Concentrations and Seasonal Variation in Heavy Metal Contamination of Leachates, Borehole Water, Soil and Edible Plants near Unengineered Dumpsites in Port Harcourt, Nigeria

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Abstract: There are two major seasons in Nigeria – wet and dry season. This study was carried out to assess concentrations and seasonal variations in heavy metals in leachates, borehole water, soil and edible plants around unengineered dumpsites in Port Harcourt, Nigeria. Samples of leachates, borehole water within 300m from each unengineered dumpsites, soil samples, and two edible plants were collected around each unengineered dumpsites; all for analysis of heavy metal contaminations. The heavy metals studied include Cadmium (Cd), Lead (Pb), Zinc (Zn), Iron (Fe), and Copper (Cu). Analysis of the leachates, borehole waters, soil and edible plants showed that there is high concentration of heavy metals in the environments studied. This may be due to transport from the dumpsite nearby to the leachates, soil, edible plants and borehole waters. Higher concentrations were recorded during wet season than dry season in most of the heavy metals studied. This may be as a result of seasonal rainfall, dilution and run-off during the wet season that flushed the contaminants from the dumpsites into the environment.

Keywords: groundwater, pollution, leachate, unengineered dumpsites, index of geoaccumulation, contamination factor, contamination degree, pollution load index.

INTRODUCTION

The disposal of most wastes in landfills is done after proper waste management processes such as recycling, reuse; sources reduction and treatment operation have been completed in developed countries, (Edward, 2001). However, these practices are not common in developing countries (Cunninghams *et al*., 2005). This results to the development of unengineered dumpsites of different materials ranging from perishable food wastes to hazardous chemicals which pollute the environment. Landfilling is one of the less expensive methods of disposal of solid waste playing an important role in integrated solid waste management (Peng, 2013). It is reported that about 90% of municipal solid waste (MSW) is disposed in open dumps and landfills in a crude manner creating problems to public health and the environment (Sharholy *et al*., 2008). Inefficient management of these dumpsites causes uncontrolled gas and liquid emissions. The emitted liquid known as 'Leachate' may contain several organic and inorganic contaminants which have detrimental effects on water, and soil environment (Kolsch and Ziehmann, 2004). Proper treatment and safe disposal of the leachate is one of the major environmental challenges worldwide especially in developing nations (Butt *et al*., 2014; Mukherjee *et al*., 2014).

Pastor and Hernández (2012) reported that complex sequence of physical, chemical, and biologically mediated events occurs within a landfill; that leads to degradation and transformation of the refuse. As water percolates through the solid waste, contaminants are leached from the waste. Aziz *et al*. (2010); Eggen *et al*. (2010) and Hennebert *et al*. (2013) outlined the mechanics of contaminant removal to include leaching of inherently soluble materials, leaching of soluble biodegradation products of complex organic molecules, leaching of soluble products of chemical reaction and washout of fines and colloids. The characteristics of leachate produced are highly variable, depending on the composition of the solid waste, precipitation rate, site hydrology, compaction, cover design, waste age, sampling procedures, and interaction of leachate with the environment as well as landfill design and operation (Nartey *et al*., 2012).

Municipal landfill leachate is a highly complex effluents which contains dissolved organic matters, inorganic compounds such as ammonium, calcium, magnesium, sodium, potassium, iron, sulphates, chlorides and heavy metals such as cadmium, chromium, copper, lead, zinc, nickel and xenobiotic organic substances (Christensen *et al*., 2001). This leachate accumulates at the bottom of the landfill and percolates through the soil (Mor *et al*., 2006).

Many factors influence the leachate composition including the types of wastes deposited in the landfill, composition of wastes, moisture content, the particle size, the degree of compaction, the hydrology of the site, the climate, and age of the landfill and other site specific conditions such as landfill design and type of liner used if any (Rafizul *et al.*, 2011). As a result, surface water, groundwater reservoirs and soil layers become vulnerable to pollution from the dumpsite.

Rapid population growth and development in Nigerian states has resulted in environmental health hazards (Adefemi and Awokunmi, 2009). Wastes are generated from human activities and in most cases not properly managed in most Nigerian cities (Aurangabadkar *et al*., 2001; Adefemi and Awokunmi, 2009). This leads to low environmental quality which accounts for 25% of all preventable ill health in the world (WHO, 2004). In most cases, wastes are collected and disposed in uncontrolled or unengineered dumpsite sites near residential buildings. These wastes are heaped up and/or burnt, polluting the environment (Akpan, 2004; Uffia *et al*., 2013). Waste generally leads to proliferation of pathogenic microbes and heavy metals which can transfer significantly to the environment (Adefehinti, 2001). Leachates from dumpsites constitute a source of heavy metal pollution to both soil and aquatic environments (Ali and Abdel-Satar, 2005). This may have serious effects on soils, crop and human health (Bahnasawy *et al*., 2011). Water contaminants have been mainly biological and chemical in origin (Uffia *et al*., 2013). The quality of underground water could be compromised if it is not distant from constant source of pollution. The quality of underground water is compromised by the indiscriminate dumping of waste in the environment and contamination by leachate. (David and Oluyege 2014).

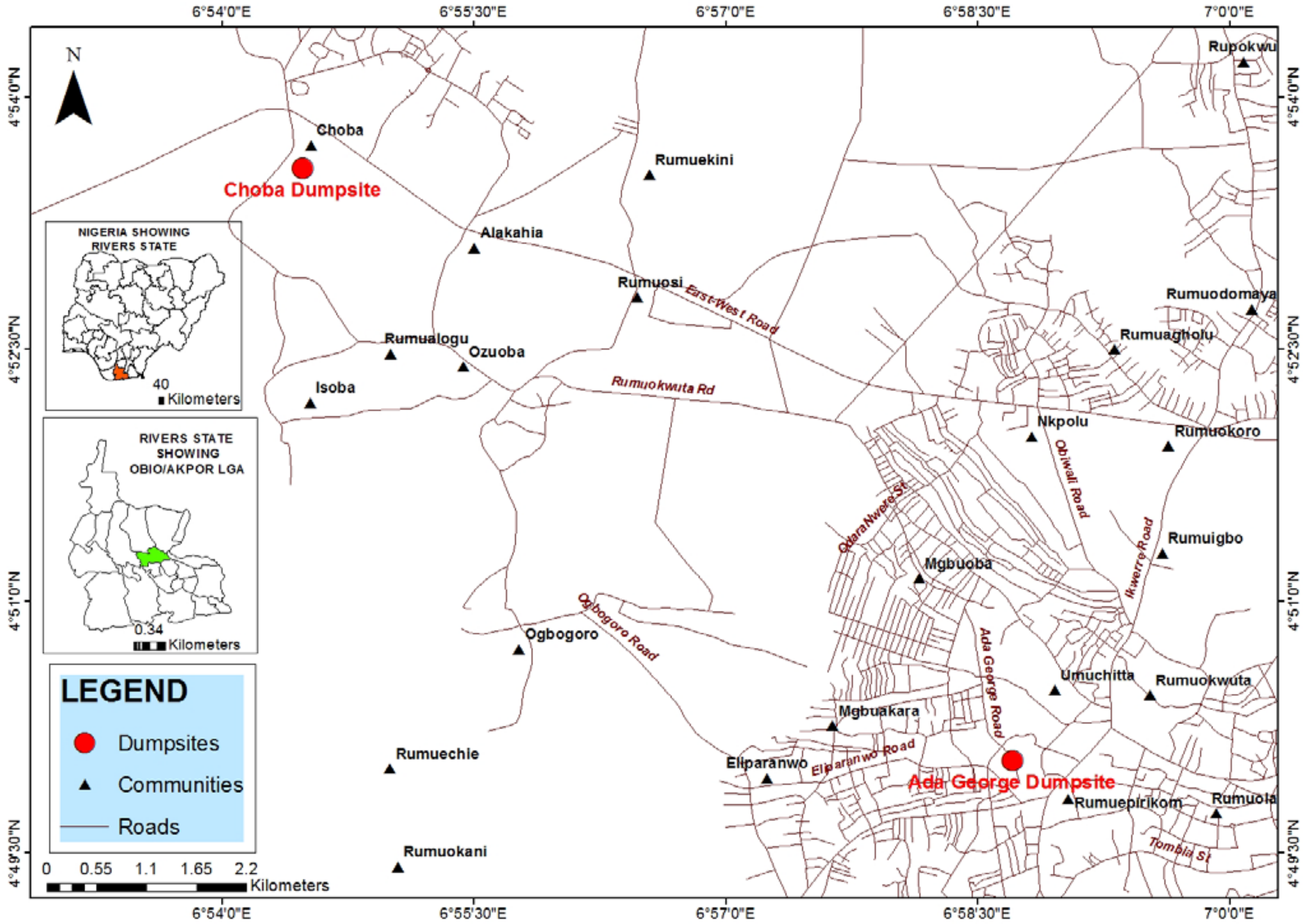
Generally, the practices in the unengineered dumpsites at Port Harcourt is unrestricted to different sources of wastes; which ends up in unengineered dumpsites. Dumpers do have access to the site at any time of the day. Scavengers have free access to the dump, and they scatter the waste to recover valuable material. Like many cities in Nigeria, Port Harcourt is faced with the problems of improper collection, handling and disposal of domestic wastes. Improper waste disposal system contributes immensely to the contaminations of groundwater with heavy metals which are not commonly found in groundwater, their presence is largely as a result of environmental contamination (Bahnasawy *et al*., 2011).

Heavy metals can be found in dumpsite leachate, air and soil produced either from plastic burning or smelting of scrap metals and e-waste. Trace metal uptake by plants is generally limited and usually shows saturation characteristics. However, phytotoxicity thresholds (lowest concentration at which decreased plant growth occurs) are generally higher than tissue toxicity thresholds for those animals consuming them. Many plants demonstrate tolerance to those metals they absorb, and cultivars with extreme tolerance are now available in commercial quantities for use in reclamation or decontamination work. Some species hyper-accumulate trace metals, making them problematic food sources, but giving them potential value as indicator species for monitoring programmes or as bioaccumulators during phytoremediation programmes (Treshow 1984, Markert 1993, Farago 1994, Ross and Kaye 1994, Saxe 1996, Brooks 1998). Material harvested from such species used in remediation work will need either to be incinerated or to go to secure landfill.

MATERIALS AND METHODS

Study Area

Cross-sectional study of selected unengineered refuse dumpsite was conducted in Port Harcourt, Rivers State, Nigeria; from July, 2017 to May, 2018 to assess the concentrations and seasonal variation in heavy metal contamination of leachates, borehole water, soil and edible plants near unengineered dumpsites of Port Harcourt, Nigeria, in both dry and wet seasons. Port Harcourt is the capital and largest city in Rivers State, Nigeria. It is located in the Niger-Delta region; and at the southernmost part of Nigeria between longitude 7^0 $00^/$ and 7^0 $15^/$ East of the Greenwich meridian and Latitude of 4^0 $30^/$ and 4^0 $47^/$ North of the equator. The average temperature throughout the year in the city is relatively constant, showing little variation throughout the year. Its average temperature is between 25^0C – 28^0C.



Samples of soil, edible plants (Pawpaw and Potatoes), leachates and borehole water were collected around two unengineered dumpsites in Port Harcourt, Rivers State Nigeria for laboratory analysis during dry and wet seasons. The borehole waters were collected from privately owned borehole. Samples were immediately transferred to the laboratory and stored in refrigerator at 4^0C. The sampling points were selected based on the availability of borehole around the unengineered dumpsites. Geomorphological study of the region indicates that most of the area where the unengineered dumpsites were located was found to have deep pediments, with shallow and buried pediments in other parts.

Analytical Procedure

The samples were analysed for heavy metals. The results obtained were compared and with standards from organisations and bodies. Five quality tools/indices were applied in this study for wider interpretations of data. These are:

1. Contamination Factor (CF)
2. Contamination Degree (CD)
3. Pollution Load Index (PLI)
4. Index of Geoaccumulation (Igeo)
5. Bioaccumulation Factor (BAF)

Contamination Factor (CF)

Contamination factor is used to determine the concentration status of the sediment in the present study. Contamination factor was calculated by comparing the mean of trace metal concentration with average shale or background concentration given by Turekian and Wedepohl (1961), which is used as global standard reference for unpolluted sediment. The CF is the single element index. CF for each metal was determined according to Thomilson, *et al*. (1980) by the following equation:

$$\text{Contamination Factor (CF)} = \frac{\text{Mean Metal Concentration at Contaminated Site}}{\text{Metal Average Shale Concentration}}$$

Hakanson (1980) classified CF values into four grades, i.e,

a) CF < 1 = low CF,
b) 1 $\leq$ CF > 3 = moderate CF,
c) 3 $\geq$ CF < 6 = considerable CF and
d) CF > 6 = very high CF.

Contamination Degree (CD)

Contamination degree is used to determine the degree of overall contamination or concentration status in the sampling site. CD is the sum of all CF values of a particular sampling site (Aksu *et al*., 1998 and Hakanson, 1980).

$$\mathrm{CD} = \sum_{i=I}^{i=n} (\mathrm{CF})$$

Where n is the number of analysed elements and CF is the contamination factor.

Ahdy and Khaled (2009) classified CD in terms of four grade ratings of sediments, i.e.
CD < 6 shows low CD,
6 $\leq$ CD < 12 shows moderate CD,
12 $\leq$ CD < 24 shows considerable CD and
CD $\geq$ 24 shows very high CD.

Pollution Load Index (PLI)

Pollution severity and its variation were determined with the use of pollution load index. Pollution load index for each site was determined by the method proposed by Thomilson *et al*. (1980). It is used for detecting pollution which permits a comparison of pollution levels between sites and at different times. The PLI was obtained as a concentration factor of each heavy metal with respect to the background value in the soil. The PLI for a single site is the nth root of n number multiplying the factors (CF values) together. PLI for each site was determined by the following equation:

$$\mathrm{PLI} = (\mathrm{n}\sqrt{}(\mathrm{CF1\ X\ CF2\ X\ CF3\ X} \ldots\ldots \mathrm{CFn})$$

Where
CF is the contamination factor and
n is the number of parameters.

Table 1: Categories of the sediment quality according to PLI

Pollution Load Index	Categories
PLI < 1	Perfection
PLI = 1	indicate only baseline levels of pollutants present and
PLI > 1	indicate progressive deterioration of sites

(After Mohiuddin et al. (2010))

Index of Geoaccumulation (Igeo)

A common approach to estimating the enrichment of metal concentrations above background or baseline concentrations is to calculate the index of geoaccumulation (Igeo) as proposed by Müller, 1969; Abrahim and Parker, 2008). Igeo is used to quantify the extent of heavy metal contamination associated with soils. This index is basically a single metal approach to quantify metal pollution in sediments when the concentration of toxic heavy metal is 1.5 or more times greater than their lithogenic background values (Gaur *et al*., 2005). Geo-accumulation index is calculated using the following equation:

$$\mathrm{Igeo} = \log 2 \frac{\mathrm{Cn}}{1.5\mathrm{Bn}}$$

Where

Cn is the measured concentration of the element n in the soil tested,

Bn is the geochemical background value of the element n in average crust (average shale concentration has been given by Turekian and Wedepohl 1961; Taylor and McLennan 1985; and Wedepohl 1995.

1.5 is the factor used to compensate possible variations in background data (correction factor), which may be attributed to lithogenic effect (Taylor, 1972).

A geochemical background value of Fe was taken from Turekian and Wedepohl (1961). The others were taken from (Reimann *et al*., 2005; Aksu *et al*. 1998) as: Cu: 17 ppm, Zn: 65 ppm, Pb: 8.5 ppm Cd: 0.003 ppm

The Igeo factor is not comparable to other indices of metal enrichment due to the nature of the Igeo calculation; it involves a log function and a background multiplication of 1.5. It is composed of seven grades (0–6) indicating various degrees of metal enrichment above the average shale value ranging from unpolluted to very high polluted sediment quality. Table 2.

Table 2: Classification of Sediment Grade based on Igeo Index (after Muller, 1969).

Igeo value	Class	Category
Igeo≤ 0	0	Unpolluted
0<Igeo ≤1	1	From unpolluted to moderately polluted
1<Igeo ≤2	2	Moderately polluted
2< Igeo≤3	3	From moderately to strongly polluted
3< Igeo≤4	4	strongly polluted
4<Igeo≤5	5	From strongly to extremely polluted
Igeo >5	6	extremely polluted

Bioaccumulation Factor (BAF)

BAF was calculated by:

$$\mathrm{BAF} = \frac{\mathrm{Cplant}}{\mathrm{Csoil}}$$

Cplant and Csoil are metals concentration in the plant shoot (mg/kg) and soil (mg/kg), respectively. Ma *et al*., 2001; and Cluis, 2004 categorized BAF further as

Excluder = BAF<1
Effective Accumulator = BAF=1
Hyperaccumulators = BAF>1

RESULTS AND DISCUSSION

Table 3: Average Result of Sampling during Dry Season

Parameter	L1	L2	W1	W2	S1	S2	Paw 1	Paw 2	Pot 1	Pot 2
Cd	12.60	< 0.01	0.040	<0.001	9.50	<0.01	0.94	<0.01	0.60	<0.01
Pb	19.50	<0.01	0.20	<0.001	16.40	<0.01	1.60	<0.01	2.30	<0.01
Zn	106.70	0.95	0.90	0.008	76.30	22.14	6.40	18.11	11.60	9.30
Fe	168.30	94.80	11.30	2.10	146.70	89.60	16.30	6.10	3.40	1.30
Cu	94.20	46.30	0.09	0.21	63.40	40.10	3.14	1.30	4.50	0.50

Where: L1 – Leachate at Choba dumpsite, **L2** = Leachate at Ada-George dumpsite, **W1** = Borehole water near Choba dumpsite, **W2** = Borehole water near Ada-George dumpsite, **S1** = Soil sample from Choba dumpsite, **S2** = Soil sample from Ada-George dumpsite, **Paw 1** = Pawpaw plant from Choba dumpsite, **Paw 2** = Pawpaw plant from Ada-George dumpsite, **Pot 1** = Potato plant from Choba dumpsite, **Pot 2** = Potato plant from Ada-George dumpsite

Table 4: Average Result for Sampling during Wet Season

Parameter	L1	L2	W1	W2	S1	S2	Paw 1	Paw 2	Pot 1	Pot 2
Cd	19.30	0.30	0.13	<0.001	14.60	1.80	1.08	<0.001	1.00	<0.001
Pb	28.30	0.09	0.60	0.003	21.30	0.90	2.10	<0.001	2.90	<0.001
Zn	143.50	43.40	1.30	0.06	94.70	24.30	8.10	21.20	13.70	10.50
Fe	193.60	154.70	14.80	4.30	154.20	103.30	18.70	6.90	4.00	1.60
Cu	113.40	64.70	0.14	0.60	66.60	43.30	4.30	1.90	5.60	0.80

Where: L1 – Leachate at Choba dumpsite, **L2** = Leachate at Ada-George dumpsite, **W1** = Borehole water near Choba dumpsite, **W2** = Borehole water near Ada-George dumpsite, **S1** = Soil sample from Choba dumpsite, **S2** = Soil sample from Ada-George dumpsite, **Paw 1** = Pawpaw plant from Choba dumpsite, **Paw 2** = Pawpaw plant from Ada-George dumpsite, **Pot 1** = Potato plant from Choba dumpsite, **Pot 2** = Potato plant from Ada-George dumpsite

Table 5: Concentrations of Metals in Leachate and Borehole Water during Dry Season

	Cd	Pb	Zn	Fe	Cu
L1	12.6	19.5	106.7	168.3	94.2
L2	0.01	0.01	0.95	94.8	46.3
W1	0.04	0.2	0.9	11.3	0.09
W2	0.001	0.001	0.008	2.1	0.21

Table 6: Concentrations of Metals in Leachate and Borehole Water during Wet Season

	Cd	Pb	Zn	Fe	Cu
L1	19.3	28.3	143.5	193.6	113.4
L2	0.3	0.09	43.4	154.7	64.7
W1	0.13	0.6	1.3	14.8	0.14
W2	0.001	0.003	0.06	4.3	0.6

High concentration of metal prevailed in the leachate. Based on the data collected from this study as shown in table 5, Cd (0.04) and Pb (0.2) were recorded during the dry season at the borehole water in Choba dumpsite (W1). During wet season, the values increase to 0.13 and 0.60 respectively for Cd and Pb. Cd and Pb were not detected in other borehole samples. Fe has the highest recorded; and insignificant traces of Cd and Pb appears at the Ada-George dumpsites. This shows that there is likely a downward movement of metals from the leachate to meet with the groundwater aquifer or borehole water. From this study, significant quantity of Cd, Pb, and Fe were recorded during dry and wet season at Choba dumpsite.

Cadmium is widely distributed in the earth's crust. Human activities (such as mining, metal production, and combustion of fossil fuels) can result in elevated cadmium concentrations in the environment. Based on the data in table 5, L1 and the borehole at Choba dumpsite (W1) sampled during dry season with Cd 12.6 and 0.04mg/L respectively did not meet NSDWQ (2007), WHO (2011) standard as they exceeds the maximum limit of 0.01 and 0.003 respectively (Table 11).. Other values recorded during dry season are within limits of 0.01 and 0.003.

During wet season, there is a general increase in the concentration of Cd. L1, L2, and W1 for the water parameters with 19.30, 0.3, 0.13 respectively did not meet NSDWQ (2007), WHO (2011) standard. W2 with <0.001 is within NSDWQ (2007), WHO (2011) standard.

Lead detected in samples originates from used batteries and other lead bearing wastes in the dumpsite. L1 (19.50) and W1 (0.20 mg/L) recorded high during dry season (table 5); which do not meet the standard set by NSDWQ (2007), WHO (2011). During wet season (table 6), except the borehole water at Ada-George (W2), all other water samples (L1=28.3, L2=0.09, W1=0.60) has exceeded the maximum value set by WHO and NSDWQ. The result shows general increase in the valus of Pb during wet season compared to dry season. This may be linked to washing of metals from the dumpsites to those water bodies.

Zinc is a transition metal that occurs naturally in soil about 70mg/kg in crystal rock. It is a very important material used in the production of batteries, rubber, paints, cosmetics, chemicals, pharmaceuticals, and a protective coating for iron and steel. It is also used as a micronutrient in agricultural fertilizers. Traces of Zn were recorded in some of the sampled parameters. Except L1 in dry season (106.7) and L1 (143.5) and L2 (43.40) in wet season, values of Zn in the sampled water parameters show that they are within the acceptable limits of NSDWQ and WHO (Table 11).

Iron is a common occurring metallic element. The value of Fe recorded during dry and wet season at both dumpsites as recorded in Table 5 and table 6 exceeds the maximum limit set by WHO and NSDWQ.

Cu was also recorded in the two borehole waters during dry and wet season (Table 5 and table 6), but they are all below maximum limit or standard set by WHO and NSDWQ.

Generally, Fe has the highest recorded concentration of the metals in W1 during the wet season with 14.80 mg/L; which indicates that all the dumpsites receives high wastes from iron and steel scrap. Presence of Cd, Pb, and Zn indicate that batteries, fluorescent lamps, petroleum compounds have contaminated the dumpsites.

The different metals detected are indications that the Port Harcourt unengineered dumpsites receive variety of wastes from different waste streams. This is due to the fact that wastes from industrial, commercial and household items are deposited there without any form of segregation.

Table 7: Concentration of Metals in the Soil and Edible Plants during Dry Season

	Cd	Pb	Zn	Fe	Cu
S1	9.5	16.4	76.3	146.7	63.4
S2	0.01	0.01	22.14	89.6	40.1
Paw 1	0.94	1.6	6.4	16.3	3.14
Paw 2	0.01	0.01	18.11	6.1	1.3
Pot 1	0.6	2.3	11.6	3.4	4.5
Pot 2	0.01	0.01	9.3	1.3	0.5

Table 8: Concentration of Metals in the Soil and Edible Plants during Wet Season

	Cd	Pb	Zn	Fe	Cu
S1	14.6	21.3	94.7	154.2	66.6
S2	1.8	0.9	24.3	103.3	43.3
Paw 1	1.08	2.1	8.1	18.7	4.3
Paw 2	0.001	0.001	21.2	6.9	1.9
Pot 1	1	2.9	13.7	4	5.6
Pot 2	0.001	0.001	10.5	1.6	0.8

Although, soil is not directly consumed by human being, studies of contaminants in them linked with other pathways are indications of possible transfer or movements of contaminants from one medium to the other. Concentrations of metals obtained from the two dumpsites during dry season include S1 (Cd=9.50, Pb=16.40, Zn=76.30, Fe=146.70, Cu=63.40), and S2 (Cd=<0.001, Pb=<0.001, Zn=22.14, Fe=89.60, Cu=40.10). From table 7, Fe in the soil sample has the highest concentration (146.70 mg/kg to 154.20 mg/kg), followed by Zn, Cu, Pb, and Cd in that order. Higher metals were recorded in S1 than S2; S2 having little or negligible concentrations during the dry season. Concentrations of metals obtained from the two dumpsites during wet season include S1 (Cd=14.60, Pb=21.30, Zn=94.70, Fe=154.20, Cu=66.60), and S2 (Cd=1.80, Pb=0.9, Zn=24.30, Fe=103.30, Cu=43.30). This shows a remarkable increase in the values from dry season to wet season. This result correlates with the values in leachate where Fe has the highest concentration, and that soil at Choba dumpsite (S1) receives more metallic waste than Ada-George dumpsite (S2). Cd and Pb are lower in the soil samples than other metals which indicate that there are fewer dumping of batteries, fluorescent lamps, photographic materials and petroleum compounds than other metallic sources.

Tables 7 and 8 shows that all the plants have taken up metal. Zn and Fe are the most absorbed metals with 21.20 mg/kg and 18.70 mg/kg respectively. Edible plants at Ada-George dumpsite was free of Cd and Pb, while edible plants at Choba dumpsites was recorded to have absorbed all the forms of metal analysed. This can be linked to the fact that Ada-George dumpsite is relatively free of any source of Cd and Pb like batteries, radiographic materials etc. There is also an increase in concentration of all the metals during the wet season both in the soil and in the edible plants. This shows that water helps in the transfer of metals from the soil to edible plants. Chlorine was negligible in the edible plants sampled, but traces of other metals were found in them.

Table 9: Effects of Season on Concentration of Heavy Metals in Leachates and Borehole Water

Parameter	**L1**		**L2**		**W1**		**W2**	
	Dry	**Wet**	**Dry**	**Wet**	**Dry**	**Wet**	**Dry**	**Wet**
Cd	12.60	19.30	< 0.01	0.30	0.040	0.13	<0.001	<0.001
Pb	19.50	28.30	<0.01	0.09	0.20	0.60	<0.001	0.003
Zn	106.70	143.50	0.95	43.40	0.90	1.30	0.008	0.06
Fe	168.30	193.60	94.80	154.70	11.30	14.80	2.10	4.30
Cu	94.20	113.40	46.30	64.70	0.09	0.14	0.21	0.60

Table 10: Effects of Season on Concentration of Heavy Metals in the Soil and Edible Plants

Parameter	**S1**		**S2**		**Paw 1**		**Paw 2**		**Pot 1**		**Pot 2**	
	Dry	**Wet**	**Dry**	**Wet**	**Dry**	**Wet**	**Dry**	**Wet**	**Dry**	**Wet**	**Dry**	**Wet**
Cd	9.50	14.60	<0.01	1.80	0.94	1.08	<0.01	<0.001	0.60	1.00	<0.01	<0.001
Pb	16.40	21.30	<0.01	0.90	1.60	2.10	<0.01	<0.001	2.30	2.90	<0.01	<0.001
Zn	76.30	94.70	22.14	24.30	6.40	8.10	18.11	21.20	11.60	13.70	9.30	10.50
Fe	146.70	154.20	89.60	103.30	16.30	18.70	6.10	6.90	3.40	4.00	1.30	1.60
Cu	63.40	66.60	40.10	43.30	3.14	4.30	1.30	1.90	4.50	5.60	0.50	0.80

The result in table 9 and 10 shows that season season has great influence on the rate of contaminant of heavy metals in leachates, borehole water, soil and edible plants. From the table, the boxes coloured green has higher contaminant level than the boxes coloured white. The boxes coloured orange is used to indicate those heavy metals studied that has the same value or no significant change in concentrations during dry and wet season.

In both L1 and L2, all heavy metals sampled shows increase in the rate of contamination from dry season to wet season. This may be as a result of dissolution of solutes of heavy metals from the dumpsites during the wet season, flushed into the leachates by the activities of rain, and dilute the leachates. In the borehole water samples, most of the heavy metals have increased in values during wet season than dry season. Overall result of leachate and borehole water samples shows that most heavy metals increased from dry season to wet season, which indicate that rain water is an important medium of transport of heavy metals from the dumpsites to the leachate and eventually borehole water.

Andrews (1972) reported that heavy rain may improve the water quality by diluting and washing away pollutants, and may also lower the water quality by flushing in pollutants such as fertilizers and suspended or dissolved solids. We can therefore conclude that season has significant effect on the concentrations of heavy metals in the leachates, borehole water, soil and edible plants; as rainwater helps to dissolve the solute for onward movement to the leachate, soil, borehole water and edible plants.

Table 11: Comparison of Groundwater Quality Parameters with International Standards WHO (World Health Organisation) and NSDWQ (Nigerian Standard for Drinking Water Quality)

Parameter	**L1**	**L2**	**W1**	**W2**	**WHO Standard**	**NSDWQ Standard**
Cd	12.60	‹ 0.01	0.040	‹ 0.001	0.01	0.003
Pb	19.50	‹ 0.01	0.20	‹ 0.001	0.05	0.01
Zn	106.70	0.95	0.90	0.008	5.0	3.0
Fe	168.30	94.80	11.30	2.10	0.3	0.3
Cu	94.20	46.30	0.09	0.21	1.0	2.0
TDS	9760	168.3	6.60	15.10	500	500
pH	6.40	6.20	6.70	7.40	6.5-8,5	6.5-8,5
EC	2040.1	69.30	3.60	2.10	300	1000
NO_3^-	998.60	21.59	4.70	1.84	50	50
PO_4^-	169.30	8.30	0.10	‹ 0.01		
Cl^-	670.40	392.3	11.30	9.94	250	250
SO_4^{2-}	267.50	83.60	0.05	0.01	200	100

**All values in mg/L, except pH and EC (µS/cm);* NSDWQ *(2007), WHO (2011).*

Data Analysis

Table 12: CF, CD, PLI, Igeo for Borehole water at Choba Dumpsite

Parameter n = 5	**W1 - dry**				**W1 - wet**			
	Field Data	**Conc.** (Bn)	**CF**	I_{geo}	**Field Data**	**Conc.** (Bn)	**CF**	I_{geo}
Cd	0.040	0.003	13.33	3.15	0.13	0.003	43.33	4.85
Pb	0.20	8.5	0.02	-5.64	0.60	8.5	0.07	-4.32
Zn	0.90	65.0	0.01	-6.64	1.30	65.0	0.02	-6.64
Fe	11.30	5.0	2.26	1.51	14.80	5.0	2.96	0.98
Cu	0.09	17.0	0.01	~	0.14	17.0	0.01	-6.64
		CD	**15.63**			**CDegree**	**46.39**	
		PLI	**0.00**			**PLI**	**0.29**	

Table 13: CF, CD, PLI, Igeo for borehole water at Ada-George Dumpsite

Parameter n = 5	**W2 - dry**				**W2 - wet**			
	Field Data	**Conc.** (Bn)	**CF**	I_{geo}	**Field Data**	**Conc.** (Bn)	**CF**	I_{geo}
Cd	‹ 0.001	0.003	0.33	-2.18	‹ 0.001	0.003	0.33	-2.18
Pb	‹ 0.001	8.5	0.00	-3.64	0.003	8.5	0.00	~
Zn	0.008	65.0	0.00	~	0.06	65.0	0.00	~
Fe	2.10	5.0	0.42	-1.84	4.30	5.0	0.86	-0.81
Cu	0.21	17.0	0.01	-6.64	0.60	17.0	0.04	-5.64
		CD	**0.76**			**CD**	**1.23**	
		PLI	**0.00**			**PLI**	**0.00**	

Table 14: Comparing Bioaccumulation Factors of Pawpaw at Choba dumpsites

Parameter	**S1-dry**	**Paw 1**	**BAF**	**S1-wet**	**Paw 1**	**BAF**
Cd	9.50	0.94	**0.10**	14.60	1.08	0.07
Pb	16.40	1.60	**0.10**	21.30	2.10	0.10
Zn	76.30	6.40	**0.08**	94.70	8.10	0.09
Fe	146.70	16.30	**0.11**	154.20	18.70	0.12
Cu	63.40	3.14	**0.05**	66.60	4.30	0.06

Table 15: Comparing Bioaccumulation Factors of Potato at Choba dumpsites

Parameter	**S1-dry**	**Pot 1**	**BAF**	**S1-wet**	**Pot 1**	**BAF**
Cd	9.50	0.60	**0.06**	14.60	1.00	0.07
Pb	16.40	2.30	**0.14**	21.30	2.90	0.14
Zn	76.30	11.60	**0.15**	94.70	13.70	0.14
Fe	146.70	3.40	**0.02**	154.20	4.00	0.03
Cu	63.40	4.50	**0.07**	66.60	5.60	0.08

Table 16: Comparing Bioaccumulation Factors of Pawpaw at Ada-George dumpsites

Parameter	S2-dry	Paw 2	BAF	S2-wet	Paw 2	BAF
Cd	<0.01	<0.01	-	1.80	<0.001	0.00
Pb	<0.01	<0.01	-	0.90	<0.001	0.00
Zn	22.14	18.11	0.82	24.30	21.20	0.87
Fe	89.60	6.10	0.07	103.30	6.90	0.07
Cu	40.10	1.30	0.03	43.30	1.90	0.04

Table 17: Comparing Bioaccumulation Factors of Potato at Ada-George dumpsites

Parameter	S2-dry	Pot 2	BAF	S2-wet	Pot 2	BAF
Cd	<0.01	<0.01	-	1.80	<0.001	0.00
Pb	<0.01	<0.01	-	0.90	<0.001	0.00
Zn	22.14	9.30	0.42	24.30	10.50	0.43
Fe	89.60	1.30	0.01	103.30	1.60	0.02
Cu	40.10	0.50	0.01	43.30	0.80	0.02

Table 18: Comparing CF, CD, PLI, Igeo for Soil at Choba dumpsites

	S1-dry				S1-wet			
Parameter n = 5	**Field Data**	**Conc.** (Bn)	**CF**	**I_{geo}**	**Field Data**	**Conc.** (Bn)	**CF**	**I_{geo}**
Cd	9.50	0.003	**3166.67**	**11.04**	14.60	0.003	**4,866.67**	**11.66**
Pb	16.40	8.5	**1.93**	**0.37**	21.30	8.5	**2.51**	**0.74**
Zn	76.30	65.0	**1.17**	**-0.36**	94.70	65.0	**1.46**	**-0.04**
Fe	146.70	5.0	**29.34**	**4.29**	154.20	5.0	**30.84**	**4.36**
Cu	63.40	17.0	**3.73**	**1.32**	66.60	17.0	**3.92**	**1.38**
		CD	**3202.84**			**CD**	**4,905.4**	
		PLI	**3.79**			**PLI**	**4.64**	

Table 19: Comparing CF, CD, PLI, Igeo for Soil at Ada-George dumpsites

	S2-dry				S2-wet			
Parameter n = 5	**Field Data**	**Conc.** (Bn)	**CF**	**I_{geo}**	**Field Data**	**Conc.** (Bn)	**CF**	**I_{geo}**
Cd	< 0.001	0.003	**0.33**	**1.15**	1.80	0.003	**600.00**	**8.64**
Pb	< 0.001	8.5	**0.00**	**-**	0.90	8.5	**0.11**	**-3.84**
Zn	22.14	65.0	**0.34**	**-2.12**	24.30	65.0	**0.37**	**-2.00**
Fe	89.60	5.0	**17.92**	**3.58**	103.30	5.0	**20.66**	**3.78**
Cu	40.10	17.0	**2.36**	**0.65**	43.30	17.0	**2.55**	**0.77**
		CD	**20.95**			**CD**	**623.69**	
		PLI	**0.00**			**PLI**	**4.19**	

If the average concentration of metal in the soil is higher than the average shale concentration, it indicates that there is an apparent metal pollution risk for the sampled soil. Excess of the shale concenrations shows that the excess comes mainly from the dumpsites. Tables 12 and 13 shows that there is increase in the concentration of most metals in the wet season than in the dry season as evidenced in the CF values obtained. Cd at W1 (43.33 against the dry season value of 13.33), Fe in W1 with 2.96 against the dry season value of 2.26). Though, other metals in the borehole are still low in CF, Cd has now increased in W1 to 43.3 (very high CF), Fe in W1 has increased to 2.96 (approaching a considerable CF).

During dry season in S1, Zn has the lowest CF with 1.17, and the highest was recorded in Cd with 3,166.67. Others are Fe (29.34), Cu (3.73), and Pb (1.93). This shows that the soil in S1 is from moderately polluted to very highly polluted. Low CF was recorded in Cd (0.03), Pb (0.00), and Zn (0.34). Cu recorded 2.36 (which is a moderate CF), and Fe 17.92 (very high CF). CF for Cd and Fe are very high in the two dumpsites. This shows that there is increase in the quantity of batteries and metallic products dumped into the unengineered dumpsites.

During wet season, the same order was repeated in S1 as the dry season with Zn having the lowest CF during wet season with 1.46; and the highest was recorded in Cd with 4,866.67. Others in descending order are Fe (30.84), Cu (3.92) and Pb (2.51). This shows that the soil in S2 is from moderately polluted to very highly polluted (i.e low CF to high CF). S2 however has lower CF in Pb and Zn with 0.11 and 0.37 respectively. Others in ascending order are Cu (2.55 – moderate CF), Fe (20.66 – very high CF) and Cd (600.00 – very high CF). CF for Cd and Fe are very high in the two dumpsites as recorded during dry season. This shows that there is increase in the quantity of batteries and metallic products dumped into the unengineered dumpsites. S1 also recorded relatively higher CF than S2. The same trend of increase in metal concentration was recorded in both Choba and Ada-George dumpsite from dry season to wet season.

Index of geoaccumulation (Igeo)

Igeo test conducted to estimate the enrichment of metal concentrations above background or baseline concentrations shows that Cd and Fe are the principal metals observed to have polluted the two borehole waters (Tables 12 and 13). It cleared Ada-George dumpsites of any additional contaminant apart from the one from the earth crust. But Cd and Fe were observed to have strongly and moderately polluted the water respectively in W1. Cd was (3.15, 4.85 for dry and wet season respectively) and Fe (1.51 and 0.98 for dry and wet season respectively). This indicates progressive deterioration of sites and moderately polluted sites respectively. It also conforms to the results from CF and CD. The result from the Ada-George borehole (W2) shows more perfection as all the CF records were low, all CD shows low result, there is perfection in PLI, and the Igeo indicated that the borehole waters were not polluted. The result obtained in tables 18 and 19 suggests that these metals may have originated from anthropogenic sources and not from natural processes or crustal materials alone. Igeo result for S1 includes Cd (11.04), Pb (0.37), Zn (-0.36), Fe (4.29), Cu (1.32); and S2 includes Cd (1.15), Pb (-), Zn (-2.12), Fe (3.58), Cu (0.65). The result shows that the most polluted metal in S1 is Cd (extremely polluted), and the least polluted metal is Zn (which indicates unpolluted). S2 has contrasting order with the highest being Fe (3.38, indicating strongly polluted), followed by Cd (1.15), Cu (0.65), Zn and Pb (with -2.12 and infinity falling in the range of unpolluted).

During wet season, the result shows that Zn still remain the only metal that did not enrich the soil with values less than 0 (S1 = -0.04, and S2 = -2.00) in the wet season. However, S2 recorded a Pb value less than 0 (-3.84) during the wet season. Other results range from unpolluted to moderately polluted, and to extremely polluted. S1 = Cd (11.66), Pb (0.74), Zn (-0.004), Fe (4.36) and Cu (1.38). S2 = Cd (8.64), Pb (-3.84), Zn (-2.00), Fe (3.78) and Cu (0.77).

Generally, Index of Geoaccumulation shows that Zn and Pb show no pollution i.e. the soil is not polluted of Zn and Pb. However, moderate pollution was recorded for Choba dumpsites during the dry and wet season. There is gradation from strongly polluted with Fe to extremely polluted with Cd in both dumpsites. This implies that urgent attention has to be given to the dumpsites to avoid or prevent further degradation of the soil.

Contamination Degree (CD)

CD analysis result shows that only W1 (borehole near Choba dumpsite) shows from considerable CD (15.63) to very high CD (46.39) during dry and wet seasons respectively. This indicates that to a very large extent, the highest polluted borehole water is the Choba dumpsite (W1). There is also a significant increase in CD from dry to wet season. It increased in W1 from 15.63 to 46.39 and in W2 from 1.62 to 2.02. The two dumpsites shows considerable CD during dry season (S1 = 20.95) to very high CD (S2 = 3,202.84). This shows that the degree of pollution or contamination of metals on the soil is very high.

CD values in the soil however increases seriously during the wet season (S1 = 4,905.4), (S2 = 623.69). This may be unconnected with the washing of contaminants from the dumpsites into the soil as a result of rain or erosion. It shows that both sites have very high degree of contamination.

Pollution Load Index (PLI)

Pollution load index to determine the severity and variation of pollution shows perfection in all the water samples analysed as 0 was recorded. Pollution Load Index that recorded 0 in the borehole water during dry season now has 0.29 in W1. This still shows perfection in W1, but a gradual build-up of metals in W1.

PLI in S1 (3.79) during dry season shows that there is progressive deterioration of site as the value is greater than 1. However, S2 (0.00) during dry season shows perfection. It is therefore possible that Ada-George dumpsite is a relatively older dumpsite with lower metabolic reactions than in Choba dumpsite that prompted perfection in metal contamination. This demonstrates the fact that S1 is more polluted than S2. During wet season, Pollution Load Index of **4.64** was recorded in S1 and S2 has **4.19** for PLI, which shows that there is progressive deterioration of the two sites during wet season.

Bioaccumulation Factor (BAF)

Bioaccumulation factor value recorded during the two seasons and at all the borehole waters are less than 1 (Tables 14 to 17). This shows that all are excluders, and that there is no transfer of heavy metals from the soil into the plants.

CONCLUSION

From the general analysis, some concentrations did not meet the standards of WHO and NSDWQ, while others met the standard. Most of the indices revealed that the study area was seriously affected by different heavy metals. Wet season recorded higher values of the overall indices than dry season. These metals with high concentrations in the studied soils may have been mixed with groundwater by leaching. Most of the leachates and borehole water at the unengineered dumpsites are of poor quality since contaminated by the leachate. The edible plants have also absorbed some traces of heavy metals which can bioaccumulate or biomagnify to create health and environmental effects.

From this study we can conclude that there are high concentrations of heavy metals reported near the unengineered dumpsites studied. The study also revealed that more contaminants were recorded during wet season than dry season.

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