Alleviation of the Environmental Impact of Solid Wastes through Compost

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COMPOSTING the solid waste materials are an alternative trail to alleviate the negative impact of its accumulation and/or avoid the environmental pollution happened as a result of the wild burning, the traditional method followed to dispose off these annoying residues.

As well known rice is the major summer season crop in Egyptian crop rotation. There is an environmental problem resulted from the direct burning of rice straw (RC) at the field after harvesting the crop as an ancient and traditional method followed by the farmers to get of the agricultural residues to prepare the soil for the winter season crop. A plenty of black smoke evolves into the air as a result of burning almost all the quantity of rice straw (3.2 million tons yearly) within few weeks causing the black cloud phenomenon.

On the other hand, municipal solid waste (MSW) in Egypt could be reached 12.775 million ton a year for population of 70 million. The organic fraction of this quantity almost reached to 60% (7.665 million ton yearly). In all cases, these large quantities of MSW accumulate in different sites and destroy the surrounded environment although it is a renewable resource for plant nutrients.

The data exhibited that temperature degrees were varied (between 31 and 61°C) up to the phase of decomposition and so moisture content. Electrical conductivity, total soluble salts and cation exchange capacity increased gradually during the composting course, whereas pH, C% OM % and C/N ratio decreased for both RS and MSW. Total macro-, micro-nutrients and heavy metals increased gradually during the composting course. Macronutrients (N, P and K) percentage of RSC was higher than that of MSWC, whereas micronutrients (Cu, Fe, Mn and Zn mg kg⁻¹) and heavy metals (Cd, Ni and Pb mg kg⁻¹) content of MSWC were higher compared to RSC. The two windrows (RS and MSW) were characterized by a heavy population of biological mass which their numbers being higher in MSW compared to those of RS. In mature compost, the existence of mesophilic and thermophilic bacteria were maintained in abundance followed by aerobic cellulose decomposers, total actinomycetes and total fungi in descending order.
These composted materials could be replacing a great portion of chemical fertilizers in case of using it in bio-organic farming system.

Keywords: Compost, Organic wastes, Organic Manure, Environment.

Composting the solid waste materials are an alternative trail to alleviate the negative impact of its accumulation and/or avoid the environmental pollution happened as a result of the wild burning, the traditional method followed to dispose off these annoying residues.

As well known rice is the major summer season crop in Egyptian crop rotation. There are seven governorates (Kafr El-Shiekh, Dakahlia, Bheira, Sharkia, Gharbia, Domitta and Fayom) growing rice with a large area (around 1.41 million feddan. Rice Research & Training, ARC, 2005). There is an environmental problem resulted from the direct burning of rice straw at the field after harvesting the crop as an ancient and traditional method followed by the farmers to get of the agricultural residues to prepare the soil for the winter season crop. A plenty of black smoke evolves into the air as a result of burning almost all the quantity of rice straw (3.2 million tons yearly, Ibrahim, 2006) within few weeks causing the black cloud phenomenon.

On the other hand, municipal solid waste (MSW) in Egypt could be reached 12.775 million ton a year for population of 70 million (daily generation = 0.5 kg per capi as reported by World Health Organization (Jaramillo, 2003). The organic fraction of this quantity almost reached to 60% (7.665 million ton yearly). In all cases, these large quantities of MSW accumulate in different sites and destroy the surrounded environment although it is a renewable resource for plant nutrients. Composting these materials could be replacing a great portion of chemical fertilizers in case of using it in bio-organic farming system.

Composting is considered a biological process in which microorganisms convert organic residues into soil-like material called compost. It is the same process that decay; leaves and other organic debris in nature under controlled conditions (OTT, 1986). At the same time, it contributes in the control of plant and animal diseases, flies, and weeds (Barrington et al., 2003).

Golueke (1972) reported windrows composting is a commonly used processing method. The microbial decomposition of organic wastes is controlled by environmental factors affecting microbial activity within the windrow piles. These factors affecting composting and directly influence the rate of decomposition, are particle size Mathur et al. (1993), moisture content Suehara et al. (1999); aeration Karl et al. (1994); temperature Raabe (2001); C/N ratio Diaz et al. (1993) and pH Rynk et al. (1992). Therefore, intensive management of the composting process by turning and moisture addition is likely to affect the N fertilizer value of the mature compost.
Different communities of microorganisms predominate during the various composting phases. Initial decomposition is carried out by mesophilic microorganisms, which rapidly breakdown the soluble, readily degradable compounds. The heat they produce causes the compost temperature to rapidly rise. As the temperature rises above 40°C, the mesophilic microorganisms become less competitive and are replaced by others that are thermophilic. At temperatures of 55°C and above, many microorganisms that are human or plant pathogens are destroyed. During the thermophilic phase, high temperature accelerates the breakdown of proteins, fats, and complex carbohydrates like cellulose and hemicellulose, that are the major structural molecules in plants. As the supply of these high-energy compounds becomes exhausted, the compost temperature gradually decreases and mesophilic microorganisms once again take over for the final phase of maturation of the remaining organic matter (Holmer et al., 1997). The decomposition process is accomplished by various microorganisms including bacteria, actinomycetes and fungi (Rynk et al., 1992).

Microbial inoculation of compostable material could allow the inoculated microorganisms (Streptomyces aureofaciens, Trichoderma viridie, T. harzianum, Bacillus subtilis, B. licheniformis) to dominate over the indigenous microbiota and successfully develop appropriate degradation (Badr El Din et al., 2000).

**Material and Methods**

**Windrows preparation**

Using windrows system, two piles were built up from rice straw (RS) mechanically chopped to 3-5 cm and the other from the organic fraction of municipal solid waste (MSW) at Kafr El-Shiekh Solid Waste Recycling Factory. The piles were treated with farmyard manure (10 % w/w) as organic activator and also with certain microorganisms (Streptomyces aureofaciens, Trichoderma harzianum and Trichoderma resi) as biological activator. The inoculation by the chosen microorganisms was done by spreading a proper volume of a liquid culture of these organisms on the surface of the residues and then moistened with water.

Three tons, of each material RS and MSW, were used in three portions. The first portion was scattered over the area (11 m²), followed by addition of farmyard manure and moistened with water. The moisture was considered satisfactory when a handful of material would wet the hand but not drip (about 60-70% WHC). The material then thoroughly tamped. The first layer of about 40 cm height was then built. The other tow layers were built over the first layer following the same manner and left for composting three months. The piles were moistened with water 2-3 times weekly and were turned twice after 30 and 60 days. Water was added to obtain suitable moisture which progressively decreased until maturity (15-20%).

Temperature observation of the piles was scored every week under surface and at the center using a mercury thermometer. Representative samples of...
surface and the central parts of the piles were taken manually after 0, 30, 60 and 90 days, mixed thoroughly and examined chemically for EC (Chen et al., 1988), OC% (AOAC, 1970), TSS, pH, CEC, OM%, C/N ratio and total N by Kjeldahl method according to (Page et al., 1982), P (Schouwenbury Van & Walingeb, 1967), K (Jackson, 1973), Cu, Fe, Mn, Zn, Cd, Ni and Pb (Cottenie et al., 1982) and also analyzed microbiologically for total bacterial count and spore-formers (Difco, 1976), total fungi and aerobic cellulose decomposers (Allen, 1953) and total actinomycetes (Szabo, 1974).

Results and Discussion

Temperature

Changes in the temperature degree in the two windrows RS and MSW during time of compost processing are shown in Table 1. It was observed that, there were three increases in temperature degrees of windrows. The first one took place at 1\textsuperscript{st} week of composting. These sharp increases could be deduced to the high proliferation of microorganisms community which perform with progressively breakdown to the easily biodegradable compounds that maintained in waste materials at the early beginning of composting. On the other hand, presence of easily decomposable component will result in high multiplication of microbial population. Meanwhile, the second and the third increases scored after the first and the second turnings of windrows were also expected because of the outer surface of the two windrows still contains raw undecomposed materials. Since the windrows constructed in summer season, started from June to August, that time the weather is hot and water loss is quite fast, then, the moisture content is not enough to start the biodegradation process at pile's surface. After turning, these materials become inside the windrows and immediately subject to the microbial action once again. On the other hand, the microbial population inside the windrows adversely affected with the increase in temperature during the thermophilic phase, turning is also enriching again the windrows with large load of different mesophilic microbes. This is why the temperature tends to increase after turning.

Three classic phases of temperature were proposed by Zhu (2007), heating phase, thermophilic phase and cooling phase. During the heating phase the mesophilic microorganisms in the wastes tends to increase temperature as a result of readily biodegradable organic compounds. During the thermophilic phase, the temperature exceeded the tolerance limit of the mesophilic microorganisms and promoted the development of the thermophilic microorganisms, while the decrease in temperature at the cooling phase deduced to the depletion of OM and the decrease in moisture content. In harmony with the present data (Khalil et al., 2001) found the temperature attained to 50 – 65 °C and may even reach 80°C in well aerated windrows compost built up of MSW, because of the active role of microorganisms under these preferable cases. Tang et al. (2006) also obtained Egypt. J. Soil. Sci.\textbf{48}, No.1 (2008)
similar findings under the circumstances of aerobic, thermophilic composting, since they found that, the temperature usually rises to over 50°C during the process and the maximum desirable composting temperature is considered to be 60 °C, based on microbial species diversity and the rate of decomposition. They also added that the temperature rise is important for public health, as pathogens in compost are destroyed during the thermophilic composting process.

**TABLE 1. Changes in temperature degree during composting process.**

<table>
<thead>
<tr>
<th>Time (day)</th>
<th>RSC</th>
<th>MSWC</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>29</td>
<td>29</td>
</tr>
<tr>
<td>7</td>
<td>68</td>
<td>70</td>
</tr>
<tr>
<td>14</td>
<td>60</td>
<td>63</td>
</tr>
<tr>
<td>21</td>
<td>58</td>
<td>60</td>
</tr>
<tr>
<td>28</td>
<td>55</td>
<td>56</td>
</tr>
<tr>
<td>35</td>
<td>59</td>
<td>61</td>
</tr>
<tr>
<td>42</td>
<td>48</td>
<td>52</td>
</tr>
<tr>
<td>49</td>
<td>42</td>
<td>45</td>
</tr>
<tr>
<td>56</td>
<td>39</td>
<td>41</td>
</tr>
<tr>
<td>63</td>
<td>50</td>
<td>53</td>
</tr>
<tr>
<td>70</td>
<td>43</td>
<td>44</td>
</tr>
<tr>
<td>77</td>
<td>38</td>
<td>41</td>
</tr>
<tr>
<td>84</td>
<td>36</td>
<td>35</td>
</tr>
<tr>
<td>90</td>
<td>32</td>
<td>31</td>
</tr>
</tbody>
</table>

It is worth to mention that, the temperature is indicative of the progress of composting process and compost is matured enough when the temperature remains more or less constant and does not vary with the turning of the material. Therefore, temperature parameter is considered as a good indicator for the end of the biooxidative phase in which the compost achieves some degree of maturity (Khalil et al., 2001).

**Moisture content**

Moisture content is one of the most important factors affecting composting process due to the necessity of water for fast development of living microorganisms. At the beginning of composting process the moisture content should be maintained at 60- 70 % for enhancing the microbial community to do their action in decaying the compostable materials. In order to maintain perfect microbial activity, water was sprayed every 3 days to keep these high rates of moisture content. Afterwards, gradual decreases were happened in moisture content owing to elimination and controlling the water supply after the first month of composting. Then, the moisture content reached the lower level at maturity stage after 90 days, ranged between 20-24% (Table 2).

TABLE 2. Compost chemical analysis during composting process.

<table>
<thead>
<tr>
<th>Time (days)</th>
<th>Moisture %</th>
<th>E.C (dcms m⁻¹)</th>
<th>*TSS %</th>
<th>pH</th>
<th>CEC Cmol kg⁻¹</th>
<th>OC %</th>
<th>OM %</th>
<th>C/N</th>
</tr>
</thead>
<tbody>
<tr>
<td>Initial</td>
<td>63</td>
<td>3.19</td>
<td>0.204</td>
<td>8.69</td>
<td>49.55</td>
<td>54.89</td>
<td>94.41</td>
<td>65.35</td>
</tr>
<tr>
<td>30</td>
<td>52</td>
<td>3.70</td>
<td>0.237</td>
<td>8.93</td>
<td>52.72</td>
<td>49.13</td>
<td>84.50</td>
<td>47.01</td>
</tr>
<tr>
<td>60</td>
<td>68</td>
<td>4.80</td>
<td>0.307</td>
<td>8.77</td>
<td>63.20</td>
<td>43.32</td>
<td>74.51</td>
<td>32.57</td>
</tr>
<tr>
<td>90</td>
<td>20</td>
<td>5.60</td>
<td>0.358</td>
<td>8.42</td>
<td>70.92</td>
<td>35.74</td>
<td>61.47</td>
<td>18.70</td>
</tr>
</tbody>
</table>

| Initial     | 78         | 3.80           | 0.243  | 8.37 | 38.10         | 38.98| 67.05| 56.08|
| 30          | 65         | 4.71           | 0.301  | 8.60 | 46.82         | 31.66| 54.46| 43.91|
| 60          | 50         | 5.11           | 0.327  | 8.40 | 51.63         | 27.44| 47.76| 26.63|
| 90          | 24         | 5.98           | 0.383  | 8.19 | 59.73         | 24.75| 42.19| 19.04|

RSC = Rice straw compost.
MSWC = Municipal solid waste compost.
Total soluble salts (TSS%) = EC x 0.064.

**EC and total soluble salts**

It was observed that EC of RS was lower than that of MSW for the initial materials, the following monthly samples and the final product (Table 2). Moldes et al. (2007) demonstrated that the components contributing most to salinity are Na⁺, K⁺, Cl⁻, ammonia, nitrate and sulphate. They also added that lower levels indicate a lack of available salts, while high levels indicate a large amount of soluble salts that may inhibit biological activity or may be unsuitable for soil application if large quantities of the compost are used. Although the gradual increase in the EC and consequently the TSS until the maturation stage of both RS and MSW compost, but they did not exceed over the recommended limits. This increase values may be attributed to loss of biomass through the biotransformation of organic materials and also to release of its some content as mineral elements. Similar results indicated an increase in EC and TSS during composting processing stages of MSW (Abd El- Maksoud et al., 2002) and RS (Abdelhamid et al., 2004).

**pH**

It is well known that the pH adjustment is important for healthy plant growth. In the present study, the pH values of raw materials were slightly alkaline, 8.69 and 8.37 for RS and MSW wastes, respectively (Table 2). At the first samples, a slight increase was detected in pH values and then decreased again in the following two samples until maturity. Tang et al. (2006) exhibited that, the pH increased to about 8.8 – 9.5 after 3 days only after starting the composting process. Ammonium released during the composting process might have

contributed to the increase in pH at the first sample, because ammonia is principal nitrogenous compound in composting materials (Kowalchak et al., 1999 and Abd El- Maksoud et al., 2002). Whereas the decrease in pH values afterwards is expected because of the organic acid formed during the metabolism of relatively readily available carbohydrates, consumption of ammonia by microorganisms and as a result of volatilization of free ammonia to the air. Finally, the pH tended to stabilize due to humus formation with its buffering capacity as also mentioned by Khalil et al. (2001).

Cation exchange capacity

The cation exchange capacity "CEC" of a substrate indicates the capacity of a substrate to absorb or exchange soluble cations. The data shown large increases in CEC during biodegradation process, this increase reached its maximum peak by the end of composting process (Table 2). It was also observed that the CEC of RS compost was larger than that of MSW compost at all stages of composting process. The values at the end of curing phase were at least 43% and 56% higher than those detected at the beginning of the composting process of RS and MSW wastes, respectively. These dada are in accordance with those obtained by Vargas-Garcia et al. (2007) who demonstrated that the microbial inoculation of heaps with certain species of genus Bacillus lead to an enhancement of the CEC of different raw materials including rice straw. They obtained an increase in CEC evaluated with more than 37% at maturity stage compared to the values detected at the starting of the composting process. Other workers, Abdelhamid et al. (2004) found that the CEC values ranged from 63.3 to 77.9 Cmol kg$^{-1}$ for all mixtures of composted material and these values were higher than the 60 Cmol kg$^{-1}$ detected by Harda & Inoko (1980). They mentioned that this increase in CEC is a good index of composting maturity. Recently, Vargas-Garcia et al. (2007) and Zhu (2007) deduced the increase in CEC of compost to the formation of carboxyl, phenolic groups and to the polymerization of the decomposed organic matter into humic substances during the decomposition and biotransformation of the macromolecules.

Organic carbon and organic matter content

As clearly seen in Table 2, the organic carbon content of RS (54.89%) was higher than that of MSW (38.98%). This low content of C percentage of MSW could consequence to socio-economic standard of that region, culture and human characters as well as the initial sorting of household wastes before waste collection, which is recycling in rural communities as a source of feeding the livestock (Saber et al., 1994). In addition, MSW may contain different components that have low organic matter such as dust. Gradually continuous decrease in C values of both residues were detected at the following stages of compost process until the maturity stage. Abdelhamid et al. (2004) recorded similar values of OC content (35.13 %) for RS, whereas Moldes et al. (2007) obtained little higher content of OC in MSW (28 %). These decreases of OC were expected owing to the evolution and volatilization of CO$_2$ throughout the biodegradation of OM by aerobic heterotrophic microorganisms.

It is useful for purposes of composting to report the initial and the final OM, as this given an idea of the extent of decomposition. As general trend, the continuous decrease in OC through composting stages, consequently led to similar decrease in OM content of residues. The data show that RS contains a high ratio of OM, whereas the MSW contains a medium value, then OM started to decrease sharply by progress of composting process until the maturity. Moldes et al. (2007) mentioned that, there is no absolute level of OM that is ideal in term of compost quality, but rather the qualities must be viewed in relation to the age of compost, its N content and its intended use.

C/N ratio

The C/N ratio is one of the main characteristics that describe the composting process. It is often used as an index of composting maturity, despite many pitfalls associated with this approach, but it seems to be a reliable parameter for following the development of the composting process (Khalil et al., 2001). However, Abdelhamid et al. (2004) mentioned that RS is rich in C and poor in N and C/N vary from 50 to 150, which limits the composting process. Some other workers (Abd El-Maksoud et al., 2001) stated that C/N ratio of raw MSW should be between 25 and 35. When it is narrow, there will not sufficient carbon for microbes to make use of nitrogen, and loss of N through volatilization will increase. Conversely, when it is too narrow, there will not be enough N for the fast multiplication of microbes. It was also observed that during the processing of compost a strong reduction in C/N values was occurred at maturity stage. In accordance with the present data, Khalil et al. (2001) demonstrated that the C/N ratio of mature compost should ideally be about 10 but this is hardly ever achievable due to the presence of recalcitrant organic compounds, or materials which resist decomposition due to their physical or chemical properties. Some other authors reported that a C/N ratio below 20 is an indicative of acceptable maturity, Moldes et al. (2007) stated that compost might be considered mature when C/N ratio is approximately 17 or less, unless lignocellulotic materials remains.

Macronutrients

Definitely, the macronutrients N, P and K are the most consumed elements by plants at the all stages of growth. The quantity and form of N, in particular, present in manure or compost is important in shaping the quality of the material and for its agronomic use and are increasingly more often defined in compost specification (Lasaridi et al., 2006 and Moldes et al., 2007). The concentrations of NPK were slightly increased during the composting process (Table 3). No appreciable differences between the initial and the final values of P were observed within the two types of compost. Generally, the increase in total NPK may have been due to the net loss of dry mass as loss of organic C as CO$_2$ during composting. Moreover, total N can also be increased by the activities of associative N-fixing bacteria at the end of composting process (Abdelhamid et al., 2004). The initial and final values of NPK are in similar levels with those obtained.

by different authors (Abd El-Maksoud et al., 2001 & 2002 and Kaviraj & Sharma, 2003). However, Bhattacharyya et al. (2007) recorded large values of total K. These differences in K could be due to the differences occurred between the local and the foreign MSW in nature and constituents.

### TABLE 3. Total macro-, micro-nutrients and heavy metals during composting process.

<table>
<thead>
<tr>
<th>Time (days)</th>
<th>Macronutrients %</th>
<th>Micronutrients mg kg⁻¹</th>
<th>Heavy metals mg kg⁻¹</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>N P K</td>
<td>Cu Fe Mn Zn Cd Ni Pb</td>
<td></td>
</tr>
<tr>
<td>Initial</td>
<td>0.84 0.29 0.13</td>
<td>38.0 690 411 170</td>
<td>1.30 5.3 3.23</td>
</tr>
<tr>
<td>30</td>
<td>1.05 0.32 0.19</td>
<td>36.0 699 423 178</td>
<td>1.50 7.6 3.76</td>
</tr>
<tr>
<td>60</td>
<td>1.33 0.34 0.21</td>
<td>35.0 710 431 181</td>
<td>1.80 8.1 3.95</td>
</tr>
<tr>
<td>90</td>
<td>1.91 0.35 0.25</td>
<td>33.0 712 440 183</td>
<td>1.90 8.8 4.12</td>
</tr>
<tr>
<td>Initial</td>
<td>0.69 0.21 0.08</td>
<td>330 3130 306 712</td>
<td>11.0 45.3 100</td>
</tr>
<tr>
<td>30</td>
<td>0.72 0.26 0.11</td>
<td>328 3250 318 732</td>
<td>13.0 78.1 107</td>
</tr>
<tr>
<td>60</td>
<td>1.04 0.28 0.16</td>
<td>315 3620 321 733</td>
<td>15.0 50.0 112</td>
</tr>
<tr>
<td>90</td>
<td>1.30 0.32 0.21</td>
<td>309 3625 323 737</td>
<td>15.8 50.2 111</td>
</tr>
</tbody>
</table>

**Micronutrients**

It was seen that the Fe content was higher than other elements in both compost Table 3, however, the Fe values of MSW amounted to about 5-folds of that recorded for RS compost. Cu was the only element behaved in different trend, it decreased with minute amount during the composting process in both composts. Conversely, the other three elements Fe, Mn and Zn recorded moderate increases until the maturity stage. Thus composting can concentrate or dilute micronutrients and heavy metals (Zorpas et al., 2002). It seems to be that the abundance of micronutrients in MSW compost is attributed to the probability of containing the MSW on some chemical pollutants.

**Heavy metals**

The initial content of heavy metals in MSW was higher than the RS, consequently were all the values recorded at the different stages of composting process. In general, slight increase were recorded in the total content of Cd, Ni and Pb throughway the processing of two compost with a little differences between the initial value and the maturity one. Maximum permissible international values are set for heavy metals (Cd, Cr, Hg, Ni and Pb) although the limits vary widely (Hogg et al., 2002).

It worth to mentioned that, evaluation of compost produced from RS and MSW proved to be the product was environmentally safe in completely for agronomic purpose and human health. Since the heavy metal content of both compost RS and MSW were several times lower than regulation limits prescribed by the US EAP for Exceptional Quality compost and Spanish legislation for

fertilization including compost according to Lasaridi et al. (2006) and Moldes et al. (2007). The international regulations limits were ranged between mean values of 10-39, 25-200 and 45-500 mg kg\(^{-1}\) for Cd, Ni and Pb, respectively. Whereas the values for same metals in the final product were 1.9, 8.8 and 4.1 mg kg\(^{-1}\) for RS and 15.8, 50.2 and 111.0 mg kg\(^{-1}\) for MSW.

Fortunately, the tendency of pH to alkaline side in Egyptian soils (over pH 8.0) renders the different soluble forms of heavy metal to unavailable forms. It means that there are no restrictions for handling dissemination of the two types of compost and would allow the compost to be spread over more area of farmland, increasing food production and improving product quality.

**Compost microbiological analysis**

The initial composting materials were characterized by a high population of total microorganisms which their numbers in MSW were exceeded that of RS possibly due to the variation occurred in the nature and source of the two types of waste materials. It can be seen that the most common microorganisms in the composting process are bacteria, mesophilic and thermophilic (spore formers).

Generally, the numbers of most microbial groups, except those of spore formers, sharply decreased at the first stage of biodegradation after 15 days because of the increased temperature indicating that the compost process involves the aerobic exothermic microbial decomposition of the initial substrate, which results to dynamic changes in temperature, moisture content, oxygen concentration and nutrient availability. These factors, in its turn, strongly affect the structure and diversity of the microbial community (Gazi et al., 2007). However, it is worth to mentioned that there is an earlier phase (active phase) comes prior to this phase of 15 days. As expected that the microbial community flourished at the first step throughout few days of beginning composting process due to the increases in moisture level and the existence of the easily degradable organic matter, but because the compost was not sampled during this active phase of processing, thus the possible large increase in microbial population to reach its maximum peak has escaped analysis. Generally, most microbial groups increased after the end of active composting phase, the time before 30 days, indicating, that microorganisms multiplied rapidly as temperature fell, although the counts declined again towards the end of maturation period.

The microbial biomass expressed as total bacterial count, the initial increases at the 15 days counts followed by another increase by the end of the thermophilic phase at 30 days, reached their highest values during composting course on day 75 for composted materials (Table 4). These increases could be attributed to the presence of noncompletely decomposed organic matter at the surface of the two windrows, which comes inside the windrows through the second turning. These data are in accordance with those obtained by Khalil et al. (2001) who demonstrated that bacteria flourished because of their ability to grow rapidly on

soluble protein and other readily available substrates and because they are the more tolerant to high temperature. They added also that, mesophilic microorganisms are responsible for the initial decomposition of organic materials and the generation of heat responsible for the increase in compost temperature. These sharply decreases in microbial population at the maturity stage could be deduced to the diminution of moisture and depletion of organic matter at this later stage of composting process.

TABLE 4. Microbial changes during composting process (CFU 10^6 g^-1).

<table>
<thead>
<tr>
<th>Microorganisms</th>
<th>Time (days)</th>
<th>0</th>
<th>15</th>
<th>30</th>
<th>45</th>
<th>60</th>
<th>75</th>
<th>90</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>RSC</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total bacterial count</td>
<td>144.0</td>
<td>60.0</td>
<td>122.0</td>
<td>137.0</td>
<td>150.0</td>
<td>205.0</td>
<td>22.00</td>
<td></td>
</tr>
<tr>
<td>Total fungi</td>
<td>0.13</td>
<td>0.10</td>
<td>0.09</td>
<td>0.23</td>
<td>0.29</td>
<td>0.35</td>
<td>0.31</td>
<td></td>
</tr>
<tr>
<td>Total actinomycetes</td>
<td>1.32</td>
<td>0.14</td>
<td>0.53</td>
<td>2.67</td>
<td>10.92</td>
<td>15.81</td>
<td>27.33</td>
<td></td>
</tr>
<tr>
<td>Aerobic cellulose decomposers</td>
<td>4.00</td>
<td>0.18</td>
<td>0.64</td>
<td>8.00</td>
<td>12.30</td>
<td>64.00</td>
<td>12.00</td>
<td></td>
</tr>
<tr>
<td>Spore-formers</td>
<td>5.73</td>
<td>5.41</td>
<td>1.82</td>
<td>2.44</td>
<td>3.93</td>
<td>5.31</td>
<td>6.25</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>MSWC</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total bacterial count</td>
<td>212.0</td>
<td>57.0</td>
<td>110.0</td>
<td>128.0</td>
<td>143.0</td>
<td>198.0</td>
<td>23.40</td>
<td></td>
</tr>
<tr>
<td>Total fungi</td>
<td>0.31</td>
<td>0.21</td>
<td>0.13</td>
<td>0.25</td>
<td>0.32</td>
<td>0.38</td>
<td>0.33</td>
<td></td>
</tr>
<tr>
<td>Total actinomycetes</td>
<td>0.94</td>
<td>0.12</td>
<td>0.42</td>
<td>3.42</td>
<td>11.15</td>
<td>12.73</td>
<td>21.10</td>
<td></td>
</tr>
<tr>
<td>Aerobic cellulose decomposers</td>
<td>3.12</td>
<td>0.14</td>
<td>0.80</td>
<td>0.62</td>
<td>17.00</td>
<td>54.00</td>
<td>16.10</td>
<td></td>
</tr>
<tr>
<td>Spore-formers</td>
<td>4.36</td>
<td>6.57</td>
<td>1.61</td>
<td>1.98</td>
<td>4.22</td>
<td>5.16</td>
<td>5.91</td>
<td></td>
</tr>
</tbody>
</table>

Total fungi were maintained in the two raw materials with moderate numbers, in relatively larger values for MSW, but subsequently declined to reach their lower values by the end of the active decomposing phase because of the increased temperature in agreement with Tang et al. (2006). Although, Gazi et al. (2007) stated that fungi could survive the thermophilic phase as spores or reinoculated into the compost from the environment or the cooler material at the edges of the windrows after turning. Thereafter their number began to increase gradually when the compost temperature started to decline, as the organisms are not temperature resistant in accordance with Ryckeboer et al. (2003). As observed slight decreases were detected at the end of composting process, but their values were still higher than the initial values of both composted materials.

Actinomycetes numbers were closed similar for both composted materials RS and MSW through the different stages of processing and they were higher than the numbers detected for fungi. As follows in the case of total bacterial count and fungi population, the numbers of total actinomycetes tended to decrease promptly during the thermophilic phase of composting to reach their lowest values in the phase after 15 days. Afterwards, consecutive gradual increases were obtained until the end of composting process. The present data are in harmony with those of Gazi et al. (2007) who found that actinomycetes increased by the end of the thermophilic phase and remained high through composting due to the possibility...
of actinomycetes to utilize complex organic compounds and their population tends to increase in later stage of composting. Their appearance as a grey-white growth at the surface of the material is often considered as an indicator of compost maturity.

The initial materials of RS and MSW involved fair numbers of cellulose decomposer with no large differences between them. During the 15 days of composting course their numbers sharply decreased to reach their minimum values. By the end of this phase, the numbers started to increase slowly until 45 days in RS and 60 days in case of MSW. Then, the cellulose decomposer realized the actually large increases, which were continued to 75 days for both materials. It is worthy to mention that owing to these sharply increases in cellulose-decomposing bacteria; they were the second predominant group comes after the total bacterial count at these later stages of composting process. The earlier starting of increase in numbers in case of RSC (45 days) compared to the MSWC (60 days) may be attributed to the content of cellulose in RS may favour than that in MSW and this in its turn could induce their microbial activity and numbers. Later on the numbers declined once again at maturity but still over those scored at the beginning of composting process. This decline in numbers could deduced to the postulates mentioned by Ryckeboer et al. (2003) that during the curing and maturity phase the cellulose may become inaccessible to enzymatic attack because of low water content or association with protective substrates such as lignin. Conversely, these data are conflicted with those of Gazi et al. (2007) who demonstrated that as high temperature favour cellulose degradation, cellulotic bacteria demonstrated a high count at the end of thermophilic phase, their numbers slightly declining the curing phase.

It was observed that the counts of spore-forming bacteria exhibited different trend compared to the other investigated bacterial groups, since they were the only bacteria tended to increase through the active thermophilic phase at 15 days and then decreased until the second sample at 30 days, whereas a slight increase was detected at the middle of composting period at 45 days. However, pronounced increase were demonstrated at 60 days, and continued in increase through the last two samples until maturity of the two windrows. These data are confirmed with those obtained by Lasaridi et al. (2006) and Gazi et al. (2007) who stated that, spore-forming bacteria were detected through the entire process at levels higher than $10^6$ CFU g$^{-1}$ of compost. They also added that the high population of spore-forming bacteria is common in compost materials as these bacteria survive at the high temperature of the process through their transformation into a very resistant form, the endospore. However, the data are in contrary to those of Khalil et al. (2001) during their work on composting of MSW, since they mentioned that, as the temperature began to rise, thermophilic microorganisms began to dominate, but the population decreased in the last phase of the composting as the product reached maturity. Hence, their total count through the process can be indicative to the state of composting maturity.

It can be concluded that improper handling of solid wastes (agricultural or municipal) results in several environmental risks such as pollution of soil, water and air. Therefore, it could be recommended that windrows composting is the more convenient and faster practice for composting of rice straw and could be replicated more than once a year for consumption a total rice straw to mitigate the environmental pollution. It is also a successful practice to dispose off the municipal solid wastes to solve its accumulation problem and alleviating its hazardous environmental impact.

It worth to mentioned that, evaluation of compost produced from RS and MSW proved to be the product was environmentally safe in completely for agronomic purpose and human health.

The authors insure that there are no restrictions anyway could be limiting the use of such compost as safe organic fertilizer under the Egyptian conditions. It means that there are no restrictions for handling dissemination of the two types of compost and would allow the compost to be spread over more area of farmland, increasing food production and improving product quality.

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Tخفيف الآثار البيئية الضارة للمخلفات الصلبة من خلال تدويرها إلى كمبوست

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علية محمد على القماح

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أجريت هذه الدراسة لمحاولة إيجاد إحدى الوسائل الأمنة للتخلص من المخلفات الزراعية في صورة قش الأرز وكذلك الجزء العضوي من القشة بدلاً من الطرق الحالية المتبعة عن طريق الحرق العشوائي لكلهما وما تسببه هذه الأطواق من نجوم بئي وخطرة اقتصادية نتيجة إهدار القيم الاقتصادية لهذه المخلفات على الرغم من إمكانية إعادة استخدامها وتدويرها في صورة أسمدة عضوية

تستخدم في برامج التسديد العضوي للترية تمزج من خصائصها وتحسين انتاجيتها بالإضافة إلى ترشيد استخدام الأسمدة الكيماوية والمبيدات فتح من التلوث البيئي كظاهرة تهدد صحة الإنسان المصري.

تراكم كميات هائلة من المخلفات الزراعية والبلدية بمصر (٢٦٠,٠٠٠,٨٧٥ مليون طن سنوياً على التوالي يمثل قش الأرز منها ٢,٤ مليون طن بينما يمثل الجزء العضوي من القشة حوالي ٧,٢ مليون طن سنوياً). مسببة العديد من المشاكل الصحية والبيئية.

تحضير السماد العضوي الصناعي:

ابتع أسلوب التخمير الهوائي Composting لإعادة تدوير هذه المخلفات في صورة أسمدة عضوية عالية القيمة السمادية مع الفضاء على ما تسببه من طبقات أو أمراض نباتية مع معالجة ما قد ينتج عنها من راحة غير متبولة وأختارنا طريقة المصفوفات لكافئتها وسرعة الوصول بالمخلفات لحالة التضحية . (Compost)

- تم بناء مصفوفتين في مصنع تدوير المخلفات الصلبة بمحافظة كفر الشيخ تحتوي كل منها على ثلاث أطنان من المخلفات (قش الأرز وقشة المدن ومخلفات المدن RS (MSW.

- استخدام مشت عضوية (سماد بلدي) بعديد ١٠٪ (وزن/وزن) بالإضافة إلى Streptomyces منشط بيولوجي يحتوي على لقاح من ميكروبات Trichoderma resi، Trichoderma harzianum، aureofaciens.

- تم ترتيب المصفوفات وحفظ نسبة الرطوبة عند ٨٠-٧٠٪ من خلال فترة الكرم مع التقلبات مرتين بعد ٣٠ و٦٠ يوم من بداية الكرم. وسجلت درجة الحرارة أسبوعياً حتى تم تضج المصفوفات (١٠٠ يومًا).

- تم اخذ عينات ممثلة من المصفوفات على فترات لإجراء التحاليل الكيماوية والبيولوجية عليها متعملاً لتقييم السماد الناتج . (Compost)

توسيع السماد العضوي الصناعي

تراوح درجة الحرارة ما بين ٢٩٪ عند بداية الكرم للمخلفات وحوالي ٨٠٪ عند نهاية الأسبوع الأول من الكرم ثم انخفضت درجة الحرارة حتى موعد التقلبات الأول (٦٠ يوم) ثم ارتفعت إلى ٥٠٪.

الانخفاض ثانوي حتى موعد التقليب الثاني (15 م) الذي أعقب ارتفاع بسيط في درجة الحرارة قبل أن تواصل انخفاضها تصل إلى حوالي 22 م. عند نهاية عملية الكرم.

النسبة المئوية للرطوبة تم الوصول بها إلى ما بين 70 - 80 % من WHC خلال فترة الكرم ثم اتجه إلى الانخفاض تصل إلى 22 % لكل من RSC و MSWC على التوالي عند النضج. كما كانت هناك زيادة تدريجية في قيم التوصيل الكهربائي C/N و السعة التبادلية الكاثيونية CEC. 

TSS pH الكربون العضوي ومادة العضوية C/N في قيم EC في قيم OM. كما أوضحت النتائج زيادة تدريجية في تركيزات العناصر الكبرى (N,P,K) والعناصر الصغرى (Cd, Ni, Pb) أثناء عملية الكرم. وكانت تركيزات العناصر الكبرى في سماد قش الأرز أعلى منها في سماد قامة المدن وعلى العكس من ذلك كانت تركيزات العناصر الصغرى والعناصر النقيطة. وكانت أعداد الميكروبات أعلى في قامة المدن منها في قش الأرز ثم تفرزت أعدادها مع التقليب وتغير درجة الحرارة وكانت السيادة البيئية وسطية الحرارة تأثيرها الميكروبات المحلة للسليلوز والاكتيوميسينات في النطاقات. 

ويتضح من الدراسة أهمية المعالجة الآمنة للمخلفات الصلبة بإعادة تدويرها إلى سماد عضوي صناعي لدعم إعداد فيميتها الاقتصادية وتقليل الأخطار البيئية الناجمة عنها.