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World
Sustainable
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Outlook 2012

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APPLICATION AND ASSESSMENT OF EARTH COMPOSTATION APPROACH DURING COMPOSTING OF HOUSEHOLD WASTES

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Abstract: *Purpose* – The purpose of this study was to address the biochemical, ecological and hygienic problems associated with the composting of household wastes via the addition of soil material to organic wastes. This approach is called “earth compostation” or the “**4Cs approach**”, and it reduces the elimination of gases, increase in temperature, humus formation and loss of minerals by mineralization during decomposition. The earth compostation approach is defined as **C**old bio **C**atalytic **C**ombustion **C**ompostation (**4Cs**). *Design/methodology/approach* – A mixture of household waste was used as a bio-standard and sandy clay loam (loess) was used as a mineral standard with different mixing ratios (loading rates). The experiment was conducted under normal air temperature during the winter season in Khartoum from November 2011 to February 2012. Average temperatures ranged from 23–30 °C. Samples from the mixture were wet separated to different fractions: mull humus fraction (F2b), and the transitional fractions (F1 and F2a) and analyzed for chemical and physical properties.

Findings – The temperature of the composted mixture ranged from 35–40 °C. The humus formation increased the cation exchange capacity and decreased the concentration of N and S liberated by mineralization in the composted mixture. The added soil material served as a biological catalyst for rapid mineralization of decomposing organic wastes and as a sorbent of mineralization products.



World Sustainable
Development Outlook
2012

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Originality/value – This approach is strongly recommended in municipal units in cities, in private agricultural schemes and for local farmers, as it is environmentally safe and cheap.

Keywords: *Earth compostation, Turnover of organic matter, Mineral transformation*

Paper type Research paper

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INTRODUCTION

The composting of biogenic wastes from gardens and kitchens in many countries without the addition of soil material is usually associated with biochemical, ecological and hygienic problems, which is why the addition of soil material to plant and animal wastes, the so-called "earth compostation" approach, is recommended. The added soil material serves as a biological catalyst for the rapid mineralization of decomposing organic wastes and acts as a physical or chemical sorbent of mineralization products (Alexander, 1977).

As the capital of Sudan with more than 6 million inhabitants, Khartoum produces about 60 tonnes of household waste per day. Recently, many suggestions have been proposed for proper management procedures.

LITERATURE REVIEW

The composting of biogenic materials generally means a full or partial mineralization of organic compounds of mixed plant materials by producing CO_2 , H_2O , NO_3 , NH_3 , sulphates and carbonates of Ca, Mg, K, oxides of Fe and Mn and phosphates. Some of these mineralization products are lost from the composting biomass as gaseous compounds (CO_2 , NO_3 , H_2O), some as solutes with the drainage water (NO_3 , SO_4 , K and Mg hydrogen carbonates) and some remain as precipitated or adsorbed compounds (NH_4^+ , K^+ , Ca^{++} , Mg^{++} , phosphates and sesquioxides) with the final compost product.

It is well known that when plant materials are incorporated into a soil they decompose rapidly and release a considerable portion of their carbon and nitrogen within a few days. After a short period of decomposition they become part of the soil organic matter (OM). The amount and proportion of OM changes dramatically during composting. Approximately 50 per cent of the added organic matter becomes fully mineralized, mostly due to the degradation of easily degradable compounds such as C and N sources. The residual OM contains newly formed macromolecules along with non-degradable OM jointly forming the humic-like substance (HS), which is the most stable fraction of the mature compost (Chefatez *et al.*, 1998).

The amount of organic material used has also been found to affect the decomposition process and carbon and nitrogen turnover (Jenkinson,

1977). During decomposition, plant materials release a considerable proportion of their nitrogen within a few days. Gaseous N losses during composting occur mainly as NH_3 (Witter and Loper-Real, 1987; Martins and Dewes, 1992), but may also occur as N_2 (Mahimairaja *et al.*, 1994) and NO_x (Martins and Dewes, 1992) including N_2O (Dendooven *et al.*, 1996). In addition, both mineralization and immobilization processes take place, changing the mineral status of the organic material added. Sulphur contained therein is mineralized. Some of the inorganic products are utilized by the microflora for cell synthesis and the terminal inorganic product is sulphate. The critical C:S ratio in materials above which immobilization is dominant to mineralization is reported to be in the range of 200:1 to 400:1 (Stewart *et al.*, 1998), equivalent to about 0.1 to 0.2 sulphur. Mineralization will predominate with organic materials having lower C:S ratios or higher sulphur percentages, but immobilization will be more prominent in substances with wider C:S ratios or lower sulphur contents.

Many other elements undergo microbiologically induced transformations during the decomposition of organic matter into a soil. There is evidence for direct or indirect biological alterations in the availability, solubility or oxidation states of potassium, calcium and magnesium.

MATERIALS AND METHODS

Two materials were used in the experiment:

- 1) Organic waste (OW) from household wastes was collected from different residential areas in Khartoum State.
- 2) Soil samples (S) were collected from the surface horizon (0–40 cm) about 40 km southwest of Omdurman City ($15^\circ 2' - 15^\circ 36' \text{N}$ & $32^\circ 0' - 32^\circ 10' \text{E}$). The climate is semi arid with a warm summer. Mean annual precipitation is 121.4 mm and maximum and minimum mean daily air temperatures are 37°C and 21.6°C , respectively (Elhag *et al.*, 2006).

Both materials were analyzed before incubation and the results are shown in Tables 1 and 2. A mixture of household waste was used as a bio-standard and sandy clay loam as a mineral standard was carried out with different mixing ratios; 5; 10; 15; 20; and 30; 40; 50 (OW:S) in metal containers and incubated under normal air temperature during the winter season in Khartoum for 15 weeks from November 2011 to February 2012. The average temperature ranged from 23–30 °C. Water

holding capacity was adjusted to 60%. The mixtures were mixed weekly to aerate the compost.

After the incubation period, the compost mixtures (CM) were air dried and sieved using a 1.1 cm sieve. The sieve was selected after the Attenberg-2-system scale to separate different compost fractions as followed:

- Fraction 1 (F1): > 1.1 cm diameter mainly OW residues with some adhering soil material.
- Fraction 2 (F2): < 1.1 cm diameter mainly soil material and brownish OW detritus.

The fraction F2 was further washed on a 2 mm sieve and separated into:

- Fraction 2a (F2a): Float, mostly organic grass borne fine residues = Moder
- Fraction 2b (F2b): Sediment, mostly soil minerals and organo-mineralic aggregates.

Samples from all fractions were collected, air dried and analyzed for the determination of ash, total carbon and total nitrogen by dry combustion using gas chromatography-system Carlo Erba ANA 1400; calcium carbonates by volumetric CO₂ determination using Scheibler Apparatus; inorganic nitrogen by steam distillation after Bremner and Keeney (1965); total S by the method described by Brumsack (1981) using C/S Analysator-Eltra CS 500; total P by the method described by Olsen and Sommers (1982); CEC by the Mehlich method; calcium, sodium, potassium and magnesium were estimated by the method described by Page *et al.* (1986).

Table 1.
Characteristics of
organic waste used
in the experiment

pH	Ash %	C _t %	N _t %	C/N	S _t %	CaO %	P ₂ O ₅ %	K ₂ O %
7.1	89.23	41.271	0.01	15.7	0.257	1.180	0.842	1.370

Table 2.
Characteristics of
soil sample used in
the experiment

pH	Ec dS/m	OC %	Nt %	C/N	CaCO ₃ %	Sand %	Silt %	Clay %	Soil texture
7.1	2.23	0.157	0.01	15.7	11.32	65.11	4.29	30.60	Sandy clay loam

Ca meq/l	Mg meq/l	Na meq/l	K meq/l	SAR	Kaolinite %	Smectite %	SO ₄ meq/l	OM %	CEC cmol/kg
3.3	0.13	9.54	0.32	5.32	61.11	38.89	5.34	0.271	13.5

The temperature of the composting mixtures was measured 4 times per week during decomposition to monitor the decomposition process.

STATISTICAL ANALYSES

Analysis of variance (ANOVA) was followed to test the significant differences among variables. Means were separated using Duncan's multiple range test (DMRT). Unless otherwise stated, the null hypothesis was rejected at $P>0.05$. SAS software was used for all statistical analyses (SAS Institute, 2000).

RESULTS AND DISCUSSION

Figure 1 shows the basis for calculation of the C-balance in the compost mixtures system after 15 weeks of incubation. The composition of the organic matter in the fractions (F1, F2a and F2b, and mull humus) is changing during the transformation process and therefore the balance was based on the organic bound C. It is known that the fate of C transfer during composting is either gaseous losses or formation of mull humus.

It can also be seen that gaseous losses of C occurring during the transformation of OW to mull humus account for about 3.496 % with the first loading rate, where the lower amounts of OW added seemed to increase the mineralization rate by increasing OW decomposition. The formation of mull humus accounts for 1.701%.

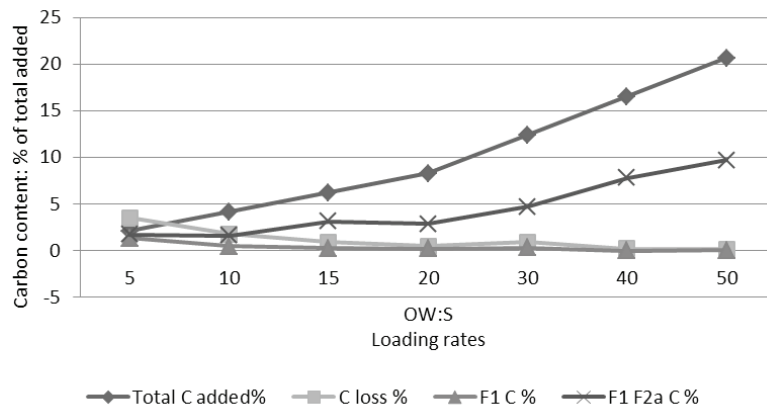
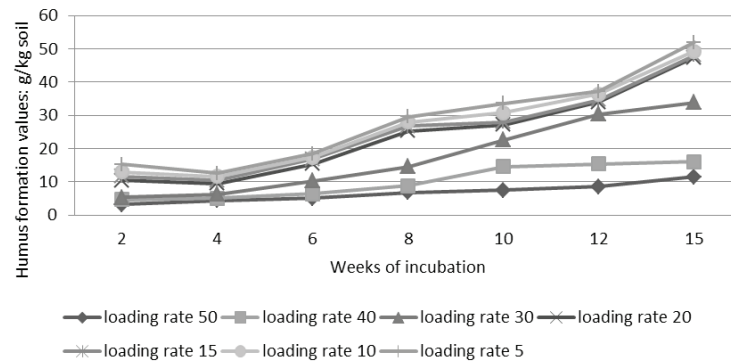


Figure 1. Carbon balance after 15 weeks of incubation: % total C added

Figure 2. Humus formation after 15 weeks of incubation, g/kg soil



The lower carbon losses were observed with the maximum loading rate (50:1) where the high amounts of OW were added, which seemed to lower the carbon mineralization rate by delaying OW decomposition.

Figure 2 shows the increase in humus formation by time of incubation in all loading rates. From soil genetic studies, the process of humate accumulation seems to be a restricted one. The restriction is given by the amount of adsorption or precipitation sites. The clay minerals are the main sites of humate fixation. Considering the fact that the added soil had 30.6% clay, it was expected that the curve of loading rate 5 would show a decrease in the accumulation rate, while the higher formation of humus was observed with a loading rate of 50, which was the treatment containing higher amounts of OW addition. Humus formation was also affected by the week of incubation, as a significant increase was obtained after 15 weeks of incubation in all loading rates.

For the transformation of minerals, Figures 3–8 showed the fate of minerals at the end of the compostation process. It is known that during the process of organic matter turnover by compostation, these elements are set free. The rate of liberation depends on the character of the elements and the conditions of the decomposition process.

The fate of Na, as shown in Figure 3, was dissolution or drying out via precipitation in the soil solution as hydrogen carbonate, chloride or nitrate. In contrast, K (Fig. 4) had the chance to become adsorbed and fixed in the three layered expanding clay minerals. In the present study, the simple adsorption at immediately exchangeable adsorption

sites on the surface of the clay minerals was impeded by the Ca in the soil solution, caused by the carbonate content of the soil material. This could be the main reason for the K sink in the system.

The original cation exchange capacity of soil material was 13.5 cmol/kg, and the exchange capacity normally increased with humus formation. This additional humus-based cation exchange capacity has a specific adsorption for bivalent cations and discriminates against monovalent ones. The liberated Mg is therefore adsorbed, whereas Na and K are removed.

Ca and Mg are set free in correspondence with the amount of organic substances that are mineralized to CO₂ and NH₄ and become liberated for adsorption to the newly formed organic adsorbents. In Figures 5 and 6, the fate of Ca and Mg liberated by the mineralization of the formation of humus can be precipitated as carbonates or adsorbed as cations; a small part is also dissolved in solution equilibrium with carbonates

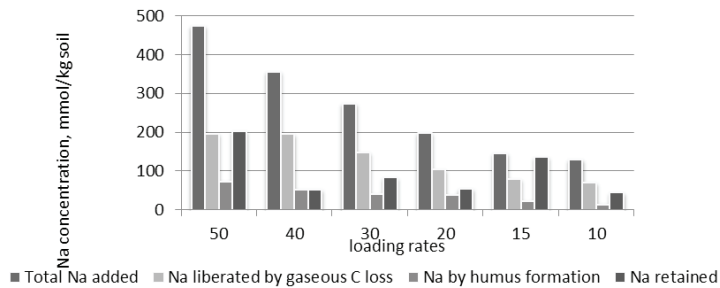


Figure 3. Na balance at the end of compostation process, mmol /kg soil

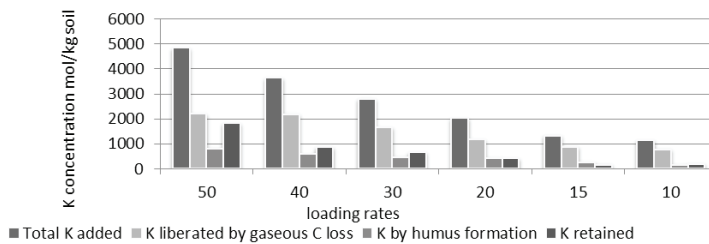


Figure 4. K balance at the end of compostation process, mmol/kg soil

Figure 5. Ca balance at the end of compostation process, mmol/kg soil

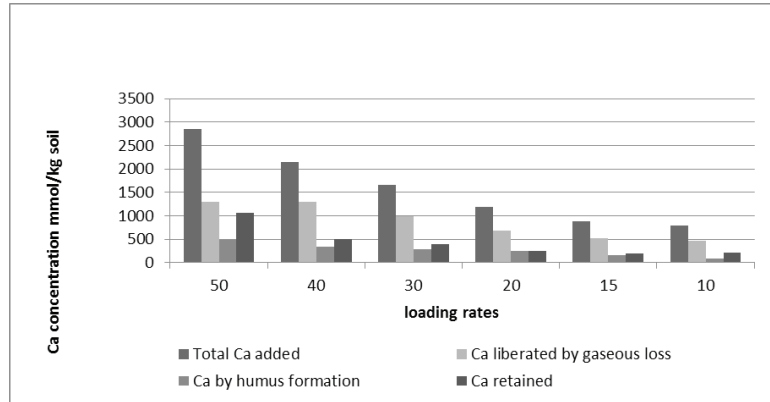


Figure 6. Mg balance at the end of compostation process, mmol/kg soil

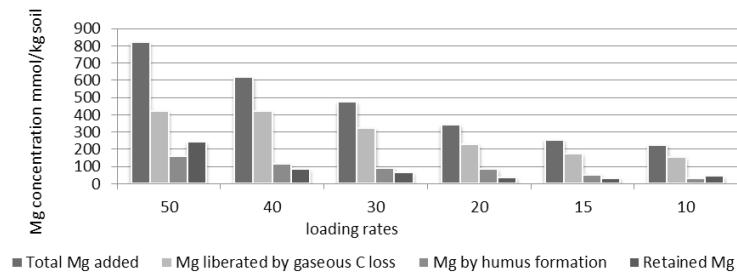
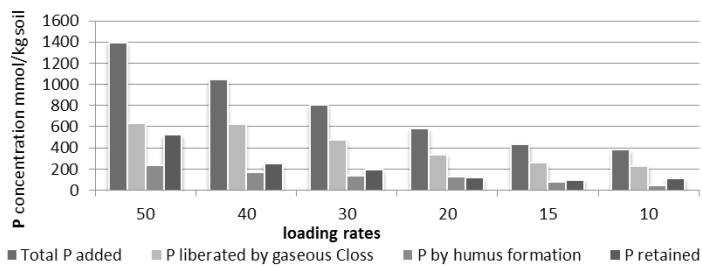


Figure 7. P balance at the end of compostation process, mmolkg/soil



and adsorbed ions in the pore water, or as cations of the newly formed nitrates and sulphates in the soil solution.

The P set free by mineralization and humus formation (Fig. 7) seems able to use the transfer of C on these pathways. It can be supposed that the fractions F1 and F2a keep their P organically bound. A question remains regarding whether the organic substance that is converted into the humus F2b fraction takes its P with it, forming organic phosphates, or whether the P becomes liberated and newly fixed by organic binding. Therefore it is assumed that the liberated P under calcareous conditions becomes rapidly transfused in hydroxyl apatite.

S is the element that can be stored in the dissolved form in the pore solution. The solubility of gypsum is about 2.3 g/l. The pore water of 1 kg soil at field capacity accounts for 214 ml and 492 mg gypsum can be dissolved in it. This corresponds to 92 mg S. In Figure 8, we find that the amount of S liberated corresponding to gaseous C losses is in all loading

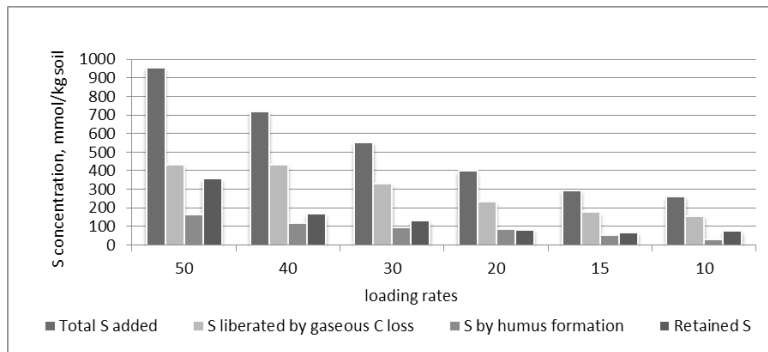


Figure 8. S balance at the end of compostation process, mmol/kg soil

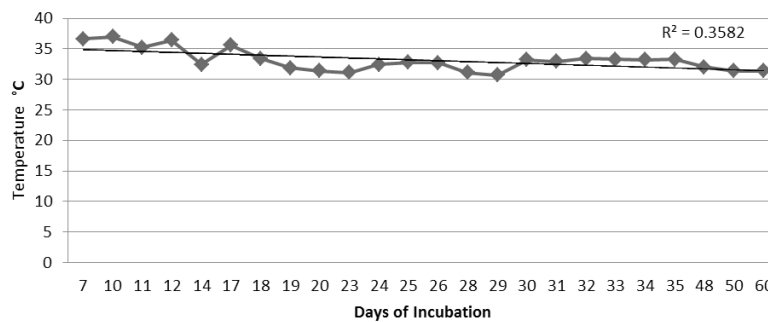


Figure 9. Temperature variation during earth compostation of household wastes

rates higher than the saturation concentration. This means that gypsum has precipitated and gypsum formation is the main reason for the S sink in the system.

The temperature values of the composting mixture are shown in Figure 9. The temperature varied between 30 and 40 °C during the composting process. This indicates that the addition of soil material served to cool the thermophilic phase of decomposition, i.e., cold compostation.

CONCLUSION

It is concluded that the addition of soil material serves as a reservoir of elements liberated during the composting process. In addition, the use of soil material is of higher advantage for compostation and compost quality. Soil amendment could be implemented in localities for the recycling of organic wastes, as it is cheap and environmentally safe.

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