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Evaluation of Pollution and Clean Index of Municipal Solid Waste Compost Used as Organic Fertilizers from Sokoto State Metropolis, Nigeria

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Abstract:

The purpose of this study was to assess the quality of compost obtained from ten (10) municipal solid waste dumps in the Sokoto metropolitan area, Nigeria. The Compost was characterized to understand its fertilizing and polluting potential to soil. The fertilization index (FI) was determined empirically from the values of TOC, TN, TP, TK and C:N ratio and the cleaning index (CI) using heavy metal concentrations. The results were compared with quality control metrics. The FI values for the composts ranged from 4.00 to 4.70, while the CI values ranged from 2.60 to 4.00, respectively. Most of the MSW composts analyzed showed good fertilizing potential and were of good quality for use as soil fertilizers.

Keywords: *fertilizing index, clean index, municipal solid waste, compost.*

Introduction

The composition of municipal solid waste varies and includes compostable material as well as paper, plastic, rags, metal, glass and metal fragments. In addition, waste materials, waste paper, dead animals, discarded chemicals, paints, hazardous hospital waste, and agricultural residues all fall under the category of municipal solid waste (Lauber, 2005). A dump is a place where solid waste is collected; however, a dump is a place dedicated to dumping waste (FEPA, 1998). The nature and volume of solid waste change with development (EEA, 2002) The generation of municipal solid waste varies from place to place in direct proportion to the socioeconomic status of the urban population. The amount of municipal solid waste generated increases with economic growth and there is need for efficient solutions (Magrinho & Semiao, 2003). The management of MSW has become a major issue due to the significant increase in MSW production both in absolute and per capita terms (Mohd et al., 2010). It has been estimated that in 2006 the total amount of municipal solid waste generated globally reached 2.02 billion tones, representing 7% annual increase since 2003, it is further estimated that between 2007-2011 global generation of MSW would rise by 37.3% equivalent to 8% increase per capita (UNEP 2009). Nigeria, with a population of 140 million (2006 census), generates approximately 25 million tonnes of municipal solid waste annually, with generation rates ranging from 0.66 to 0.44 kg/capita-day (Ogwueleka et al., 2009). However, only 5 % (approximately 400–450 tonnes) of MSW per day is processed for composting in Nigeria. Approximately 20 % of MSW usually remained unattended in open areas, which is posing health hazards and also causing ecological imbalances to land, water and air (Kansal 2002). Unattended municipal solid waste clogs sewers, creating stagnant water, causing insect blooms and flooding during the monsoon season (Alam & Ahmade, 2013).

These wastes are dumped in low-lying areas without any preventive measures and operational controls, thus causing nuisance to the economy, environment and human health (CPCB 2010). Waste disposal is characterized by odour, smog and greenhouse gas emissions which pose pollution problems to the environment and can cause serious health hazards and various respiratory problems among habitats (State of the Environment India, 2006). However, municipal solid waste (MSW) management is a serious problem in most cities due to the large volumes of waste generated and the lack of suitable and cost-effective treatment and disposal technologies (Kumar et al., 2009; Bundela et al.). This means that the time is not far; if waste is not managed properly, our world could soon be completely covered in waste (Nadeem, Farhan, and Ilyas, 2016). In addition, Sokoto's dump was full of rubbish, so a replacement needed to be found. Therefore, rules and standards for various aspects of solid waste management are important and require special attention. Waste minimization, reuse, recycling and conversion of organic waste into valuable compounds is one of the ways to reduce the problem of solid waste disposal (Fathi et al., 2014; Ziaee et al., 2012). Therefore, composting appears to be an appropriate waste management method (Amouei et al., 2009; Abdoli et al., 2005). Composting is the most promising strategy for improving MSW management systems, including minimizing solid waste generation, maximizing waste recycling, and resource recovery (Mbuligwe et al., 2005). Composting is the process of converting solid waste into plant nutrients (Fathi et al., 2014; Jha et al., 2013; Mbuligwe et al., 2005). During composting, organic waste, including household waste (after removing metal, glass and plastic), food waste, waste from farms and forests, leaves and grass from parks and gardens, is biodegraded and converted into stable substances at high temperatures, such as humic substances (Amouei et al., 2009; Abbasi et al., 2010; Yaghmaeian et al., 1980). During composting, microorganisms break down the chemical bonds between organic materials and convert them into carbon dioxide, water, heat (energy) and compost (Ziaee et al., 2012; Zazooli et al., 2009). Different analyses on municipal waste in Nigeria indicate that there are a high percentage of perishable materials (food wastes by more than 70% of the composition of such type of waste). In recent years, many countries around the world have used organic fertilizers such as compost due to the economic, environmental and health concerns associated with the organic matter and nutrients contained in them (Rastgar et al., 2012; Sharholy et al., 2008). Applying compost to agricultural fields is a low-cost alternative to open landfill disposal or incineration (Bruun et al., 2006). Compost is a good soil conditioner as it contains major plant nutrients (TN, TP and TK), plant micronutrients (Cu, Fe and Zn) and organic matter which improves soil aeration and water holding capacity Soil properties (Ingelmo et al., 2012). Composting increases productivity, minimizes erosion, reduces compaction, increases soil porosity, and reduces phytotoxicity and waste volumes. It also protects the soil from the wind. Additionally, compost provides nutrients to plants and increases yield and quality in terms of flavor and aroma (Ziaee et al., 2012; Rastgar et al., 2012; Malakootian et al., 2014; BioAbfV1998). A major issue in sustainable agriculture and resource management in Nigeria is the generation of municipal solid waste composting. Since it is more expensive to operate and maintain a composting facility than open dumping in Nigeria, it is not a viable or sustainable alternative. In addition, most municipal solid waste composts do not meet the specifications required by the government Some European countries, North American countries and India have specific regulations, mainly to control the composting market with desirable quality (Briton 2000; FAI 2007).

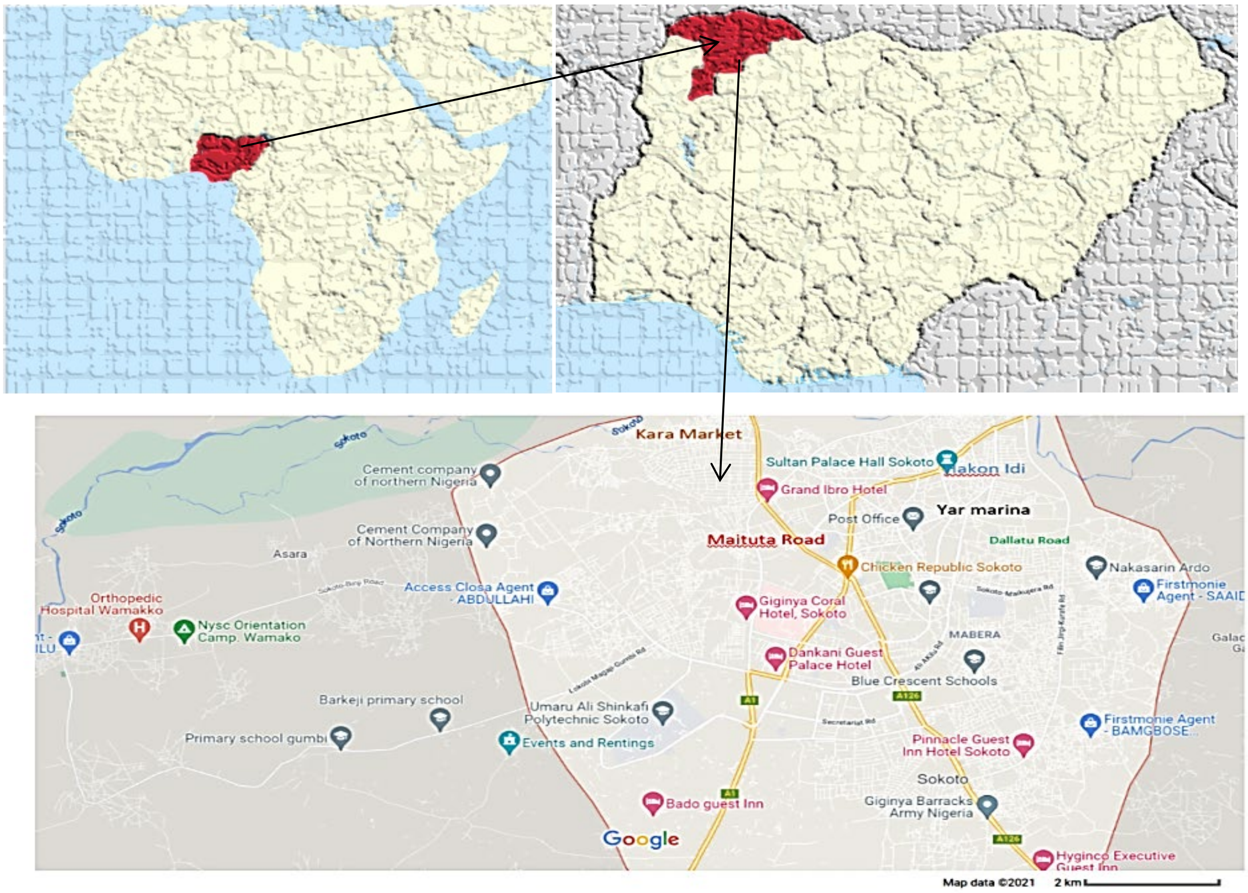

Figure 1. Locations of the Studied Dumpsites Areas in Sokoto, Nigeria

Many countries have set maximum allowable limits (mg/kg dry compost) for heavy metal content in compost. Quality control requirements do not differentiate between several marketable compost qualities. Users want to know about the types of compost that can be used for a variety of purposes including development of high value crops, food crops, non-edible fiber, soil amendments, turf establishment, and reclamation and restoration of old mining sites, among others. The effectiveness of the composting process and its quality are influenced by several factors. The three key factors are oxygen, moisture and C/N ratio. Other useful characteristics are organic matter, temperature and waste acidity (Amouei et al., 2009; Yaghmaeian et al., 1980; Tchobanoglous & Theisen, 2003). Given the properties of soil and compost, it is necessary to determine the concentration of these heavy metals in compost before using it as a soil supplement in agricultural areas. The quality of MSW compost is influenced by the source and type of waste, facility design, composting procedure and maturity period (Hargreaves et al., 2009). The fertilization capacity and associated toxicity of MSWC is significantly influenced by the geographical origin of MSW and/or composting procedures (Jibihika et al., 2021; Jodar et al., 2021; Jalal et al., 2019). Compost production and effective product promotion are major hurdles for business owners. Poor marketing is the result of making poorer quality MSW compost. Some countries in Europe and the North American continent have adopted specific laws to control the marketing of compost of acceptable quality. These laws also control the marketing of appropriate grades of compost (Briton, 2000; FAI, 2007). This should make it easier for end users to sort compost for a variety of applications, including growing high-value crops, food crops, non-edible fiber or flowering crops, creating lawns and gardens, recycling or restoring specific types of degraded land and mining areas.

Study area

Sokoto is a city located in the extreme northwest of Nigeria, near the confluence of the Sokoto River and the Rima River. It occupies 25,973 square kilometres with apopulation of 563,861. Geographically situated between latitude 130°.05 and 13°.0830 north and longitude 05° 15 and 5.250° east with an average elevation of 272 m above sea level. The ten (10) sampling dumpsites selected were all within Sokoto Metropolis. These were Bado (BDO), Dallatu (DLT), Gawon – Nama (GNM), Kalanbaina (KBN), Kwannawa (KMW), Gidan dare (GDR), Marina (MRN), Tudun-wada (TWD) and Runbukawa (RKW).

Materials and Methods

Sample Collection and Treatment

Compost samples were collected in triplicate from various windrow depths and portions at each location (compost plants) to create composite samples. To guarantee complete population representation, samples of the compost manure were taken from the upper 2-3m, middle 1-2m, and lower 0-1m levels. Each sample weighed about 200g. Each composite sample was thoroughly mixed, separated, and 20g of it was sub-sampled (reduced). This portion was then air-dried at room temperature to stop biological activity, ground in a mechanical motor and pestle, sieved through an agriculture 2 mm screen to ensure a homogeneous mixture, placed in air-tight, labelled, clean polyethylene bags, transported to the lab in an icebox, and stored for additional analysis.

Physicochemical Characterization

Moisture of the samples was analyzed using residual moisture analysis (ASTM 3173) while ash following a standard ASTM method (ASTM 3174). Organic matter was measured using ASTM-3175. pH and conductivity were measured in aqueous solution of the samples using pH and conductivity meter in 1:10 % (AOAC-973.04). Total P and N were determined by Kjeldhal method as reported by Okalebo *et al,* (2002). Potassium and Sodium content were determined by flame photometer while Calcium and Magnesium by EDTA titration (Horwitz *et al.,* 2005). After drying the original samples at 105°C, the samples were digested in nitric acid and perchloric acid mixture for heavy metals analysis (Zn, Cu, Cd, Pb, Ni, Cr, Fe, As and Mn) using atomic absorption spectroscopy (AAS).

Fertility and Clean Index

Table 1 shows the criteria used for composting "Weighting Factors" and "Scores value". The maximum weighting factor value for TOC is 5 because of its important role in increasing soil fertility. Weighting factors for other fertility parameters ranged from 1 to 5 (Mandal et al., 2014). The FI values of the compost were determined using equation 1.

$$\text{FI} = \frac{\sum_{n}^{i=1} S_i W_i}{\sum_{n}^{i=1} W_i} \qquad (1)$$

Where 'S_i' is the score value and 'W_i' is weighing factor of the ith fertility parameter of the data.

Table 1. Criteria for Weighing Factor and Score Values to Fertility Parameters

Fertility Properties	Score Values (S_i)					Weighing Factor (W_i)
	5	4	3	2	1	
TOC (% dm)	> 20	15.1-20	12.1-15	9.1-12	< 9.11	5
TN (% dm)	> 1.255	1.01-1.25	0.81-1.00	0.51-0.80	< 0.511	3
TP (% dm)	> 0.6	0.41-0.6	0.21-0.4	0.11-0.20	< 0.111	3
TK (% dm)	> 1.0	0.76-1.0	0.51-0.75	0.26-0.50	< 0.250.25	1
C:N (% dm)	< 10.11	10.1-15	15.1-20	20.1-25	> 20	3

Clean index was determined using a standard as presented in (Table 2) and calculated as adopted by Saha *et al*, (2010) using equation 2.

$$CI = \frac{\sum_{n}^{j=1} S_j W_j}{\sum_{n}^{j=1} W_j} \qquad (2)$$

Where S_j is the score value and W_j is the weighting factor of the jth heavy metal parameter of the heavy metals. The weighting factors also varied from 1 to 5 depending on the toxicity level of the different parameters. Higher CI values indicate less heavy metal pollution and vice versa (Mandal et al., 2014).

Table 2. Criteria for Weighing Factor and Score Values to Heavy Metals Parameters

Fertility Properties		Score Values (S_i)					Weighing factor (W_i)
	5	4	3	2	1	0	
Zn (mg/kg)	< 151	151-300	301-500	501-700	701-900	> 900	1
Cu (mg/kg)	< 51	51-100	101-200	201-400	401-600	> 600	2
Cd (mg/kg)	< 0.3	0.30-0.60	0.70-1	1.10-2.0	2.0-4.0	> 4.0	5
Pb (mg/kg)	< 51	51-100	101-150	151-250	251-400	> 40000	3
Ni (mg/kg)	< 21	21-40	41-80	81-120	121-160	> 160	1
Cr (mg/kg)	< 51	51-100	101-150	151-250	251-350	> 350	3

Results and Discussion

Table 3. Fertility and Clean Indices of the Composts and Their Respective Classes

Sample Site	FI	CI	Class	Quality of the Compost	Remarks
BDO	4.33	3.00	C	Good quality	Higher fertilizing potential and medium heavy metal content
DLT	4.70	3.40	C	Good quality	Higher fertilizing potential and medium heavy metal content
FKI	4.33	3.13	C	Good quality	Higher fertilizing potential and medium heavy metal content
GNM	4.70	2.60	RU-3	Restricted use	Restricted use. Should not be allowed to market. Can be used only for developing lawns/gardens

					(with single application), rehabilitation of degraded land
GDR	4.33	3.30	C	Good quality	Higher fertilizing potential and medium heavy metal content
MRN	4.33	2.60	RU-3	Restricted use	Restricted use. Should not be allowed to market. Can be used only for developing lawns/gardens (with single application), rehabilitation of degraded land
KBN	4.00	2.60	RU-3	Restricted use	Restricted use. Should not be allowed to market. Can be used only for developing lawns/gardens (with single application), rehabilitation of degraded land
KNW	4.00	3.00	C	Good quality	Higher fertilizing potential and medium heavy metal content
RKW	4.67	4.00	C	Good quality	Higher fertilizing potential and medium heavy metal content
TWD	4.33	3.60	C	Good quality	Higher fertilizing potential and medium heavy metal content

Classification of compost on the basis of fertilizing potential (FI) and pollution potential (CI) was used as the tool to identify different grades of quality marketable compost. Compost classifications A, B, C and D represent the quality of the compost and its potential for agricultural use at the commercial level (Saha et al., 2010). It also provides information on the degree of treatment required prior to application. FI and CI values of composted manure from Sokoto municipal solid waste (MSW) are shown in (Fig. 2). The FI value of the compost varied between 4 - 4.7. Values below 4 are classified as restricted use (RU) because they do not improve the fertility of the soil to which they are applied. From the results obtained, the fertilization potential (FI value) of all samples was greater than 4. This indicates that they are of moderate quality and have met quality control compliance guidelines (Table 4).

The CI values for the samples varied from 2.60 to 4.00. This may be due to the high Pb and relatively low Zn content in the compost samples. CI values below 3.00 do not meet heavy metal requirements and are not suitable for use as fertilizers. Except for Gawonnama (GNM), Kalambaina (KBN) and Marina (MRN) samples, the CI values indicated that the compost was of good quality and met the heavy metal standards.

Table 4. Standard Quality Control Compliance

Quality Control Compliance	FI	CI	CLASS	REMARKS
Complying for heavy metal parameters	>3.5	>4.0	A	Best quality. High manurial value potential and low heavy metal content and can be used for high-value crops, such as in organic farming
Complying for heavy metal parameters	3.1 – 3.5	>4.0	B	Very good quality. Medium fertilizing potential and low heavy metal content
Complying for heavy metal parameters	>3.5	3.1 – 4.0	C	Good quality. High fertilizing potential and medium heavy metal content
Complying for heavy metal parameters	3.1 – 3.5	3.1 – 4.0	D	Medium quality. Medium fertilizing potential and medium heavy metal content
Complying for heavy metal parameters	<3.1	-	RU-1	Should not be allowed to enter market due to low fertilizing potential. However, these can be used as soil conditioners

Compost from Bado (BDO), Dallatu (DLT), Fakon-Idi (FKI), Gidan-dare (GDR), Kwannawa (KNW), Tudun-wada (TWD) and Runbukawa (RKW) is of good quality (grade C) and It has high fertilization potential and moderate heavy metal content (Table 4). They can be easily applied to small farms and gardens. Gawunnama (GNM), KBN and Marina (MRN) do not meet the heavy metal criteria and are therefore classified as restricted use (RU-3) and should not be allowed to be placed on the market. It should only be used to develop lawns/gardens (single use) or for restoration of degraded land.

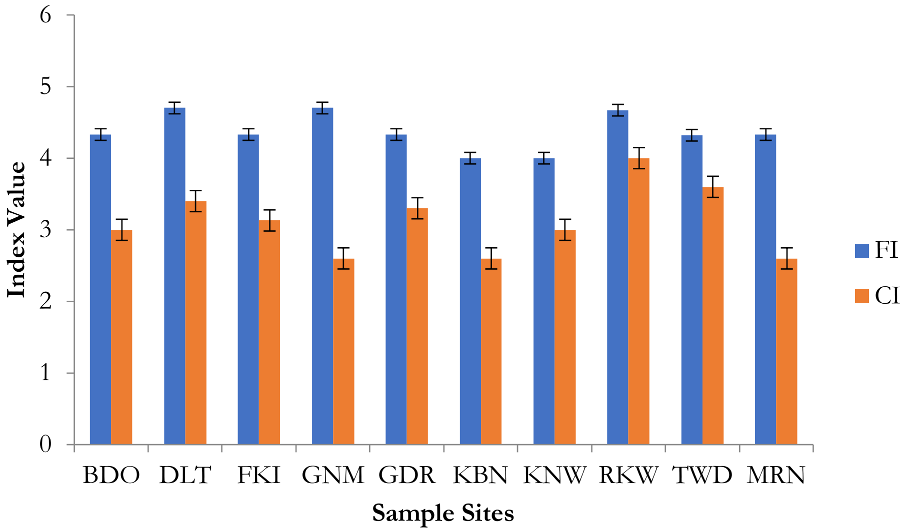

Figure 2. Fertility and Clean Index Values of the Composts

Conclusion

The Fertilization Index (FI) and Pollution Potential (CI) can be used as means to identify the quality grade of compost. It further helps to provide information on the degree of treatment required for compost before being applied directly to agricultural land. The Fertilization Index values of the MSW composts studied were within the quality control compliance guidelines, while the Cleaning Index values of the composts from Gawonnama (GWM), Marina (MRN) and Kalanbaina (KBN) were below the standard and therefore unsuitable for use as fertilizer crops, use as a soil conditioner only under restricted conditions.

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