Physico-Chemical Characteristics of Leachate from Waste Dumpsites in Port Harcourt Metropolis

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Abstract

Leachates are known to contain dissolved or suspended solid materials which may be toxic when it finds its way to water bodies or land meant for agricultural purposes. The study however investigated the physicochemical properties and heavy metals concentration of leachates from the solid waste dumpsites in Port Harcourt Metropolis using standard methods of analyses and Atomic Absorption Spectrophotometer for heavy metals. Leachate samples from East/West road, Choba and Rumuokoro market, all in Obio/Akpor Local Government Area, Port Harcourt were analysed. The results of the analysis showed that the leachates from the two dumpsites have the following ranges of mean concentrations; pH (5.65), Electrical conductivity (1,930.27µs/cm), Turbidity (8.27NTU), Temperature (29.95^{o}C), Nitrate ion (1,380.205mg/l), Sulphate ion (150.41mg/l), Phosphate ion (21.51mg/l), COD (1,534.065mg/l), BOD (561.225mg/l), DO (2.425mg/l), Total Hardness (52.27mg/l), TSS (986.07mg/l),TDS (9,374.815mg/l), Pb (24.71mg/l), Fe (299.33/l) and Cu (4.6mg/l). The heavy metals concentrations however, exceeded the WHO and FMNEV Standards. The Organic strength of Choba (L1) and Rumuokoro (L2) dumpsites signifies the degree of their biodegradation and gives information on the age of the dumpsites, with Rumuokoro dumpsite being the oldest and highly polluted. Analysis shows that leachates from the dumpsites are a potential source of heavy metals poisoning and source of pollution within the environment.

Keywords: *Municipal solid waste, Leachate, Heavy metals, Landfill, Environment.*

Introduction

Groundwater pollution is mainly due to the process of industrialization and urbanization that has progressively developed over time without any regard for environmental consequences. Port Harcourt city lies between latitude 4^{o} 49’ 27” N and longitude 7^{o} 2’1” E in the southern part of Nigeria. The urban city has experienced increase in population and industrial activities in the last few decades since it became the capital of Rivers State. In order to meet up with man’s daily needs a lot of industries were established in the state capital from which quantities of solid wastes are generated from industrial activities. Municipal Solid Waste (MSW) disposal is a global concern (Aderemi et al., 2011), especially in developing counties across the world, as poverty, population growth and high urbanization rates combine with ineffectual and underfunded government to prevent the efficient management of waste.

Landfilling is the simplest, cheapest and most cost effective method of disposing of waste in both developed and developing nations of the world. Municipal landfill leachate is a highly concentrated effluents which contain dissolved organic matters, inorganic compounds such as ammonium, calcium, magnesium, sodium, potassium, iron, sulphate, chlorides, and heavy metals such as cadmium, chromium, copper, lead, zinc, nickel, and xenobiotic organic substances (Christensen et al, 2001). Landfills have been identified as one of the major threats to groundwater resources. Waste placed in landfills or open dumps are subjected to either groundwater under flow or infiltration from precipitation.

A number of scholars (Akinbile and Yusoff, 2011; Kumar and Allapat, 2003a; Jhamnani and Singh, 2009; Sabahi et al., 2009; Vasanthi et al., 2008; Abid and Jamal, 2005; Abu-Rukah et al., 2001) have examined the possible water contamination around municipal landfills by using physicochemical analysis of leachate. The main focus was to find out the impact of landfills on ground water quality and quantitative analysis of level of water contamination. Groundwater is the major source of potable water supply in the study area and its contamination is a major environmental and health concern. Its quality is based on the physical and chemical soluble parameters due to weathering from source rocks and anthropogenic activities.

Leachate migration from waste landfills and the release of pollutants from sediments (under certain conditions) pose a high risk to groundwater resource if not adequately managed. Major component of these compounds include heavy metals, combustible and putrescible substances, hazardous waste, explosives and petroleum products. The essence of this study is to determine the effect of landfill leachate on ground water supply, and its effect on human health.

Materials and Methods

Description of study area

The study area is within Obio/Akpor Local Government Area. Due to its proximity to Port Harcourt city which is highly populated, it falls within the sub-equatorial climate belt. Temperature and Humidity are high throughout the year. The area is marked by two distinct seasons: the wet and dry seasons, with 70% of the annual rainfalls falling between April and August, while 22% is spread in the three months of September and November. The driest months are from December to March (Ayotamuno and Gobo, 2004; Gobo, 2002). It is an important industrial city with a lot of industrial waste being generated combined with the household and commercial waste. The management of this waste is vested in the Rivers State Environmental Sanitation Authority (RSESA) who in turn employs vast contractors to manage waste dumpsites.

For the purpose of this study, two major dumpsites have been earmarked and they are situated at East/West Road, Choba (L1) and Rumuokoro market (L2).

Collection of leachate samples

Leachate samples were collected from vicinities of the municipal solid waste dumpsites (L1 and L2), and a control sample (borehole water) was collected 100m away from the dumpsites. A drench was created around the wastedumps so that the leachate can drip into it. A 50ml plastic bottle was washed first and then rinsed with the leachate sample to ensure homogeneity and the leachate was collected into the plastic bottles, after filtering the sample initially with a Whatman filter paper before it was finally administered into the container. The Leachate sample was filled to the brim of the container and the cap was corked so that no air space was remained inside the bottle. The physico-chemical properties of the samples were analysed using the standard methods for determination of water samples as described by APHA, 2005 while heavy metals were analysed with the use of the atomic absorption spectrophotometer.

Results and Discussion

The results of the physicochemical properties and heavy metals concentration in the study area are presented in Tables 1 and 2, and Figs. 1-5 below. The pH values of the leachate samples from the waste dumpsites ranged from 5.58-5.72, with a mean value of 5.65 and control having a pH value of 6.48. This shows that the leachates were acidic. Leachates are generally found to have pH values between 4.5 and 9.0 (Christensen et al., 2001). The pH of young leachates is less than 6.5 while old leachates have pH values higher than 7.5 (Aderemi et al, 2011; Abu-Rukah et al., 2001). Stabilized leachates show fairly constant pH with little variation and it may range between 7.5 and 9.0. The dumpsites could be classified as representatives of young dumpsites. The pH values could be attributed to a result of the biological stabilization of the organic matter present in the dumpsite. Total Dissolved Solid (TDS) comprises mainly of inorganic matter. The amount of TDS reflects the extent of mineralization, and a higher TDS concentration can change the physical and chemical characteristics of receiving water (Alimba et al., 2013). The TDS of the dumpsites investigated ranged from 8338.25-10,411.38mg/l with Control (L3) having the lowest value (118.05mg/l) and Rumuokoro market (L2) having the highest value. The leachate from L2 can be said to have undergone more mineralization process and has a very high tendency to change the physical and chemical characteristics of the receiving water more than the leachates from other dumpsites. The mean TDS value (9,374.82mg/l) of the dumpsites is greater than the Federal Ministry of Environment (FMENV) standard of 500mg/l. The high concentration of TDS in the Leachate samples of Rumuokoro may be responsible for the reduction in the palatability of water, and could inflict gastrointestinal inconveniences in human and may also cause laxative effect.

The electrical conductivity of any medium is reflection of the quantity of ionic constituents dissolved in it. The electrical conductivity of the dumpsites ranged between 1589.34µs/cm and 2271.20µs/cm for L1 and L2 respectively, with a mean concentration of 1,930.27µs/cm, far exceeding the World Health Organization (WHO) standard of 500µs/cm while the control was 62.03us/cm. Once the leachate percolates, it increases the electrical conductivity of the water in contact and therefore reduces the portability of the water. The high value of electrical conductivity in this study area is indicative of the presence of inorganic materials in the samples, indicating high degree of pollution. The BOD_5 values of the dumpsites ranged from 510.39-612.06.mg/l, with a mean of 561.23mg/l, while the control was 5.44mg/l. In the initial acidogenic biodegradation stage, the leachate was characterized by high BOD_5 and COD (Jones et al., 2006). For stabilized leachates, COD generally ranges between 5,000-20,000mg/l (Li and Zhao, 2002). The mean value of BOD_5 (561.225mg/l) of the leachate was greater than WHO standard of 6.00mg/l, COD with a mean of 1,534.07mg/l also exceeded WHO standard of 10mg/l. The BOD_5 and COD values indicate the presence of a high amount of putrescible organic matter in the dumpsite. Phosphate concentration of L1 was 18.22mg/l, L2 had 24.80mg/l, the control had a concentration of 3.04mg/l and the mean concentration for the test locations (L1 and L2) was 21.51mg/l. The mean concentration of phosphate in the study area fell above WHO limit of 0.1mg/l and this may result in the water being slimy and could promote the growth of algae.

Table 1: Mean Physicochemical Parameters of Leachate from E/W Road, Choba and Rumuokoro market

Parameters	East/West Road, Choba (L1)	Rumuokoro market (L2)	Mean of L1 and L2	Control (L3)
Ph	5.72	5.58	5.65	6.48
Electrical Conductivity (EC)(µs/cm)	1,589.34	2,271.20	1,930.27	62.03
Turbidity (NTU)	7.20	9.34	8.27	0.65
Temp. (^oC)	30.5	28.0	29.25	25.0
NO_3^- (mg/l)	1170.14	1590.27	1,380.205	36.08
SO_4^{2-} (mg/l)	104.05	196.77	150.41	21.73
PO_4^{3-} (mg/l)	18.22	24.80	21.51	3.04
COD (mg/l)	1333.11	1735.02	1,534.065	80.00
BOD (mg/l)	510.39	612.06	561.225	5.44
DO (mg/l)	2.81	2.04	2.425	9.76
Total Hardness(mg/l)	48.21	56.33	52.27	4.20
TSS (mg/l)	870.84	1,101.31	986.075	20.02
TDS(mg/l)	8338.25	10,411.38	9,374.815	118.05
Pb (mg/l)	18.33	31.09	24.71	2.08
Fe (mg/l)	273.09	325.58	299.335	30.18
Cu (mg/l)	6.20	3.00	4.6	ND

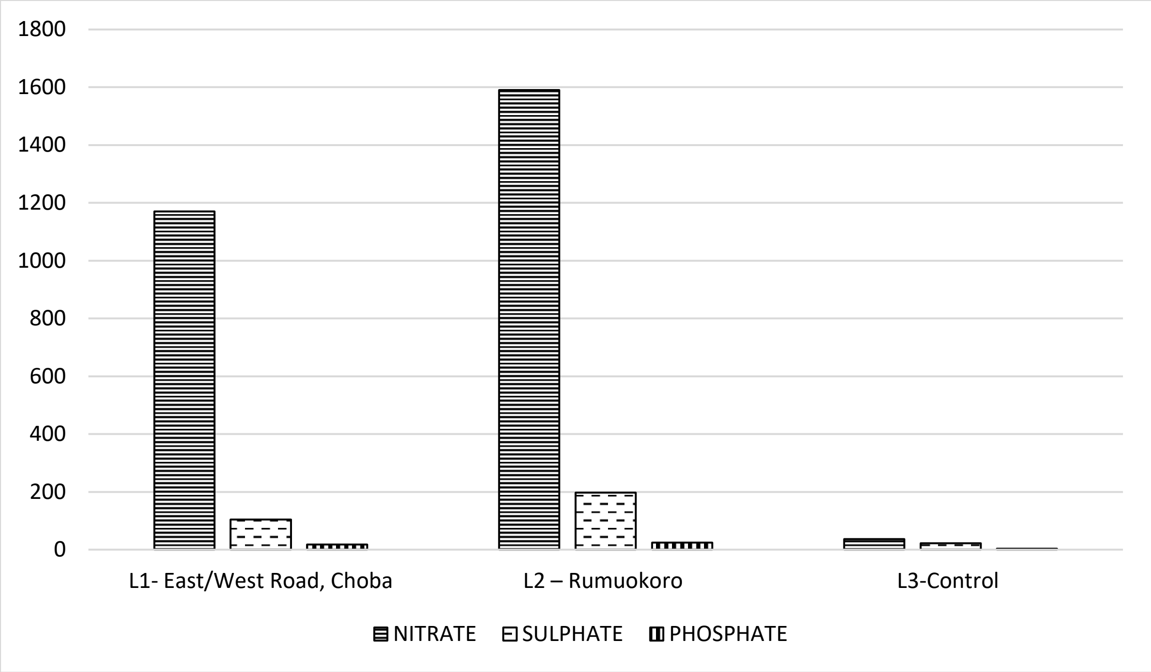

Fig 1: A Bar Chart on the Concentration of some Physicochemical Parameters (Nitrate, Sulphate and Phosphate Ion) Analysed.

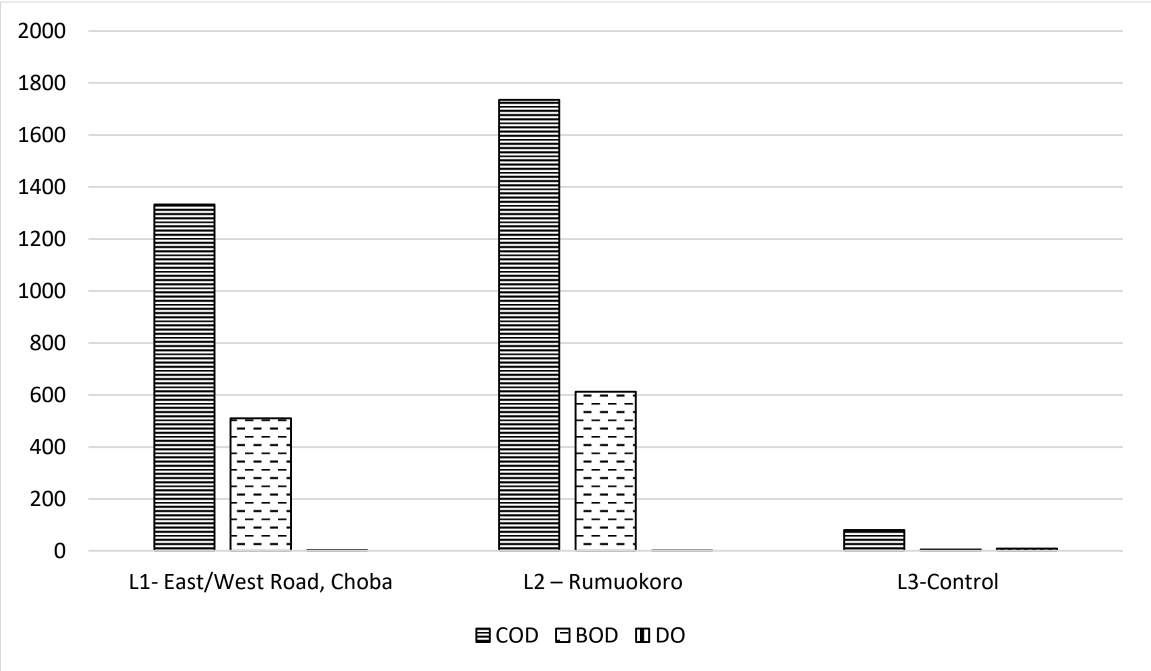

Fig 2: A Bar Chart on the Concentration of some Physicochemical Parameters (COD, BOD and DO) of Leachates Studied.

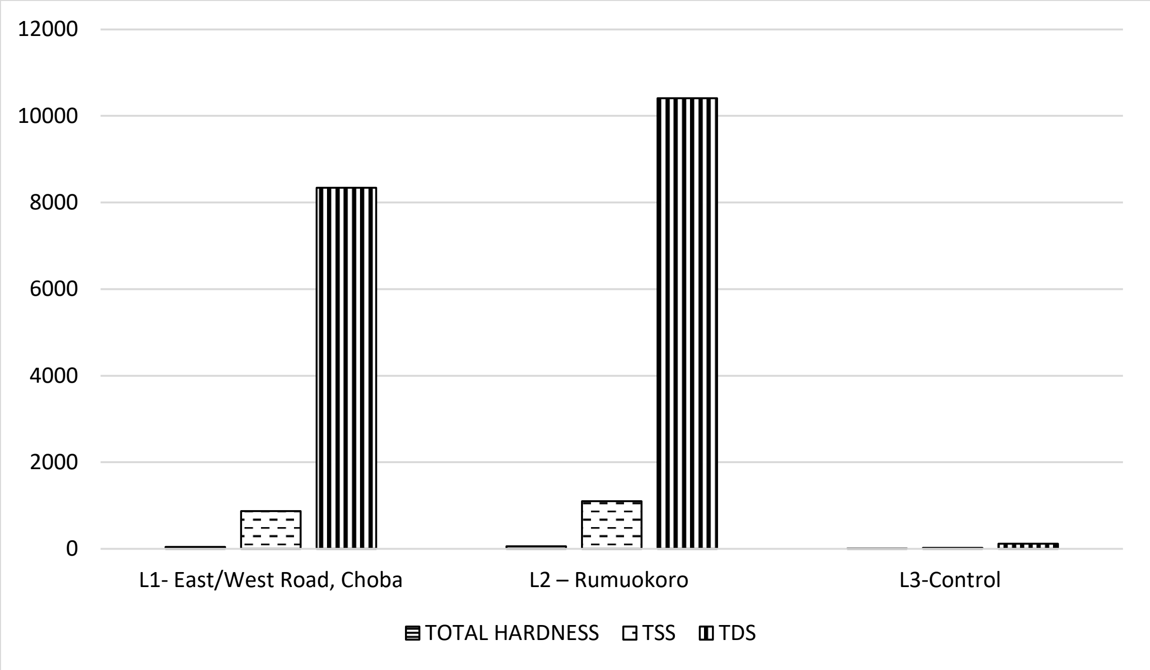

Fig 3: A Bar Chart on the Concentration of Total Hardness, Total Suspended Solids (TSS) and Total Dissolved Solids (TDS) Analysed.

Heavy metals concentration in these landfill leachates is relatively high or low. From the results of the study, Lead (Pb) in the dumpsites ranged from 18.33-31.09mg/l, Copper (Cu) ranged from 3.00-6.20mg/l and Iron (Fe) ranged from 273.09-325.58mg/l (Table 1), with mean of 24.71, 4.6 and 299.34mg/l, respectively while the value of control was 2.08, and 30.18mg/l for Pb and Fe, respectively. Cu was not detected in the control sample. Table 2 shows the crustal abundance of the heavy metals in the leachate, while Fig. 4 illustrates the distribution of these metals in the study area. The release of constituents from solid waste is governed by the decomposition processes and the rate and volume of water infiltrating through the fill. Concentration of heavy metals in a landfill is generally higher at early stages because of higher metal solubility as a result of low pH caused by production of organic acids (Christensen et al., 2001).

Table 2: The Crustal Abundance of Heavy Metals Analyzed

Heavy Metals	L1-E/W Road Choba	L2-Rumuokoro	L – Mean	Crustal Abundance
Pb (mg/l)	18.33	31.09	24.71	0.0016
Fe (mg/l)	273.09	325.58	299.34	5
Cu (mg/l)	6.20	3.00	4.6	0.007

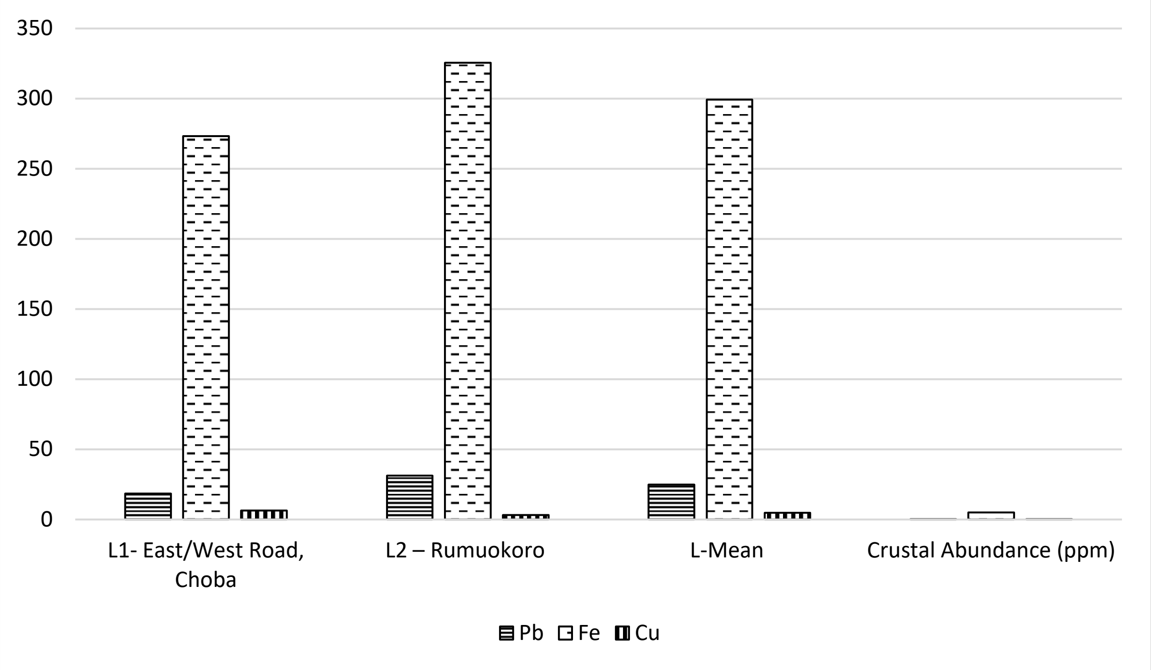

Fig 4: A Bar Chart Showing the Concentration of Heavy Metals and their Respective Crustal Abundance

Therefore since all the heavy metals concentration far exceeded the WHO standard, it is indicative of a significant amount of heavy metals in the leachate from the two dumpsites which may leach into the aquifer and eventually pollute the environment. Some heavy metals, such as lead, even at low levels are toxic while others such as copper and iron are essential to soil microorganisms. However, excess of iron in soil causes hyper-toxicity in crops (eg. Zea mays L.).

Organic Strength, BOD_5/COD (Table 3) which are the organics in the leachate is characterized by different levels of biodegradability. Generally, the organic strength describes the degree of biodegradation and gives information on the age of a dumpsite. A decline in BOD_5 concentration can be attributed to a combination of reduction in organic contaminants available for leachate and the increased biodegradation of organic compounds (Krug and Ham, 1995). A constant decrease in COD is also expected as there was degradation of organic matter (in agreement with Ehrig, 1989) in all the locations. The biodegradability of the leachate would also vary with time. The BOD_5/CODratio for the respective dumpsites was 0.382 (L1), 0.352 (L2), with a mean ratio of 0.367, while the control (L3) was 0.068. This figure shows that the organic matter in the leachates is readily biodegradable and has a high organic strength which can be attributed to the fact that the study sites are active or open, being waste fed on a daily basis.

Table 3: Organic Strength (BOD_5 and COD ratio)

Parameters	L1	L2	Mean	L3	FMENV Standard
BOD_5 (mg/l)	510.39	612.06	561.23	5.44	30
COD (mg/l)	1,333.11	1,735.02	1,534.07	80.00	75

Organic strength=BOD_5/COD	0.382	0.352	0.367	0.068	-

CONCLUSION

The results indicate that there were variations in the concentration of the parameters tested for at the various sampling points. Rumuokoro (L2) has the highest concentration of the parameters tested for. Illustration of this is indicated on the bar charts (Figs. 1-5). This may be due to its proximity to the road and hence, easy access by the people. It may also be due to the large amount of trash deposited on this point of the study site. This means it contains a greater constituent of waste to be leached out of the waste during rainfall or water percolation. This location also has a higher slope which makes leaching more possible down the gradient. Choba (L1) has lesser concentration of the physicochemical parameters and heavy metals tested for compared to Rumuokoro (L2). This may be due to the fact that Choba (L1) is a young dumpsite, with less accumulation of waste. Control sample (L3) was taken outside the dumpsites which served as a standard to compare the concentration of the parameters tested for, from the two locations (L1 and L2) within the dumpsites. This location (L3) had by far the lowest concentration of the physicochemical parameters tested for which may be accounted for to be as a result of the fact that it is outside the dumpsite and had no form of waste deposition from which any leachate could have contaminated it at the time of study. Thus, Rumuokoro site (L2) could be attributed to be the most contaminated location of the study sites.

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