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Cover Page Footnote

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INFLUENCE OF MUNICIPAL SOLID WASTE DUMPSITE ON SOIL PHYSICOCHEMICAL PROPERTIES AND VERTICAL DISTRIBUTION OF HEAVY METALS

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ABSTRACT

The management of municipal solid waste (MSW) through open dumping or open burning has been a very common practice in Nigeria. The work investigated the impact of these practices on soil physicochemical properties and the vertical distribution of heavy metals at two dumpsites at Obollo-Afor and Nsukka in Southeastern Nigeria. Soil samples were collected at 10 m apart at depths of 0-20, 20-40, 40-60 cm from the dumpsite and at 100 m away from the dumpsite for the determination of soil physicochemical properties. A profile pit was dug at the centre of each dumpsite while soil sample collection was done from 0-100 cm for heavy metal determination. Soil chemical properties (TN, Av. P, OM, TEB, CEC, H^+, Al^{3+}, Ca^{2+}, Mg^{2+}, Na^+, K^+) and some soil physical properties e.g. aggregate stability (AS) and available water capacity (AWC) differed significantly ($P < 0.05$) across locations and depths. Municipal solid wastes significantly ($P < 0.05$) influence all soil chemical and some physical properties such as mean weight diameter (MWD), AS, clay, and sand contents. The impact of MSW was more pronounced at the surface soil (0-20 cm) and decreased with increasing depth. In addition, significant ($P < 0.05$) interaction effects of MSW on soil chemical and physical properties were recorded across locations and depth zones. In both locations, heavy metal concentrations were higher in MSW dumpsites relative to the control. However, the heavy metal concentrations were too low to cause any ecological or health risk when compared to the heavy metal permissible limit in agricultural soils as recommended by WHO.

Keywords: Cultivation, dumpsite, ecological risk, fertility, waste management.

INTRODUCTION

A major consequence of current industrialization and the desire for a better quality of life is an increased rate of soil contamination due to municipal waste disposal (WHO 2007). In Nigeria, open dumping or open burning is commonplace. This has caused severe environmental, health, and economic problems (Ikpe, et al., 2019). Open dumping and indiscriminate waste disposal is a common practice in many low-income and upper-middle-incomes in developing countries. These indiscriminate dumps of waste could lead to degrading the environment, polluting soil and water resources, as well as posing a health risk to humans, animals, and plants (Baderna et al., 2011). Many factors influence how municipal waste is generated and managed. These factors include the human population, the economic growth of the country and its citizens, the level of technological development in the society, the culture and the habits of the citizens (Ezeoha, 2014).

As in many developing countries, Nigeria has no other options for solid waste disposal than an open dump. Chopra et al., (2010) defined waste dumps practices practice as the removal of municipal solid waste through filling depressions in the soil. These depressions are usually used to dump solid wastes, such as valleys or excavations. These sites can pose serious risks to human health, as they are often low-laying and pose a threat to soil and groundwater resources. Kanga et al., (2006) identified the main risk factor as soil contamination with toxic household wastes, paints, pesticides and oil.

Dumpsites could be sources of air pollution. Rong et al., (2015) stated that methane, a greenhouse gas, is produced by the decomposition of organic wastes dumped onto dumpsites. This gas can pose a serious risk to local residents due to its flammability. They are also a nuisance, causing significant environmental pollution due to the production of biogas and leachate (Aronsson et al., 2010). The municipal solid waste dumpsite does not serve as a safe place to store discarded material. It is a biochemically activated unit in which toxic substances are slowly released into the environment from combinations of nontoxic precursors over several decades (Papadopoulou et al., 2006). Environmental effects of exudates from municipal waste disposal sites are rising at alarming rates, particularly the leaching of heavy metals (Iqbal et al., 2015; Prechthai et al., 2008). Leachate is formed primarily by precipitation. It infiltrates through the refuse and usually causes soil and groundwater contamination (Samuding, 2009; Kanmani, and Gandhimathi, 2012). The soil around dumpsites may be contaminated by heavy metals, such as copper, zinc and iron. These heavy metals can be difficult to biodegrade and cause serious problems. The risk posed by leachates of municipal solid waste is dependent on several factors: waste composition, volume (temperature, lifetime), soil morphology, and distance between the dumpsite, agricultural land and the water body that the human community uses (Badmus et al., 2014). However, Ideriah et al., (2006) and Eze (2015) noted that wastes types or sources and topography notably influenced heavy metal concentrations of soils, especially around waste dumps.

The work of Araújo et al., (2010) had previously reported the significant impact of MSW leachate on soil's physical and chemical properties. It promoted encouraged soil aggregation, reduce surface crusting, reduced pH in calcareous soils and increased soil organic matter (Anikwe and Nwobodo, 2002; Iglesias-Jimenez et al., 1993). Understanding how municipal solid waste dumpsite (MSWD) affects soil's physicochemical properties is essential for improving soil health and environmental quality. The study seek study seeks to determine the impact of municipal solid waste dumpsite on physicochemical properties and heavy metal concentration in some soils of southeastern Nigeria. Specifically, the study aims to evaluate and compare the effect of MSWD on physicochemical properties of soils across depths and locations, and heavy metal distribution across the profiles of dumpsite.

MATERIALS AND METHOD

Location

The site of this study was two dumpsites in Nsukka and Obollo-Afor located in Enugu state, southeastern Nigeria. Nsukka dumpsite is within the University of Nigeria, Nsukka main campus and lies between latitude 6˚51’ N and longitude 7˚23’ E at 474 m a.s.l. The obollo-Afor dumpsite is located along Obollo-Eke road and lies between latitude 6° 54' N and longitude 7° 31' at 347 m a.s.l. The prevalent climate climatic condition of the area is a wet and dry tropical climate characterized by uniform temperature usually high for the most part of the year. The rainforest savannah type of vegetation that is native to the study sites has been greatly destroyed by man’s activities. The type of farming practices around the dumpsites is pasture land for animal grazing, cassava and plantain production for the University of Nigeria Nsukka dumpsite while for Obollo-Afor dumpsite, permanent crops such as cashew and palm trees are cultivated.

Criteria for Selecting the Dumpsites

The major criteria used for the selection of the dumpsites are; the duration or age of the dumpsite and the mode of solid waste disposal i.e. burning. The dumpsites in the two locations are continuously burnt and well above 10 years but 7 years ago, the dumpsite located at Obollo-Afor was altered by road construction.

Field Soil Sampling

At each location, samples (disturbed and undisturbed soil) were collected at ten sampling points separated by 10 m spacing within the dumpsite at three depths of 20 cm depth increment using soil auger and core samplers respectively. For each location, similar soil samples were collected 100 m away from the dumpsite at ten sampling points and at 0-60 cm depth at 20 cm depth increment to serve as the control. In addition, a profile pit was dug at the centre of each dumpsite in each location and disturbed soil samples were collected at depths of 0-100 cm depth at 20 cm depth increment for heavy metal determination. The soil samples were labeled appropriately and carefully transported to the Department of Soil Science laboratory, University of Nigeria, Nsukka for further processing and analysis.

Laboratory Analysis

The soil samples were prepared and analyzed using the standard analytic procedures for physical properties (Dane and Topp 2002) and chemical properties (Sparks 1996). The soil samples were analyzed for the following important parameters; soil bulk density, pore size distribution, soil aggregate stability, mean weight diameter, saturated hydraulic conductivity, cation exchange capacity (CEC), total nitrogen, soil organic matter (SOM), exchangeable acidity (EA), exchangeable cations, available phosphorus. Total exchangeable bases (TEB) was determined through the calculation method by summation of all the exchangeable cations (Ca^{2+}, Mg^{2+}, Na^{+}, K^{+}).

Zinc was determined by titrimetric method of Vogel (1965) as modified by Lal and Singh (2020). In this method, Zinc is first masked by adding sodium cyanide as tetracyano-sodium zincate $Na_2Zn\ (CN)_4$ and free Mg is titrated with EDTA at pH 10. Later the zinc is again de-masked with formaldehyde acetic acid and titrated against EDTA. It Zinc (Zn) content was calculated as follows:

$$Zn\ (\%) = \frac{10XV2}{v1}$$

Where V1 = volume of EDTA solution (ml) used for 10 ml of standard Zn solution

V2 = volume of EDTA solution (ml) used for titration of sample solution

Lead was determined by sulphide method using 10 % tartaric acid solution, 10 % potassium cyanide (KCN) and 1:2 ammonia solution and 10 % NaS solution. Absorbance was taken at 430 nm using a spectrophotometer (Vogel, 1965).

Cadmium was determined by the xylenol orange method using dilute 5N H_2SO_4, powdered hexamine crystal, standard 0.01N EDTA. Absorbance was taken at 460 nm using a spectrophotometer (Vogel, 1965).

Statistical Analysis

The statistical analysis of data on soil physicochemical properties was performed using GENSTAT, Edition 4.

The means for the main effects of location, municipal solid waste dumpsite and depth were compared for significant differences at 5 % probability level using Fischer's least significant difference (F-LSD) approach (Obi, 2002).

RESULTS

Soil Physical Properties as Influenced by Location, MSWD and Depth

The main effects of location, dumpsite status and depth on soil physical properties (Table 1) showed that microporosity (MicP), total porosity (TP), available water capacity (AWC), aggregate stability (AS), clay, sand and silt contents of the soils differed significantly ($P < 0.05$) across the locations studied. Generally, the results showed that microporosity (MicP), total porosity (TP), available water capacity (AWC), aggregate stability (AS), clay, sand and silt contents were higher in Nsukka soil compared to Obollo-Afor soil. However, the results showed a non-significant ($p < 0.05$) effect of location on saturated hydraulic conductivity (Ksat), macroporosity (MacP), bulk density (Bd) and mean weight diameter (MWD) of the soils.

Similarly, significant ($P < 0.05$) influence of MSWD on AS, MWD, clay and sand contents was observed. Generally, the results showed that AS and sand contents were higher in the MSWD relative to the control. However, the results showed that MWD and clay contents were lower in the MSWD compared to the control site.

In addition, the results showed that AS, MWD, silt and clay contents, and silt/clay ratio differed significantly ($P < 0.05$) across the depths of soil studied. The results showed that MWD, silt and sand contents, and silt-clay ratio consistently decreased with increasing depth whereas clay increased consistently with an increase in depth. However, the results showed that AS increased with increasing depth recording its highest value of 43.10 % at 40-60 cm depth and its lowest value of 39.80 % at 0-20 cm depth.

Location, Municipal Solid Waste Dumpsite (MSWD) and Depth Effects on Soil Chemical Properties

The main effects of location, MSWD and depth on some selected soil chemical properties are shown in Table 2. The pH, CEC, available phosphorus (Av. P), total nitrogen (TN), organic matter (OM), total exchangeable bases (TEB) and all the exchangeable cations (H^+, Al^{+3}, Ca^{2+}, Mg^{2+}, Na^+, K^+) differed significantly ($P < 0.05$) across the two locations investigated. Interestingly, our findings showed that higher values of these soil properties were found in Nsukka soils compared to Obollo-Afor soils. Specifically, Av. P, calcium and magnesium were 450 %, 810 % and 1260 % respectively higher in Nsukka soils compared to Obollo-Afor soils.

Similarly, pH, CEC, available phosphorus (Av.P), total nitrogen (TN), organic matter (OM), total exchangeable bases (TEB) and all the exchangeable cations (H^+, Al^{+3}, Na^+, K^+, Mg^{2+}, Ca^{2+}) were significantly ($P < 0.05$) influenced by the MSWD. Higher values for soil pH, Av. P, TN, TEB, CEC and all the exchangeable cations except H^+ and Al^{3+} were obtained in the MSWD relative to the control.

The pH of the MSWD soil was moderately alkaline (8.1) compared to the moderate acidic (5.8) pH obtained at the control. In addition, the result showed that organic matter (OM) was 22.3% lower in the MSWD when compared to the control.

In addition, the results showed that soil pH, H^+, Al^{3+}, OM, TN, Ca^{2+}, Na^+, K^+, TEB, and Av. P differed significantly ($P < 0.05$) across the depths of soil studied. From the results, it was observed that these soil properties decreased and increased inconsistently with increasing depth.

Table 1: Main effect of location, municipal solid waste dumpsite and depth on soil physical properties

Treatment	Bd (g/cm^3)	Ksat ($cmhr^{-1}$)	Mic.P	Mac.P	TP	AWC	AS	MWD (mm)	Clay	Silt	Sand	Silt/Clay
			%						%			
Location												
Nsukka	1.44	17.30	48.31	7.20	55.51	19.51	48.50	1.11	25.0	5.0	70.0	0.32
Obollo-afor	1.57	41.90	35.24	5.95	41.18	12.45	33.40	1.11	10.0	3.0	87.0	0.36
$F\text{-}LSD_{0.05}$	**NS**	**NS**	**3.09**	**NS**	**2.42**	**3.54**	**12.08**	**NS**	**2.19**	**1.27**	**2.66**	**NS**
MSWD												
Dumpsite	1.52	16.90	40.60	6.07	46.67	15.71	57.70	0.97	13.0	5.0	82.0	0.36
Control	1.49	42.20	42.95	7.08	50.02	16.25	24.40	1.24	20.0	4.0	76.0	0.32
$F\text{-}LSD_{0.05}$	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**17.27**	**0.15**	**1.15**	**NS**	**0.69**	**NS**
Depth (cm)												
0-20	1.46	36.30	42.58	6.51	49.09	16.64	39.80	1.34	14.0	5.0	81.0	0.47
20-40	1.55	27.80	41.48	6.43	47.91	15.46	40.20	1.04	18.0	4.0	78.0	0.32
40-60	1.51	24.60	41.26	6.78	48.04	15.84	43.10	0.93	20.0	4.0	76.0	0.22
$F\text{-}LSD_{0.05}$	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**6.35**	**0.14**	**0.97**	**0.65**	**1.13**	**0.06**

Note: MSWD= municipal solid waste dumpsite. Ksat= saturated hydraulic conductivity, Bd= Bulk density, TP= Total porosity, AS = Aggregate stability, MWD= mean weight diameter, MicP = microporosity, MacP = macroporosity, AWC = available water capacity, $F\text{-}LSD_{0.05}$= Fischer's least significant difference at 5 % probability level.

Table 2: Effect of location, municipal solid waste dumpsite (MSWD) and depth on soil chemical properties

Treatment	pH (H_2O)	H^+	Al^{3+}	%OM	%TN	Ca^{2+}	Mg^{2+}	Na^+	K^+	TEB	CEC	Av.P ppm
		Cmol/kg					Cmol/kg					
Location												
Nsukka	7.3	2.10	1.33	2.90	0.19	6.40	5.57	0.08	0.93	12.97	13.39	20.66
Obollo-Afor	6.7	1.54	0.84	1.28	0.07	0.79	0.44	0.04	0.35	1.63	5.05	4.50
$F\text{-}LSD_{0.05}$	**0.32**	**0.55**	**0.21**	**0.09**	**0.05**	**0.70**	**1.31**	**0.02**	**0.17**	**1.86**	**0.58**	**11.25**
MSWD												
Dumpsite	8.1	2.13	1.91	1.88	0.17	6.58	5.67	0.07	0.98	13.31	8.79	22.07
Control	5.8	2.51	0.27	2.30	0.09	0.61	0.34	0.05	0.29	1.29	9.65	3.10

F-LSD$_{0.05}$	**0.16**	**0.26**	**0.13**	**0.14**	**0.01**	**0.66**	**0.51**	**0.00**	**0.04**	**1.12**	**0.24**	**7.23**
Depth (cm)												
0-20	6.9	1.68	1.03	2.51	0.14	3.83	3.15	0.07	0.73	7.77	9.40	9.55
20-40	7.1	1.67	1.19	1.71	0.14	3.26	2.93	0.05	0.57	6.80	9.46	16.74
40-60	6.8	2.13	1.05	2.05	0.11	3.70	2.94	0.06	0.63	7.33	8.80	11.46
F-LSD$_{0.05}$	**0.14**	**0.16**	**0.12**	**0.16**	**0.02**	**0.19**	**NS**	**0.01**	**0.05**	**0.46**	**NS**	**3.01**

Note: MSWD = municipal solid waste dumpsite, H=Hydrogen, K= potassium, Ca= Calcium, Mg= Magnesium, Al = Aluminum, Na= Sodium, TEB = total exchangeable base, CEC= Cation exchange capacity, OM= Organic matter, Av.P = Available phosphorus, TN = Total nitrogen

Table 3: Interaction effect of location and municipal solid waste dumpsite (MSWD) on soil physical properties

Location	MSWD	Bd (g/cm^3)	Ksat (cmhr^{-1})	Mic.P	Mac.P	TP	AWC	AS	MWD (mm)	Clay	Silt	Sand	Silt/Clay
					%						%		
Nsukka	Dumpsite	1.31	16.0	47.73	6.00	53.73	19.81	32.8	0.97	14.0	7.0	79.0	0.51
	Control	1.38	18.6	48.89	8.40	57.29	19.20	64.2	1.25	34.0	4.0	62.0	0.13
Obollo-Afor	Dumpsite	1.74	17.9	33.47	6.14	39.61	11.61	16.0	0.98	13.0	3.0	84.0	0.21
	Control	1.59	65.8	37.00	5.75	42.75	13.29	51.1	1.23	7.0	3.0	90.0	0.50
F-LSD$_{0.05}$		**NS**	**NS**	**NS**	**NS**	**9.896**	**NS**	**NS**	**NS**	**1.738**	**1.101**	**2.285**	**0981**

Note: Ksat= saturated hydraulic conductivity, Bd= Bulk density, TP= Total porosity, AS = Aggregate stability, MWD= mean weight diameter, MicP = microporosity, MacP = macroporosity, AWC = available water capacity.

Table 4: Interaction effect of location and municipal solid waste dumpsite (MSWD) on soil chemical properties

Location	MSWD	pH (H_2O)	H^+	Al^{3+}	%OM	%TN	Ca^{2+}	Mg^{2+}	Na^+	K^+	TEB	CEC	Av.P ppm
			Cmol/kg						Cmol/kg				
Nsukka	Dumpsite	8.9	1.00	0.00	2.09	0.26	12.23	10.77	0.09	1.52	24.61	13.24	38.70
	Control	5.6	3.20	2.67	2.72	0.13	0.57	0.37	0.06	0.34	1.34	13.53	2.62
Obollo-Afor	Dumpsite	7.4	1.27	0.53	1.68	0.08	0.93	0.57	0.05	0.45	2.01	4.33	5.43
	Control	6.1	1.82	1.16	1.89	0.06	0.64	0.32	0.03	0.25	1.25	5.77	3.58
F-LSD$_{0.05}$		**0.256**	**0.436**	**0.1728**	**0.1371**	**0.043**	**0.703**	**1.047**	**0.0216**	**0.149**	**1.517**	**0.460**	**9.313**

Interaction Effect of Location and MSWD on Physical Properties of the Soil

The result of the interaction effect of location and MSWD on soil physical properties is shown below (Table 3). The results showed that total porosity (TP), Clay, silt and sand contents including silt-clay ratio was the only soil physical properties influenced by the interaction of location and MSWD.

The highest total porosity of 57.29 % and clay content of 34 % was obtained at the control site in Nsukka while the highest silt content of 7 % and the silt-clay ratio of 0.51 were obtained at the MSWD in Nsukka. However, sand content was highest (90 %) at the control site in Obollo-Afor.

Interaction Effect of Location and Municipal Solid Waste Dumpsite (MSWD) on Soil Chemical Properties

The result showed a significant ($p < 0.05$) interaction effect of location and MSWD on most of the soil chemical properties (Table 4). In both locations, the values of all the chemical properties except H^+, $Al^{3+}$and CEC were higher at the MSWD relative to the control. However, MSWD at Nsukka gave the highest values for all the chemical properties studied except H^+ and $Al^{3+}$when compared to that at Obollo-Afor. In both locations, soil pH, total nitrogen (TN), all exchangeable bases (Na^+, K^+, Mg^{2+}, Ca^{2+}), total exchangeable bases (TEB) and Av. P increased significantly at the dumpsite compared to the control. On the other hand, H^+, Al^{3+}, organic matter content (OM), and CEC were all higher at the control site than at the dumpsite.

Interaction Effect of Municipal Solid Waste Dumpsite (MSWD) and Depth Zone on Soil Physical Properties

The result of the interaction effect of MSWD and depth zone on soil physical properties is shown in Table 5 below. The result showed a significant ($p < 0.05$) interaction effect of MSWD and depth zone on saturated hydraulic conductivity (Ksat), macroporosity (MacP), aggregate stability (AS), sand content and silt-clay ratio. Generally, Ksat, MacP and AS were significantly higher across the three depths at the control site relative to the MSWD. However, the MSWD contains more have significantly ($p < 0.05$) higher sand and have higher silt-clay ratio per depth when compared to the control site.

Interaction Effect of Municipal Solid Waste Dumpsite (MSWD) and Depth Zone on Soil Chemical Properties

The result (Table 6) showed a significant ($p < 0.05$) interaction effect of MSWD and depth zone on soil chemical properties except for exchangeable magnesium (Mg^{2+}). The results showed that all the chemical properties except H^+, Al^{3+} and OM were highest higher significantly ($p < 0.05$) across the three depth zones at the MSWD than at the control sites

The Concentration of Heavy Metals along the Soil Profile at the Municipal Solid Waste Dumpsite

Heavy metal distribution of dumpsite soils in the two study locations are given in Table 7. The results showed that zinc concentrations varied from 18.8-31.6 mg kg^{-1} in Nsukka at the dumpsite in Nsukka and from 4.0-8.4 mg kg^{-1} at the dumpsite in Obollo-Afor.

Zinc concentration is comparatively lower at the control site than at the dumpsites and ranges from 7.2-9.2 mg kg^{-1} in Nsukka and from 4.4 3.9-6.4 mg kg^{-1} in Obollo-Afor. Zinc concentration decreased with an increase in depth at the control site while there was no clearly defined trend at the dumpsites.

Table 5: Interaction effect of municipal solid waste dumpsite (MSWD) and depth on soil physical properties

MSWD	Depth	Bd (g/cm^3)	Ksat ($cmhr^{-1}$)	Mic.P	Mac.P	TP	AWC	AS	MWD (mm)	Clay	Silt	Sand	Silt/Clay
					%						%		
Dumpsite	0-20	1.52	14.6	42.02	4.60	42.67	16.14	17.0	1.17	11.0	5.0	84.0	0.55
	20-40	1.57	13.8	40.93	6.42	41.17	15.61	26.8	0.94	15.0	4.0	81.0	0.28
	40-60	1.49	22.4	38.85	7.19	43.67	15.38	29.3	0.81	16.0	4.0	80.0	0.25
Control	0-20	1.41	58.0	43.15	8.42	46.67	17.14	62.5	1.52	18.0	4.0	78.0	0.40
	20-40	1.53	41.8	42.03	6.43	43.00	15.31	53.7	1.15	21.0	4.0	76.0	0.36
	40-60	1.52	26.8	43.66	6.38	42.67	16.30	56.8	1.05	23.0	4.0	73.0	0.19
F-LSD$_{0.05}$		**NS**	**34.97**	**NS**	**3.112**	**NS**	**NS**	**16.98**	**NS**	**NS**	**NS**	**1.389**	**0.0899**

Table 6: Interaction effect of municipal solid waste dumpsite and depth zone on soil chemical properties

MSWD	Depth	pH (H_2O)	H^+	Al^{3+}	%OM	%TN	Ca^{2+}	Mg^{2+}	Na^+	K^+	TEB	CEC	Av.P ppm
			Cmol/kg							Cmol/kg			
Dumpsite	0-20	7.9	0.95	0.25	2.00	0.16	7.15	6.05	0.09	1.18	14.47	8.30	15.16
	20-40	8.2	1.20	0.25	1.45	0.19	5.85	5.42	0.06	0.78	12.11	9.67	30.69
	40-60	8.3	1.25	0.30	2.19	0.15	6.75	5.53	0.07	1.00	13.35	8.40	20.35
Control	0-20	5.9	2.40	1.80	3.02	0.11	0.50	0.25	0.05	0.28	1.07	10.50	3.93
	20-40	6.0	2.13	2.13	1.98	0.08	0.67	0.43	0.05	0.35	1.50	9.25	2.80
	40-60	5.6	3.00	1.80	1.91	0.08	0.65	0.35	0.05	0.26	1.31	9.20	2.57
F-LSD$_{0.05}$		**0.202**	**0.280**	**0.170**	**0.205**	**0.0204**	**0.641**	**NS**	**0.0141**	**0.0645**	**1.112**	**0.847**	**7.174**

Table 7: The concentration of heavy metals at the waste dumpsites in Nsukka and Obollo-Afor

Depth (cm)	Zinc	Lead	Cadmium
	Nsukka		
0-20	29.2	18.7	0.40
20-40	31.2	21.4	0.42
40-60	31.6	21.5	0.46
60-80	28.8	21.4	0.45
80-100	18.8	19.2	0.33
Control			
0-20	9.2	20.1	0.45
20-40	8.8	23.1	0.52
40-60	7.4	19.9	0.49
60-80	7.3	19.7	0.48
80-100	7.2	18.9	0.47
	Obollo-Afor		
0-20	8.0	22.8	0.50
20-40	8.4	17.9	0.37
40-60	7.2	20.7	0.50
60-80	6.0	22.0	0.45
80-100	4.0	18.1	0.47
control			
0-20	6.4	17.8	0.42
20-40	4.4	20.3	0.43
40-60	4.4	12.0	0.42
60-80	4.2	11.8	0.40
80-100	3.9	11.5	0.41
WHO PML	**0.1-50**	**0.1-85**	**0.01-0.8**

Note: WHO PML= WHO Permissible limit

The concentration of lead (Pb) ranged from 19.2-22.4 mg kg^{-1} in soils of Nsukka dumpsite and from 17.9-22.8 mg kg^{-1} in soils of Obollo-Afor dumpsite.

In the control site, Pb concentration ranged from 18.9-23.1 mg kg^{-1} in Nsukka and from 11.5-20.8 mg kg^{-1} in Obollo-Afor. Similarly, cadmium concentrations are in the range from 0.33-0.46 mg kg^{-1} in Nsukka dumpsite and from 0.37-0.50 mg kg^{-1} in soils of Obollo-Afor. In the control site, cadmium concentration ranged between 0.45-0.52 mg kg^{-1} in Nsukka and from 0.40-0.43 mg kg^{-1} in Obollo-Afor.

DISCUSSIONS

Soil physical properties tend to vary across locations, depth and municipal solid waste dumpsite (MSWD) as obtained from our study. This assertion is further corroborated in the findings of several authors (Sharma et al., 2011; Azuka and Igué, 2020). However, our result showed that bulk density (Bd), macroporosity and a highly variable property such as saturated hydraulic conductivity (ksat) did not differ across the two locations studied. The relatively high sand but predominantly silt and clay contents of the soils in the study location was also reported by Akamigbo and Asadu (1985). Other authors (Amos-Tautua et al., 2014; Ideriah et al., 2006) also reported similar high sand contents as obtained in this study from the dumpsites relative to the control sites. Generally, soils with high sand and lower clay contents are highly permeable to water and leachates, and thus have high pollutant leaching potentials (Nyles and Ray, 1999). These soils are highly permeable as seen from their high Ksat values and may pose a serious environmental risk to groundwater pollution. According to Singhal and Islam (2008), higher reductions in soil hydraulic conductivity is observed in finer-grained soils than in their larger-grained counterpart. Generally, the hydraulic conductivity decreased with increasing depth across locations due to increased bulk density and compaction but increased with increasing depth at the MSWD. This could be attributed to frequent burning witnessed at the dumpsites which have induced water repellency or hydrophobicity in the soil. According to DeBano (1969), intense burning produces hydrophobic organic compounds, which coat the soil aggregates and induce the development of a water repellent layer in the soil. The implication of such reduced permeability will be reduced leaching and transport of pollutants to the groundwater. This corroborates the findings of Mehmood-ul-Hassan et al., (2010), who reported that solute and water including contaminant movement in the soil is controlled by soil hydraulic properties such as soil hydraulic conductivity. In addition, the accumulation of hydrophobic substances produced during the burning of vegetation and soil organic matter by fires reduced the wettability and infiltration on the soil surface, and correspondingly increase runoff (Wittenberg et al., 2014). This may explain the lower available water capacity (AWC) obtained at the MSWD often subjected to burning relative to the control or unburned site. By reducing infiltration and increasing surface runoff generation, water repellency may likely enhance the risk of soil erosion at the location (Samanta et al., 2010; Shakesby and Doerr, 2006). Moreso, the higher aggregate stability (AS) obtained in the dumpsite relative to the control could be attributed mainly to the burning effects but not organic matter. The result of our study agrees with the submissions of Thomaz (2017) who reported a 10 % increase in aggregate stability of burned soil in comparison with unburned soil. Although the organic matter is believed to improve soil aggregate stability tremendously, our results showed that organic matter was lower in the dumpsites relative to the control. The higher bulk density and lower total porosity obtained at the MSWD relative to the non-dumpsite or control site contradicts the findings of Anikwe and Nwobodo (2002). The increase in soil bulk density and low porosity may be attributed to the burning of the dumpsite, which significantly reduced SOM that is responsible for improving hydrological and structural properties of the soil.

Generally, the pH of the soil in most of the dumpsites was high and ranged from neutral to alkaline compared to the control. Other authors (Ideriah et al.; 2006, Kanmani and Gandhimathi, 2012; Obasi et al., 2012) also made a similar observation. According to Kanmani and Gandhimathi (2012), free volatile acids concentration decreases mainly as a result of anaerobic decomposition and partial ionization of fatty acids contribute to higher pH value. This high pH could also be attributed to the open burning approach adopted for waste disposal at the sites investigated. This corroborates the findings of Amoako and Gambiza (2019) who reported higher pH in burned than in unburned woodland and crop fields. The burning of these wastes produces ash which has some liming effect on acidic soils (Knicker, 2007; Moreira et al., 2013). According to Knicker (2007), such liming effect has a positive impact on the biological recovery of soil. The higher pH values for dumpsite soils of Nsukka, as opposed to dumpsite soils of Obollo-Afor, may be due to the age differences of the two dumpsites. The dumpsite at Nsukka was well above 10 years while the Obollo-Afor dumpsites were altered 7 years ago during road construction. This observation is consistent with the findings of Praveena and Rao (2016) and El-Fadel et al., (2002) who pointed out that pH levels increased tremendously at dumping sites after 10 years of waste disposal.

Soil pH controls the availability of essential nutrients and heavy metals. This may explain the significant increase in the content of these nutrients (TN, Av. P, OM, TEB, H^+, Al^{3+}, Ca^{2+}, Mg^{2+}, Na^+, K^+) at the MSWD relative to the control. This result corroborates the findings of other researchers (Amos-Tautua et al., 2014; Aydinalp and Marinova, 2003) who reported significant-high content of these nutrient elements in dumpsites relative to the control.

Generally, the high content of TN, Av. P, OM, TEB, H^+, Al^{3+}, Ca^{2+}, Mg^{2+}, Na^+, K^+ at the MSWD relative to the control indicate that municipal solid waste improves the nutrient status of the soil. A similar report was given for dumpsite soils of Ekwulobia in Anambra State, Nigeria (Ndukwu et al., 2016**)**. However, our result showed that CEC and OM were higher in the control sites compared to the MSWD. This could be attributed to the burning of the dumpsites which reduced the OM content of the soils. This result corroborated the findings of several authors (Azuka et al., 2015; Habtamu et al., 2009; Lal et al., 2003) who reported that burning destroys organic materials, and consequently reduced OM significantly in the soils investigated. Similarly, Parker et al., (2010) estimated that the burning of organic materials such as crop residues resulted in a 21 % decrease of organic carbon addition to soil. Stoof et al., (2010) also reported that burning and heating soil to temperatures of 300 °C and above decreased OM in the soil. It is important to note that the differences in OM contents of soils at the two dumpsites may be as a result of the nature and composition of the municipal solid wastes.

Generally, the concentration of zinc, lead and cadmium at the municipal solid waste dumpsite in both locations are below the permissible limit (90-400 mg kg^{-1}) recommended by the “world health organization (WHO)” in 1996 and the “national environment protection council of Australia (NEPCA)” in 2010 for agricultural soil. This result corroborates several findings of other authors who did similar investigation in cities across Nigeria (Amos-Tautua et al., 2014; Asawalam and Eke, 2006; Njoku and Ayoka, 2007; Umoh and Etim, 2013). In addition, the higher concentration of zinc in both dumpsites and control sites of Nsukka soils compared to Obollo-Afor soils is an indication that heavy metal vary from one location to another. Obasi et al., (2017) also reported that heavy metal concentration differed significantly from one dumpsite to another. The higher concentration of zinc in soils of Nsukka dumpsite relative to Obollo-Afor dumpsite as obtained in this study suggest that the source is anthropogenic instead of natural. Abdus-Salam (2009) who noted that the high zinc contents of dumpsite soils in Ilorin was of anthropogenic source made similar assertion. Other authors (Lisk, 1988; Iwuchukwu et al., 2018) attributed the high zinc content of the soil to the decomposition and burning of waste materials such as zinc roofing sheets, electrical gadgets and chemical effluents containing zinc. Similarly, the use of wood preservatives has been reported to releases toxic compounds or substances into the soil and its surrounding environment (Kabata-Pendias and Pendias, 2001).

CONCLUSION

In this study, an attempt was made to evaluate the effect of municipal solid waste on physicochemical properties and heavy metal distribution of two dumpsites in Enugu State, southeastern Nigeria.

Though some of the soil physical properties did not differ across the two locations, the result revealed that municipal solid waste significantly affected the soil physicochemical across three depths. Cation exchange capacity and organic matter showed tremendous decline due to the continuous burning of wastes at the dumpsites.

The concentration of heavy metal especially zinc is higher at the dumpsite relative to the control site. However, the results highlighted a low reduction in the amount of these heavy metals in the waste disposal sites in comparison to the permissible limit of heavy metals in agricultural soil as recommended by WHO. The study concluded that the dumpsites are not currently harmful to agricultural purposes and do not pose any health risk. However, long-term burning of the dumpsites may constitute a health hazard due to air pollution and cause a reduction in the content of soil nutrients caused by the decline in organic matter storage.

AUTHOR CONTRIBUTIONS

Azuka, C.V., did the conception and design of this study. Ezeme C. in collaboration with Azuka, C. V. experimented with the acquisition, analysis, or interpretation of data. Ezeme C. produced the first draft of the manuscript while Azuka C. V. edited and made some inputs to the manuscript.

CONFLICT OF INRTEREST

The authors hereby declare no conflict of interest.

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