Analysis of the Interactions of Dumpsite with Leachate and Groundwater in Benin City and Port Harcourt

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Abstract
This paper is focused on evaluating the extent to which a dumpsite interacts with its leachate and groundwater environment. Selected dumpsites in Benin City and Port Harcourt were used for this study. Samples of soils and leachates' were collected from the dumpsites, while groundwater samples were collected from boreholes at designated distances from the dumpsites. Hydro-geological parameters of the dumpsite soil samples were measured. In the same vein, the physicochemical and biological parameters of leachate and groundwater samples were also measured. From the dumpsite soil hydro-geology, the mean porosity (53 and 59 %) and mean saturation hydraulic conductivity (45.1 and 110.2 cm/h) for Benin City and Port Harcourt respectively were obtained. Also, the leachates' from both Benin City and Port Harcourt dumpsites showed parameters with values above the FEPA compliance limits, especially for TDS, conductivity, turbidity, BOD, COD, cadmium, chromium and lead, while microbe's concentrations were in minute quantities. Groundwater characteristics for Benin City and Port Harcourt showed decrease in values as the distance between the groundwater source and dumpsite increases, just as evident in conductivity: at 50 m (50, 100 µS/cm); 100 m (49, 98 µS/cm) and 500 m (38, 89 µS/cm). Minute or insignificant concentrations of microbes were noticed for groundwater collected in Port Harcourt at 50 and 100 m distances away from dumpsite. Therefore, the high values of dumpsite soil porosity and saturation hydraulic conductivity evident in the dumpsite soil hydro-geology, the leachates' characteristics that were well above FEPA compliance and the decreasing trend in concentrations of groundwater parameters even as the distance between the groundwater source and dumpsite increases are all strong indications of interactions between dumpsite and its leachate and groundwater environment.

Keywords: *Dumpsite soil, leachate, groundwater, interaction parameter and pollutant*

1. Introduction

Benin City and Port Harcourt are both headquarters of two state Governments in the Niger-Delta region of Nigeria. The states are respectively Edo and Rivers. Conservative population figures for Benin City and Port Harcourt municipalities are respectively 5 and 8 million people. These large populations, engaging in vast activities can impacts greatly on waste generation, collection and disposal systems. Although, Benin City and Port Harcourt are both in oil bearing states, but the major oil drilling activities in the states takes place in the hinterlands. Therefore, pollutants of groundwater in these cities will normally come from indiscriminate disposal of solid wastes and sewage (Achadu et al, 2017).

Just like other towns in the country, Benin City and Port Harcourt lacks adequate facilities for handling solid wastes. For example they do not have engineered landfills or central sewage disposal systems. Therefore, solid waste generated within the cities are gathered and disposed of at local pits or at government/community designated dumpsites. These wastes are basically composed of organic and inorganic matters. But as they contacts continuously with water, sunlight, microbes and other agents in the dumpsites, they begin to degrade slowly by method of solubilization, hydrolysis, corrosion, bio-digestion, biodegradation and chemical decomposition (Emenike et al, 2012).

Products of the degraded solid wastes may be toxic and can be transferred into liquid medium which can form corrosive liquid, also called leachate (Abdus-Salam, 2009;De et al, 2016; Schueler and Mahlere, 2007). Since the walls and floors of these dumpsites are not lined (or blinded), interaction of these wastes (or the leachate) with soil environment can be enhanced by capillary action, eutrophication and gravity force. Note that the extent of fluidity of the toxics (or pollutants) can also increase its mobility across the soil subsurface. Consequently, there may be high tendency of the mobile leachate to contaminate groundwater within the vicinity.

Evidently, Benin City and Port Harcourt showed similar meteorology and soil hydro-geology. It also generates similar kinds of solid wastes in their environs which are predominantly organic and are biodegradable. Therefore, the tendencies for leachate formation and subsequent contamination of groundwater for both locations may be relatively high and comparable. These information corroborates the findings of Pillai et al (2014) wherein leachate quantity at dumpsite location were found to depend on quantity of degradable wastes, amount of water available and other supporting conditions.

The chemical composition of leachate may also vary from one location to another depending on the nature of waste contained in dumpsite, geography of the location, type of natural resource available in the sub-surface and level of industrial activities around the dumpsite location. The composition of leachate from dumpsite can also be affected by other factors: temperature, humidity, level of rainfall and microbes presence. The volume of leachate generated from dumpsites is expected to be higher in humid region than in arid region (Pillai et al, 2014 and Mor et al, 2006).

Hydro-geological properties of soils have also been viewed to help in locating to a large extent areas where possible groundwater contamination will occur as a result of dumpsite soils contact with solid waste (Iaconi et al, 2006). For instance, the Niger-Delta region have been reported to be generally characterized by moderately drained surface soils which create possibilities for interaction between it and dumpsite leachate (Wright *et al*, 1985). These interactions can cause groundwater pollution which can also have significant negative effect on the geotechnical properties of the soil and groundwater (Ukpong and Agunwamba, 2011).

The aim of this paper is on the use of physicochemical and biological analysis to evaluate the extent or degree to which dumpsites in Benin City and Port Harcourt interact with leachates'' generated and the groundwater around the environments. This study is important because there are no adequate databases for interpreting dumpsites interactions with the environments in the region. However, for some locations the available interaction data are inaccurate and limited in scope; hence, there is the need for an expanded study.

2. Materials and Method

2.1 Materials

The main materials used for this work are soil, leachate and groundwater samples which served as test samples. They were collected from selected dumpsites and nearby borehole pumps in Benin City and Port Harcourt. The equipment used for the analysis includes Atomic Absorption Spectrophotometer (AAS), pH meter (HI 8424), turbidity meter (HI 9835) and conductivity meter (HI 9835). Others are dissolved oxygen meter (or DO meter), microscope, incubator and some glassware.

2.2 Method

2.2.1 Collection of sample

Samples of soil and leachate were collected from Asoro dumpsite in Benin City and from Eliozu dumpsite in |Port Harcourt. The soil samples were obtained at different depth within the dumpsite: 0–15 cm, I m, 2 m and 3 m. Groundwater samples were also collected from three different borehole pumps at radial distances of 50, 100 and 500 m from the dumpsites including control groundwater samples taken at 10 km distance away from each dumpsite. These samples were collected in black 4 liters plastic containers, corked and locked firmly with labels as they en-route to the laboratory.

Hydro-geological (or physical) parameters were measured for soil samples, while physicochemical and biological parameters were measured for leachate and groundwater samples. Experimental methods established by the American Public Health Association (APHA) were majorly adopted. The Federal Environmental Protection Agency (FEPA) standard values were also used as reference.

2.2.2 Hydro-geological property test for dumpsite soil sample

The parameters measured for these tests were hydraulic conductivity, soil texture, moisture content, bulk density and soil porosity.

(A).Hydraulic Conductivity

Using method of constant hydraulic head, a straight glass column with solid bottom having thin-hole-perforations (length, L =250 mm, diameter, D = 60 mm) was clamped and filled with a dumpsite soil sample to a height of 210 mm. A transparent plastic basin was placed at the base to receive water eluting from the bottom-side of the column. In order to maintain constant pressure head in the column, water was introduced from the column top from a regulated water flow source. The estimated water flow rate is dependent on volume of water eluted from the column and the time required.

The saturation hydraulic conductivity, K_{sat} is calculated using Darcy's law of fluid flow through porous medium as expressed by eq. 1.

$$K_{sat}\,(cm/h) = \frac{QL}{A\Delta h} \qquad (1)$$

Where, Q = volumetric rate for water flow, cm^3/h; A = cross sectional area of column, cm^2; Δh = static pressure head difference, cm and L = length of column, cm.

(B). Soil Texture

The method of fractionation was adopted for this measurement, wherein the soil samples were placed in cylindrical glass fractionators containing water filled to normal capacity. After vigorous agitation, the different components of the soils were allowed to sediment by gravity force. It was observed that the sand settled first, followed by the silt and then the clay. These different components were separated out and recovered by drying, after which they were weighed and the fractions were determined.

(C). Soil Moisture Content, Bulk Density and Porosity

Using a measuring cylinder, the total volume of an unknown quantity of soil sample was measured as V_t. Also, 250 ml beaker was weighed empty as w_1, while soil sample was poured into it and was reweighed as w_2. The beaker plus soil sample was kept in a vacuum oven dryer at 40 ^oC and 750 mmHg for 20 minutes, after which it was allowed to cool and reweighed as w_3. The oven dried soil sample was recovered, and using a measuring cylinder, its solid space volume was measured as V_s. The total (or bulk) volume, V_t, is the sum of the volume of pore space, V_p and that of solid space, V_s. as in eq. 2.

$$V_t = V_p + V_s \qquad (2)$$

The soil moisture content (MC) is calculated using eq. 3.

$$MC\ (\%) = \frac{(w_2 - w_3)}{(w_3 - w_1)} x \frac{100}{1} \text{(dry basis)} \qquad (3)$$

Where, w_1= weight of empty 250 ml beaker, g; w_2 = weight of beaker plus soil sample, g; w_3 = weight of beaker plus oven dried soil sample, g.

Also, the bulk (ρ_b) and solid (ρ_s) densities of the soil samples are calculated using eqs.4 and 5 respectively.

$$\rho_b\ (g/cm^3) = \frac{(w_3 - w_1)}{V_t} \quad \text{(bulk density)} \qquad (4)$$

$$\rho_s\ (g/cm^3) = \frac{(w_3 - w_1)}{V_s} \quad \text{(solid density)} \qquad (5)$$

Where, V_t = total volume of soil sample, cm^3 and V_s = solid space volume of the soil sample, cm^3.

The porosity (ε) of soil sample is measured using eq. 6.

$$Porosity, \in(\%) = \frac{V_p}{V_t} x \frac{100}{1} = \left[1 - \frac{\rho_b}{\rho_s}\right] x \frac{100}{1} \qquad (6)$$

2.2.3 Physicochemical property test for leachate and groundwater samples

(A). pH, Conductivity and Total Dissolved Solid

These parameters were determined by direct measurement using a pH meter (Hanna HI8424), and conductivity meter (Hanna HI9835*)*. Note that the conductivity meter measures both conductivity and total dissolved solid (TDS). These instruments were first calibrated prior to use with buffer standards using potassium chloride solution and zero oxygen solution (from HACH). The instrument probe was dipped directly into each test sample thrice, after which the displayed readings were recorded for each dip. Note that the probe was normally rinsed in distilled water after each measurement to avoid errors. This procedure was repeated for the three parameters measured.

(B). Turbidity and Total Suspended Solid

Before use, the turbidity meter (Hach 2100Q) was first calibrated using a standard formazin solution of 100 NTU in accordance with APHA (2012). Each test sample was transferred into a cuvette and placed in the sample holder for measurement. The turbidity value was obtained by turning a dial knob to display a stable reading in nephelometric turbidity unit (NTU).The total suspended solid (TSS) was measured using APHA 209D test method for which a Whatman filter paper (0.45 µm) was used. The TSS content was calculated using eq. 7.

$$TSS\ (mg/l) = \frac{(w_2 - w_1)\,1000}{Sample\ volume\ (ml)} \qquad (7)$$

Where, w_2 = weight of filter paper + residue (g), w_1 = weight of filter paper (g)

(C). Biochemical Oxygen Demand

20 ml of test samples were each measured into different biochemical oxygen demand (BOD) bottles and diluted with distilled water to fill the 300 ml capacity (amidst vigorous agitation). Initial dissolved oxygen (D_1) for the test samples were first measured with a dissolved oxygen meter (DO meter), after which the BOD bottles were sealed and corked, and placed in an incubator for five (5) days at 20 ^oC. After incubation, a final dissolved oxygen value (D_2) was measured for each test sample, while the actual BOD_5 values were estimated using eq. 8.

$$BOD_5 (mg/l) = \frac{(D_1 - D_2)}{P} \qquad (8)$$

Where, D_1 = initial dissolved oxygen of test sample, D_2 = final dissolved oxygen of test sample and P = fractional volume of test sample used.

(D). Chemical Oxygen Demand

1 g of mercuric sulphate was each placed in reflux flask containing 10 ml of the respective test samples. In addition, 10 ml of 0.1 N Potassium dichromate acidified with 20 ml H_2SO_4 (85 % w/w) were added to each test samples amidst vigorous agitation. Another flask containing 10 ml of distilled water instead of a test sample was prepared to serve as blank. The flasks containing the test samples were each cooled under running water while adding 1.0 ml of silver sulphate solution. Boiling chips were then added to each flask before being fixed to the condenser.

Each flask containing test samples were refluxed at 150 ^oC for 2 h. After cooling, test samples contained in the flasks were each contacted with 45 ml of distilled water for the purpose of dilution. At room temperature, 2 drops of Ferroin indicator was added to each test samples, given rise to light blue-green or brick red coloration. The residual dichromate was then titrated against ferrous sulphate to reddish-brown end point. The same procedure was repeated for the blank sample. COD was measured using eq. 9.

$$COD\ (mg/l) = \frac{(Blank\ \ titre - Test\ \ sample\ \ titre)\ x\ 0.1\ x\ 8000}{Volume\ \ of\ \ Test\ \ sample} \qquad (9)$$

(E). Biological Parameter

Test samples from leachate and groundwater were analyzed for biological parameters: total coliform, total hydrocarbon bacteria (IHB) and total hydrocarbon fungi (THF). THB and THF were determined using the spread-plate technique, in which 1 ml of each test sample was added separately into its test tube containing 9 ml of physiological saline which was diluted with distilled water. The diluted samples were transferred to sample plates containing mixed nutrient medium (Rose-Bengal chloramphenicol agar plus Bushnell-Haas agar). The plates were then cultured in an incubator for 10 days. The concentration of the microbes was measured in cfu/ml.

Total coliform count was measured using the most probable number (MPN) technique. Dilute samples were introduced into its separate tubes containing MacConkey broth. The tubes were incubated for 24 h at 37 ^oC. Only tubes which indicated acid and gas productions were taken as positive. Total coliform counts were then measured in cfu/ml.

(F). Heavy Metals Content

The atomic absorption spectrophotometer (AAS) was used for this measurement, while APHA 3111B method was adopted. In it, direct aspiration of each test sample into a nitrous oxide/acetylene flame was carried out; this was incident by light rays from a hollow cathode light source emitting narrow spectral line of characteristic energy. This energy was used to excite free atoms of metals of interest in the test samples. The concentration of the excited metal atom in the sample was calculated by comparison with standard curves for metals.

3. Results and Discussion

The results obtained from this study were discussed under the following sub-headings: dumpsite soil hydro-geology, dumpsite influence on leachate characteristics and dumpsite influence on groundwater characteristics.

3.1 Dumpsite soil hydro-geology

The results of the hydro-geological parameter evaluations carried out for soil samples collected from selected dumpsite in Benin City and Port Harcourt are shown in Table 1. In it, sandy-clay texture characteristics was evident for dumpsite soils from both locations, while the mean porosities (across different depth) for Benin City and Port Harcourt dumpsite soils showed 53 and 59 % respectively. A saturation hydraulic conductivity (across different depth) for Port Harcourt dumpsite soil is ranged as 109 – 122 cm/h while that of Benin City dumpsite soil is ranged as 44 – 47 cm/h. In addition, the Port Harcourt dumpsite soil showed bulk density values (across different depth) in the range of 1.05 – 1.21 g/cm^3, while that of Benin City showed bulk density of 1.45 – 1.67 g/cm^3.

Thus, the observed higher values of saturation hydraulic conductivity and the lower values of soil bulk density evident in the Port Harcourt dumpsite soils are strong indications that Port Harcourt dumpsite soils will permit higher ease of flow or migration of liquid (or solution) through its porous media than that of Benin City. By implication, the Port Harcourt dumpsite soil will show higher degree of interaction with groundwater environment than the Benin City dumpsite. This finding corroborates the works of Iaconi et al (2006), Pillai et al (2014) and Ukpong and Agunwamba (2011) wherein authors agreed that hydro-geological properties of dumpsite soils influences to a large extent its level of interaction with groundwater and leachates'.

Table 1: Hydro-geological properties of dumpsite soil samples collected at different depth in Benin City and Port Harcourt

Parameter	Benin City				Port Harcourt			
	Soil Depth				Soil Depth			
	0 -15 cm	1 m	2 m	3 m	0 -15 cm	1 m	2 m	3 m
Porosity, %	55.8	54.2	50.5	50.2	60.5	58.3	59	58.7
Hydraulic Conductivity, cm/h	46.6	44.5	44.2	45	121.5	108 .7	101.2	109.4
Moisture content, %	38.1	40.4	40.8	42.2	44.5	44.4	43.4	44.1
Bulk Density, g/cm^3	1.45	1.50	1.52	1.67	1.05	1.21	1.21	1.20
*PSD (or texture), % :								
• Sand	88.4	88.8	87.7	88.8	84.8	84.6	84.4	84.1
• Silt	0.5	0.2	0.2	0.2	4.2	4.3	4.4	4.8
• Clay	11.1	11.0	12.1	11.0	11.0	11.1	11.2	11.1
Textural Class	Sandy-Clay Soils				Sandy-Clay Soils			

Note: *PSD = Particle size distribution. Also, values in table are mean of triplicate.

3.2 Dumpsite influence on leachate characteristics

The results of the physicochemical and biological property measurements for leachates' collected from Benin City and Port Harcourt dumpsites are shown in Table 2. For both locations, the sampled leachates' showed predominantly alkaline media, for which high content of basic salts and some other inorganic impurities are suspected. These inferences are drawn based on the evident high values of pH, conductivity, TDS and turbidity in the leachate samples as against FEPA standards. For instance, conductivities of leachates' for Benin City and Port Harcourt showed 17,400 and 21, 800 µS/cm respectively, for which the FEPA standard was 12,500 µS/cm. In the same vein, TDS showed 2000 and 2100 mg/l respectively for Benin City and Port Harcourt. These analyses are indications that strong interactions exist between pollutants and dumpsite water in these locations.

The presence of organic impurities in the leachates' is evident from the high BOD and COD values obtained for both dumpsites. For Benin City dumpsite, sampled leachates' showed BOD and COD of 6,853 and 17,200 mg/l respectively, while that of Port Harcourt showed BOD and COD of 7,544 and 19,996 mg/l respectively. Since FEPA allowable limit for BOD and COD in leachates' are 30 and 75 mg/l respectively, then the excesses recorded for BOD and COD concentrations for Benin City and Port Harcourt dumpsite are another demonstration of strong interactions between pollutants and dumpsite water.

Heavy metals contamination of sampled leachates' from Benin City and Port Harcourt dumpsites were almost non-existent, except for few metals such as lead, cadmium and chromium for which the concentrations were relatively moderate. Also, evidence of microbes in the leachates' from Benin City and Port Harcourt dumpsites was noticed in minute concentrations. For example, total hydrocarbon bacteria (TBH), total hydrocarbon fungal (THF) and total coliform were all in the concentration range of 1.5 x 10^{-3} to 3.4 x 10^{-3} cfu/ml for both locations. Therefore, evidence of microbes in the leachates' from Benin City and Port Harcourt dumpsites is also another indication of interaction between water running off from the dumpsites and organic pollutants.

These findings are supported by the reports of Abdus-Salam (2009), De et al (2016) and Schueler and Mahlere (2007) wherein it were emphasized that interactions between the wastes and water in a dumpsite are the causes of leachates' formation. Mechanisms for these interactions were also identified amongst others as solubilization, corrosion, hydrolysis and biodegradation.

Table 2: Characteristics of leachate collected at near dumpsite locations in Benin City and Port Harcourt.

Parameter		Value		
		Benin City	**Port Harcourt**	**FEPA**
pH		8.11 (0.031)	7.94 (0.147)	-
Conductivity (µS/cm)		17,400 (0.54)	21,800 (0.17)	**12,500**
BOD$_5$ (mg/l)		6853 (3.559)	7544 (4.546)	**30**
COD (mg/l)		17200 (50.77)	19996 (147.762)	**75**
TDS (mg/l)		2000 (8.799)	2100 (16.989)	NA
TSS %		0.06 (0.001)	1.4 (0.02)	NA
Turbidity (NTU)		28.2 (0.187)	31. 4 (0.198)	5
Heavy Metals (mg/l)	Chromium	0.69 (0.022)	0.16 (0.005)	0.20
	Cadmium	0.8 (0.026)	0.09 (0.012)	0.01
	Copper	0.42 (0.021)	0.52 (0.029)	5.00
	Lead	0.48 (0.029)	0.53 (0)	0.05
	Nickel	0.32 (0.012)	0.83 (0.017)	0.01
	Zinc	2.01(0.039)	2.06(0.029)	6.00-9.00
	Iron	0.71(0.034)	59.3(0.527)	0.05
	Arsenic	<0.50	<0.50	NA
	Mercury	<1.00	<1.00	NA
Total Coliform (cfu/ml)		2.5×10^{-3}	2.3×10^{-3}	0.0
THB (cfu/ml)		2.1×10^{-3}	3.4×10^{-3}	0.0
THF (cfu/ml)		Nil	1.5×10^{-3}	0.0

Note: Values in table are mean of triplicates, *NA = Not available*

3.3 Dumpsite influence on groundwater characteristics

Samples of groundwater collected from boreholes at 50, 100 and 500 m distance away from selected dumpsites in Benin City and Port Harcourt were analyzed for physicochemical and biological parameters. A control sample was also collected at 10 km away from the dumpsite. The results obtained are shown in Tables 3, 4 and 5. Groundwater characteristics for all sampling points showed fair level of compliance with WHO standards, while it appeared higher in values than that of the control sample. For instance, groundwater sampled at 50 m away from Benin City dumpsite showed results for both water sample and its control as follows: conductivity (50, 47 µS/cm); BOD (7.12, 4 mg/l); COD (8.93, 4.13 mg/l) and TDS (27, 19.2 %) (Table 3).

Similar trends were evident for groundwater parameters obtained from all sampling points. The reason could be adduced to the distance between the groundwater sampling and control points from the dumpsites. However, the parameters of groundwater obtained from designated sampling points in Port Harcourt showed higher values relative to Benin City. For example, the conductivity of groundwater's obtained at designated distances for Benin City and Port Harcourt dumpsites showed respectively: at 50 m (50, 100 µS/cm); 100 m (49, 98 µS/cm) and 500 m (38, 89 µS/cm) (Table 3 -5). The reasons for this trend may be attributed to higher volumes of dumping and rainfall in Port Harcourt than Benin City, as well as hydro-geological factors.

Microbes were also observed to be totally absent from Benin City groundwater, while very minute (or insignificant) concentrations were evident in Port Harcourt groundwater, specifically at 50 and 100 m away from dumpsite. This is also an indication of interaction between dumpsite and groundwater.

Table 3: Characteristics of groundwater sample taken at 50 m away from selected dumpsites in Benin City and Port Harcourt.

Parameter		Value				WHO Standard
		Benin City		Port Harcourt		
		Water Sample	Control	Water Sample	Control	
pH		6.15(0.025)	6.7	6.42(0.043)	6.6	6.5 – 8.5
Temperature, °C		27.1 (0.21)	27.2	26.9 (0.3)	26.7	NA
Conductivity (µS/cm)		50 (0.277)	47	100(1.539)	57	NA
BOD_5 (mg/l)		7.12(0.053)	4.00	20.5(0.081)	<1.00	NA
COD (mg/l)		8.93(0.131)	4.13	351(2.494)	4.00	NA
TDS, %		27(0.074)	19.2	94(0.162)	48.1	1000
TSS, %		0.002 (0)	0	0.02 (0)	0	NA
Turbidity, NTU		1.72(0.022)	<1.00	14.12(0.13)	<1.00	5
Heavy Metals (mg/l)	Chromium	0.7(0.017)	<0.001	0.1(0.008)	<0.001	0.05
	Cadmium	0.13(0.008)	<0.001	<0.001	<0.001	0.003
	Copper	0.01(0)	<0.01	0.11(0.012)	<0.01	1.0
	Lead	1.1(0.017)	<0.001	<0.001	<0.001	0.05
	Nickel	1.8(0.024)	1.16	1.1(0.025)	0.87	NA
	Zinc	<0.001	<0.001	0.3(0.021)	0.01	3.0
	Iron	0.15(0.017)	0.10	0.1(0.008)	0.10	0.3
	Arsenic	<0.001	<0.001	<0.001	<0.001	0.01
	Mercury	<0.0001	<0.0002	<0.0001	<0.0002	0.001
Total Coliform (cfu/ml)		0.0	0.0	0.00041	0.0	0.0
THB (cfu/ml)		0.0	0.0	0.00044	0.0	0.0
THF (cfu/ml)		0.0	0.0	0.0	0.0	0.0

Note: Values in table are mean of triplicates, NA = Not available

Table 4: Characteristics of groundwater sample taken at 100 m away from selected dumpsites in Benin City and Port Harcourt.

Parameter		Value				WHO Standard
		Benin City		Port Harcourt		
		Water Sample	Control	Water Sample	Control	
pH		6.5(0.02)	6.7	6.56 (0.043)	6.6	6.5 – 8.5
Temperature, °C		25.1 (0.21)	27.2	26.2 (0.22)	26.7	NA
Conductivity (µS/cm)		49 (0.242)	47	98(1.54)	57	NA
BOD_5 (mg/l)		5.7 (0.041)	4.00	22.5(0.072)	<1.00	NA
COD (mg/l)		8.7 (0.11)	4.13	38.1(2.494)	4.00	NA
TDS, %		24 (0.07)	19.2	78 (0.16)	48.1	1000
TSS, %		0.002(0)	0	0.024 (0)	0	NA
Turbidity, NTU		1.42(0.012)	<1.00	10.7 (0.13)	<1.00	5
He	Chromium	<0.001	<0.001	<0.001	<0.001	0.05

	Cadmium	<0.001	<0.001	<0.001	<0.001	0.003
	Copper	<0.01	<0.01	<0.01	<0.01	1.0
	Lead	<0.001	<0.001	<0.001	<0.001	0.05
	Nickel	1.16	1.16	0.89	0.87	NA
	Zinc	<0.001	<0.001	0.04	0.01	3.0
	Iron	0.17	0.10	0.12	0.10	0.3
	Arsenic	<0.001	<0.001	<0.001	<0.001	0.01
	Mercury	<0.0002	<0.0002	<0.0002	<0.0002	0.001
Total Coliform (cfu/ml)		0.0	0.0	0.00021	0.0	0.0
THB (cfu/ml)		0.0	0.0	0.00022	0.0	0.0
THF (cfu/ml)		0.0	0.0	0.0	0.0	0.0

Note: Values in table are mean of triplicate, NA = Not available

Table 5: Characteristics of groundwater sample taken at 500 m away from selected dumpsites in Benin City and Port Harcourt.

Parameter		**Value**				**WHO Standard**
		Benin City		**Port Harcourt**		
		Water Sample	Control	Water Sample	Control	
pH		6.7(0.03)	6.7	6.5(0.04)	6.6	6.5 – 8.5
Temperature, ^{o}C		28.1 (0.27)	27.2	27 (0.35)	26.7	NA
Conductivity (μS/cm)		38 (0.24)	47	89(1.5)	57	NA
BOD_5 (mg/l)		8.5 (0.045)	4.00	20.0 (0.07)	<1.00	NA
COD (mg/l)		8.9(0.13)	4.13	351(2.7)	4.00	NA
TDS, %		34 (0.04)	19.2	64(0.14)	48.1	1000
TSS, %		0.002(0.0)	0	0.02(0.0)	0	NA
Turbidity, NTU		1.24 (0.022)	<1.00	4.1(0.11)	<1.00	5
Heavy Metals (mg/l)	Chromium	<0.001	<0.001	<0.001	<0.001	0.05
	Cadmium	<0.001	<0.001	<0.001	<0.001	0.003
	Copper	<0.01	<0.01	<0.01	<0.01	1.0
	Lead	<0.001	<0.001	<0.001	<0.001	0.05
	Nickel	1.2	1.16	0.80	0.87	NA
	Zinc	<0.001	<0.001	0.01	0.01	3.0
	Iron	0.10	0.10	0.01	0.10	0.3
	Arsenic	<0.001	<0.001	<0.001	<0.001	0.01
	Mercury	<0.0002	<0.0002	<0.0002	<0.0002	0.001
Total Coliform (cfu/ml)		0.0	0.0	0.0	0.0	0.0
THB (cfu/ml)		0.0	0.0	0.0	0.0	0.0
THF (cfu/ml)		0.0	0.0	0.0	0.0	0.0

Note: Values in table are mean of triplicates, *NA = Not available*

4. Conclusion

Studied dumpsites located in Benin City and Port Harcourt showed meaningful level of interactions between it and the leachate and groundwater environment. The hydro-geological properties of the Benin City and Port Harcourt dumpsite soils showed amongst other properties, high values of saturation hydraulic conductivity and porosity which enhanced the interactions between the dumpsites and the groundwater environment. Also, high level interactions between dumpsite pollutants and water were evident in both Benin City and Port Harcourt dumpsites. This resulted in leachates' having physicochemical parameters that were above FEPA compliance limit, with minute (or insignificant) concentrations of metals and microbes. The results of the groundwater samples analyses also showed evidences of interactions between it and dumpsites, for which it was noticed that the groundwater parameters decreases just as the distance between the groundwater source and dumpsite increases.

Abbreviation

AAS = Atomic Absorption Spectrophotometer
APHA = American Public Health Association
BOD = Biochemical Oxygen Demand
CFU = Coliform Forming Unit
COD = Chemical Oxygen Demand
DO = Dissolved Oxygen
FEPA = Federal Environmental Protection Agency
MC = Moisture Content
MPN = Most Probable Number
NTU = Nephelometric Turbidity Unit
PSD = Particle Size Distribution
TDS = Total Dissolved Solid
THB = Total Hydrocarbon Bacteria
THF = Total Hydrocarbon Fungal
TSS = Total Suspended Solid
WHO = World Health Organization

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