Effect of Municipal Solid Waste (MSW) Leachate on Groundwater Quality in Port Harcourt, Nigeria

ABSTRACT

Aims: This study was carried out to assess the effect of Municipal Solid Waste (MSW) leachate on groundwater quality in Port Harcourt, Nigeria. Cross-sectional study was conducted around two dumpsites in Port Harcourt, Nigeria on leachates and borehole water.

Study design: Cross-sectional study of selected refuse dumpsite was conducted in Port Harcourt, Nigeria to assess the effect of Municipal Solid Waste (MSW) leachate on groundwater quality in Port Harcourt, Nigeria. The physio-chemical parameters such as pH, Total Dissolved Solids (TDS), Biochemical Oxygen Demand (BOD), Chemical Oxygen Demand (COD), Electrical Conductivity (EC), Nitrite ion, Phosphate ion, Sulphate ion, Chloride ion and heavy metals (Cd, Pb, Zn, Fe, and Cu) were determined by standard protocol of APHA (2012). The samples were analysed by three quality tools/indices such as the Water Quality Index (WQI), Contamination Factor (CF) and Contamination Degree (CD).

Results and discussion: The result shows that some parameters in the borehole water did not meet the standards of World Health Organization (WHO) and Nigerian Standards for Drinking Water Quality (NSDWQ), and most leachates and borehole water qualities near the un-engineered dumpsites are of poor quality. There was a decreasing trend in concentrations of hazardous contaminants from the leachate to nearby borehole water and eventually the distant borehole water. This shows that the leachates exert great effect on the concentrations of contaminants in the surrounding borehole waters and distant ones.

Conclusion: It is concluded that there is an increase in risk to the borehole and public health that is reported near the unengineered dumpsites; which can spread to other region on bioaccumulation. The result indicated that the dumpsite leachate is producing many potent contaminants to the environment and to the people nearby.

Keywords: Leachate, water, physico-chemical, Water Quality Index, Port Harcourt

1. INTRODUCTION

Municipal Solid waste leachate is a highly complex effluent 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 (14). This leachate accumulates at the bottom of the landfill and percolates through the soil (26).

Rapid population growth and development in Nigerian states has resulted in environmental health hazards (2). Wastes are generated from human activities and in most cases not properly managed in most Nigerian cities (11; 2). This leads to low environmental quality which accounts for 25% of all preventable ill health in the world (40). In most cases, wastes are collected and disposed of in uncontrolled or unengineered dumpsite sites near residential buildings. These wastes are heaped up and/or burnt, polluting the environment (6; 38). Leachates from dumpsites constitute a source of heavy metal pollution to both soil and aquatic environments (8). Water contaminants have been mainly biological and chemical in origin (38). The quality of underground water is compromised by the indiscriminate dumping of waste in the environment and contamination by leachate. (15).

Waste generated from Port Harcourt metropolis is disposed of directly into random 'borro' pits close to streams, valleys, open fields, water lands without adequate handling and treatment (32). In Port Harcourt today, wastes generated and gathered at source are disposed of in communal bins or communal collection points stipulated by the Government. Most of these wastes appear to come from domestic sources and are characterised mostly by household waste. Generally, the practices at unengineered dumpsites in Port Harcourt are unrestricted to different sources of wastes; dumpers have access to the site at any time of the day, which increases 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. One of the major environmental problems at unengineered dumpsites is the loss of leachates from the site and subsequent contamination of groundwater (23).

(29) reported that high turbidity of water samples is due to the infiltration of leachate from the dumpsites into the wells or borehole. The contaminants are largely soluble compounds and microorganisms (4; 37). Heavy metals are not commonly found in groundwater, their presence is large as a result of environmental contamination (12). Urban wastes constitute a large source of pollution and have a significant impact on the ecosystem (1; 16; 30). A compost factory in a landfill site is a good idea to compost out some portion of MSW to organic fertilizer, although it would produce compost leachate in the process (31). Contamination of groundwater often occur in places where the groundwater table is shallow and activities on- going at that particular area contributes to leaching of contamination to groundwater. This normally happens in landfill areas or industries, especially metal plating industries, where a lot of produced water is channelled out into the surface water which will eventually infiltrate into the groundwater (32, 33, 34).

The risk of ground water pollution is probably the most severe environmental impact from dumpsite because historically, most dumpsites are without engineered liners and leachate collection and treatment systems (13). Leachate may also contain hazardous and non-hazardous substances that can be found in most groundwater systems. These include dissolved metals (e.g., iron and manganese), salts (e.g., sodium and chloride), and abundance of common anions and cations (e.g., bicarbonate and sulphate). Several studies revealed that the impacts of exposure to nearby residents can cause still birth, low birth weight, congenital malformation, Cancer and other public health problems (17, 20, and 21).

2. METHODOLOGY

A cross-sectional study of selected refuse dumpsite was conducted in Port Harcourt, Nigeria to assess the effect of Municipal Solid Waste (MSW) leachate on groundwater quality in Port Harcourt, Nigeria. 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 $25^{0}C$ – $28^{0}C$.

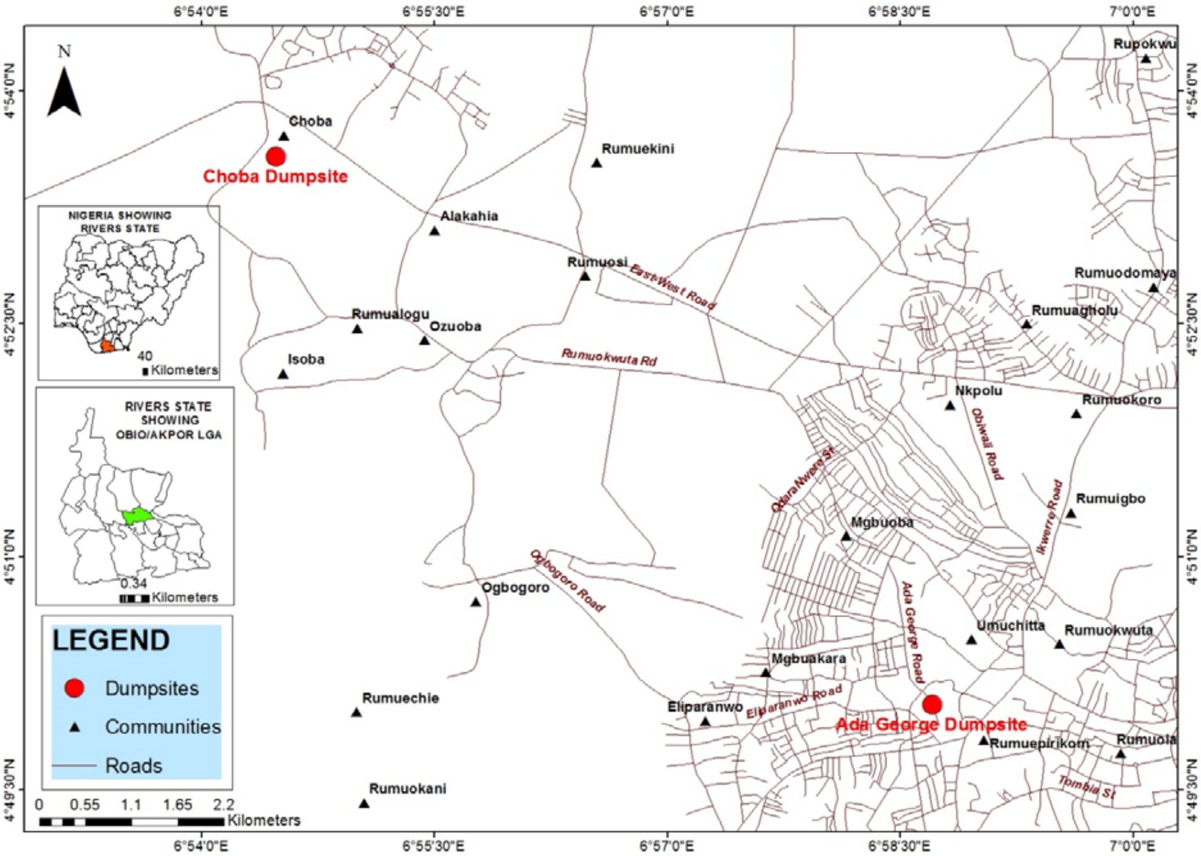

Figure 1: Map of study area

Samples of leachates and borehole water were collected at and around two unengineered dumpsites in Port Harcourt, Nigeria for laboratory analysis. The physio-chemical parameters such as pH, Total Dissolved Solids (TDS), Biochemical Oxygen Demand (BOD), Chemical Oxygen Demand (COD), Electrical Conductivity (EC), Nitrite ion, Phosphate ion, Sulphate ion, Chloride ion; and heavy metals (Cd, Pb, Zn, Fe, and Cu) were determined by standard protocol of APHA (2012).

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. The samples were analysed and three quality tools/indices were applied in this study. These are:

1. Water Quality Index (WQI)
2. Contamination Factor (CF)
3. Contamination Degree (CD)

2.1 WATER QUALITY INDEX (WQI)

Water quality index (WQI) represents water quality assessment through the determination of physico-chemical parameters of ground water; it can act as an indicator of water pollution because of natural inputs and anthropogenic activities (47). WQI is one of the most effective tools to provide feedback on the quality of water to the policy makers and environmentalists. It provides a single number expressing overall water quality status at a certain time and location. It is actually the categorisation counting the combined influence of different important water quality parameters; as it is calculated based on the concentration of several important attributes (38)

Three steps followed for the computing water quality index were:

In the first step, each of the parameters was assigned a weight (wi) according to its relative importance in the overall quality of water for drinking purposes. Maximum weight of 5 has been assigned to the parameter nitrate due to its major importance in water quality assessment (35). Zinc and phosphate which are given the weight of 1 by themselves may not be that harmful (10).

In the second step, relative weight (Wr) was computed from the following equation:

$$\mathbf{wr} = \frac{\mathbf{wi}}{\sum_{\mathbf{i-I}}^{\mathbf{n}} \mathbf{wi}}$$

Where

wr is the relative weight,

wi is the assigned weight of each parameter and

'n' is the number of parameters.

In the third step, a quality rating scale (qi) for each parameter was assigned by dividing its concentration in each water sample by its respective standard according to the guidelines laid down in the NSDWQ – Nigerian Standard for Drinking Water Quality (which conforms with WHO standard) and the result is multiplied by 100:

$$\mathrm{qi} = \frac{\mathrm{Ci}}{\mathrm{Si}}\ X\ 100$$

Where qi is the quality rating, Ci is the concentration of each parameter in each water sample in mg/l, and Si is the NSDWQ water standard for each chemical parameter in mg/l according to the guidelines of the Nigerian Standard for Drinking Water Quality (28); and (45). For computing the WQI, the sub index (SIi) was first determined for each parameter, which is then used to determine the WQI as per the following equation:

SIi = **wr** * qi

WQI = Σ SIi

SIi is the sub index of I^{th} parameter, qi is the rating based on concentration of i^{th} parameter and n is the number of parameter. (46) stated that the computed WQI values are classified into five types "excellent water", "good water", "poor water" "very poor water" and "water unsuitable for drinking" as shown in Table 1.

Table 1. Water quality classification based on WQI value (WHO, 2006)

WQI Value	Water Quality
<50	Excellent
50 – 100	Good
100 – 200	Poor
200 – 300	Very poor
>300	Water unsuitable for drinking

2.2 CONTAMINATION FACTOR (CF)

Contamination factor is used to determine the concentration status of metal in the present study. Contamination factor was calculated by comparing the mean of heavy metal concentration with average shale or background concentration given by (40), which is used as a global standard reference for unpolluted sediment. The CF is the single element index. CF for each metal was determined according to (39) by the following equation:

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

Hakanson (22) 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.

2.3 CONTAMINATION DEGREE (CD)

Contamination degree is used to determine the degree of overall contamination or concentration status of heavy metals in the sampling site. CD is the sum of all CF values of a particular sampling site (7 and 22).

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

Where n is the number of analysed elements and CF is the contamination factor.
(5) 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.

3. RESULTS AND DISCUSSION

The result shows that the concentration in the leachate is far greater than that in the borehole water (both near and far away from the dumpsite) for the two dumpsites; except in pH. This shows that the leachates are more acidic in nature, indicating conditions undergoing active metabolic activities with higher organic materials. Higher BOD and COD in the leachate than the borehole water indicate that the leachate has higher organic strength than the borehole water which conforms to (48). Generally, W1a have more metal and anion concentrations at Choba dumpsite than W1b (Table 2, figure 2 and 3). TDS was higher in W1a than in W1b; however, pH and EC are higher in W1b than W1a. This shows that W1a is more acidic and undergoing more metabolic phase than W1b, and the higher EC recorded in the W1b may be unconnected with the solids or salts that dissolve in water as it moves through the earth crust to the distal end of the dumpsite. However, Ada-George dumpsite has higher TDS, pH, and EC in W2a than W2b (Table 2, figure 2 and 3). W2b that is more acidic than W2a may be as a result of reaction or hydrolysis of NO_3^- with other compounds to form acidic compound either before getting to W2b or on getting to W2b. Higher TDS in W2a than W2b shows that there may be higher decomposition rate at W2a than W2b; and that there is more organic material in W2a than W2b. High TDS recorded shows that significant organic components may have successfully entered the groundwater to increase its TDS. This shows that the borehole close to Ada-George dumpsite is gradually been polluted with dissolved organic substances.

Table 2: General Average Result of Sampling

Parameter	L1	W1a	W1b	L2	W2a	W2b
Cd	12.60	0.040	<0.001	< 0.01	<0.001	< 0.001
Pb	19.50	0.20	<0.001	<0.01	<0.001	<0.001
Zn	106.70	0.90	0.60	0.95	0.008	0.006
Fe	168.30	11.30	6.40	94.80	2.10	1.60
Cu	94.20	0.09	0.03	46.30	0.21	0.10
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	21.59	1.84	3.14
PO_4^{3-}	169.30	0.10	0.07	8.30	<0.01	<0.01
Cl^-	670.40	11.30	4.60	392.3	9.94	3.98
SO_4^{2-}	267.50	0.05	<0.001	83.60	0.01	<0.001

***Where: L1** – Leachate at Choba dumpsite, **W1a** = Borehole water near Choba dumpsite, **W1b** = Borehole water about 10 km from Choba dumpsite. **L2** = Leachate at Ada-George dumpsite, **W2a** = Borehole water near Ada-George dumpsite, **W2b** = Borehole water about 10 km from Ada-George dumpsite.*

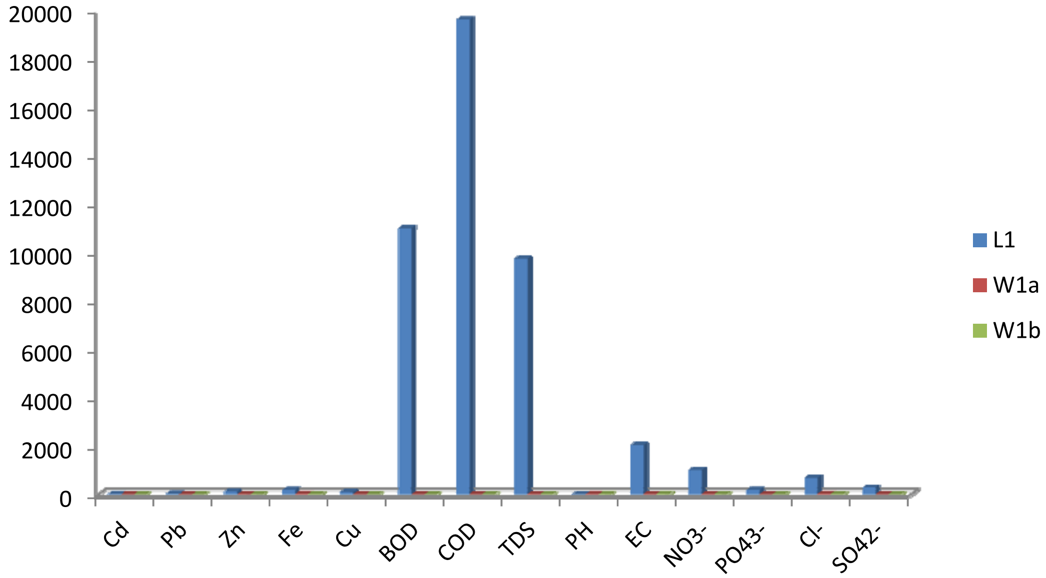

Figure 2: Metals and physico-chemical properties in leachates and borehole water at Choba dumpsite

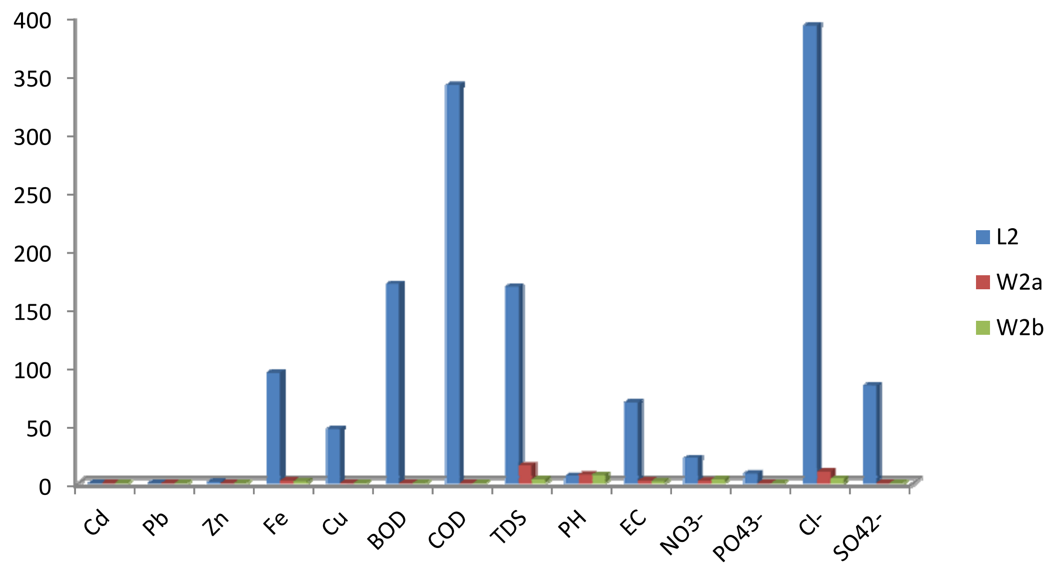

Figure 3: Metals and physico-chemical properties in leachates and borehole water at Ada-George dumpsite

The two leachates, W1a and W1b have pH values slightly below the neutral value of 7 (L1=6.4, L2=6.2, w1a=6.7, W1b=6.9) which shows slight acidity. This condition, therefore, aids the dissolution of some metals and other pollutant in water thereby releasing toxic elements that may pollute groundwater. Low value of pH in the leachates than borehole waters is a strong reflection of an acid-producing phase during decomposition of wastes. According to (9), the low pH value is an indication of leachate or water undergoing anaerobic or methanogenic phase. (19) observed that the initial period of leachate formation is characterised by very low pH values.

TDS is a reflection of the quantity of ionic or mineral constituents that are dissolved in the water. The EC obtained ranges from 69.30 S/cm in L1 to 2,040.1 S/cm in L1. The values recorded in the borehole water imply a reduction in concentration from leachate into borehole water, which conforms to (26) and (25). The higher the TDS, the lower the palatability of water and may possibly cause gastro-intestinal irritation in human and laxative effects particularly upon transits (43). EC may be related to problems such as excessive hardness, corrosive characteristics or other mineral contaminations (24). High concentration of metal prevailed in the leachate.

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 2, L1 and the borehole close to Choba dumpsite (W1a) with Cd 12.6 and 0.04mg/L respectively did not meet NSDWQ (28), WHO (45) standard as they exceed the maximum limit of 0.01 and 0.003 respectively. Other values of metals recorded are within limits of 0.01 and 0.003. Lead detected in samples originates from used batteries and other lead bearing wastes in the dumpsite. L1 (19.50) and W1a (0.20 mg/L) recorded high; which do not meet the standard set by NSDWQ (2007), WHO (2011). Traces of Zn were recorded in some of the sampled parameters. Except L1 (106.7), values of Zn in the sampled water parameters show that they are within the acceptable limits of NSDWQ and WHO. Cu was also recorded but below maximum limit or standard set by WHO and NSDWQ.

In this study, leachate and borehole water concentrations of metals such as Cd, Pb, and Fe were identified in the analytes as have several potentially significant groundwater and public health challenges that require urgent attention and additional study as they exceeded the maximum limits set by WHO and NSDWQ health based drinking water criteria (see table 3).

Table 3: Comparison of Groundwater Quality Parameters with International Standards

Parameter	L1	L2	W1a	W1b	W2a	W2b	WHO Standard	NSDWQ Standard
Cd	12.60	‹ 0.01	0.040	‹ 0.001	‹ 0.001	‹ 0.001	0.01	0.003
Pb	19.50	‹ 0.01	0.20	‹ 0.001	‹ 0.001	‹ 0.001	0.05	0.01
Zn	106.70	0.95	0.90	0.60	0.008	0.006	5.0	3.0
Fe	168.30	94.80	11.30	6.40	2.10	1.60	0.3	0.3
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	300	1000
NO_3^-	998.60	21.59	4.70	0.80	1.84	3.14	50	50
PO_4^{3-}	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	200	100

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

High concentration of anion also prevailed in the leachate than borehole water; with the least at the distant borehole. However, anion concentration in the borehole water is generally low and meets the standard set by WHO and NSDWQ. The major sources of NO_3^- are organic matter from man-made pollutants such as agricultural fertilisers (18). NO_3^- concentrations in the borehole water are very low, since plants are expected to take up most of the nitrogen near the ground surface before it can reach the water table. However, a level of NO_3^- in the leachate at Choba dumpsite (L1) is relatively high (998.60 mg/L). This can be explained by the fact that the land is contaminated by man-made pollutants such as agricultural fertilisers from nearby resident farmlands. NO_3^- concentrations in borehole samples near the dumpsites and at about 10 km away from the dumpsites were well within standards of WHO and NSDWQ. Phosphate ion concentration in L1 is 169.30 mg/L; and 8.30 mg/L for L2. Although the concentration of phosphate ion in the borehole water are low, it has been noted that a minute value of phosphate ion as low as 0.01mg/l in groundwater promotes the growth of algae (3). Though traces of chloride ion were detected in the borehole water, significant quantity was recorded in the leachates at the different dumpsites, which are more than the maximum permissible level stipulated by WHO and NSDWQ (Table 4). The strong content in leachate chloride could only be of organic origin, because the ion chloride accompanies the ion nitrate in the case of groundwater pollution by domestic waste (37). The values of Sulphate ion (SO_4^{2-}) are lower than the standard of 100 g/L and 200mg/L set by WHO respectively for portable drinking water.

Water Quality Index (WQI)

Table 4: Water Quality Index In and Around Choba Dumpsite

				W1a			W1b		
Parameter	**NSDWQ Standard** (Si)	**Weight** (wi)	**Relative Weight (Wi)**	**Field Data** W1a (Ci)	**Quality rating** (qi)	**Sub Index SI_i**	**Field Data** W1b (Ci)	**Quality rating** (qi)	**Sub Index SI_i**
Cd	0.003	2	0.0426	0.040	1,333	56.79	‹ 0.001	33.33	1.42
Pb	0.01	3	0.0638	0.20	2,000	127.60	‹ 0.001	10.0	0.6
Zn	3.0	1	0.0213	0.90	30.0	0.64	0.60	20.0	0.43
Fe	0.3	4	0.0851	11.30	3,767	0.96	6.40	2,133	181.52
Cu	2.0	4	0.0851	0.09	4.50	0.38	0.03	1.50	0.13
BOD	5.0	5	0.1064	‹ 0.01	0.20	0.02	‹ 0.001	0.02	0.002
COD	5.0	5	0.1064	‹ 0.001	0.02	0.02	‹ 0.001	0.02	0.002
TDS	500	4	0.0851	6.60	1.32	0.11	4.70	0.94	0.08
Ph	6.5 – 8.5 (7.5)	4	0.0851	6.70	89.33	7.60	6.90	92.0	7.83
EC	1000	2	0.0426	3.60	0.36	0.02	7.10	0.71	0.03
NO_3^-	50	5	0.1064	4.70	9.40	1.00	0.80	1.60	0.17
PO_4^{3-}	5.0	1	0.0213	0.10	2.00	0.04	0.07	1.40	0.03
Cl^-	250	3	0.0638	11.30	4.52	0.29	4.60	1.84	0.12
SO_4^{2-}	100	4	0.0851	0.05	0.05	0.004	‹ 0.001	0.001	0.00
n = 14		**Σwi = 47**	**ΣWi =** 1.000			**WQI = 195.48**			**WQI = 192.36**

The result of the two respective dumpsites indicates that the concentrations of contaminants were found to be higher around the dumpsites than the one farther from it (Table 5, 6). This shows that the contamination drop with increase in distance from the dumpsite. Though the concentrations of few contaminants are negligible and may not have exceeded maximum drinking water standard, some exceeded the standard; and bioaccumulation of others can lead to an increase in their concentration and possible side effects. The result conforms to (27) who emphasised in his study the strong relationship between depth and distance from landfills with underground water wells; where he noted that water samples taken from adjacent to landfills were the most vulnerable to pollution and decrease of contaminants result as the horizontal distance from landfills increase.

Table 5: Water Quality Index in and Around Ada-George Dumpsite

				W2a			W2b		
Parameter	**NSDWQ Standard** (Si)	**Weight** (wi)	**Relative Weight (Wi)**	**Field Data** W1a (Ci)	**Quality rating** (qi)	**Sub Index SI_i**	**Field Data** W1b (Ci)	**Quality rating** (qi)	**Sub Index SI_i**
Cd	0.003	2	0.0426	‹ 0.001	33.33	1.42	‹ 0.001	33.33	1.42
Pb	0.01	3	0.0638	‹ 0.001	10.0	0.6	‹ 0.001	10.0	0.6
Zn	3.0	1	0.0213	0.008	0.27	0.01	0.006	0.20	0.04

Fe	0.3	4	0.0851	2.10	700	59.57	1.60	533.33	45.39
Cu	2.0	4	0.0851	0.21	10.5	0.90	0.10	5.00	0.43
BOD	5.0	5	0.1064	‹ 0.001	0.02	0.002	‹ 0.001	0.02	0.002
COD	5.0	5	0.1064	‹ 0.001	0.02	0.002	‹ 0.001	0.02	0.002
TDS	500	4	0.0851	15.10	3.02	0.26	3.40	0.68	0.06
Ph	6.5 – 8.5 (7.5)	4	0.0851	7.40	98.67	8.40	7.10	94.67	8.06
EC	1000	2	0.0426	2.10	0.21	0.01	1.60	0.16	0.01
NO_3^-	50	5	0.1064	1.84	3.68	0.39	3.14	6.28	0.67
PO_4^{3-}	5.0	1	0.0213	‹ 0.01	0.20	0.004	‹ 0.01	0.20	0.004
Cl^-	250	3	0.0638	9.94	3.98	0.25	3.98	1.59	0.10
SO_4^{2-}	100	4	0.0851	0.01	0.01	0.00	‹ 0.001	0.001	0.00
n = 14		**Σwi = 47**	**ΣWi =** 1.000			**WQI = 71.82**			**WQI = 56.79**

Table 6: Classification of Water Quality based on WQI Value (WHO, 2006)

S/N	WQI Value	WQI Remark
1	< 50	Excellent
2	50 - 100	Good Water
3	100 - 200	Poor Water
4	200 - 300	Very Poor Water
5	> 300	Water unsuitable for Drinking

The result of the Water Quality Index as shown in Table 7 shows that both boreholewater around Choba dumpsite is poor (close to very poor with W1a = 195.48 and W1b = 192.36) as they contain considerable concentrations of contaminants. Ada-George borehole waters, however, have good water quality. Cadmium has very high CF of 13.33 in W1a, followed by Fe with 2.26 (moderate CF). Others in the borehole close to the dumpsite recorded low CF as they are less than 1. The distant borehole in Choba dumpsite, however, has low CF, with exception of Fe with 1.28 (which is moderate) (Table 8, 9). Contamination Degree at W1a is greater than W1b (15.63 and 1.62 respectively). From the result obtained, W1a shows condiderable CD, while W1b shows low CD. It buttresses the fact that the borehole close to the dumpsite is more contaminated than the distant one. W2a and W2b show low CD (Table 7).

Table 7: Result of Water Quality Index Analysis Obtained

SN	Sample Code	WQI Data	WQI Range	Remark
1	W1a	195.48	100 – 200	Poor water
2	W1b	192.36	100 - 200	Poor water
3	W2a	71.82	50 - 100	Good water
4	W2b	56.79	50 - 100	Good water

Table 8: CF and CD at Choba Dumpsite

Parameter n = 5	**W1a**			**W1b**		
	Field Data	**Conc.** (Bn)	**CF**	**Field Data**	**Conc.** (Bn)	**CF**
Cd	0.040	0.003	13.33	‹ 0.001	0.003	0.33
Pb	0.20	8.5	0.02	‹ 0.001	8.5	0.00
Zn	0.90	65.0	0.01	0.60	65.0	0.01
Fe	11.30	5.0	2.26	6.40	5.0	1.28
Cu	0.09	17.0	0.01	0.03	17.0	0.00
		CD	**15.63**	**1.62**		

Table 9: CF and CD at Ada-George Dumpsite

	W2a			W2b		
Parameter n = 5	**Field Data**	**Conc.** (Bn)	**CF**	**Field Data**	**Conc.** (Bn)	**CF**
Cd	‹ 0.001	0.003	0.33	‹ 0.001	0.003	0.33
Pb	‹ 0.001	8.5	0.00	‹ 0.001	8.5	0.00
Zn	0.008	65.0	0.00	0.006	65.0	0.00
Fe	2.10	5.0	0.42	1.60	5.0	0.32
Cu	0.21	17.0	0.01	0.10	17.0	0.01
		CD	**0.76**			**0.66**

4. CONCLUSIONS AND RECOMMENDATIONS

This study focused on the effect of Municipal Solid Waste (MSW) leachate on ground water quality in Port Harcourt, Nigeria. Apart from quantitative and direct observation of data, Statistical Indices analysis using water quality index (WQI), contamination factor (CF), and contamination degree (CD) were successfully applied for the analysis. The result shows that some parameters did not meet the standards of WHO and NSDWQ, and most leachates and borehole water qualities near the unengineered dumpsites are of poor quality. There was a decreasing trend in concentrations of hazardous contaminants from the leachate to nearby borehole water and eventually the distant borehole water. The study also revealed that there is contaminants movement from the leachate along the water table through underground water aquifer to distant water boreholes. It is concluded that there is an increase in risk to borehole and public health which reported near the unengineered dumpsites; which can spread to other region on bioaccumulation. The result indicated that the dumpsite leachate is producing many potent contaminants to the environment and to the people nearby. The following statement is therefore recommended.

1. The government with other environmental and public health organizations concerned should give attention to the problem of dumpsite, in respect to public health and ground water risks.
2. Operation of unengineered dumpsite should be monitored and new engineered landfill with proper collection and treatment of leachate has to be constructed.
3 Source of drinking water supply should be routinely monitored for contaminants and appropriate measures taken to correct (if an) contaminations.

REFERENCES

1. Adebayo, O. T., Balogun, A. M., and Olubiyi, O. A. (2007). Chemical analysis of some industrial effluents that discharge into Lagos Lagoon, Nigeria. *Res. J. Environm. Sci., 1*(4), 196-199. http://dx.doi.org/10.3923/rjes.2007.196.199
2. Adefemi, O. S., and Awokunmi, E. E. (2009). The impact of municipal solid waste disposal in Ado-Ekiti metropolis, Ekiti State, Nigeria. *Afri. J. Environ. Sci. Technol., 3*(8), 186-189.
3. Adekunle, I.M., Adetunji, M.T., Gbadebo, A.M. and Banjoko, O.B. (2007).Assessment of groundwater quality in a typical rural settlement in Southwest, Nigeria. Int. J. Environ. Res. Public Health, 4(4): 307-318.
4. Aderiye, B. I., Igbedioh, S. O., and Adebobuyi, A. A. (1992) Incidence of coliforms in well water and outbreak of water borne diseases: Environmental considerations and empirical evidence from Owo, Nigeria. *Asia Mediterr di Patolog Infet.Tropic., 11*, 1-6.
5. Ahdy HHH, Khaled A (2009) Heavy metals contamination in sediments of the western part of the Egyptian Mediterranean Sea. Aust J Basic Appl Sci 3:3330–3336
6. Akpan, A. Y. (2004). Physico-chemical studies on the pollution potential of Itu River, Akwa Ibom State, Nigeria. *World J. Agric. Sci*., *5*(1), 1-4.
7. Aksu, A.E., Yaşar, D. and Uslu, O. (1998). Assessment of marine pollution in Izmir Bay: Heavy metal and organic compound concentrations in surficial sediments. Translations and Journal of Engineering and Environmental Science, 22:387-415.
8. Ali, M. H., and Abdel-Satar, A. M. (2005). Studies of some heavy metals in water, sediment, fish and fish diets in some fish farms in El-Fayoum province. *Egypt. J. Aquat. Res., 31*, 261-273.
9. Alloway, B.J. (1995). *Heavy metals in soils.* 2nd edition. Chapman and Hall, London, UK.

10. APHA (2012). Standard methods for the examination of water and waste water, 22ndEdn, American Public Health Association, Washington.
11. Aurangabadkar, K., Swaminathan, S., Sandya, S., and Uma, T. S. (2001). Impact of municipal solid waste dumpsite on ground water quality at Chennai, *Environ.Poll.Control., 5*, 41-44.
12. Bahnasawy, M., Khidr A., and Dheina, N. (2011). Assessment of heavy metal concentrations in water, plankton, and fish of Lake Manzala, Egypt. *Turk. J. Zool., 35*(2), 271-280.
13. Christensen TH, Kjeldsen P (1995). Landfill emissions and environmental impact: An introduction. in SARDINIA '95, Fifth International Landfill Symposium, Proceedings, Volume lll, Christensen, T.H., Cossu, R., and Stegmann, R., Eds., CISA, Cagliari, Italy. 3.
14. Christensen, T.H., Kjeldsen, P., Bjerg, P.L., Jensen, D.L, Christensen, J.B., Baun, A., Albrechtsen H.J. and Heron, G. (2001). Biogeochemistry of landfill leachate plumes. *Appl. Geochem*., 16: 659-718.
15. David, O. M., and Oluyege, A. O , (2014) Effect of Open Refuse Dumpsite on the Quality of Underground Water Used for Domestic Purposes in Ado-Ekiti, Nigeria - A Public Health Awareness Study, Journal of Environment and Ecology, Vol. 5, No. 2, ISSN 2157-6092
16. Edema, M. O, Omemu, A. M., and Fapetu, O. M. (2001). Microbiology and Physicochemical Analysis of different sources of drinking water in Abeokuta. Nigeria. *Nig. J. Microbiol*, *15(*1), 57-61.
17. Elliott, P., Briggs, D., Morris, S., De Hoogh, C., Hurt, C., Jensen, T.K., Maitland, I., Richardson, S., Wakefield, J. and Jarup, L. (2001) Risk of adverse birth outcomes in populations living near landfill sites. *BMJ*.**323** (7309):363-368.
18. Ezeh VO, Eyankware MO, Irabor OO, Nnabo PN (2016). Hydrochemical Evaluation of Water Resources in Umuoghara and its Environs, near Abakaliki, South Eastern Nigeria. Intern. J. Sci. Healthcare Res. 1(2): 23-31.
19. Fatta D., Papadopoulos, A. and Loizidou, M., (1998). A study on the landfill leachate and its impact on the groundwater quality of the greater area. *Environ. Geochem. Health,* 21(2): 175-190.
20. Flieder, H., C. Poon-King (2000). "Assessment of impact on health of residents living near the Nant-y-Gwyddon landfill site: retrospective analysis." BMJ **320**(7226): 19-22.
21. Goldberg, M., J. Siemiatycki (1999). "Risks of developing cancer relative to living near a municipal solid waste landfill site in Montreal, Quebec, Canada." Archives of Environmental Health **54**(4): 291-296.
22. Hakanson L (1980). An ecological risk index for aquatic pollution control, a sedimentological approach. Water Res 14(8):975–1001
23. Jagloo, K., 2002. Groundwater risk analysis in the vicinity of a landfill, a case study in Mauritius. M.Sc. Thesis, Royal Institute of Technology, Stockholm.
24. Jain, C.K., A. Bandyopadhyay and Bhadra A., (2010) .Assessment of ground water quality for drinking purpose, District Nainital, Uttarakhand, India. Environmental Monitoring and Assessment. 166: 663-676.
25. Longe, E.O. and Enekwechi, L.O. (2007), Investigation on potential groundwater impacts and influence of local hydrogeology on natural attenuation of leachate at a municipal landfill.Int. J. Environ. Sci. Technol., 4(1): 133- 140.
26. Mor S, Ravindra K, Dahiya RP, Chandra A (2006). Leachate Characterization and assessment of groundwater pollution near municipal solid waste landfill site. Environ. Monit. Assess., 4: 325-334.
27. Mor S, Vischher A, Ravindra K, Dahiya RP, Chandra A, Van Cleemput O: (2006). Induction of enhanced methane oxidation in compost: Temperature and moisture response. Waste Manage 2006, 26(4):381–388.
28. NSDQW (Nigerian Standard for Drinking Water Quality) (2007). Nigerian Industrial Standard NIS 554, Standard Organization of Nigeria. Pp. 15-17.
29. Ogedengbe, C., and Akinbile, C. O. (2007). Well waters disinfection by solar radiation in Ibadan, Nigeria. *Nig. J. Technolog. Develop., 5*(1), 39-47.
30. Pirsaheb, M., Khosravi, T., Sharafi, K., Babajani, L., and Rezaei, M. (2013).Measurement of Heavy Metals Concentration in Drinking Water from Source to Consumption Site in Kermanshah – Iran.World Appl. Sci. J., 21(3), 416-423.
31. Asadi A, Shariatmadari N, Moayedi H and Huat BB (2011) Effect of MSW leachate on soil consistency under influence of electrochemical forces induced by soil particles. International Journal of Electrochemical Science, 6(7): 2344-2351.

32. Huat H, Moayedi H, Moayedi F, Asadi A and Ali TAM (2011) Groundwater quality assessment of Labuan Island using GIS. Electronic Journal of Geotechnical Engineering, 16

33. Mazloomi K, Sulaiman Nb and Moayedi H (2012) An Investigation into the Electrical Impedance of Water Electrolysis Cells – With a View to Saving Energy. International Journal of Electrochemical Science, 73466-3481.
34. Moayedi H, Huat BB, Moayedi F, Ali TAM and Moghaddam AA (2011) 23 Years Water Level Monitoring Through Earthfill Dam (Case Study). Electronic Journal of Geotechnical Engineering, 16.
35. Ramakrishnaiah C. R., Sadashivaiah C. and Ranganna G. (2009). Assessment of Water Quality Index for the Groundwater in Tumkur Taluk, Karnataka State, India. ISSN: 0973-4945; CODEN ECJHAO. E-Journal of Chemistry http://www.e-journals.net 2009, 6(2), 523-530
36. RSESA, (2013). Taking Port Harcourt Back to Garden City Status. www.thetidenewsonline.com.
37. Saadi, S., D.Khattach and Kharmouz, M., (2014). Geophysics and physico chemical coupledapproach of the groundwater contamination.Application in pollution by the landfillleachate of Oujda city (Eastern Morocco).*Larhyss Journal*.19: 7-17.
38. Sengupta, M. and Dalwani, R., (2008). Determination of water quality index and sustainability of an urban water body in Shimoga town, Kornataka, Proceedings of Taal 2007: The 12th World Lake Conference: 342-346].
39. Thomilson, D. C.; Wilson, D. J.;Harris, C. R. and Jeffrey, D. W. (1980). “Problem in Heavy Metals in Estuaries and the Formation of Pollution Index,” Helgol. Wiss. Meere-sunlter, Vol. 33, No. 1-4, , pp. 566-575.
40. Turekian KK, Wedepohl DH (1961) Distribution of the element in some major units of the earth’s crust. Bull Geol Soc Am 72:175–192
41. Udoessien, E. I. (2004). Ground Water and Surface Water Pollution by Open Refuse dump in Akwa Ibom State, Nigeria. *J. Environ. Sci*., *3*(1), 24 - 31.
42. Uffia, I. D., Ekpo, F. E., and Etim, D. E. (2013). Influence of heavy metals pollution in borehole water collected within abandoned battery industry, Essien Udim, Nigeria. *J. Environ. Sci. Water Resources, 2*(1), 022 – 026.
43. World Health Organization WHO (1997). Guideline for Drinking Water Quality Vol.2 Health criteria and other supporting information. 2nd edition. Geneva: World Health Organization; 1997:940–949.
44. World Health Organization WHO (2004), Guidelines for Drinking Water Quality, Vol 1: Recommendations, 3rd edn, Geneva: World Health Organization.WHO (2011). Guidelines for Drinking-Water Quality. 4th ed. Geneva, Switzerland, pp 541.
45. World Health Organization WHO (2011). Guidelines for Dinking-Water Quality. 4th ed. Geneva, Switzerland, pp 541.
46. World Health Organization WHO (a), (2006). Guidelines of drinking water quality Recommendation: the 3rd edition. Geneva: World Health Organisation. 2nd ed. Geneva.
47. Yisa, J. and Jimoh, T., (2010). Analytical Studies on Water Quality Index of River Landzu, American Journal of Applied Sciences, 7(4): 453-458.
48. Zgajnar Gotvajn A, Tisler T, Zagorc-Koncan J (2008): Minimizing N_2O fluxes from full-scale municipal solid waste landfill with properly selected cover soil. J Environ Sci, 20(2):189–194.