fractions of the three which form the domestic refuse were separated manually. The plastics, rubber, textiles and leather were removed from the combustible fraction, leaving paper only. The mixture of the total fermentable fraction plus the paper constituted the material of the domestic refuse to be composted. This mixture weighed 856 kg (44.11% moisture) to which were added 375 kg of sludge (17.80% moisture). The sewage sludge was aerobic sludge from an activated sludge plant, dewatered on drying beds. The compost heap had the dimensions 3 m long × 2 m wide × 1 m high.

Evolution of temperature, moisture and aeration

During the process of composting organic solid wastes there are three fundamental parameters to be controlled—temperature, moisture and aeration (Gray et al., 1971; Poincelot, 1975).

The temperature evolution was followed at 10 cm (surface) and 50 cm
<table>
<thead>
<tr>
<th>Days</th>
<th>pH</th>
<th>EC (μmhos cm⁻¹)</th>
<th>$Ca^{++}$</th>
<th>$Mg^{++}$</th>
<th>$Na^{+}$</th>
<th>$K^{+}$</th>
<th>$CO_3^{2-}$</th>
<th>$HCO_3^-$</th>
<th>$Cl^-$</th>
<th>$NH_3$</th>
<th>$NO_3^-$</th>
<th>$P_2O_5$</th>
<th>$Fe$</th>
<th>$Cu$</th>
<th>$Mn$</th>
<th>$Zn$</th>
</tr>
</thead>
<tbody>
<tr>
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<td>7.1</td>
<td>1350</td>
<td>1.28</td>
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<td>9.13</td>
<td>0.81</td>
<td>0.00</td>
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<td>6.08</td>
<td>40</td>
<td>17</td>
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<td>0.14</td>
<td>0.04</td>
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<tr>
<td>15</td>
<td>7.3</td>
<td>1250</td>
<td>0.76</td>
<td>1.80</td>
<td>9.26</td>
<td>0.77</td>
<td>0.00</td>
<td>7.72</td>
<td>2.26</td>
<td>38</td>
<td>19</td>
<td>36</td>
<td>0.17</td>
<td>0.06</td>
<td>0.03</td>
<td>0.06</td>
</tr>
<tr>
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<td>7.7</td>
<td>1250</td>
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<td>1.76</td>
<td>9.00</td>
<td>0.78</td>
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<td>6.88</td>
<td>4.48</td>
<td>39</td>
<td>20</td>
<td>31</td>
<td>0.15</td>
<td>0.02</td>
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<tr>
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<td>7.2</td>
<td>1350</td>
<td>1.16</td>
<td>2.08</td>
<td>9.47</td>
<td>0.82</td>
<td>0.00</td>
<td>6.56</td>
<td>6.36</td>
<td>41</td>
<td>22</td>
<td>35</td>
<td>0.18</td>
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<td>1.60</td>
<td>10.00</td>
<td>0.76</td>
<td>0.00</td>
<td>4.46</td>
<td>8.88</td>
<td>36</td>
<td>20</td>
<td>31</td>
<td>0.19</td>
<td>0.03</td>
<td>0.07</td>
<td>0.04</td>
</tr>
<tr>
<td>63</td>
<td>6.9</td>
<td>1200</td>
<td>0.48</td>
<td>2.24</td>
<td>9.56</td>
<td>0.77</td>
<td>0.00</td>
<td>5.84</td>
<td>6.40</td>
<td>39</td>
<td>18</td>
<td>32</td>
<td>0.21</td>
<td>0.04</td>
<td>0.05</td>
<td>0.06</td>
</tr>
</tbody>
</table>
(centre of heap). Each reading is the average of four measurements taken at symmetrical locations at each level with a digital thermometer probe, the readings being taken every 3 days until the temperature stabilized at around 30°C.

Moisture was maintained, during the whole of the fermentation phase, between the limits of 40% and 60% considered optimum (Spohn, 1978). To control these levels, tensiometers, placed at depths of 10 and 50 cm, were used. In addition, we followed the criterion of Golueke (1972) who recommends that moisture determinations should be taken periodically in samples during composting because of the lack of uniformity in unenclosed heaps. To damp the pile, treated wastewater was used following the indications of certain authors that this water helps to enrich the final product and offset, in part, N losses through volatilization of NH₃ during composting (Cárdenas & Wang, 1980). Table 1 shows the physico-chemical composition of the water used during the process. The analyses were carried out at intervals of 12 days.

The determination of the chemical oxygen demand is the best system for directly determining the oxygen consumption in a compost heap. Nevertheless, in practice, aeration, or turning over, is carried out when the temperature of the mass exceeds 70°C and the humidity is above 60%, or when bad smells, a clear symptom of anaerobiosis, are noticed (Poincelot, 1974). Normally, 6 weeks of composting, with six to eight turnings over, are considered enough to ensure an adequate oxygen supply (Kochtitzky et al., 1969). This is the criterion followed in this work, the turning over carried out being shown in Fig. 1.

Analytical determinations

During the composting process a series of samples was collected at 10, 18, 25, 34, 46, 62, 75 and 165 days. Each sample (3 kg) was from eight subsamples. In a fraction of approximately 1 kg the moisture was determined (Wiley & Spinalle, 1956) and the remainder dried in the open air and later ground in a hammer mill with a 1 mm mesh and analysed as follows:

pH and EC: Compost–water suspension (1:5).
Ash: Incineration at 480°C for 4 h.
C and organic matter (total): carmograph 12-H Omega.
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The organic matter concentration was calculated from \( C \times 1.724 \).

Humic and fulvic acids: Extraction according to the method of Kononova (1982) determined as total C.

N: Kjeldahl method.

Ca, Mg, Na, K and total P: Digestion by the dry ash method (480 °C for 4 h) and dissolution of the ash in 6N HCl, the cations being determined by atomic absorption spectrophotometry and P by the vanadate–molybdate method.

P, K available: P by extraction by the Olsen method and determination by colorimetry. K by extraction with NH\(_4\)Ac \( \text{pH} 7(1:5) \) and determination by atomic absorption spectrophotometry.

Fe, Cu, Mn, Zn, Pb, Co, Ni and Cd: Digestion by means of aqua regia according to the extraction method recommended by the FAO (1979) and determination by atomic absorption spectrophotometry.

**RESULTS AND DISCUSSION**

**Yield**

At the end of 165 days of composting, 265 kg (dry weight) were obtained, being equivalent to 32.72% of the initial weight of the heap. The large
weight loss indicates a highly effective process. Poincelot (1975) noted weight losses of the order of 26 % in 34 days of fermentation in heaps and 40 % in the laboratory.

**Temperature evolution**

Temperature evolution in compost heaps is a reflection of microbial activity. The optimum level should be between 60 °C and 71 °C (Schulze, 1961) and be maintained between these limits for several days to destroy pathogens and encourage the development of thermophilic microorganisms, mainly fungi and thermophilic actinomycetes (Finstein & Morris, 1975). Moreover, temperature is a good indicator of the degree of maturity of the compost which may be considered at its optimum degree of maturity when the temperature remains more or less constant and does not vary with the turning of the material (Stickelberger, 1975).

Figure 1 shows the temperature evolution during the bio-oxidation phase of the composting process. During the whole process the temperature, measured at a depth of 10 cm, is always higher than that at 50 cm. This finding agrees with that of Clairon et al. (1982) and is to be explained by a more intense aeration of the upper layers of the heap. A temperature increase of 61 °C on the surface and 54 °C in the centre is noted after 24 h, reaching 70 °C after 48 h of composting both on the surface and in the centre. The maximum value reached was 78 °C, but generally it stayed around 70 °C until about day 34. From that time, a slow decrease is noted until stabilization at 30 °C on the 75th day of composting. The mesophilic phase is therefore 20 days. The process is highly effective due to the long maintenance of the thermophilic phase and the later slow development of the mesophilic phase. The temperature is high enough to destroy, in only a few hours, all the pathogenic microorganisms, parasite larvae, etc., present in urban wastes and sewage sludge, a list of which is published by Cárdenas & Wang (1980), as well as spores and vegetable seeds (Mesnil & Baguenier, 1967).

**Evolution of physico-chemical characteristics**

Table 2 sets out the evolution of the physico-chemical characteristics of the material during composting and the relative changes in the content of the different elements from the first samples taken to the 165th day of composting.
TABLE 2
Evolution of the Physico-chemical Characteristics During Composting of Domestic Refuse Sewage Sludge

<table>
<thead>
<tr>
<th>Days</th>
<th>pH Ext. 1:5</th>
<th>EC (mmhos cm⁻¹)</th>
<th>Moisture</th>
<th>Ash</th>
<th>Total N</th>
<th>Total C</th>
<th>Oxid. C 150°</th>
<th>Total Ca</th>
<th>Total Mg</th>
<th>Total K</th>
<th>Avail. K</th>
<th>Total P (ppm)</th>
<th>C/N</th>
<th>Total P × 100</th>
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<tbody>
<tr>
<td>10</td>
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<td>33.4</td>
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<td>3.54</td>
<td>0.73</td>
<td>1.28</td>
<td>1.22</td>
<td>0.73</td>
<td>1460</td>
<td>20.00</td>
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<tr>
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<td>8.3</td>
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<td>37.13</td>
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<td>0.72</td>
<td>1.33</td>
<td>1.23</td>
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<td>3.71</td>
<td>0.82</td>
<td>1.61</td>
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<td>0.76</td>
<td>2200</td>
<td>28.90</td>
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<td>4.42</td>
<td>0.90</td>
<td>1.78</td>
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<td>0.81</td>
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<td>45.5</td>
<td>49.88</td>
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<td>1.73</td>
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<td>2160</td>
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</table>

Maturity (50 days)

<table>
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<tr>
<th>Days</th>
<th>pH</th>
<th>EC (mmhos cm⁻¹)</th>
<th>Moisture</th>
<th>Ash</th>
<th>Total N</th>
<th>Total C</th>
<th>Oxid. C 150°</th>
<th>Total Ca</th>
<th>Total Mg</th>
<th>Total K</th>
<th>Avail. K</th>
<th>Total P (ppm)</th>
<th>C/N</th>
<th>Total P × 100</th>
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<td>27.7</td>
<td>56.37</td>
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<td>25.30</td>
<td>21.66</td>
<td>5.16</td>
<td>1.07</td>
<td>1.63</td>
<td>1.60</td>
<td>1.25</td>
<td>1680</td>
<td>13.44</td>
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</table>

Final %

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<th>Moisture</th>
<th>Ash</th>
<th>Total N</th>
<th>Total C</th>
<th>Oxid. C 150°</th>
<th>Total Ca</th>
<th>Total Mg</th>
<th>Total K</th>
<th>Avail. K</th>
<th>Total P (ppm)</th>
<th>C/N</th>
<th>Total P × 100</th>
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</thead>
<tbody>
<tr>
<td>80</td>
<td>67</td>
<td>45.5</td>
<td>37.27</td>
<td>3.58</td>
<td>33.31</td>
<td>33.06</td>
<td>3.71</td>
<td>0.82</td>
<td>1.61</td>
<td>1.53</td>
<td>0.76</td>
</tr>
</tbody>
</table>

Initial %
Moisture, pH and EC

The moisture content in all samples taken throughout the process confirms that the control system was correct since it remained between 40% and 60%.

During composting pH always remained at values between 6.7 and 7.5, finally reaching a level of 7.1 which is considered normal in this type of product if composting development has been optimum (Gray et al., 1971).

An EC increase is noted throughout the process due, in part, to the concentration of salts through weight loss in the heap. One of the causes of this EC increase might have been the salts carried by the wastewater used, since it contained relatively high levels of soluble salts (mainly Na⁺, \( \text{CO}_3^- \), \( \text{HCO}_3^- \) and \( \text{Cl}^- \)) (Table 1). Nevertheless, the effect was minimal; thus, in the case of Na⁺, the calculated supply throughout the process was of the order of 45g which represents 1.65% of the Na total of the compost. In the case of K, Ca and Mg the supply is even smaller—0.15%, 0.03% and 0.18%, respectively.

Carbon, C/N ratio

During composting, losses of total and oxidizable C are noted, giving a progressive decrease of the C/N ratio, as the N levels do not vary much. There was a loss of 33.1% of total C in relation to the first sample. An important aspect is the fact that the percentage of oxidizable C in all the samples analyzed is only slightly below the total C, which indicates that practically all the C is in the oxidizable form, due mainly to the initial cleaning of the material to be fermented from resistant fractions, mostly plastics. Juste (1980) indicates that only 1% to 15% of the C content of plastics is destroyed by chemical oxidants such as potassium dichromate.

The organic matter contents, total and oxidizable, obtained in the final compost were 43.62% and 37.34% (C x 1.724), respectively. The high levels reached can make this product an important source of humus for island soils.

The C/N ratio, together with temperature evolution, is a good parameter of fermentation development (Poincelot, 1975). In the heap a slow decrease of this ratio is noted until it stabilizes, without appreciable variations, about the 34th day, no marked variations occurring during the 90 complementary maturation days, with a value of 8.97 at the end of the process. Thus, a compost is considered mature enough when the C/N ratio stabilizes at a value below 20, preferably of the order of 15 or less,
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with 180 days of composting (Juste, 1980). Some authors, however, point out that this is not an absolute criterion of maturity and propose alternative methods: Chromatography (Inoko, 1979), cation exchange capacity (Harada & Inoko, 1980), etc. In our case we consider that the compost obtained reached an acceptable degree of maturity, as shown by the final C/N ratio, the stabilization of temperature, the humic acids (13.59%) and fulvic acids (3.26%) contents and the Fulvic acids/Humic acids ratio (0.24) in the 165 days of composting.

Nutrients

A relative increase in the P, K, Ca and Mg concentrations is observed, varying from 1.27 for K to 1.71 for P, which is explained by weight losses in the heap. These variations do not occur in the case of N, which indicates a loss of this element through volatilization during composting, due mainly to the low C/N ratio of the initial product.

A slight increase in the P available/P total × 100 ratio occurs during the fermenting period, a finding which contradicts the results of Snell (1954) in the composting of domestic refuse without sewage sludge. Snell noted a decrease in inorganic P because the developing cells of microorganisms continually assimilate the inorganic P present and incorporate it into their organic structures whereas, in our case, the observed increase could be explained by the presence of excess inorganic P in the initial material, supplied mainly by the sludge, since, normally, the inorganic P content of this sludge can reach values of up to 85% of total P (Sommers, 1977). In our case this percentage was 51.1%.

In all the samples analysed throughout the process practically all the total K is in the available form.

With regard to the water used in wetting the heap, the nutrient amounts

| TABLE 3
Content of Microelements and Non-essential Heavy Metals of the Compost |
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>ppm (dry matter)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fe</td>
<td>31976</td>
<td>Pb</td>
</tr>
<tr>
<td>Cu</td>
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<td>Co</td>
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<td>Ni</td>
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<tr>
<td>Zn</td>
<td>619</td>
<td>Cd</td>
</tr>
</tbody>
</table>
entailed in this supply were not significantly important, since they represent only 0.10% N, 0.09% P and 0.15% K of the total of these elements in the compost obtained (Table 1).

The oligoelement levels of the compost obtained (Table 3), although of relatively high content, do not exceed those usually quoted in the literature, with the exception of Fe which is in the same range as that indicated by Clairon et al. (1982). With regard to non-essential heavy metals, it should be pointed out that the levels found do not exceed the limits laid down by current legislation in European countries and the USA for the direct use of sewage sludge in agriculture (Rodriguez Ruiz, 1982), with the exception of Pb which exceeds the 300 ppm allowed as a maximum in Norway and Sweden.

CONCLUSIONS

The compost obtained from the composting of domestic waste and sludge from the Tenerife sewage station, because of the high percentage of organic matter rich in humus, its relatively high content of the fertilizer elements N, P and K, and its balanced oligoelement levels, can be considered, in principle, a good organic fertilizer with possibilities for use in agriculture in Tenerife.

This process can also constitute an effective method of recycling as there is no risk of contamination of the final product by non-essential heavy metals. The use of treated wastewater for wetting the compost heap is also advisable, as, although it does not provide a significant increase of nutrients, neither does it affect the EC of the final product, and can represent a great saving of drinking water in the composting process on an industrial scale, especially in countries with a serious water shortage, such as the Canaries.

ACKNOWLEDGEMENTS

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REFERENCES


