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SHORT COMMUNICATION

HEAVY METALS POLLUTION AT MUNICIPAL SOLID WASTE DUMPSITES IN KANO AND KADUNA STATES IN NIGERIA

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ABSTRACT. Soil samples collected from two major dumpsites each in Kano and Kaduna states were investigated for heavy metals pollution. Each of the dumpsite was divided into north, south, east and west. Four soil samples were collected at a depth of 0-15 cm from each part and pooled to form a composite sample. Soil samples from reserve areas within the same geographical locations as the dumpsites were collected as control. Acid-extractable cadmium (Cd), chromium (Cr), nickel (Ni) and lead (Pb) were determined using 2 M nitric acid solution and atomic absorption spectroscopy. The ranges of Cd, Cr, Ni and Pb levels for all the dumpsites were 0.30–49.8, 5.76–139, 0.39–19.1 and 42.6–9662 mg/kg, respectively. Kano dumpsite 2 was found to pollute most with Cd, Cr and Pb in 50-100 % soil samples collected having concentrations higher than the threshold limits set by regulatory body. Paper and food scraps showed higher percentages in both Kano and Kaduna dumpsites. The soil was high is sand for all the dumpsites implying high leaching potentials of the heavy metals pollutants.

KEY WORDS: Pollution, Soil, Municipal solid waste, Heavy metals, Kano, Kaduna, Nigeria

INTRODUCTION

Basel convention in 1989 defined waste as any substance or object which is supposed to be disposed or intended to be disposed by the provisions of the law. Waste creation by mankind is inevitable as far as the manipulation of the chemical environment continues. The worry by environmentalists is the quantity and toxic level posed by the wastes produced. Waste has always been created by mankind since the prehistoric times [1]. History has it that the manipulation of the chemical environment that produced waste may have begun with the domestication of fire [2]. Like garbage today in most developing countries and some developed countries, waste was burned, tossed into waterways, buried or dumped above ground [1]. However, the wastes of the early people were mostly food scraps and other less harmful substances that broke down easily by natural decay processes. Prehistoric populations were also much smaller and were spread out over larger areas and as a result, people were less concentrated in one place and caused fewer problems.

In Nigeria just like in the rest of the world, rapid urbanisation and population growth have brought about a proportional increase in the amount of waste that is generated. The inability to manage these wastes effectively in most developing and some developed countries becomes an issue of great concern because apart from the destruction of aesthetics of landscape by the waste dumpsites, some of the municipal solid wastes contain both organic and inorganic toxic pollutants (such as heavy metals) that threaten the health of humans and the entire ecosystem. A study in Nigeria showed that municipal solid wastes are produced in the urban areas at a mean rate of 0.43 kg/head/day [3, 4]. This is evident as it is not uncommon going through the length

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and breadth of the country to find heaps of refuse littering the entire landscape, road sides, commercial market places, even on the premises of primary, secondary and tertiary institutions as a result of improper management strategies [5].

Municipal solid waste in Nigeria are composed mainly of paper, food scraps, vegetable matter, plastics, metals, textiles, rubber, and glass [6-8]. The big challenge with solid waste management in major Nigerian cities is not only the volume of the wastes, but also the composition of the wastes. All categories of wastes including toxic or non-toxic, biodegradable or non-biodegradable, recyclable or non-recyclable are dumped together making their management very difficult. The reason(s) for this attitudinal occurrence in developing countries may not be far fetched. It could be as a result of lack of awareness, poverty, population growth, and high urbanisation rates combine with lack of governments' policies on waste management issues especially on waste management and separation. In places where there are governments' policies, the agencies saddled with the mandate to enforce the policies are either under funded by the governments or are not monitored for efficiency [6, 9].

The adverse effect of toxic heavy metals generated by municipal solid waste dumpsites on humans, aquatic lives and the entire ecosystem have been extensively explored [10-20]. It is imperative to monitor the pollution status of major dumpsites in Nigeria from time to time to provide statistical data that could aid the government in policy making, regulation and enforcement.

This study therefore investigated the characterisation of solid wastes and heavy metals pollution on the receiving soils of two major municipal solid waste dumpsites each in Kano and Kaduna states, respectively.

EXPERIMENTAL

Study area. Two municipal solid waste dumpsites each in Kano and Kaduna states were considered. The first Kano dumpsite, the largest in Kano state was located in Mai-Malari-Bompai in Nasarawa L.G.A. It was situated in a pit where laterite was formally dug from. This pit was right inside the Bompai industrial estate. The second Kano dumpsite was located in Gyadi, new court road in Tarauni L.G.A. This dumpsite was surrounded by residential houses, mosques, churches, schools, clinics and offices. The first Kaduna municipal solid waste dumpsite was a dormant domestic dumpsite located along constitution road in Kaduna north L.G.A. in Kaduna state. The state government prohibited dumping of waste in this site, but illegal dumping of waste was still going on at the time of this study. It was among the biggest dumpsites in the state. The second Kaduna dumpsite was the biggest in the state comprising a mixture of both domestic and industrial solid wastes. It was located along Zaria road in Igabi L.G.A. in Kaduna state.

Sampling design. Each dumpsite was divided into four parts–north, south, east and west. Soils were collected randomly with a plastic scoop at a depth of 0-15 cm at four points each from every part for each dumpsite. Soil samples from each part per dumpsite were pooled together to form composite soil samples. This implied that for the four dumpsites studied, there were four composite soil samples from each dumpsite. Control samples were also collected from reserve areas within the Local Government Area for each dumpsite.

Solid waste characterisation. One kilogram of a representative sample of the general solid waste from each dumpsite was weighed out. Each of the weighed waste samples was sorted into food scraps, plastic, paper, metals, glass, textiles, leather, and others (such as ashes, sand and leaves). Each of the waste constituents was reweighed and the percentage composition for each was calculated.

Soil preparation and analyses. Leaves, stones and other unwanted materials were handpicked from the soil samples. The composite soil samples were air dried, ground with agate mortar and sieved using a 0.5 mm mesh to have soil of uniform particle size. The soil samples were packed in black polythene bags. They were properly labelled and kept in a dry place until analyses.

About 5 g of each air dried soil sample were accurately weighed into a 100 mL beaker and 50 mL of 2 M HNO_3 were measured with a 50 mL burette into the beaker with the soil. The beaker was then covered with a watch glass. This was shaken properly and transferred to a water bath which was boiling at a temperature of 95 ± 3 ^{0}C. There was intermittent shaking of the beaker with its content after every 20 minutes. Acid-extractable Cd, Cr, Ni and Pb were extracted for 2 hours. The content was filtered through a Whatman No. 1 filter paper and diluted with deionised water in a standard flask to give a final volume with HNO_3 concentration of about 1 %. Dilution was made such that about 1 % of the acid was present in the final volume. The metals were analysed with a flame atomic absorption spectrophotometer (Perkin Elmer product, China, Analyst 200, 2003 model). A reagent blank sample was also taken through the method. This was analysed and subtracted from the sample to correct for reagent impurities and other sources of errors from the environment. Other parameters determined on the soil samples included: moisture which was determined gravimetrically; pH which was determined with a calibrated glass electrode pH meter on 1:1 soil: deionised water extracts [21]; percentage organic carbon was determined using Walkey-Black method [22]; particle size analysis (i.e. % of sand, silt and clay) employed hydrometer method [21]; cation exchange capacity (CEC) was determined according to Stewart [23].

Quality control/assurance. Soil samples were collected with plastic made implements to avoid contamination. Samples were kept in polythene bags that were free from heavy metals and organics and well covered while transporting from field to the laboratory to avoid contamination from the external environment. Reagent blanks were used in all analyses to check reagent impurities and other environmental contaminations during analysis. BDH Analar grade reagents were used for all analyses. All the reagents were standardised against primary standards to determine their actual concentrations. All the glassware used were soaked in appropriate dilute acids overnight and washed with Teepol and rinsed with deionised water before use. All the instruments used were calibrated before use. Tools and work surfaces were carefully cleaned for each sample during grinding to avoid cross contamination. Duplicate samples were analysed to check precision of the analytical methods and instruments. The spike recovery test on some soil samples for Pb was found to be within 100 ± 10 % similar to [24].

RESULTS AND DISCUSSION

Characterisation of solid waste in Kano and Kaduna dumpsites. The mean waste constituents in Kano dumpsites followed the pattern: paper (28 %) > food scraps (25 %) > metals (17 %) > plastics (12 %) > textiles (8 %) > leather (6 %) > glass (3 %) > others (1 %) while the pattern for Kaduna dumpsites was food scraps (30 %) > plastics (20 %) > paper (15 %) = metals (15 %) > leather (6 %) > textiles (5 %) = glass (5 %) > others (4 %).

These patterns may not have been unconnected with the type of activities that went on around the waste dumpsites. The elevated percentage of food scraps in Kaduna dumpsites compared to Kano dumpsites could probably because Kaduna dumpsites were receiving waste mainly from domestic activities, but a higher percentage of wastes in Kano dumpsites were from plastic, textile and tannery industries that surrounded the dumpsite at Mai-Malari-Bompai in Nasarawa L.G.A. Paper all over the world is known to occupy a high percentage in dumpsites. A survey by the U.S. Environmental Protection Agency in 1992 showed that paper was the major constituent in landfills, perhaps as much as 50 % by volume and 40 % by weight with the largest single item as newspaper [25]. This was evident as paper showed the highest percentage in Kano dumpsites (Figure 1). Other constituents showed comparable percentages in Kano and Kaduna dumpsites (Figures 1 and 2).

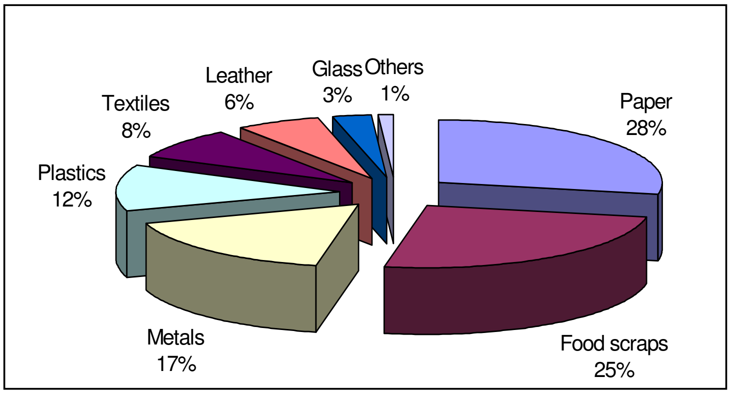

Figure 1. Characterisation of solid waste in Kano dumpsites.

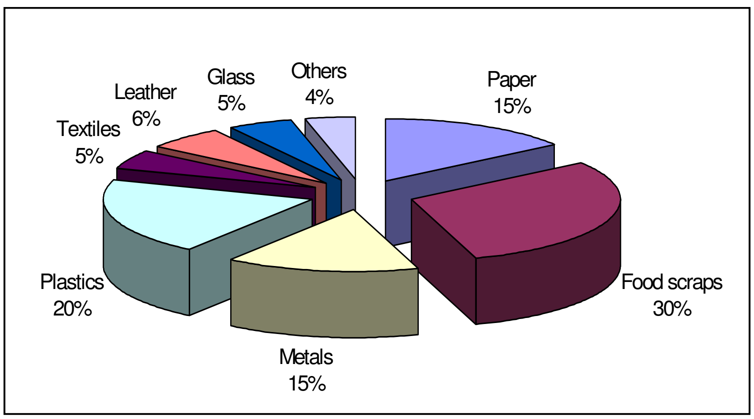

Figure 2. Characterisation of solid waste in Kaduna dumpsites.

Physico-chemical properties of soil. The results of the physico-chemical properties of the soil in Kano and Kaduna dumpsites are presented in Tables 1 and 2. The mean percentage moisture contents of the soil in Kano dumpsites were 30.5 ± 20.5 % and 30.1 ± 6.10 % for dumpsites 1 and 2, respectively (Table 1). Kaduna dumpsites also showed mean percentage moisture as 39.4 ± 25.2 % and 36.7 ± 11.0 % for dumpsites 1 and 2, respectively. The high percentages of moisture could be attributed to the fact that most wastes are dumped when still wet especially food scraps that showed high percentage in these dumpsites. The high variations in the moisture content as shown by the standard deviations could come from the complex nature of wastes in the dumpsites as the wastes are not always sorted into the various constituents before dumping.

Table 1. Physico-chemical properties of dumpsites in Kano.

	Kano dumpsite 1						Kano dumpsite 2					
	D_1 North	D_1 South	D_1 East	D_1 West	D_1 Control	Mean±SD	D_2 North	D_2 South	D_2 East	D_2 West	D_2 Control	Mean±SD
Moisture (%)	14.7	25.2	21.5	60.5	30.2	30.5±20.5	38.9	28.7	24.8	28.1	28.1	30.1±6.10
CEC (mmol_c/kg)	0.51	1.20	1.34	2.40	0.61	1.36±0.78	0.53	0.92	0.60	2.20	1.00	1.06±0.78
pH	7.3	7.6	7.6	7.2	7.8	7.43±0.21	7.2	7.0	7.3	7.4	6.7	7.23±0.17
Org. carbon (%)	1.73	1.49	1.79	1.38	0.39	1.60±0.19	1.69	1.53	1.91	1.51	0.84	1.66±0.19
Cd (mg/kg)	1.37	1.14	1.34	1.71	ND	1.39±0.24	10.6	21.7	49.8	7.17	0.55	22.3±19.3
Cr (mg/kg)	6.94	5.76	9.30	6.81	4.06	7.20±1.49	53.7	124	139	8.12	3.67	81.2±61.3
Ni (mg/kg)	0.39	0.58	0.99	1.24	0.06	0.80±0.39	19.1	1.55	2.66	0.93	0.22	6.06±8.72
Pb (mg/kg)	246	54.9	284	91.9	18.3	169±113	295	9662	1531	180	23.7	2917±538
Sand (%)	81.8	80.4	78.2	79.4	82.0	80.0±1.53	81.6	80.2	76.8	78.2	81.8	79.2±2.12
Silt (%)	13.4	13.2	14.4	14.2	12.8	13.8±0.59	11.6	14.8	15.6	13.2	12.0	13.8±1.77
Clay (%)	4.80	6.40	7.40	6.40	5.20	6.25±1.08	6.80	5.00	7.60	8.60	6.20	7.00±1.52

D_1 = Kano dumpsite 1, D_2 = Kano dumpsite 2, ND = not detected, CEC = cation exchange capacity.

Table 2. Physico-chemical properties of dumpsites in Kaduna.

	Kaduna dumpsite 1						Kaduna dumpsite 2					
	W_1 North	W_1 South	W_1 East	W_1 West	W_1 Control	Mean±SD	W_2 North	W_2 South	W_2 East	W_2 West	W_2 Control	Mean±SD
Moisture (%)	37.9	20.7	23.5	75.5	32.5	39.4±25.2	40.1	32.0	50.2	24.5	32.4	36.7±11.0
CEC (mmol_c/kg)	1.53	1.53	1.52	3.00	1.21	1.90±0.74	0.42	0.86	0.90	4.00	0.92	1.55±1.65
pH	7.1	7.9	7.8	8.2	6.2	7.75±0.47	7.90	7.6	7.3	7.2	6.8	7.50±0.32
Org. carbon (%)	0.55	1.91	1.87	1.93	0.77	1.57±0.68	1.87	1.63	0.94	1.83	1.16	1.57±0.43
Cd (mg/kg)	0.30	1.12	26.4	1.59	ND	7.35±12.7	1.91	0.72	0.42	1.64	0.37	1.17±0.71
Cr (mg/kg)	9.95	9.43	14.0	13.6	9.16	11.7±2.39	11.9	9.95	9.69	11.7	8.38	10.8±1.15
Ni (mg/kg)	0.70	0.93	1.52	1.09	0.45	1.06±0.35	0.55	0.60	0.41	1.13	0.41	0.67±0.32
Pb (mg/kg)	44.6	87.2	86.5	124	42.6	85.6±32.4	114	42.6	55.4	125	39.9	84.3±41.3
Sand (%)	67.8	60.8	65.2	64.8	69.2	64.7±2.89	67.4	67.4	65.4	61.6	68.2	65.5±2.73
Silt (%)	21.4	25.8	22.4	20.6	20.6	22.6±2.29	19.8	22.8	20.2	23.6	18.4	21.6±1.88
Clay (%)	10.8	13.4	12.4	14.4	10.2	12.8±1.54	12.8	9.80	14.4	14.8	13.4	13.0±2.27

W_1 = Kaduna dumpsite 1, W_2 = Kaduna dumpsite 2, ND = not detected, CEC = cation exchange capacity.

The mean cation exchange capacities (CEC) and organic carbon of the soils from all the dumpsites ranged from 1.00 ± 0.78 to 1.90 ± 0.74 mmol_c/kg and 1.57 ± 0. 43 % to 1.66 ± 0.19 %, respectively. The low CEC and organic carbon exhibited by soils in this study could be due to the high proportion of sand. Cation exchange capacity is known to decrease proportionally with increase in sand in most soil samples because there is always lesser exchange sites that effect retention of heavy metals in sand compared to clay and organic matter. Low organic carbon (matter) is always experienced in soils with high percentage of sand. The reason could be that, a high percentage of organic matter is lost through leaching in sand. Also, the low organic matter exhibited in these dumpsites could also be due to the high net percentage of non-biodegradable solid wastes present in all the dumpsites studied. Low CEC and organic carbon implied high leachability of heavy metals from the soil underneath the wastes into underground water posing a health hazard to humans and other animals that drink this water.

The mean pH of soil in this study ranged from 7.23 ± 0.17 to 7.75 ± 0.47 for the four dumpsites in the two states. Most metals in the pH range of 6.0-9.0 are not always in the free form [26]. The pHs of all the soil samples from all dumpsites studied fell within this range. This would eventually influence lower release of heavy metals into sub-soil and ground water. pH is known to be a very unstable soil property that is easily influence by other properties. Higher release of heavy metals down the horizons could occur when conditions become favourable.

The result of acid-extractable Cd, Cr, Ni and Pb in the four dumpsites is presented in Tables 1 and 2. All the heavy metals studied showed elevated levels in soil samples from Kano dumpsite 2 compared to other dumpsites.

The range of Cd level in soil from all the sampling points for Kano dumpsite 2 was 7.17–49.8 mg/kg and control sampling point showed 0.55 mg/kg implying gross pollution of the soil by the wastes. Cadmium level in three (D_2 North, D_2 South and D_2 East, Table 1) out of the four soil samples except for control (D_2 Control) were higher than the threshold value of 10 mg/kg set by Canadian soil quality guidelines for residential area [27]. Cadmium level in soil samples from all the other dumpsites was within the threshold value of 10 mg/kg except for one sampling point in Kaduna dumpsite 1 that showed elevated Cd concentration of 26.4 mg/kg. This could come from a localised non-point source. Damaged Cd/Ni rechargeable batteries or damaged materials coated with Cd could be possible sources.

Chromium showed concentration in two (D_2 South and D_2 East, Table 1) out of the four soil samples collected from Kano dumpsite 2 higher than the threshold value of 64 mg/kg set by Canadian soil quality guidelines for residential area [27]. Possible sources of Cr in this dumpsite could be from chrome steel where Cr is added to Fe to make steel used in industrial materials like ball bearings and armor plates. Chromium level in soil collected from the other three dumpsites was far lower than the threshold limit.

Nickel in soil collected from all the dumpsites showed level lower than the threshold limit of 50 mg/kg set by Canadian soil quality guidelines for residential area. The low level of Ni could partly have arisen from poor analytical sensitivity when Ni is determined by flame atomic absorption spectrophotometric (FAAS) analysis [28].

Kano dumpsite 2 showed gross pollution of Pb as soil samples from all the sampling points in this dumpsite showed Pb level higher than 140 mg/kg set by Canadian soil quality guidelines for residential area except for the control soil sample that showed lower Pb concentration of 23.7 mg/kg. Soil samples from two (D_1 North and D_1 East, Table 1) out of four sampling points for Kano dumpsite 1 also showed Pb level higher than the threshold limit. Lead is among the most recycled non-ferrous metals and its secondary production has therefore grown steadily in spite of declining lead prices. Its physical and chemical properties are applied in the manufacturing, construction and chemical industries. The metal is used in lead-acid accumulator batteries and cable sheathing as lead shot, rolled and extruded products, alloys pigments in paints and other compounds, petrol additives (though no longer allowed in the EU). These are all possible sources from which Pb can get into waste in the dumpsites. Soil samples from all the dumpsites in Kaduna showed Pb level lower than the threshold limit (Table 2). It could be right to say that, the Kano dumpsites were more polluted, hence posed a greater health risk on the environment than the Kaduna dumpsites.

Correlation studies computed using Microsoft Excel on all the soil properties in this study to check their relationship generally did not show any regular pattern (Table 3). This could be due to the influence from the complex nature of the wastes found in dumpsites in Nigeria. A particular relationship between soil properties could be better studied if there is some uniformity in the nature of wastes in the dumpsites under study.

The sand fraction in this study was generally higher in Kano dumpsites than Kaduna dumpsites as shown in Table 4 when one way ANOVA was used to compare the soil properties. Sand, silt and clay in Kano dumpsites compared with Kaduna dumpsites showed significant difference at 0.05 confidence level while comparison of sand, silt and clay in the dumpsites within the states showed no significant difference (Table 4). This from all indication could come from the influence of the geographical locations of these two cities as Kano is closer to the desert than Kaduna hence Kano should be sandier. The wastes also could impart some influence on the particle size distribution on the soil beneath them. Soil samples with high sand and low clay content have high pollutant leaching potentials [29]. It could therefore be deduced that the underground water in this dumpsites could be threatened by pollutants from the wastes.

Table 3. Correlation of physico-chemical parameters for Kaduna and Kano dumpsites.

		Kaduna dumpsites										
		Moisture	CEC	pH	O.C.	Cd	Cr	Ni	Pb	Sand	Silt	Clay
1	Moisture	1	0.83 (0.43)	0.10 (0.07)	0.02 (0.35)	0.11 (0.09)	0.19 (0.03)	<0.01 (0.51)	0.30 (0.08)	0.02 (0.11)	0.37 (0.27)	0.21 (0.02)
2	CEC	0.73 (0.09)	1	0.44 (0.10)	0.25 (0.13)	0.02 (0.13)	0.38 (0.16)	0.12 (0.86)	0.69 (0.33)	0.06 (0.85)	0.09 (0.46)	0.60 (0.25)
3	pH	0.18 (<0.01)	0.27 (0.10)	1	0.73 (0.34)	0.09 (0.36)	0.43 (0.46)	0.60 (<0.01)	0.80 (0.15)	0.62 (0.02)	0.16 (0.06)	0.38 (0.20)
4	O.C	0.06 (0.01)	0.06 (0.05)	0.32 (0.68)	1	0.18 (0.78)	0.38 (0.67)	0.60 (0.44)	0.81 (0.53)	0.66 (0.07)	0.22 (0.30)	0.81 (0.06)
5	Cd	0.07 (0.19)	0.39 (0.19)	0.71 (0.17)	0.76 (0.56)	1	0.47 (0.90)	0.70 (0.38)	0.04 (0.88)	0.01 (0.15)	0.01 (0.12)	0.01 (0.02)
6	Cr	0.02 (0.06)	0.12 (0.33)	0.14 (0.05)	0.71 (0.47)	0.53 (0.78)	1	0.74 (0.42)	0.52 (0.86)	0.02 (0.28)	0.07 (0.26)	0.33 (0.02)
7	Ni	0.33 (0.86)	0.82 (0.23)	0.36 (0.05)	0.35 (0.14)	0.68 (0.01)	0.49 (<0.01)	1	0.45 (0.52)	0.25 (0.73)	0.05 (0.65)	0.34 (0.07)
8	Pb	0.22 (0.03)	0.01 (0.23)	0.10 (0.03)	0.60 (0.02)	0.28 (0.06)	0.77 (0.40)	0.10 (0.06)	1	0.42 (0.40)	0.02 (0.14)	0.94 (0.20)
9	Sand	0.08 (0.42)	0.49 (0.07)	0.03 (0.51)	0.30 (0.40)	0.36 (0.55)	0.63 (0.21)	0.76 (0.16)	0.17 (< 0.01)	1	0.71 (0.47)	0.63 (0.36)
10	Silt	0.12 (0.50)	0.50 (0.01)	0.26 (0.10)	0.43 (0.30)	0.59 (0.73)	0.78 (0.68)	0.85 (0.25)	0.37 (0.30)	0.81 (0.61)	1	0.12 (0.03)
11	Clay	0.05 (0.02)	0.39 (0.29`)	<0.01 (0.54)	0.18 (0.10)	0.18 (0.01)	0.42 (0.11)	0.60 (< 0.01)	0.06 (0.52)	0.92 (0.36)	0.81 (0.61)	1
		Kano dumpsites										

Dumpsite 1, Dumpsite 2, O.C. - organic carbon, CEC - cation exchange capacity. (Correlation was computed using Microsoft excel package).

Table 4. Comparison of the physico-chemical parameters of both Kaduna and Kano dumpsites using one way ANOVA.

	Parameters	P Kaduna dumpsite	P Kano dumpsite	P (Kaduna/Kano)		
		D_1/D_2	D_1/D_2	D_1/D_1	D_1/D_2	D_2/D_2
1	Moisture	0.845	0.935	0.565	0.437	0.253
2	CEC	0.653	0.730	0.272	0.144	0.620
3	pH	0.848	0.051	0.877	0.424	0.314
4	O.C.	0.829	0.670	0.587	0.806	0.970
5	Cd	0.372	0.089	0.381	0.265	0.086
6	Cr	0.467	0.071	0.009^*	0.091	0.086
7	Ni	0.195	0.270	0.333	0.301	0.267
8	Pb	0.948	0.269	0.294	0.256	0.256
9	Sand	0.655	0.611	$<<0.05^*$	$<<0.05^*$	$<<0.05^*$
10	Silt	0.407	0.852	$<<0.05^*$	$<<0.05^*$	$<<0.05^*$
11	Clay	0.517	0.329	$<<0.05^*$	$<<0.05^*$	$<<0.05^*$

There is significant difference at $P \leq 0.05$. *Show significant difference. D_1 = Dumpsite 1. D_2 = Dumpsite 2.

The means of all the soil properties studied in all the dumpsites showed no significant difference at 0.05 confidence level analysed with one way ANOVA exception of Cr, sand, silt and clay (Table 4). The mean of chromium showed significant difference between Kano dumpsite 1 and Kaduna dumpsite 1 while the percentage means of sand, silt and clay showed significant difference between the two dumpsites in Kano and Kaduna (Table 4). This study compares with [7-8] in Nigeria and the characterisation of solid waste in this study compares with a study carried out by US EPA [25].

CONCLUSIONS

Soil samples in two dumpsites each from Kano and Kaduna states were studied for heavy metal pollution. Kano dumpsites were found to be more polluted with Cd, Cr and Pb in 50-100 % soil samples collected from Kano dumpsite 2 having concentrations higher than the threshold limits set by Canadian soil quality guidelines for residential area. Paper, food scraps, plastics and metals were found to have higher percentages in both Kano and Kaduna dumpsites compared to other waste constituents. The soils were found to have a high percentage of sand with Kano dumpsites being sandier. High sand content of any soil implies high pollutants leaching potentials. The waste dumpsites investigated pose danger on sub-soil and ground water underneath them.

REFERENCES

1. Udoessien, E.I. *Pollution in Petroleum and Allied Industries*, M.E.F. (Nig.) Ltd: Uyo, Nigeria; **1998**; pp 2-5.
2. *Encyclopedia of Physical Science and Technology*, 2nd ed., McGraw-Hill: New York; **1992**; Vol. 13; p 137; Vol. 17; p 56-467.
3. Sridhar, M.K.C.; Bammeke, A.O.; Omishakin, M.A. *Water Manage. Res.* **1985**, 3, 91.
4. Sridhar, M.K.C.; Ojediran O. *J. Environ. Health* **1989**, 46, 28.
5. Onibokun, A.G.; Adedipe, N.O.; Sridhar, M.K.C. *Centre for African Settlement Studies and Development (CASSAD) Monograph Series No. 13*, CASSAD Publication: Ibadan, Nigeria; **2000**; pp 1-134.
6. Cointreau, S.J. *A project guide*, Urban Development Department, World Bank, **1982**; http://www.worldbank.org/html/fpd/urban//solid-wm/techpaper5.pdf.
7. Amusan, A.A.; Ige, D.V.; Olawale, R.; *J. Hum. Ecol.* **2005**, 17, 167.
8. Uba, S.; Uzairu, A.; Harrison, G.F.S.; Balarabe, M.L.; Okunola, O.J. *African J. Biotechnol.* **2008**, 7, 122.
9. Doan, P.L. *Habitat International* **1998**, 22, 27.
10. Alan, W. *Soil and the Environment*, University Press: Cambridge; **1996**; pp 193-203.
11. Brady, N.C.; Weil, R.R. *The Nature and Properties of Soil*, 12th ed., Prentice Hall Inc.: New York; **1999**; pp 740-753.
12. Cunningham, W.P. *Environmental Science: A global concern*, 5th ed., McGraw Hill: Boston; **1999**; pp 516-520.
13. Benka-coker, M.O.; Bafor, B.E. *Waste Management and Water Pollution*, 25th WEDC Conference on Integrated Development for Water Supply and Sanitation: Addis Ababa, Ethiopia; **1999**.
14. Anikwe, M.A.; Nwabodo, K.C. *Bioresour. Technol*. **2002**, 83, 241.
15. Adekunle, A.A.; Adekunle, I.M.; Ndahi, N.P. *Solid Waste Management by Combustion: Implication on the metals in the environment*, 29th WEDC International Conference on Towards the Millennium Development Goals: Abuja, Nigeria; **2003**.
16. Okoronkwo, N.E.; Odemelam, S.A.; Ano, O.A. *African J. Biotechnol.* **2006**, 5, 1241.

17. ABC News *E-waste dumps threaten child health*, ABC news posted Monday, November 12, **2007**.
18. Edorh, P. *Third World Academy of Science (TWAS) Newsletter*, **2007**, 19, 42.
19. Adekunle, L.M.; Adetunji, A.M.; Banjoko, O.B. *Int. J. Environ. Res. Public Health* **2007**, 4, 307.
20. Integrated Regional Information Networks (IRIN); *Nigeria: Lagos pays the price of population surge*, IRIN humanitarian news and analysis service of the UN office for the co-ordination of humanitarian affairs: New York, Thursday 21 August; **2008**.
21. International Institute of Tropical Agriculture (IITA): *Selected methods for soil and plant analysis*, Manual series No.1: Nigeria; **1979**; p 6.
22. Walkey, A.; Black, I.A.; *Soil Science* **1934**, 37, 29.
23. Stewart, E.A.; *Chemical Analysis of Ecological Materials*, 2nd ed., Blackwell Scientific: Oxford, London; **1989**.
24. Lena, Q.M.; Gade, N.R. *J. Environmental Quality* **1997**, 26, 259.
25. Botskin, D.B.; Keller, E.A.; *Environmental Science*, 2nd ed., John Wiley and Sons: Canada; **1995**.
26. Porteus, A. *Hazardous Waste Management Handbook*, Butterworths and Co Publishers: UK; **1985**; pp 146–166.
27. Canadian Council of Ministers of the Environment (CCCME) *Canadian soil quality guidelines for the environmental and human health*, Summary Tables in *Canadian Environmental Quality Guidelines*, CCME Publication: Winnipeg in Manitoba, Canada; **1999**.
28. Hickey, M.G.; Kittrick, J.A. *Environmental Quality* **1984**, 13, 372.
29. Nyle, C.B.; Ray, R.N.; *The Nature and Properties of Soils*, 12th ed., Macmillan: United States of America; **1999**; p 743.