Assessment of Concentrations and Potential Exposure Pathways for Physiochemical Parameters near Unengineered Dumpsite in Port Harcourt, Nigeria

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ABSTRACT

This study assessed the concentrations and potential exposure pathways for physiochemical parameters near unengineered dumpsite in Port Harcourt, Nigeria. Cross sectional study was conducted on leachates, borehole water (from less than 1 km and another about 10 km away from the dumpsite), soil and two edible plants (Pawpaw and Potatoes). The physicochemical parameters studied include pH, Total Dissolved Solids (TDS), Biochemical Oxygen Demand (BOD), Chemical Oxygen Demand (COD), Electrical Conductivity (EC), Nitrate, Phosphate, Sulphate, Chlorine and heavy metals (namely Cd, Pb, Zn, Fe, and Cu). The result showed that leachate at the two dumpsites have higher physiochemical characteristics than the borehole water, and that there are biological activities which correspond to the acid phase of anaerobic degradation. TDS was higher at the water samples closer to the dumpsites than the one farther. The pH value ranged from 6.2 – 7.40; and are consistent with WHO and NSDWQ. The pH recorded in the borehole waters shows that biological activities have decreased as the water gets to the ground level. The result shows that higher proportion of metals was present in the soil than borehole water. The result shows that most of the underground water meets the minimum quality of international standard WHO (World Health Organisation) and NSDWQ (Nigerian Standard for Drinking Water Quality); though lead was recorded above the minimum drinking water standard in the borehole water near Choba dumpsite; with concentration 0.2 mg/l compared to the maximum standard of 0.01mg/l. The concentrations of contaminants were found to be higher around the dumpsites (leachates and soil) than the one farther from it (borehole waters), which shows that contaminations drop with increase in distance from the dumpsites. Analysis of the leachates, soil, edible plants and borehole waters showed possible gradual movement of contaminants, with concentrations decreasing as we move from the leachate to the soil (from where plants absorb metals), nearby borehole and distant borehole water. This study shows that there is high pollution around the unengineered dumpsites that can lead to high health risk in Port Harcourt, Rivers State. Nigeria.

Keywords: groundwater, pollution, leachate, unengineered dumpsites

INTRODUCTION

Some habitable parts of the earth surface with accumulated solid wastes are called refuse dumps but a designated place for dumping is known as dumpsites. Unengineered dumpsite is a disposal site where there is indiscriminate deposit of solid waste with either no or limited engineering measures (such as liner system) to control the operation and to protect the environment. Improper waste management processes in developing countries 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). The emitted liquid from dumpsites known as 'Leachate' may contain several organic and inorganic contaminants which have detrimental effects on water, soil and 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).

Within a landfill, complex sequence of physical, chemical, and biologically mediated events occurs as have been reported by Pastor and Hernández (2012) that degrade and transform the wastes. As water percolates through the solid waste, contaminants are leached from the solid waste. The mechanism of contaminant removal outlined by Aziz *et al*., (2010); Eggen *et al*., (2010) and Hennebert *et al*., (2013) 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.

Municipal landfill leachate is a 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). Groundwater pollution is mainly due to the process of industrialization and urbanization that has progressively developed over time without any regard for environmental consequences (Longe and Balogun, 2010).

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). Population growth and economic development lead to enormous amounts of solid waste generation by the dwellers of urban areas. 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). The quality of underground water is compromised by the indiscriminate dumping of waste in the environment and contamination by leachate. (David and Oluyege, 2014).

The collection, transport, treatment, and disposal of solid wastes have become a relatively difficult problem to solve for those responsible for their management (UNEP, 2005), which has manifested in the form of piles of indiscriminately disposed heaps of uncovered waste and illegal dumpsites along major roads and at street corners in cities and urban areas. Presently, the waste generated from Port Harcourt metropolis is disposed of directly into random pits without adequate handling and treatment (RSESA, 2013). Such mode of disposal can cause serious threat to the environment especially those living around them.

Many unengineered dumpsites located in various parts of Port Harcourt and its environment are located at or close to streams, valleys, open fields, water lands and in abandoned pits. Wastes generated and gathered at source are disposed of in communal bins or communal collection points (that are spread out at different location across the city) stipulated by the Government. In Port Harcourt, refuse is generated from domestic, commercial and industrial sources. The rate of generation has been steadily increasing and will likely continue to do so in future with the rapid increase of population and industrial activities in the city. Heaps of these wastes are conspicuous on roads and public places, clogging drains and contaminating water sources close to dump sites.

When solid wastes are released into improperly designed environment, it can cause several impacts on human and the environment. Most countries do not have any specific technique of managing hospital and clinical wastes. So, they are mixed with MSW and pose a threat to health of human population and surrounding environment (Pattnaik and Reddy, 2009). Once leachate is formed, it migrates downward through the unsaturated zone of the groundwater until it reaches the saturated zone. Several forces may act on or react with the migrating leachate, resulting in changes of chemistry and a general reduction of strength from the original release. These forces are physical (filtration, sorption, advection, and dispersion), chemical (oxidation-reduction, precipitation-dissolution, adsorption-desorption, hydrolysis, and ion exchange), and biological (microbial degradation).

Contaminants in groundwater are largely soluble compounds and microorganisms (Aderiye *et al*., 1992; Udoessien, 2004). Heavy metals are not commonly found in groundwater, their presence is largely as a result of environmental contamination (Bahnasawy *et al*., 2011). They get accumulated and affect different organs and caused several ailments in the body. Their amount in the water depends on pH, temperature, water hardness, standing time of the water among other factors (IPCS, 2003; WHO, 1997). Urban wastes constitute a large source of pollution and have a significant impact on the ecosystem (Adebayo *et al*., 2007; Edema *et al*., 2001; Pirsaheb *et al*., 2013).

Generally, dumping in 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, which increase dumping of restricted materials, such as car batteries and metals. Scavengers have free access to the dump, and they scatter the waste to recover valuable material. Some scavengers even pitch their tent in and around the unengineered dumpsites. Like many cities in Nigeria, Port Harcourt is faced with the problems of improper collection, handling and disposal of domestic wastes.

Okafor and Onwuka (2013) reported that the concern over soil contamination stems primarily from health risks, from direct contact with the contaminated soil, vapours from the contaminants, and from secondary contamination of water supplies within the soil. High potential risk may result from infiltration of hazardous chemicals in the soil into groundwater aquifers used for human consumption. Agriculture in these areas faces major problems when pollutants and heavy metal are transferred into crops and subsequently into the food chain. Industrial or man-made concentrations of naturally-occurring substances, such as nitrate and ammonia associated with livestock manure from agricultural operations have also been identified as health hazards in soil and groundwater (USEPA, 2002). Heavy metals can be found in dumpsite leachate, soil and borehole water.

A key route for entry of metals into the food chain is via uptake by plants from the soil or as a result of accumulation in tissues of aquatic animals. Approaches to evaluating the fate and distribution of contaminants in ecosystems are discussed by Markert (1993), Ross and Kaye (1994), and Walker *et al.* (1996), who also outline biomonitoring procedures. Analytical techniques are also detailed in Stoeppler (1992). Tessier and Turner (1995) specifically address the chemistry and bioavailability of trace metals in aquatic systems. Uptake by plants is affected by soil pH (Alloway 1995). Much of what is taken up is held in the roots, which may minimise implications for the food chain from foliage or seed crops. 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 & 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.

The potential exposure pathways are dumpsites, leachates, groundwater, air, soil and (locally produced) edible food. Exposures to the local population could be ingestion, inhalation or through the skin (trans-dermal). Some exposure of the wider population might occur through eating food produced near landfill site.

MATERIALS AND METHODS

Cross-sectional study of selected unengineered dumpsites was conducted in Port Harcourt, Rivers State to assess the physiochemical characteristics in leachate, groundwater soil and plant uptake near unengineered dumpsite in Port Harcourt, Nigeria. Port Harcourt is the capital and largest city of Rivers State, Nigeria. It is located 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. It is bounded on the Eastern and Western parts by meandering creeks; and to the southern part by Bonny River and mangrove swamps. The average temperature shows little variation throughout the year.

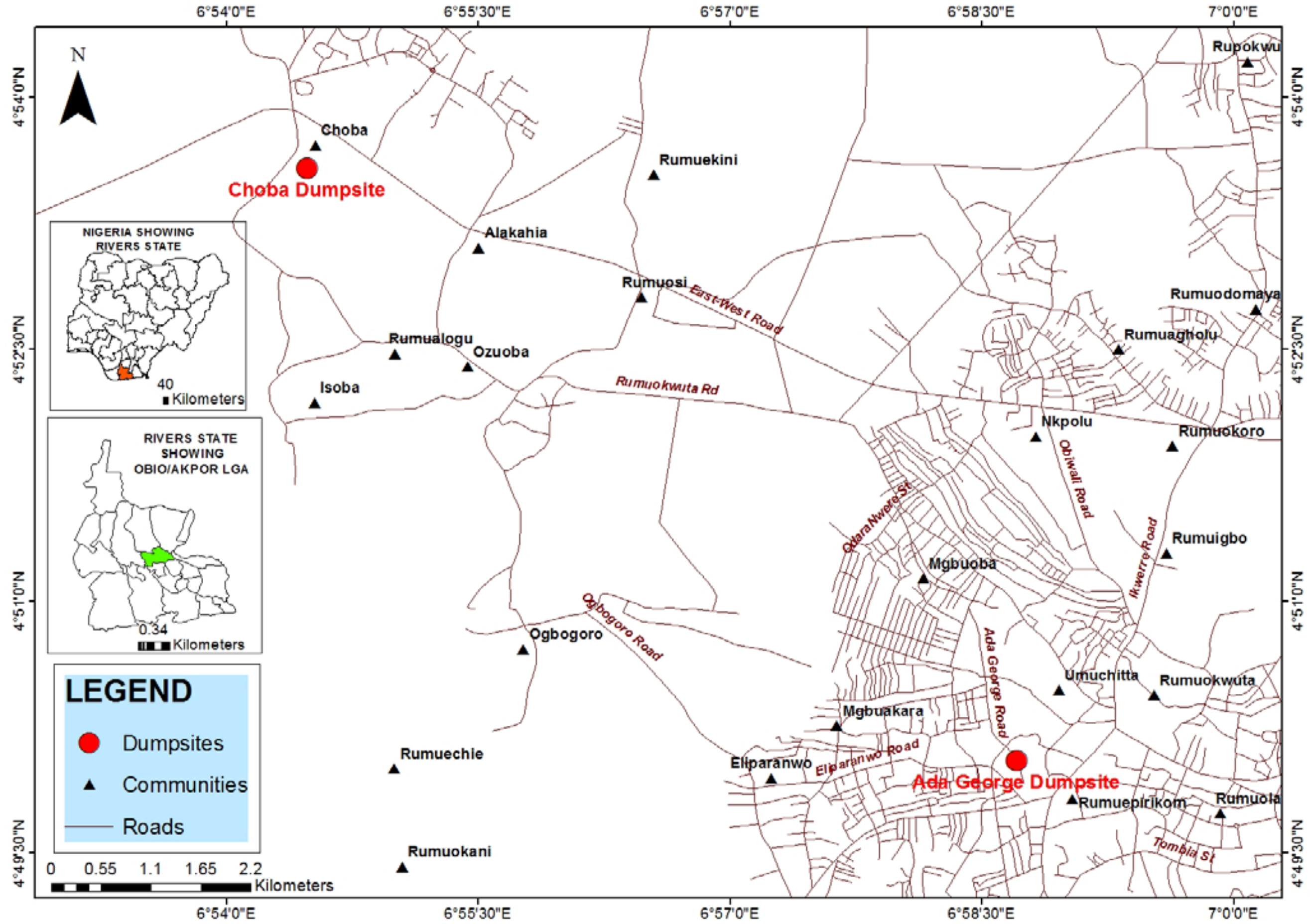

Figure 1: Sectional Map of Port Harcourt, Rivers State. Nigeria showing the location of the Dumpsites

Leachate, borehole water, soil, edible plant, and control borehole water (about 10 km away from the unengineered dumpsites) samples were collected from unengineered dumpsites for laboratory analysis. Attempts were made to minimize changes in the chemistry of the samples. Preservation methods for the samples that are used generally include pH control, refrigeration and protection from light. Sampling plan was coordinated with the laboratory so that appropriate sample receipt, storage, analysis, and custody arrangements will be provided. All physicochemical parameters were determined based on American standard methods for examination of water and wastewater (APHA, 2005). The available standard procedures and apparatuses were used.

RESULTS AND DISCUSSION

REPRESENTATION OF DATA

Physicochemical parameters and characteristics for the soil, leachate, borehole and edible plants around the dumpsite were determined in the Laboratory. Table 1 displayed average physicochemical characteristics at the two dumpsites.

Table 1: General Average Results

Para-meter	L1	W1a	W1b	S1	Paw 1	Pot 1	L2	W2a	W2b	S2	Paw 2	Pot 2
Cd	12.60	0.040	‹ 0.001	9.50	0.94	0.60	‹ 0.01	‹ 0.001	‹ 0.001	‹ 0.01	‹ 0.01	‹ 0.01
Pb	19.50	0.20	‹ 0.001	16.40	1.60	2.30	‹ 0.01	‹ 0.001	‹ 0.001	‹ 0.01	‹ 0.01	‹ 0.01
Zn	106.70	0.90	0.60	76.30	6.40	11.60	0.95	0.008	0.006	22.14	18.11	9.30
Fe	168.30	11.30	6.40	146.70	16.30	3.40	94.80	2.10	1.60	89.60	6.10	1.30

Cu	94.20	0.09	0.03	63.40	3.14	4.50	46.30	0.21	0.10	40.10	1.30	0.50
BOD	11,015.60	‹ 0.01	‹ 0.001				170.56	‹ 0.001	‹ 0.001			
COD	19,670.10	‹ 0.001	‹ 0.001				341.1	‹ 0.001	‹ 0.001			
TDS	9760	6.60	4.70				168.3	15.10	3.40			
pH	6.40	6.70	6.90				6.20	7.40	7.10			
EC	2040.1	3.60	7.10				69.30	2.10	1.60			
NO_3^-	998.60	4.70	0.80	246.10	1.60	0.95	21.59	1.84	3.14	13.18	0.05	0.10
PO_4^-	169.30	0.10	0.07	17.60	1.20	0.80	8.30	‹ 0.01	‹ 0.01	3.19	0.12	0.24
Cl^-	670.40	11.30	4.60	130.60	‹ 0.01	‹ 0.01	392.3	9.94	3.98	39.76	‹ 0.01	‹ 0.01
SO_4^{2-}	267.50	0.05	‹ 0.001	103.40	0.60	3.12	83.60	0.01	‹ 0.001	68.70	0.90	1.60

Where W1a = Borehole water near Choba dumpsite, W1b = Borehole water 10 km away, from Choba dumpsite, W2a = Borehole water near Ada-George dumpsite, W2b = Borehole water 10 km away from 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 from Ada-George dumpsite, L1 = Leachate from Choba dumpsite, L2 = Leachate from Ada-George dumpsite

BOREHOLE WATER AND LEACHATE SAMPLE RESULTS

Leachate sample collected is black in colour. Physiochemical characteristics, anion, and metals were analysed from the collected samples. High concentration of pollutants prevailed in the leachate. Average concentrations of leachate and water samples collected from the Choba and Ada-George dumpsites are presented in table 2.

Table 2: Average Physiochemical properties of Leachate and Borehole water samples

Parameters	L 1	L 2	W1a	W1b	W2a	W2b
BOD	11,015.60	170.56	‹ 0.01	‹ 0.001	‹ 0.001	‹ 0.001
COD	19,670.10	341.1	‹ 0.001	‹ 0.001	‹ 0.001	‹ 0.001
TDS	9760	168.3	6.60	4.70	15.10	3.40
pH	6.40	6.20	6.70	6.90	7.40	7.10
EC	2040.1	69.30	3.60	7.10	2.10	1.60

Biochemical Oxygen Demand (BOD) and Chemical Oxygen Demand (COD): The result shows that leachate generally has higher physiochemical characteristics than the borehole water. Higher physiochemical characteristics were recorded in L1 than L2. BOD and COD have negligible/not observed results of approximately 0.001 mg/l in the borehole waters; both at the dumpsites and about 10 km away from the dumpsites (Table 2). Chofgi *et al*., 2004 reported that young leachates are more polluted than the mature ones where BOD may reach up to 81,000 mg/l for young and 4200 mg/l for mature leachates. BOD recorded in L1 was 11,015.60 mg/l, and L2 was 170.56 mg/l. According to Chofgi *et al*., 2004, the two dumpsites sampled are relatively matured dumpsites, with L2 more matured than L1. COD recorded in L1 was 19,670.10 mg/l, and L2 is 341.1 mg/l. Bashir *et al*., 2009 stated that BOD/COD ratio in young landfill, where biological activity corresponds to the acid phase of anaerobic degradation, reaches values of 0.85. From the result obtained, BOD/COD ratio is 0.56. With reference to Bashir *et al*., 2009, the dumpsites studied is not too old as the BOD/COD ratio is 0.56 greater than 0.1. This shows that there are biological activities which correspond to the acid phase of anaerobic degradation. Higher BOD and COD in L1 than L2 indicates that L1 has higher organic strength than L2 (Zgajnar *et al*. 2008). The low values of BOD in the borehole water may be as result of dilution caused by heavy rains during the period samples were collected. Chofgi *et al*., 2004 also confirmed that old landfills produce stabilized leachate with relatively low COD and low biodegradability (BOD:COD ratio< 0.1).

Total Dissolved Solids (TDS): L1 has average TDS of 9760 mg/l, and L2 168.3mg/l. TDS was higher at the water samples closer to the dumpsites than the one farther; and the one in L1 higher than L2 shows that there are more inorganic material in L1 than L2. The result shows that L1 has more anaerobic activities than L2. This may be as a result of some dissolved components or composition and water content of the waste. Average TDS in W1a, W1b, W2a, and W2b are 6.60, 4.70, 15.10, and 3.40 respectively, which shows a downward trend from the figures obtained in their respective leachates. This shows reduction in dissolved substances as we move from the leachate to the borehole water.

Hydrogen ion Concentration (pH): The pH value for leachate samples from the two dumpsites ranges from slightly acidic to neutral (L1 has pH 6.40, while L2 has pH 6.20). Although pH usually has no direct impact on consumers, it is one of the most important operational water quality parameters, which influences other water parameters (WHO, 2011). The pH recorded in the borehole waters tends to neutral. The average values of borehole water concentrations are W1a (6.70), W1b (6.90), W2a (7.40) and W2b (7.10). This shows that biological activities have decreased as the water gets to the ground level, and there is gradual increase in alkalinity of the water as we move away from the dumpsite.

Electrical Conductivity (EC): Electrical conductivity (EC) of water is a reflection of the quantity of ionic constituents dissolved in it. The obtained conductivity ranges from 1.6 S/cm to 7.1S/cm for borehole water samples, while the leachate water samples varied from 69.30 S/cm to 2040.1 S/cm. The high level of electrical conductivity in the leachate may be attributable to the bedrock materials around the vicinity of the dumpsite. It may be high if the bedrock material cannot limit the percolation of leachates from the refuse dumpsite into the groundwater. A similar trend was recorded in the value of total dissolved solids in the water bodies. According to (WHO, 2011) high level of TDS may be responsible for reduction in the palatability of water, inflict gastrointestinal inconveniences in human, may cause laxative effect particularly upon transits and may be objectionable to consumers.

Metals in Borehole Water, Leachate and Soil

Table 3: Average Concentration of Metals (mg/L) in Borehole water, Leachates and Soil

Variables	W1a	W1b	W2a	W2b	L1	L2	S1	S2
Cd	0.040	‹ 0.001	‹ 0.001	‹ 0.001	12.60	‹ 0.01	9.50	‹ 0.01
Pb	0.20	‹ 0.001	‹ 0.001	‹ 0.001	19.50	‹ 0.01	16.40	‹ 0.01
Zn	0.90	0.60	0.008	0.006	106.70	0.95	76.30	22.14
Fe	11.30	6.40	2.10	1.60	168.30	94.80	146.70	89.60
Cu	0.09	0.03	0.21	0.10	94.20	46.30	63.40	40.10

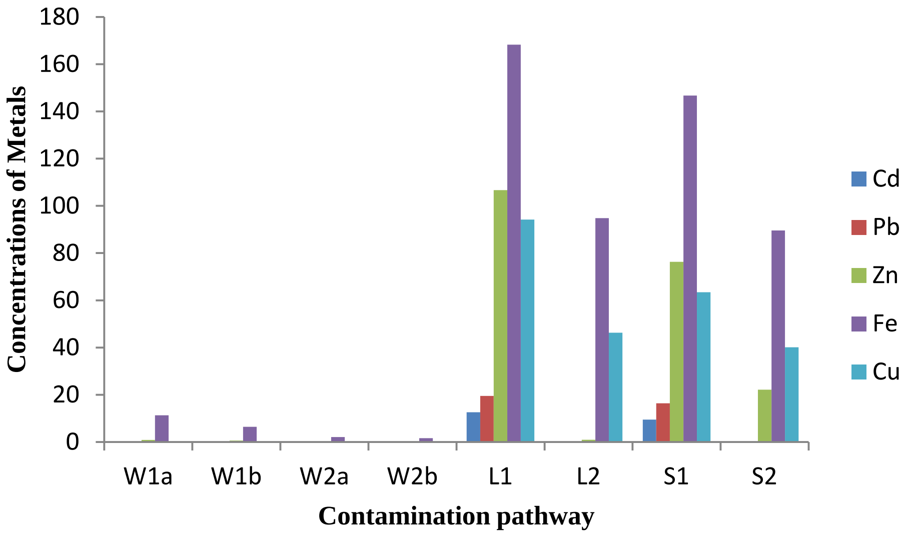

Figure 2: Concentration of Metals (mg/L) in the Borehole water, Leachates and Soil

Table 3 and figure 2 shows that Leachate in Choba has Cd and Pb concentrations of 12.60 mg/l and 19.50 mg/l respectively; and none/negligible in Ada-George dumpsite. Traces of Cd and Pb (0.04mg/l and 0.2mg/l respectively) were found in the borehole close to Choba dumpsites (W1a). Cd and Pb were not detected in other borehole samples. This could be attributable to the fact that Choba dumpsite receives more batteries, florescent lambs, petroleum compounds and photographic materials than Ada-George dumpsite. Because traces of Cd (0.04) and Pb 0.20) were recorded in the borehole water close to the Choba dumpsite, it is possible that the Cd and Pb has travelled to the borehole water and are yet to get to the distant borehole water. Fe has the highest recorded concentrations of metal in both leachate (168.30 mg/l) and borehole samples (W1a = 11.30 mg/l). It was followed by copper and zinc; while cadmium has the lowest value. Choba dumpsite with the highest figure in both leachate and borehole samples therefore likely receives more waste from iron and steel scrap or metallic waste than Ada-George dumpsite. Traces of Zn and copper indicate that batteries and florescent lamps must have contaminated the dumpsites. This result shows that there is a downward trend in the concentrations of metals from leachates to the borehole water near the dumpsites, and then the borehole water farther from the dumpsites; with Fe more predominant than other metals. Choba dumpsite receives more metallic wastes than Ada-George dumpsites. Cd and Pb are lower, indicating fewer dumping of batteries, florescent lamps and photographic materials. This is a possible indication that most metals and metallic substances are still held bound in the dumpsites and are released gradually into the groundwater. The low value of heavy metals obtained may be attributed to the dumping of mainly municipal wastes and small percentage of industrial wastes. Heavy metals tend to be immobile in the waste or waste-rock interface due to redox controlled reaction (Yanful *et al.*, 1988).

Table 4: Average Concentration of Metals (mg/kg) in Edible Vegetables

Parameters	Pawpaw 1	Potatoes 1	Pawpaw 2	Potatoes 2
Cd	0.94	0.60	‹ 0.01	‹ 0.01
Pb	1.60	2.30	‹ 0.01	‹ 0.01
Zn	6.40	11.60	18.11	9.30
Fe	16.30	3.40	6.10	1.30
Cu	3.14	4.50	1.30	0.50

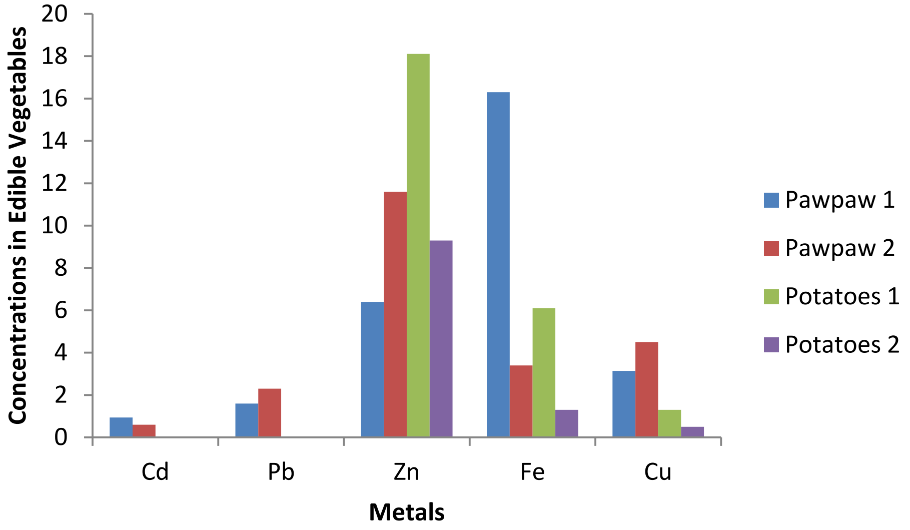

Figure 3: Concentration of Metals (mg/kg) in Edible Plants

Table 4 shows that all the plants have taken up one form of metals or the other. Zn and Fe are the most dominant metals absorbed by the edible plants. Fe has the highest concentrations in pawpaw (16.3mg/kg) in Ada-George dumpsite, while Zn has the highest concentrations in pawpaw (18.11mg/kg) in Choba dumpsite. Pawpaw at Ada-George dumpsite do not have traces of Cd and Pb. Table 1 shows that the average concentrations of heavy metals in the edible plants are less than that in the soil. The result obtained shows possible absorption of some of the metals from the soil and or leachate, while the rest still abound in the soil.

Anion Concentration in Borehole Water, Leachate and Soil

Table 5: Average Concentration of Anions in Leachate, Borehole water and Soil

Variables	L1	L2	W1a	W1b	W2a	W2b	S1	S2
NO_3^-	998.60	21.59	4.70	0.80	1.84	3.14	246.10	13.18
PO_4^-	169.30	8.30	0.10	0.07	‹ 0.01	‹ 0.01	17.60	3.19

Cl^-	670.40	392.3	11.30	4.60	9.94	3.98	130.60	39.76
SO_4^{2-}	267.50	83.60	0.05	‹ 0.001	0.01	‹ 0.001	103.40	68.70

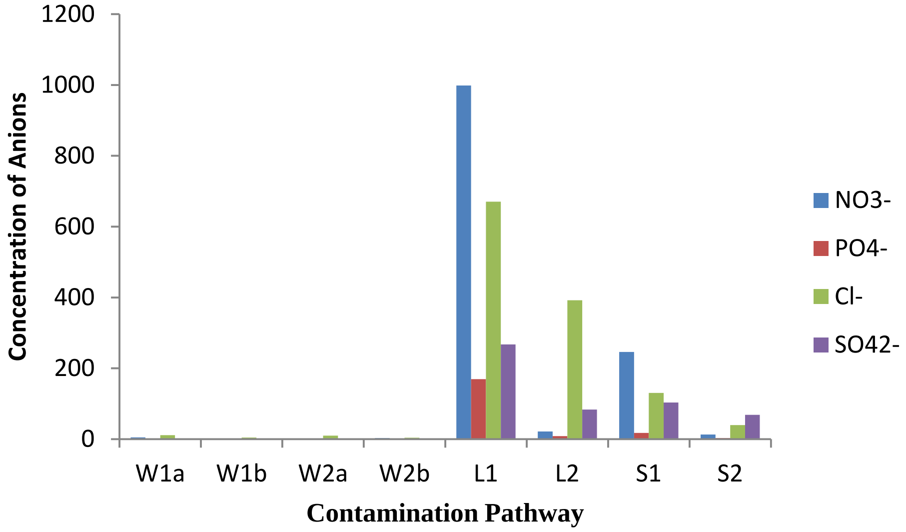

Figure 4: Concentrations of Anion in Borehole water, Leachate and Soil

Table 5 and figure 4 shows that the concentration of anions was highest in Choba leachate and soil than the corresponding Ada-George dumpsite. Choba dumpsites also have more concentrations in the underground water than Ada-George dumpsite. The higher rate of chlorine in Ada-George dumpsites leachates (670.40 mg/L) compared to Choba dumpsites (392.3 mg/L) correspond with the higher rate in the borehole water found in the respective dumpsites (11.30 mg/L and 9.94 mg/L respectively). We can also deduce from this result that the rate of percolation to the underground water corresponds with the concentration of chlorine at the dumpsites.

Natural concentrations of nitrates in groundwater are very low, since plants take up most of the nitrogen near the ground surface before it can reach the water table. However, background levels of nitrates in the leachate and nearby borehole recorded are relatively high (998.60, 4.70 and 21.59, 1.84 mg/l). This might be explained by the fact that contamination might have been brought by the application of fertilizers to nearby farmland. Nitrate does not break down quickly in the soil and does not stick to soil particles. Instead, it travels rapidly with the groundwater and can seep a long way from its source. Nitrate is particular health concerns in the body because it inhibit the distribution of oxygen within the human body by reducing the amount of oxygen that the blood can carry (methemoglobinemia); especially in children as a result of drinking water contaminated with elevated nitrates. (Chapman, 1992).

Sulphates values for the samples of leachate examined are quite variable and may have emanated from oxidation of iron sulphide present in the dump. The maximum value obtained was 267.50 mg/l for sulphate, while the maximum concentration recorded for phosphate was 169.3 mg/l; both from Choba dumpsites. The presence of phosphates in a leachate is dangerous as its presence in water increases eutrophication and also promotes the growth of algae in water bodies. Algal bloom may blanket surface water, used up the available dissolved oxygen and thereby prevent other aquatic organisms from accessing this life-supporting substance. Sulphate and phosphate levels are negligible in the borehole water sampled. Although the concentration of phosphate in the borehole water is low, a minute value of phosphate as low as 0.01mg/l in groundwater promotes the growth of algae (Adekunle *et al.*, 2007). The range of sulphate concentration in borehole samples varied from 0.001 mg/l to 0.05 mg/l. A similar trend was observed in the surface water samples. High concentration of sulphate in water is dangerous as it causes dehydration and diarrhoea in children (Longe and Balogun, 2010).

Anion Concentration in Edible Plant

Table 6: Average Concentration (in mg/kg) of Anion in Edible Plant

Parameters	Pawpaw 1	Potatoes 1	Pawpaw 2	Potatoes 2

NO_3^-	1.60	0.95	0.05	0.10
PO_4^-	1.20	0.80	0.12	0.24
Cl^-	‹ 0.01	‹ 0.01	‹ 0.01	‹ 0.01
SO_4^{2-}	0.60	3.12	0.90	1.60

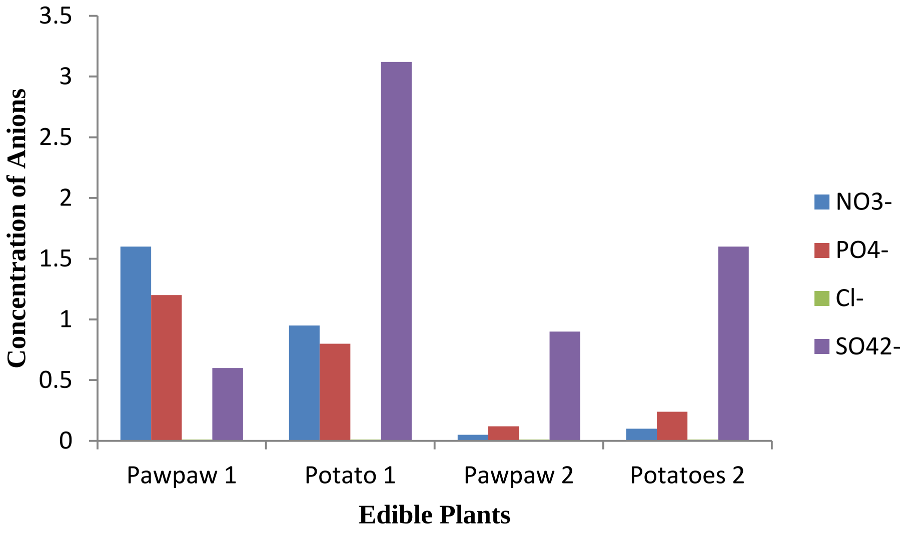

Figure 5: Concentration of Anion (Mg/kg) in Edible Plant

Results obtained in table 6 and figure 5 shows that the concentration of chlorine is negligible/not recorded in all the sampled plants. Choba dumpsite also recorded the highest value of anion – SO_4^{2-} in potatoes with concentration of 3.12 mg/g. All anions were higher in the edible plants than in borehole waters except Cl^- but less than concentrations in the soil and leachate respectively. It also confirms that plants seldom absorb Cl^- from the soil.

Table 7: Comparison of groundwater quality parameters with International (WHO) Standards and NSDWQ (Nigerian Standard for Drinking Water Quality) (WHO, 1997).

Parameter	L1	L2	W1a	W1b	W2a	W2b	WHO Standard	NSDWQ Standard
Cd	12.60	‹ 0.01	0.040	‹ 0.001	‹ 0.001	‹ 0.001	0.003	0.003
Pb	19.50	‹ 0.01	0.20	‹ 0.001	‹ 0.001	‹ 0.001	0.01	0.01
Zn	106.70	0.95	0.90	0.60	0.008	0.006	3.0	3.0
Fe	168.30	94.80	11.30	6.40	2.10	1.60	0.5-50	0.5-50
Cu	94.20	46.30	0.09	0.03	0.21	0.10	1.0	2.0
BOD	11,015.60	170.56	‹ 0.01	‹ 0.001	‹ 0.001	‹ 0.001	0.8-5	
COD	19,670.10	341.1	‹ 0.001	‹ 0.001	‹ 0.001	‹ 0.001	‹10	
TDS	9760	168.3	6.60	4.70	15.10	3.40	500	500
pH	6.40	6.20	6.70	6.90	7.40	7.10	6.5-8.5	6.5-8,5
EC	2040.1	69.30	3.60	7.10	2.10	1.60	-	
NO_3^-	998.60	21.59	4.70	0.80	1.84	3.14	50	50
PO_4^-	169.30	8.30	0.10	0.07	‹ 0.01	‹ 0.01		
Cl^-	670.40	392.3	11.30	4.60	9.94	3.98	250	250
SO_4^{2-}	267.50	83.60	0.05	‹ 0.001	0.01	‹ 0.001	100	300

Table 7 shows that most of the underground water meets the minimum quality of international standard (WHO) and NSDWQ (Nigerian Standard for Drinking Water Quality); though lead was recorded above the minimum drinking water standard in the borehole water near Choba dumpsite; with concentration 0.2 mg/l compared to the minimum standard of 0.01mg/l.

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CONCLUSION

The result of the two dumpsites indicates that the concentrations of contaminants were found to be higher around the dumpsites than the one farther from it. It shows that the contaminations drop with increase in distance from the dumpsites. Though the concentrations of few contaminants are negligible and may not have exceeded drinking water standard.

One of the analyzed borehole water sample obtained near the refuse dump site evidently reflect water quality that is affected by the leachates from the refuse dumpsite. Some contaminants were taken up by the edible plants in the study sample. The result also shows a gradual gradation of concentrations from the leachate, to the soil, to plant, to borehole near the dumpsites and finally the distant borehole water. It shows that the distance of borehole from the source of leachate (dumpsites) has greater impact on the degree and extent of contamination of groundwater. This study reveals that there is an increase in risk to ground water and public health far and near the unengineered dumpsites; although biases and confounding factors cannot be excluded as explanations for this finding. Thus, there is need for the following:

- Distance of dumpsites from human settlement should be maintained.
- Protect, monitor and manage the various dumpsites to minimize public health risk and environmental degradation.
- Establish and enforce effective and efficient solid waste management programme.
- Ensure adherence to regulatory limits, it is better to upgrade the unengineered dumpsite into well engineered sanitary landfill by the stake holders in collaboration with relevant government agencies.

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