Open Access Library Journal
2023, Volume 10, e9837
ISSN Online: 2333-9721
ISSN Print: 2333-9705

Assessment of Physiochemical Properties and Heavy Metals Concentration of Municipal Solid Compost (MSWC): A Case Study in Sokoto Metropolis, Nigeria

Muhammad Salisu Adamu, Imrana Bello, Buhari Idris, Malami Usman Muhammad, Bashar Abdullahi Hadi

Department of Chemistry, Shehu Shagari College of Education, Sokoto, Nigeria
Email: buhariidris2017@gmail.com

How to cite this paper: Adamu, M.S., Bello, I., Idris, B., Muhammad, M.U. and Hadi, B.A. (2023) Assessment of Physiochemical Properties and Heavy Metals Concentration of Municipal Solid Compost (MSWC): A Case Study in Sokoto Metropolis, Nigeria. *Open Access Library Journal*, **10**: e9837.
https://doi.org/10.4236/oalib.1109837

Received: February 3, 2023
Accepted: March 17, 2023
Published: March 20, 2023

Abstract

Nowadays, farmers use municipal solid waste compost (MSWC) as fertilizer on their farmlands. Very scarce information on the quality of MSWC compost is available. As a result, the physiochemical characteristics of compost from ten (10) different dump sites in Sokoto City were evaluated in this study, and the results were compared with standards. According to the findings, the compost has a pH value ranging from 6.78 to 7.47, an electric conductivity between 2.16 to 6.48, organic carbon between (10.0% to 16.5%), organic matter between (0.94% to 14.78%), and a C:N ratio between 2.28 to 9.51. The heavy metals analysis shows an average value of 275.47 ± 89.86, 1.82 ± 1.04, 82.44 ± 28.28, 263.46 ± 91.46, 45.23 ± 11.72, 1.53 ± 0.095, 71.71 ± 21.46 and 0.29 ± 0.39 mg/kg for Zn, Cd, Fe, Cu, Ni, As, Pb, Mn and Cr respectively. The results of the analysis of variance revealed that the levels of heavy metals did not differ significantly between the locations (p-value 0.05). Some of the parameters studied were found to be within the permissible limits established by USA, UNBS/ICS, and WHO regulations.

Subject Areas

Environmental Chemistry

Keywords

Physiochemical, Municipal Solid Waste, Compost, Heavy Metal

1. Introduction

Municipal solid waste is a by-product of human activities, that is unwanted and abandoned (Ibikunle *et al.,* 2018) [1]. These wastes are collected by waste collectors and vary by location (Lin *et al.,* 2015 [2]; Huseyin *et al.,* 2016 [3]; Read, 1999 [4]). Combustible and non-combustible materials make up the waste generated and their indiscriminate disposal leads to environmental degradation, pollution and global warming (Zhou *et al.,* 2014 [5]; Ibikunle *et al.,* 2018 [1]). According to the latest estimates from the World Bank (2022) [6], 1.3 billion tons of solid waste is generated globally every year, or 1.2 kg per person per day. The situation is expected to worsen as 2.2 billion tons of waste is expected to increase by 2025 (Izionworu and Akpa, 2018) [7]. However, out of 32 million tons of solid waste Nigeria produced each year only 20-30% is recycled (Bakare, 2022) [8] and the remaining end in open dumpsite. According to Babatunde *et al*, (2013) [9], about 25 million tons of municipal solid wastes are generated annually, at 0.44 to 0.66 kg per day. This harms the environment but if managed will make adequate materials available for energy production, composting, and recycling, respectively (Bhat *et al.,* 2018) [10]. However, rapid urbanization in Nigeria has made municipal solid waste management a serious environmental issue (Chen *et al.,* 2012 [11]; Banna *et al.,* 2014 [12]; Ziraba *et al.,* 2016 [13]). In sub-Saharan African countries like Nigeria, waste management receives less than 10% of urban council budgets (Oosterveer *et al.,* 2010) [14]. This leads to uncollected MSW and poor management of landfills (Rogger *et al.,* 2011 [15]; Komakech *et al.,* 2014 [16]; Komakech *et al.,* 2016 [17]). Most of these wastes (more than 90%) are used for unscientific land filling or uncontrolled dumping on the outskirts of towns and cities (Sharholy *et al.,* 2008 [18]; Narayana, 2009 [19]). However, excessive waste in soil may increase the heavy metal content in groundwater and soil. Soil, crops and human health can all be negatively affected by heavy metals (Nyle and Ray 1999 [20]; Smith *et al.,* 1996 [21]).

Time is running out; our world will soon be covered in waste if waste is not managed properly (Nadeem, Farhan, and Ilyas, 2016) [22]. Composting of MSW appears to be an excellent choice for disposing of MSW. It's an inexpensive technology to keep organic waste out of landfills and produce quality products for agriculture (Nsimbe *et al.,* 2018) [23]. Municipal waste increased nitrogen, pH, cation exchange capacity, % alkali saturation and organic matter, it was claimed. Given that organic waste can enhance plant development by providing nutrients, continued land use of these wastes may be encouraged (Anikwe and Nwobodo, 2001 [24]; Nyles and Ray 1999 [20]). MSWC can be used in agriculture as a soil conditioner and fertilizer, which is more cost-effective for small farmers to use than inorganic fertilizers (Mandal *et al.,* 2014 [25]; Jodar *et al.,* 2017 [26]). In addition, there are concerns about the toxicity of solid waste when it is separated at source to reduce composting (Hargreaves *et al*., 2008) [27].

Lack of pre-separation during composting can result in poor quality compost. Crop growth is negatively affected by nutrient abundance and deficiency, which also adversely affects the soil and creates bioaccumulation (Emamverdian *et al.,* 2015) [28]. Toxic metals migrate into crops as a result of application of municipal solid waste compost to agricultural fields in excess of heavy metals. Large amounts of these heavy metals can cause nausea, vomiting, diarrhea, and pneumonia (Jaishankar *et al.,* 2014) [29]. These heavy metals can bind to biological components. Depending on the characteristics of the soil and compost, it is crucial to evaluate the characteristics and heavy metal content of the compost before applying it as a soil supplement in agricultural areas.

This study, therefore aimed at assessing physiochemical parameters and concentration of some selected heavy metals in solid municipal waste compost from different dumpsites within Sokoto metropolis.

1.1. Study Area

Sokoto is a city located in the extreme northwest of Nigeria, near the confluence of the Sokoto River and the Rima River (**Figure 1**). It occupies 25,973 square kilometres with a population 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).

1.2. 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

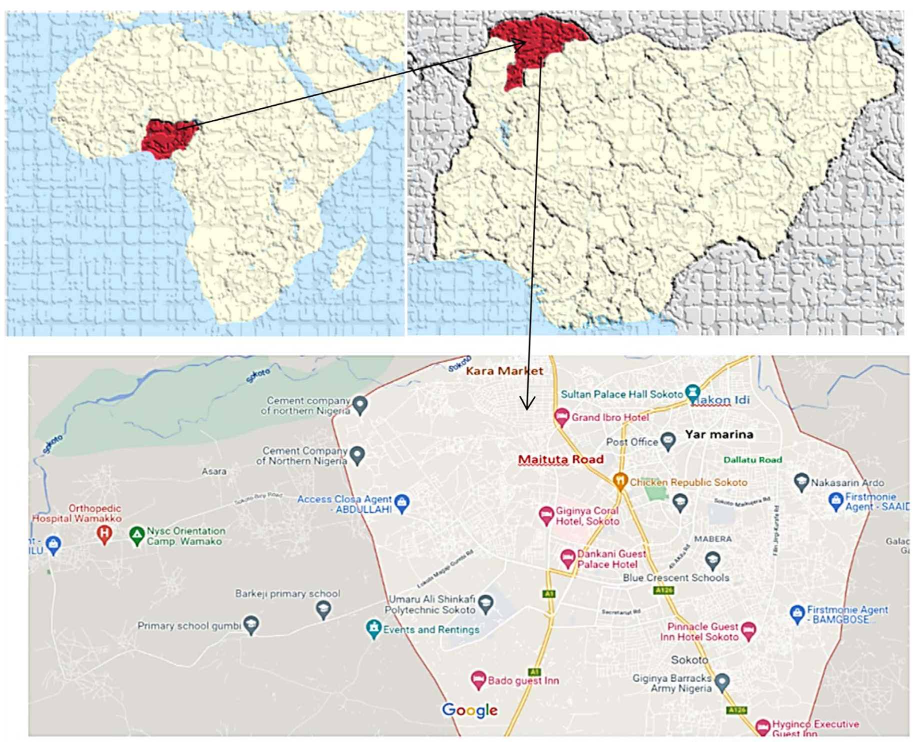

Figure 1. Location of the dumpsites area studied in Sokoto, Nigeria.

were taken from the upper 2 - 3 m, middle 1 - 2 m, and lower 0 - 1 m levels. Each sample weighed about 200 g. Each composite sample was thoroughly mixed, separated, and 20 g 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.

2. Materials and Methods

2.1. Determination of Total P and Total N

Total P and Total N were determined by Kjeldhal process using a standard AOAC Method 978.02, as reported by Okalebo et al, (2002) [30].

2.2. Determination of Ca, Na, Mg and K

The samples were digested using wet digester method. After digestion, the produced solutions were used to analyzed K and Na using flame photometer by inserting appropriate filter. Ca and Mg content of the samples were determined using EDTA titration method (Horwitz *et al.,* 2005) [31] and their amount calculated using Equations (1) & (2)

$$Ca^{2+}Mg^{2+} = \frac{T \times N \times V}{\text{Mils of Aliquot} \times wt} \times 100 \quad (1)$$

$$Ca^{2+} = \frac{T \times N \times V}{\text{Mils of Aliquot} \times wt} \times 100 \quad (2)$$

where: T is titre of the sample, N normality of EDTA, wt weight of sample and V of the leachate collected.

Amount of Mg^{2+} was determined by subtracting amount of Ca^{2+} from $Ca^{2+}Mg^{2+}$ obtained in Equation (1)

2.3. Proximate Analysis

The pH and EC of the samples were measured in aqueous suspension using a pH meter and conductivity meter in 1:10 % using AOAC standard method (AOAC 973.04) [32]

The moisture contents of the samples were determined using standard test method for residual moisture analysis (ASTM 3173) [33].

$$\%\ \text{Moisture Content} = \frac{W_2 - W_1}{W_2 - W_0} \times 100 \quad (3)$$

where W_0 = weight of empty crucible, W_2 = weight of crucible and the sample before oven drying, and W_1 = weight of crucible and the sample after drying.

Ash content of the samples was determined using Equation (4), following a standard ASTM method (ASTMD, 3174) [34]

$$\text{Ash}(\%) = \frac{W_1 - W_0}{W_2 - W_0} \times 100 \quad (4)$$

where W_0 = weight of empty crucible, W_2 = weight of crucible and the sample before combustion and W_1 = weight crucible and the sample after combustion.

Organic Volatile Matter was determined using standard method (ASTMD, 3175) [35] and calculated using Equation (5)

$$V(\%) = \frac{W_1 - W_2}{W_1} \times 100 \quad (5)$$

where W_1 = weight of the sample and W_2 = weight of the Sample after incineration

Fixed carbon was determined by difference using Equation (6).

Fixed Carbon (%) = 100 − (% moisture content + %Ash + % volatile matter) (6)

2.4. Heavy Metal Analysis

Heavy metals were determined by atomic absorption spectroscopy (AAS) using the standard methods adapted by USEPA 7000a (Schrenk *et al.,* 2012) [36]. Extractor and AAS controls were turned on and the thin tube, atomizer parts was cleaned with purge wire, while the burner opening with an alignment card. The ASS worksheet was opened. The lamp was turned on, to allow the light beam from the cathode strike the target area of the card. The fine was placed in 10 ml graduated chamber filled with deionized water. An analytical blank was prepared together with series of calibration solutions of known amounts of analyte. Blanks and standards were nebulized in sequence and their responses measured. A calibration chart is drawn for each solution, after which the sample solution is nebulized and measured. The metal concentration was determined based on the absorbance obtained for the unknown sample from the calibration.

3. Results and Discussion

One of the parameters used to check the quality of compost is its heavy metal concentration. Dyes, batteries, electronics, cosmetics and pharmaceutical residues are the main sources of heavy metals in compost (Amouei *et al*., 2009) [37]. Due to the harmful effects of heavy metals on humans and the environment, some standards have been established for the concentration of these metals in compost. In this study, the average concentrations of heavy metals detected in the compost from different landfills were 275.47 ± 89.86, 1.82 ± 1.04, 82.44 ± 28.28, 263.46 ± 91.46, 45.23 ± 11.72, 1.53 ± 0.095, 71.71 ± 21.46 and 0.29 ± 0.39 mg/kg for Zn, Cd, Fe, Cu, Ni, As, Pb, Mn and Cr respectively. The mean concentrations of the heavy metals were all within the allowed limits of the USA and the UNBS/ICS Standard (**Figure 2**). High concentrations of heavy metals limit the use of compost on farmland. Environmental impact of heavy metal-contaminated compost varies with soil type, plant species, and compost quality (Zhao *et al.* 2011) [38].

All the compost samples show high concentration of Zn compared to others heavy metals detected with Cd concentration been the least. This is in line with the findings of Ibrahim *et al,* (2020) [39], for the heavy metals analysed in municipal solid waste from Potiskum (Yobe State, Nigeria). The higher concentration

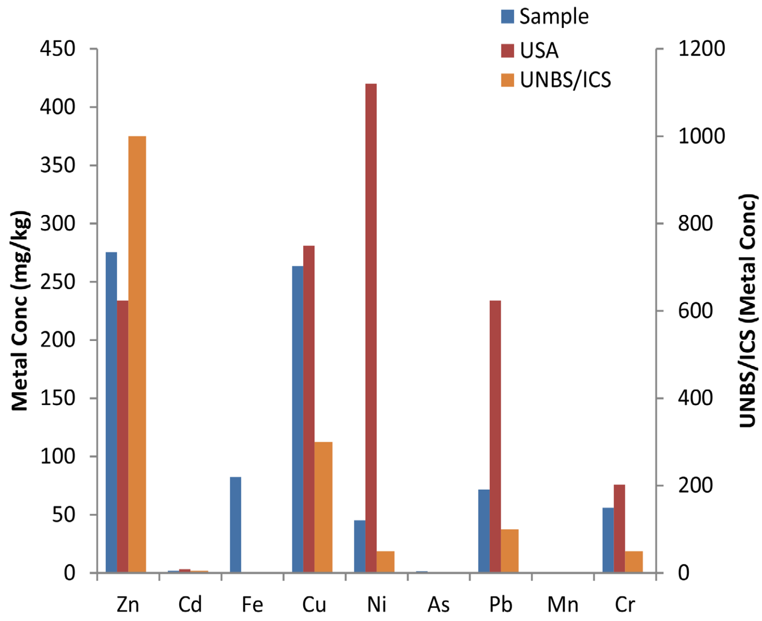

Figure 2. Heavy metals concentration of the compost compared with the standard.

of Zn in the compost may be due to the stability of ZnO, as ZnO in soil has a higher stability coefficient (Ma and Rao, 1997) [40]. The low concentration of Cd may be attributed to the weak adsorption properties of Cd (Mido and Satake, 2003) [41].

3.1. Correlation between Heavy Metal Concentrations in the Compost

Pearson's correlation analysis was carried out to analyze correlations between heavy metal concentrations in the compost from different sites. Result of the analysis is shown in (Table 1). It represents the correlation between different dumps in terms of heavy metal concentrations. The analysis revealed a strong positive correlation of heavy metal between the sites. This may be due to the correlation in composition of the solid waste from the different dumping sites.

3.2. Statistical Analysis

A one-way analysis of variance (Table 2) was performed to determine significant differences in terms of heavy metal concentrations among the different studied sites. The analysis was based on probability level (α) of 0.05. The ANOVA results revealed that there were no significant differences in concentrations of heavy metals from the dump sites (p-value > 0.05). A low value of calculated F (0.2531) also predicts a non-significant difference when compared to the critical F value of 1.999.

The moisture content of the sample was in the range of 1.13 - 2.23 with an average value of 2.00% ± 0.52%. High moisture content reduces air space, so the compost can become clumpy. Dusty compost is often generated by compost ventilation, causing ambient air pollution in the surrounding area (Mandal *et al.*,

Table 1. Pearson's correlation coefficient for heavy metal concentrations in the compost.

	BDO	*DLT*	*FKI*	*GNM*	*GDR*	*KBN*	*KNW*	*MRN*	*TWD*	*RKW*
BDO	1									
DLT	0.6399	1								
FKI	0.8239	0.9140	1							
GNM	0.8496	0.7952	0.9691	1						
GDR	0.8407	0.8870	0.9942	0.9824	1					
KBN	0.8635	0.7934	0.9666	0.9981	0.9823	1				
KNW	0.9139	0.8278	0.9730	0.9754	0.9798	0.9823	1			
MRN	0.8804	0.8335	0.9799	0.9912	0.9889	0.9950	0.9936	1		
TWD	0.8747	0.8781	0.9840	0.9632	0.9842	0.9704	0.9932	0.9879	1	
RKW	0.7808	0.8719	0.9729	0.9590	0.9697	0.9637	0.9638	0.9752	0.9797	1

Table 2. Result of one way analysis of variance (ANOVA).

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	29,948.41	9	3327.601	0.253112	0.984809	1.999115
Within Groups	1,051,739	80	13146.73			
Total	1,081,687	89				

2014) [25]. The pH of the compost varied from 6.78 to 7.47 with an average value of 7.06 ± 0.22, which indicates that it was almost acidic to slightly alkaline, and was found to be within the standard recommended range of 6 to 8 (WHO). A high pH accelerates the release of ammonia from the compost into the ambient air. A gradual increase in ammonia emissions to ambient air corresponds to an increase in compost temperature (35˚C - 60˚C) and alkaline pH value (Omrani *et al.* 2004) [42]. Disease-causing pathogens may be present in compost, during waste sorting and transportation; pathogenic bacteria can cause illness in those who handle them. The values of pH obtained indicated that the composts were not adulterated with pathogenic bacteria. This may be due to increased temperatures, which destroy pathogens (Day and Shaw 2001) [43].

The nutrients in the compost were analyzed to determine its suitability for agricultural land. Nutrients are needed in compost piles because microbes need them to grow, besides their importance in terms of fertilizer value (Sadeghi *et al.,* 2015) [44]. Among the nutrients, Carbon, Nitrogen, Phosphorus, Potassium, Calcium, Iron, and Manganese are the most important (Abbasi *et al.*, 2010) [45]. The average values of Nitrogen, Phosphorus, and Potassium in the compost are 2.29 ± 0.86, 1.92 ± 0.3, and 55.27 ± 13.68 mg/kg, respectively. WHO standards for nitrogen, phosphorus and potassium in compost are 0.4 - 3.5, 0.3 - 3.8 and 0.5 - 1.8, respectively (**Table 3**). The values recorded in this study meet WHO standards with exception of potassium, which was found to be higher than the

Table 3. Physiochemical properties of the compost.

Parameters	Units	Range	Average	WHO Standard
pH		6.78 - 7.47	7.06 ± 0.22	6 - 8
Electrical conductivity (EC)	ds/m	2.16 - 6.48	3.31 ± 1.18	-
Organic carbon (O.C)	%	10.0 - 16.55	14.39 ± 1.94	-
Moisture content (M.C)	%	1.13 - 2.23	2.00 ± 0.52	-
Ash content (A.C)	%	87.55 - 95.53	92.54 ± 2.50	-
Organic matter (O.M)	%	0.94 - 14.78	7.02 ± 3.92	10% - 20%
Carbon/Nitrogen ratio (C:N)		2.28 - 9.51	7.02 ± 1.92	-
P	mg/kg	1.73 - 2.81	1.92 ± 0.3	0.3 - 3.8
N	mg/kg	1.52 - 4.48	2.29 ± 0.86	0.4 - 3.5
K	mg/kg	40.0 - 70.5	55.27 ± 13.68	0.5 - 1.8
Ca	mg/kg	1.0 - 2.50	1.49 ± 0.41	-
Na	mg/kg	80.0 - 207	155.24 ± 46.34	-
Mg	mg/kg	1.50 - 2.25	1.97 ± 0.27	-

specified limit. Electrical conductivity indicates concentration of dissolved salts in the compost. Composts with high concentrations of EC can cause problems such as soil salinity and biotoxicity (Malakootian *et al.,* 2014) [46]. The average electric conductivity of the compost was found to be 3.31 ± 1.18. High electrical conductivity in compost inhibits seed germination and plant growth (Rahman *et al.,* 2020) [47]. The C:N ratio of the composts varied from 2.28 to 9.51 with an average value of 7.02 ± 1.92. Stable mature composts that do not contain lignocellulosic material have CN ratios below 17 (Silva *et al.,* 2007) [48]. Some literature suggests an ideal value of 12, while others suggest a CN ratio of 20-40 as most suitable for use as a fertilizer (Rawat *et al.,* 2013) [49]. Composts with CN ratio values above or below the recommended values may inhibit seed germination, reduce plant growth, and cause phytotoxicity due to insufficient biodegradable organic matter, thereby damaging crops (Kabasiita *et al.,* 2022) [50]. Organic matters affect the quality of compost. The results in this study showed that organic matter in the compost ranges from 0.94 - 14.78 having average value of 14.39% ± 1.94%. Organic matter indicates the presence of heavy metals in compost as they are known to form complexes with organic matter (Jimoh and Sabo, 2013) [51]. A low OC indicates mature and stable composts (Kabasiita *et al.,* 2022) [50]; thus, these composts will be stable and usable for on-farm applications due to the low organic matter content of the composts.

4. Conclusion

The application of municipal solid waste compost for agricultural purposes is rapidly growing. The composts are made of different sources of materials. To ensure the quality and safety of compost, it is necessary to analyze and monitor its physical and chemical characteristics. In this study, the physiochemical properties and heavy metal analysis of municipal solid waste compost from different dumpsites within Sokoto City were investigated. Results indicated a good quality of the studied compost with only a limited number of parameters outside the specified limits of USA, UNBS/ICS, and WHO standards.

Acknowledgements

The authors acknowledged and expressed their gratitude and appreciation to the Tertiary Education Trust Fund (TETFund) for financial support to carry out this research under Institutional Based Research (IBR) with a number (Bach 7: 2015-2021 Merged Intervention S/NO7).

Conflicts of Interest

The authors declare no conflicts of interest.

References

[1] Ibikunle, R.A., Titiladunayo, I.F., Akinnuli, B.O., Lukman, A.F., Ikubanni, P.P. and Agboola, O.O. (2018) Modelling the Energy Content of Municipal Solid Waste and Determination of Its Physicochemical Correlation, Using Multiple Regression Analysis. *International Journal of Engineering and Technology*, **9**, 220-232.

[2] Lin, X., Wang, F., Chi, Y., Huang, Q. and Yan, J. (2015) A Simple Method for Predicting the Lower Heating Value of Municipal Solid Waste in China Based on Wet Physical Composition. *Waste Management*, **36**, 24-32. https://doi.org/10.1016/j.wasman.2014.11.020

[3] Huseyin, K.O., Senem, Y.G., Lokman, G. and Goksel, D. (2016) Municipal Solid Waste Characterization According to Different Income Levels: A Case Study. *Sustainability*, **8**, Article 1044. https://doi.org/10.3390/su8101044

[4] Read, A.D. (1999) Making Waste Work: Making UK National Solid Waste Strategy Work at the Local Scale. *Resources*, *Conservation and Recycling*, **26**, 259-285. https://doi.org/10.1016/S0921-3449(99)00015-4

[5] Zhou, H., Meng, A.H., Long, Y.Q., Li, Q.H. and Zhang, Y.G. (2014) An Overview of Characteristics of Municipal Solid Waste Fuel in China:Physical, Chemical Composition and Heating Value. *Renewable and Sustainable Energy Reviews*, **36**, 107-122. https://doi.org/10.1016/j.rser.2014.04.024

[6] World Bank (2022) Solid Waste Management. https://www.worldbank.org/en/topic/urbandevelopment/brief/solid-waste-management

[7] Izionworu, V.O. and Akpa, J.G. (2018) Characteristics and Composition Analysis of Municipal Solid Waste in Port Harcourt City, Nigeria—A Prelude to Methane Emission Estimation in the City's Dump Sites. *International Journal of Scientific & Engineering Research*, **9**, 2004-2009.

[8] Bakare, W. (2022) Solid Waste Management in Nigeria. *BioEnergy Consult*.

[9] Babatunde, B.B., Vincent. A.I.F., Woke, G.N., Atarhinyo, E., Aharanwa, U.C., Green, A.F. and Isaac, J.O. (2013) Comparative Analysis of Municipal Solid Waste (MSW) Composition in Three Local Government Areas in Rivers State, Nigeria. *African Journal of Environmental Science and Technology*, **7**, 874-881.

[10] Bhat, R.A., Dar, S.A., Dar, D.A. and Dar, G. (2018) Municipal Solid Waste Genera-

tion and Current Scenario of Its Management in India. *International Journal of Advance Research in Science and Engineering*, **7**, 419-431.

[11] Chen, X. (2012) Life Cycle Assessment (LCA) of Five Municipal Solid Waste Management Systems (MSWMS): A Case Study of Nanjing, China. Doctoral Dissertation, Norwich Research Park, University of East Anglia, Norwich, 1-48.

[12] Banna, F.M., Bhada-Tata, P., Ho, R., Kaza, S. and Lee, M. (2014) Results-Based Financing for Municipal Solid Waste. Main Report (English) in Urban Development Series Knowledge, Vol. 2, World Bank Group, Washington, DC, 1-84.

[13] Ziraba, A.K., Haregu, T.N. and Mberu, B. (2016) A Review and Framework for Understanding the Potential Impact of Poor Solid Waste Management on Health in Developing Countries. *Archives of Public Health*, **74**, Article No. 55. https://doi.org/10.1186/s13690-016-0166-4

[14] Oosterveer, P. and Van Vliet, B. (2010) Environmental Systems and Local Actors: Decentralizing Environmental Policy in Uganda. Environmental Management, **45**, 284-295. https://doi.org/10.1007/s00267-009-9423-4

[15] Rogger, C., Beaurain, F. and Schmidt, T.S. (2011) Composting Projects under the Clean Development Mechanism: Sustainable Contribution to Mitigate Climate Change. *Waste Management*, **31**, 138-146. https://doi.org/10.1016/j.wasman.2010.09.007

[16] Komakech, A.J., Banadda, N.E., Kinobe, J.R., Kasisira, L., Sundberg, C., Gebresenbet, G. and Vinnerås, B. (2014) Characterization of Municipal Waste in Kampala, Uganda. *Journal of the Air & Waste Management Association*, **64**, 340-348. https://doi.org/10.1080/10962247.2013.861373

[17] Komakech, A., Zurbrügg, C., Miito, G., Wanyama, J. and Vinnerås, B. (2016) Environmental Impact from Vermicomposting of Organic Waste in Kampala, Uganda. *Journal of Environmental Management*, **181**, 395-402. https://doi.org/10.1016/j.jenvman.2016.06.028

[18] Sharholy, M. (2008) Municipal Solid Waste Management in Indian Cities—A Review. *Waste Management*, **28**, 459-467. https://doi.org/10.1016/j.wasman.2007.02.008

[19] Narayana, T. (2009) Municipal Solid Waste Management in India: From Waste Disposal to Recovery of Resourses. *Waste Management*, **29**, 1163-1166. https://doi.org/10.1016/j.wasman.2008.06.038

[20] Nyle, C.J. and Ray, R.N. (1999) The Nature and Properties of Soils. 12th Edition, WMC, Brown Publishers, California, USA, 743-785.

[21] Smith, C.J., Hopmans, P. and Cook, F.J. (1996) Accumulation of Cr, Pb, Cu, Ni, Zn, and Cd in Soil Following Irrigation with Untreated Urban Effluents in Australia. *Environmental Pollution*, **94**, 317-323. https://doi.org/10.1016/S0269-7491(96)00089-9

[22] Nadeem, K., Farhan, K. and Ilyas, H. (2016) Waste Amount Survey and Physio-Chemical Analysis of Municipal Solid Waste Generated in Gujranwala-Pakistan. *International Journal of Waste Resources*, **6**, Article No. 196.

[23] Nsimbe, P., Mendoza, H., Wafula, S.T. and Ndejjo, R. (2018) Factors Associated with Composting of Solid Waste at Household Level in Masaka Municipality, Central Uganda. *Journal of Environmental and Public Health*, **2018**, Article ID: 1284234. https://doi.org/10.1155/2018/1284234

[24] Anikwe, M.A.N and Nwobodo, K.C.A. (2001) Long Term Effect of Municipal Waste Disposal on Soil Properties and Productivity of Sites Used for Urban Agriculture in Abakaliki, Nigeria. *Bioresource Technology*, **83**, 241-250.

https://doi.org/10.1016/S0960-8524(01)00154-7

[25] Mandal, P., Chaturvedi, M.K., Bassin, J.K., Vaidya, A.N. and Gupta, R.K (2014) Qualitative Assessment of Municipal Solid Waste Compost by Indexing Method. *International Journal of Recycling of Organic Waste in Agriculture*, **3**, 133-139. https://doi.org/10.1007/s40093-014-0075-x

[26] Jordao, C., Cecon, P. and Pereira, J. (2003) Evaluation of Metal Concentrations in Edible Vegetables Grown in Compost Amended Soil. *International Journal of Environmental Studies*, **60**, 547-562. https://doi.org/10.1080/0020723032000093982

[27] Hargreaves, J.C., Adl, M.S. and Warman, P.R. (2008) A Reviews on the Use of Composited Municipal Solid Waste in Agriculture. *Agriculture*, *Ecosystem and Environment*, **123**, 1-14. https://doi.org/10.1016/j.agee.2007.07.004

[28] Emamverdian, A., Ding, Y., Mokhberdoran, F. and Xie, Y. (2015) Heavy Metal Stress and Some Mechanisms of Plant Defense Response. *The Scientific World Journal*, **2015**, Article ID: 756120. https://doi.org/10.1155/2015/756120

[29] Jaishankar, M., Tseten, T., Anbalagan, N., Mathew, B.B. and Beeregowda, K.N. (2014) Toxicity, Mechanism and Health Effects of Some Heavy Metals. *Interdisciplinary Toxicology*, **7**, 60-72. https://doi.org/10.2478/intox-2014-0009

[30] Okalebo, J.R., Gathua, K.W. and Woomer, P.L. (2002) Laboratory Methods of Soil and Plant Analysis: A Working Manual. 2nd Edition, Sacred Africa Nairobi Office, Nairobi, **21**, 25-26.

[31] Horwitz, W. and Latimer, G.W. (2005) Official Methods of Analysis of AOAC International. AOAC International, Gaithersburg, MD.

[32] AOAC (1990) Official Methods of Analysis. Method 973.04 PH of Peat.

[33] ASTM E830-87 (2004) Standard Test Method for Ash in the Analysis Sample of Refuse-Derived Fuel. ASTM International, West Conshohocken, PA.

[34] ASTM E897-88 (2004) Standard Test Method for Volatile Matter in the Analysis Sample of Refuse-Derived Fuel. ASTM International, West Conshohocken, PA.

[35] Onuegbu, I.V. and Gunorubon, A.J. (2004) Characteristics and Composition Analysis of Municipal Solid Waste in Port Harcourt City, Nigeria—A Prelude to Methane Emission Estimation in the City's Dump Sites. *International Journal of Scientific & Engineering Research*, **9**, 2004-2009.

[36] Schrenk, W. (2012) Analytical Atomic Spectroscopy (Modern Analytical Chemistry). Springer Science & Business Media, Manhattan, KS.

[37] Amouei, A., Asgharnia, H.A. and Khodadi, A. (2009) Study of Compost Quality from Rural Solid Wastes (Babol, Iran). *Journal of Mazandaran University of Medical Sciences*, **20**, 55-61.

[38] Zhao, S., Lian, F. and Duo, L. (2011) EDTA-Assisted Phytoextraction of Heavy Metals by Turfgrass from Municipal Solid Waste Compost Using Permeable Barriers and Associated Potential Leaching Risk. *Bioresource Technology*, **102**, 621-626. https://doi.org/10.1016/j.biortech.2010.08.006

[39] Ibrahim, G.D., Nwaichi, E.O. and Abu, G.O. (2020) Heavy Metals Contents of Municipal Solid Waste Dumpsites in Potiskum, Yobe State Nigeria. *Journal of Environmental Protection*, **11**, 709-717. https://doi.org/10.4236/jep.2020.119043

[40] Ma, L.Q. and Rao, G.N. (1997) Chemical Fractionation of Cadmium, Copper, Nickel and Zinc in Contaminated Soils. *Journal of Environmental Quality*, **26**, 259-264. https://doi.org/10.2134/jeq1997.00472425002600010036x

[41] Mido, Y. and Satake, M. (2003) Chemical in the Environment. In: Sethi, M.S. and Igbal, S.A., Eds., *Toxic Metals*, Discovery Publishing House, New Delhi, 45-68.

[42] Omrani, G., Safa, M. and Ghafghazy, L. (2004) Utilization of Biofilter for Ammonia Elimination in Composting Plant. *Pakistan Journal of Biological Sciences*, **30**, 192-201.

[43] Day, M. and Shaw, K. (2001) Biological, Chemical and Physical Processes of Composting. In: Stoffella, P.J., Kahn. B.A., Eds., *Compost Utilization in Horticultural Cropping Systems*, Lewis Publishers, Boca Raton, 17-50.

[44] Sadeghi, S., Dehvari, M., Bahmani, P., Teymouri, P., Fattahi, A., Sadeghnia, M. and Fallahzadeh, R.A. (2015) Physical-Chemical Analysis and Comparison with Standards of the Compost Produced in Sanandaj, Iran. *Open Access Library Journal*, **2**, e1855. https://doi.org/10.4236/oalib.1101855

[45] Abbasi, F.M., Ahmad, H., Perveen, F., Sajid, M. and Brar, D.S. (2010) Assessment of Genomic Relationship between *Oryza sativa* and *Oryza australiensis*. *African Journal of Biotechnology*, **9**, 1312-1316. https://doi.org/10.5897/AJB10.1689

[46] Malakootian, M., Yaghmaeian, K. and Mobini, M. (2014) Feasibility of the Compost Production Using Pistachio Hull and Mixed of Pistachio Hull and Broiler Litter. *TB: The Journal of Toloo-e-behdasht*, **12**, 24-35.

[47] Rahman, M.M., Bhuiyan, M., Rouf, M., Sarker, R. and Rashid, M.H. (2020) Quality Assessment of Municipal Solid Waste Compost. *ACMY: Acta Chemica Malaysia*, **4**, 33-39. https://doi.org/10.2478/acmy-2020-0006

[48] Silva, M.T., Menduína, A.M., Seijo, Y.C. and Viqueira, F.D. (2007) Assessment of Municipal Solid Waste Compost Quality Using Standardized Methods before Preparation of Plant Growth Media. *Waste Management & Research*, **25**, 99-108. https://doi.org/10.1177/0734242X07075514

[49] Rawat, M., Ramanathan, A. and Kuriakose, T. (2013) Characterisation of Municipal Solid Waste Compost (MSWC) from Selected Indian Cities—A Case Study for Its Sustainable Utilisation. *Journal of Environmental Protection*, **4**, 163-171. https://doi.org/10.4236/jep.2013.42019

[50] Kabasiita, J.K., Opolot, E. and Malinga, G.M. (2022) Quality and Fertility Assessments of Municipal Solid Waste Compost Produced from Cleaner Development Mechanism Compost Projects: A Case Study from Uganda. *Agriculture*, **12**, Article 582. https://doi.org/10.3390/agriculture12050582

[51] Jimoh, W.L.O. and Sabo, Y. (2013) Evaluation of Physicochemical Properties and Heavy Metals Concentration in Municipal Dumpsite Compost in Kano Metropolis, Nigeria. *ChemSearch Journal*, **4**, 26-30.