Assessment Of Groundwater Contamination By Leachate From Unengineered Dumpsites In Port Harcourt, Nigeria

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Abstract: A significant portion of waste is disposed on unengineered dumpsite. These dumpsites have no liner system and other groundwater pollution control mechanism. This study was carried out to assess physiochemical parameters of soil, edible vegetables, leachate, and borehole water around Unengineered Dumpsite in Port Harcourt. Nigeria. Samples of leachates, soil, edible vegetables and borehole water within and 300m away from each unengineered dumpsites were collected and analysed for physicochemical parameters which include pH, Total Dissolved Solids, Biochemical Oxygen Demand (BOD), Chemical Oxygen Demand (COD), Electrical Conductivity (EC), Nitrate, Phosphate, Sulphate, Chlorine and heavy metals. Analysis of the leachates, soil and borehole waters showed that there is gradual movement of contaminants along the potential pathway – with concentrations decreasing as we move from the leachate to the soil and eventually groundwater resources. This may be due to leachate transport from dumpsite to ground water. This study shows that there is high pollution around the unengineered dumpsites, which can lead to high health risk in Port Harcourt, Rivers State. Nigeria.

1. Introduction

Unengineered dumpsite is used to describe 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). 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).

Within a landfill, complex sequence of physical, chemical, and biologically mediated events occurs as have been reported by Pastor and Hernández (2012). As a consequence of these processes, refuse is degraded or transformed. As water percolates through the solid waste, contaminants are leached from the solid waste. The mechanics 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. 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 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).

Landfill can be classified into three groups based on age: young, medium and old. Normally land filling that commences within five years is termed young age landfill. It consists of large amount of biodegradable matters and higher COD value of 20000 mg/L. The 5 to 10 years old landfill site is known as medium age landfill and it consists of COD values in range between 3000 to 15000 mg/L. After 10 years, the landfill contains very less amount of biodegradable matters and its COD is less than 2000 mg/L. At this age, it is designated as old landfill (Renou *et al.*, 2008).

Rapid population growth and development in Nigeria 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 implies that the current waste collection and disposal capacity of the city could not match with the growing population and generation of waste.

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). This problem 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, is compounded by the rapid urbanization and population growth, and by the ill attitude and poor understanding of the public towards solid waste management. Presently, the waste generated from Port Harcourt metropolis is disposed of directly into random borrow 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 indiscriminately located at or close to streams, valleys, open fields, water lands and in abandoned borrow pits. In Port Harcourt today, wastes generated and gathered at source are disposed of in communal bins or communal collection points stipulated by the Government. These communal points are spread out at different location across the city. 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.

Groundwater is a valuable resource that is often overlooked in most cases when considering all water on Earth because they are not visible. Protecting and conserving groundwater from contamination will ensure its sustainability as an important part of ecosystems and human activity. Groundwater travels through pores in soil and rock, fractures, and weathered bedrock. Biological, chemical and physical processes within the dumpsite promote the degradation of wastes and result in the production of leachate and gases. Improper waste disposing system contributes immensely to the contaminations of groundwater. High turbidity of the water samples is due to the infiltration of leachate from the dumpsites into the wells as reported by Ogedengbe and Akinbile (2007). The contaminants are largely soluble compounds and microorganisms (Aderiye et al., 1992; Udoessien, 2004).

Generally, the practices in the unengineered dumpsites at Port Harcourt are not encouraging. Dumping is unrestricted to different sources of wastes; which ends up in one site – 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 as seen in the diagram below. Like many cities in Nigeria, Port Harcourt is faced with the problems of improper collection, handling and disposal of domestic wastes.

This paper assesses the potential exposure pathways for physiochemical parameters in unengineered dumpsites in Port Harcourt, Nigeria.

2. Material and Methods

Cross-sectional study of selected unengineered dumpsites was conducted in Port Harcourt, Rivers State on March, 2018 to assess the potential exposure pathways of contaminants. Port Harcourt is the capital and largest city of Rivers State, Nigeria. It is located in the Niger-Delta region with an estimated population of 1,865,000 inhabitants. 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.

Leachate, soil, edible plant, and borehole water (near and about 10 km away from the unengineered dumpsites) samples were collected from 2 selected unengineered dumpsites for laboratory analysis. In borehole water and leachate sampling, every attempt was 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. The samples were labelled as follows; 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. All physicochemical parameters were determined based on American standard methods for examination of water and wastewater (APHA, 2005).

3. Results and Discussion

Table 1: Physiochemical properties of leachate and 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

Table 2: The concentration of metals (mg/kg) in the soil, borehole water and leachates

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

Table 3: 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

Table 4: Concentration of anions (mg/kg) in Borehole water, Leachate and Soil

Variables	W1a	W1b	W2a	W2b	L1	L2	S1	S2
NO_3^-	4.70	0.80	1.84	3.14	998.60	21.59	246.10	13.18
PO_4^-	0.10	0.07	‹ 0.01	‹ 0.01	169.30	8.30	17.60	3.19
Cl^-	11.30	4.60	9.94	3.98	670.40	392.3	130.60	39.76
SO_4^{2-}	0.05	‹ 0.001	0.01	‹ 0.001	267.50	83.60	103.40	68.70

Table 5: The concentration (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

Table 6: 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
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	100

4. Discussion.

From the result, leachate generally has higher physiochemical characteristics than both borehole water samples. Higher physiochemical characteristics were recorded in L1 than L2. BOD and COD concentrations were negligible/not observed results of approximately 0.001 mg/L in the borehole waters; for near the dumpsites and about 10km away from the dumpsites (Table 1). 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. From the result obtained in this work, 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 un-engineered dumpsites were relatively matured dumpsites, with L2 more matured than L1. The concentration of COD obtained in L1 was 19,670.10 mg/l, and 341.1 mg/L, for L2. 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 concentration of 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 rainfall 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).

The concentration of TDS for L1 and L2 were 9760 mg/L, and L2 168.3mg/L respectively. TDS was higher at the borehole water samples near the dumpsites than the one farther (10 km away); and the concentration of total dissolved solid obtained for L1was higher than L2 which 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.

The pH value for leachate samples from the two dumpsites were slightly acidic with values 6.40 and 6.20 for L1 and L2 respectively. These values fall within the range of potable water as prescribed the Nigeria standard for drinking water quality (WHO, 1997). Generally the pH ranged from 6.2 – 7.40; and are consistent with regulatory limits from national bodies like WHO and NSDWQ. 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. This shows that biological activities have decreased as the water gets to the ground level.

From table 1, the 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. All the leachate and borehole water values fall within the acceptable national regulatory limits. 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 observed in the value of total dissolved solids in the water bodies; though they conform to both WHO and NSDWQ standards. 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. The dumpsite leachate has minimal effects on the TDS and conductivity of both leachate and underground water sources.

Based on the data collected from this study as shown in table 2, 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 water 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 mg/kg) and Pb (0.20 mg/kg) were recorded in the borehole water close to the Choba dumpsite. Correspondingly, the concentrations of zinc, iron, copper were high in both leachate and borehole water at the Ada-George dumpsites than Choba dumpsites.

The concentration of lead (Pb) in borehole water close to the unengineered dumpsites in Choba exceeded WHO and NSDWQ health based drinking water criteria (table 6). And when we compare the nearby borehole water and faraway borehole water, the concentration of the metals in borehole water near the dumpsites are greater than the borehole water farther from it. This may be due to contamination from the disposal site leachate.

From table 2, Fe has the highest concentrations of metal in both leachate (168.30 mg/L) and borehole samples (11.30 mg/L) while cadmium has the lowest value. Choba dumpsite with the highest figure in both leachate and borehole water 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.

The result of this study as presented in table 2 shows that higher proportion of metals was detected in the soil than borehole water, 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.

As can be seen in table 2 and figure 1, more metals are concentrated in leachates and soil than borehole/underground water. 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 3 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 dumpsites do not have traces of Cd and Pb. Though the result indicate less of those metals in the edible plants, traces or records obtained shows possible absorption of the metals from the soil and or leachate.

From table 4, Concentration of all the anions were 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.

There is also high level of chlorine in the two leachates studied compared to WHO standard. The higher rate of chlorine in Ada-George dumpsites leachates (670.40 mg/kg) compared to Choba dumpsites (392.3 mg/kg) correspond with the higher rate in the borehole waters found in the respective dumpsites (11.30 mg/kg and 9.94 mg/kg 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.

From table 5, concentration of chlorine is negligible/not detected 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/L. Higher concentrations of anions were recorded in Choba dumpsite than Ada-George dumpsite. 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 is a concern because it 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.

High concentration of nitrate was recorded in the leachate from Choba dumpsite (998.6 mg/L) which is below international WHO standards and NSDWQ. Leachate in Ada-George dumpsite recorded 21.59 mg/L of nitrate which falls below international and national water standard. Nitrate 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).

Other anions analyzed were sulphates and phosphates. 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 however negligible in the borehole water sampled. Although the concentration of phosphate in the borehole water is low, it has been noted that a minute value of phosphate as low as 0.01mg/L in groundwater promotes the growth of algal (Adekunle *et al.*, 2007).

The range of the concentration of sulphates in borehole samples varied from 0.001 mg/L to 0.05 mg/L. The obtained values are lower than the standard of 100 mg/L stipulated by (WHO, 1997) for portable drinking water except the L1 with 267.50 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).

Table 6 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.

Conclusion

Most dumpsites in Port Harcourt has mixtures of potentially hazardous chemicals, In fact, some scavengers actually reside close to or within the dumpsites. This has generated significant groundwater and public health concerns. One of the analyzed borehole water sample obtained near the unengineered dumpsite evidently reflect water quality that is affected by the leachates from the waste dumpsite. Some contaminants were taken up by the edible plants in the studied sample. The result also shows a gradual degradation of concentrations from the leachate, to the soil, to plant, to borehole near the dumpsites and finally borehole water 10 km away from the dumpsite. The distance of the borehole from the source of leachate 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;

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