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ASSESSING THE ENVIRONMENTAL IMPLICATIONS OF OPEN DUMPING ON GROUNDWATER IN WARRI SOUTH LGA, DELTA STATE, NIGERIA

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Article Info

Keywords: Municipal Solid Waste (MSW), waste management, open dumping, environmental impact, Delta state, Nigeria, landfill engineering, waste segregation, recycling, resource recovery, circular economy

Abstract

Municipal Solid Waste (MSW) poses a significant environmental ch globally, and Nigeria is no exception. As a consequence of eco development and rapid industrialization, Delta state in Nigeria has expe a substantial increase in population density and urbanization, leadin significant rise in MSW generation. The prevailing waste management m in the region is open dumping, primarily due to financial constrain inadequate waste management practices. Although open dumping i effective for MSW disposal, it results in the acceptance of a wide range o and liquid wastes from various sources, including industrial, hou agricultural, medical, and commercial establishments. Consequently dumping sites become repositories for a diverse array of contaminants, inorganic chemicals, toxins, detergents, complex organic chemicals, meta even hazardous substances from gasoline spills and other toxic materials.The uncontrolled microbial activity within these dumping sites exacerbates the problem, potentially releasing additional toxic elemen were not initially present in a free or reactive form in the waste. The pres such hazardous components not only poses a direct threat to human hea also endangers the surrounding environment. The current waste mana practices in Delta state do not adhere to acceptable sanitary landfilling pr leading to severe environmental consequences. Addressing the cha associated with MSW management in Delta state requires urgent attenti

effective strategies. This study aims to investigate the environmental im open dumping and propose sustainable waste management alternat mitigate the adverse effects. By exploring innovative waste mana techniques, such as landfill engineering, waste segregation, recyclin resource recovery, the study seeks to promote circular economy approa minimize the ecological footprint of MSW management.

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Introduction

Municipal Solid Waste (MSW) is the solid waste which consist of all domestic refuse and non-hazardous wastes (such as commercial and institutional wastes, street sweepings and construction debris etc.) (Magutu *et al*., 2010). MSW (also referred to as garbage or trash) is an unavoidable consequence of anthropogenic activity (Srigirisetty *et al*., 2017). In Nigeria, economic development and rapid industrialization have led to higher urbanization and like many other states, Delta state is undergoing rapid development which has led to greater population density than ever before in the state. This increased population has seriously increased the rate of generation of MSW such that management of these wastes have become a serious environmental problem. In most developing countries, solid wastes are being dumped on land without adopting any acceptable sanitary land filling practices (Vasanthi *et al*., 2008). In Nigeria, due to lack of finance which result to improper waste management practices, open dumping of solid waste is the most common method of waste disposal and like every other part of the country, it is the prevailing method in Delta state. Although open dumping of solid waste is quite economical for MSW disposal (Ustohalova *et al*., 2006), however the dumping sites accept a variety of semi-solids, non-hazardous solids, and liquid wastes from diverse sources, such as industrial, households, businesses, agricultural, medical facilities, restaurants, and schools (Nyandwaro, 2017) and contaminants from gasoline spills, households and other toxic wastes find their way to the dumping sites (Calvo, 2005). As a result, the solid wastes in the dumped sites will be composed of different types of chemicals such as detergents, inorganic chemicals, toxins, complex organic chemicals and metals (Nandwana and Chhipa, 2014). Again, uncontrolled microbial action may result in the release of more toxic elements which were not present in a free or reactive form in the waste (Nandwana and Chhipa, 2014). These components threaten human health and the surrounding environment. Open dumping of MSW contributes significantly to causing different types of pollution including air, land and water pollution. The dumpsite located close to both surface (rivers, streams etc.) and ground water areas easily release pollutants during the flow of leachate to this water bodies. The MSW at the dumped sites generate a liquid called leachate (a toxic liquid that seeps from solid waste whose extracts contains dissolved or suspended materials from the waste) which contains bacteria, toxic substances and heavy metals (Sudha and Uma, 2009). During the season of rainfall, this leachate infiltrates into the surrounding groundwater and thus contaminates it. Contaminated water has a great potential for transmitting a wide variety of diseases (Ogbeifun *et al*., 2019). About 80% of the diseases that affect the global population today and more than one-third of the deaths in developing countries are all attributed to contaminated water (Adegbite *et al*., 2018). These diseases are as a result of drinking contaminated water (Chan *et al*., 2007). Contamination of

Ground water by the leachate generated from the dumped site is a very common phenomenon in recent time (Khan *et al*., 2015) and is beginning to receive considerable attention globally. Pipe borne water is not readily available in most part of Nigeria including Delta state, hence groundwater has become a major source of water supply to the populace. But this groundwater is under threat by pollutants from uncontrolled dumping of MSW, therefore monitoring the groundwater quality close to MSW dumped site is crucial for environmental safety (Saidu, 2011). In relation to this, previous study has suggested that continuous analysis of natural water for physical and chemical properties including traces of element content are very important for public health studies (Kot *et al*., 2000, Saidu, 2011) since solid waste dumps is heterogeneous in nature, and the degradation time results in longer retention of the waste which as a result increases the chances of movement of leachate down the ground water source and there by contaminating it (Igbal and Gupta, 2009, Saidu, 2011). In line with this, fewer studies have been conducted on the impact of open dumping of MSW on groundwater in Nigeria and limited areas including Port Harcourt, Lagos, Minna and Benin City have been covered (Udom *et al*., 1999,

Udom and Esu, 2005, Saidu, 2011, Kola-Olusanya, 2015, Achadu *et al*., 2018). Still there is little or no study covering Delta state. Therefore, this study aimed at assessing the effect of open dumping of municipal solid waste on groundwater quality in Ekurede Itsekiri of Warri South Local Government Area (LGA), Delta State, Nigeria.

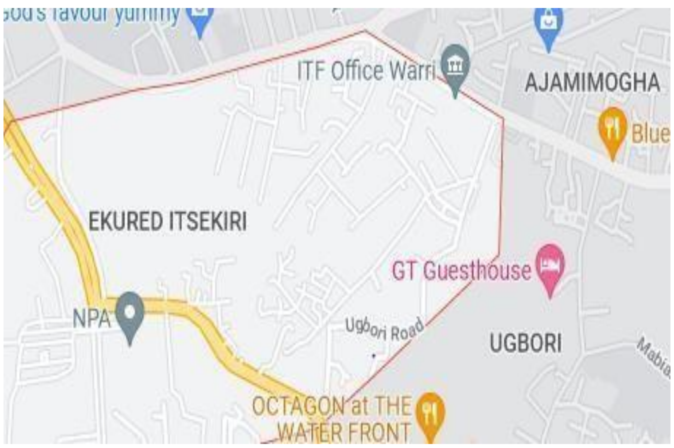
2.0 MATERIALS AND METHODS 2.1 Study Area

Ekurede Itsekiri is a town located in Warri South LGA of Delta State, Nigeria (Figure 1a).

Warri South LGA (Figure 1b) has its headquarters in Warri city which lies between latitude 5°33'15.84"N and longitude 5°47'35.52"E and has an annual rainfall amount of about 2,770 mm (109 in) and a mean annual temperature of about 32.8 °C (91.0 °F) (Akudo *et al*., 2010). It has an area of 542.2km^2 (Brinkhoff, 2020) and a population of about 311, 970 people (NPC, 2006) which was projected to year 2016 to be 429, 600 people (Brinkhoff, 2020). Warri South LGA is well noted for its riverine area and mangrove forest including being the attraction centre for various commercial activities. It has two distinct seasons, wet and dry seasons. The rainy season occurs between the months of March to October with a short break in August. The dry season on the other hand lasts from November to Feburary with dry harmattan winds between December and February, but with the effect of global warming and climate change, rains have been observed to fall irregularly almost in every month of the year with double peak periods in July and September (Rawlings and Ikediashi, 2020).

The people of Ekurede Itsekiri community practise open dumping method of waste disposal.

Ekurede Itsekiri dump site (EIDS) was created by the community over 15 years ago (Delta State Waste Management Board, 2021). It lies at latitude 5.5238° N and longitude 5.7359° E and spread over an area of 450m^2. As at 2021, the volume of waste being dumped on the site is 174.785m^3/week with the waste filling a height of about 0.3884m. The wastes dumped on this site are mainly domestic waste, commercial waste (agricultural products), industrial waste (animal products, automobile etc.), paper waste, scrap waste etc. The site is a non-engineered low lying open dump and the wastes are dumped irregularly without segregation. There are two major industries (oil and gas; oil support) in the community namely: Shell Petroleum Development Company (SPDC) of Nigeria and FENOG Nigeria Limited. Although SPDC stopped major oil and gas jobs about 7 years ago in the community, however they still do minor oil and gas jobs.



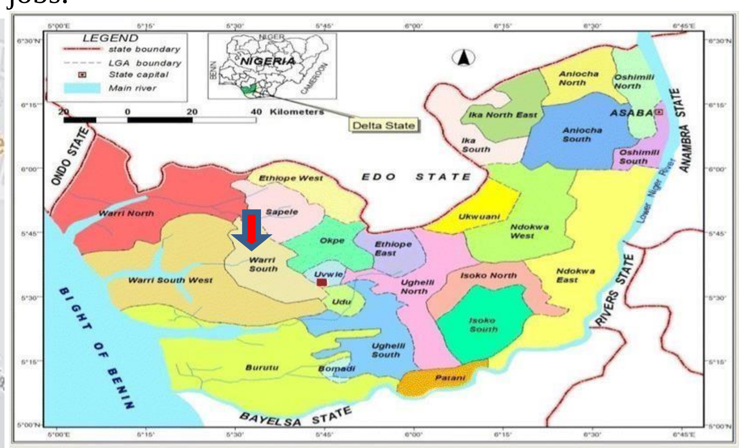


Figure 1a: Map Showing the Study Area, Ekurede Itsekiri Community (Source: Google Maps, 2020).

Figure 1b: Map of Delta State Showing Warri South LGA (Source: Ozoemenam et al., 2018)

2.2 Sample Collection and Physiochemical Analysis

Ten borehole samples were collected at distances between the ranges of 60-230m from an open dumpsite in the study area (Table 1 and Figure 2). Also, five leachate samples were collected randomly from five different leachate points (L1, L2, L3, L4 and L5) around the dumpsite (Figure 2). These samples were collected using 1l plastic bottles in May, 2021 (rainy season). The sample bottles were properly cleaned, sterilized before use and they were rinsed with the borehole water/leachate samples before sampling were done. The samples (borehole water and leachate) were labelled and transported to Martlet Environmental Research laboratory, Benin City for analysis. The samples were analysed for twenty-five physiochemical parameters, namely: pH, Electrical Conductivity (EC), Turbidity, Total Suspended Solids (TSS), Total Dissolved Solids (TDS), Chemical Oxygen Demand (COD), Bicarbonate (HCO_3^-), Sodium (Na), Potassium (K), Calcium (Ca), Magnesium (Mg), Chloride (Cl), Phosphorous (P), Nitrite (NO_2^-), Nitrate (NO_3^-), Ammonium Nitrogen (NH_4N), Sulfate (SO_4^{2-}), Iron (Fe), Manganese (Mn), Zinc (Zn), Copper (Cu), Chromium (Cr), Cadmium (Cd), Nickel (Ni), Lead (Pb) and a biological parameter (Coliforms Count (Col.)). All laboratory analyses were conducted in accordance with the techniques described by American Public Health (APHA, 1985, 1992 and 2005) and the methods adopted for analysing the samples parameters are shown in Table 2.

Table 1: GPS Coordinates of the Groundwater and Leachate Samples

Sample	Sampling Location	Distance from the Dump Site (m)	Latitude (degree)	Longitude (degree)
BH1	28 Ekurede Itsekiri	60	5.5239^{o}	5.7362^{o}
BH2	5 Ugbori	210	5.5232^{o}	5.7311^{o}
BH3	18 Ugbori	100	5.5245^{o}	5.7353^{o}
BH4	Redeemed Church	80	5.5237^{o}	5.7353^{o}
BH5	Four Square Church	150	5.5260^{o}	5.7343^{o}
BH6	Plaza Borehole	220	5.5256^{o}	5.7309^{o}
BH7	17 Ekurede Itsekiri	160	5.5267^{o}	5.735^{o}
BH8	13 Ekurede Itsekiri	200	5.5271^{o}	5.7332^{o}
BH9	30 Ekurede Itsekiri	230	5.5278^{o}	5.7330^{o}
BH10	Olu Palace	170	5.5262^{o}	5.7383^{o}
L1	Front Side of the EIDS	-	5.5245^{o}	5.7366^{o}
L2	Right Side of the EIDS	-	5.5234^{o}	5.7372^{o}
L3	Back Side of the EIDS	-	5.5232^{o}	5.7360^{o}
L4	Left Side of the EIDS	-	5.5230^{o}	5.7346^{o}
L5	Entrance of the EIDS	-	5.5238^{o}	5.7359^{o}

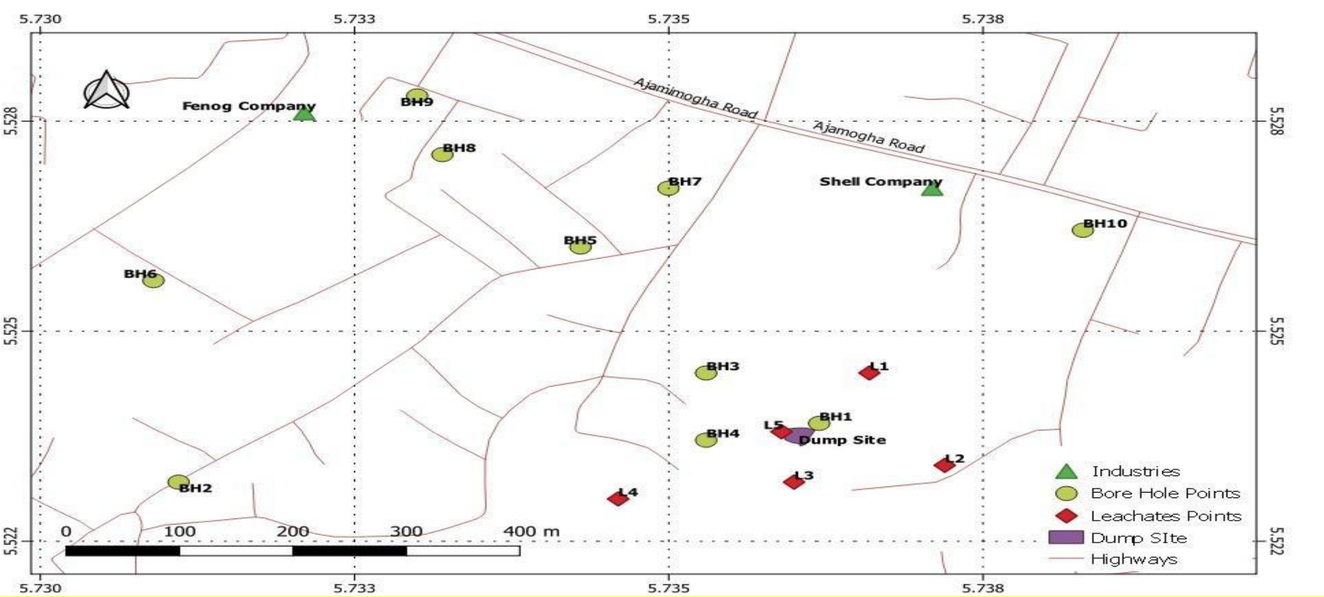


Figure 2: Map of the Study Area Showing the Sampling Points (both for Groundwater and Leachate)

Table 2: Analytical Methods for Borehole and Leachate Parameters

Parameters	Analytical Methods
pH	Flame Photometric Method

Electrical Conductivity	Flame Photometric Method
Turbidity	Spectronic 20D^{+} Spectrophotometry Method
Total Suspended Solids	Flame Photometric Method
Total Dissolved Solids	Flame Photometric Method
Chemical Oxygen Demand	Dichromate Method
Bicarbonate	Titrimetric Method
Sodium	Flame Photometric Method
Potassium	Flame Photometric Method
Calcium	Titrimetric Method
Magnesium	Titrimetric Method
Chloride	Titrimetric Method
Phosphorus	Spectrophotometry Method (Atomic Absorption)
Nitrite	Spectrophotometry Method (Atomic Absorption)
Nitrate	Spectrophotometry Method (Atomic Absorption)
Ammonium Nitrogen	Titrimetric Method
Sulfate	Spectrophotometry Method (Atomic Absorption)
Iron	Spectrophotometry Method (Atomic Absorption)
Manganese	Spectrophotometry Method (Atomic Absorption)
Zinc	Spectrophotometry Method (Atomic Absorption)
Copper	Spectrophotometry Method (Atomic Absorption)
Chromium	Spectrophotometry Method (Atomic Absorption)
Cadmium	Spectrophotometry Method (Atomic Absorption)
Nickel	Spectrophotometry Method (Atomic Absorption)
Lead	Spectrophotometry Method (Atomic Absorption)
Coliforms Count	Membrane Filtration Method

2.3 Heavy metal Pollution Index (HPI)

The overall quality of the groundwater and leachates were examined using the heavy metal pollution index (HPI). The HPI was carried out using Microsoft excel (2013 version). According to Reza and Singh (2010), Abdullah (2013), HPI is a method of rating that indicates the composite influence of individual heavy metal on the overall quality of water. HPI is an effective tool for characterizing both ground and surface water pollution (Prasad and Kumari, 2008; Reza and Singh, 2010) and is based on the weighted arithmetic quality mean method (Kwaya *et al*., 2019) which reduces the bulk of data into a single value so that it can be compared with the critical value to assess the level of pollution load (Abdullah, 2013). The weighted arithmetic index method from Reza and Singh (2010), Abdullah (2013) was used for the calculation of the HPI of the groundwater and leachate. From this method, the HPI was calculated using the following equation (Reza and Singh, 2010, Abdullah, 2013):

$$HPI = \frac{\sum_{i=1}^{n} Q_i W_i}{\sum_{i=1}^{n} W_i} \quad (1)$$

Where,

HPI =Heavy metal Pollution Index n = Number of parameters considered

Q_i = Sub index of ith parameter, which is $\frac{V_i}{S_i} 100$

V_i = Monitored value of the ith parameter in mg/l S_i = Standard or permissible limit for the ith parameter

W_i = Unit weightage of the *ith* parameter, which is $\frac{K}{S_i}$

K = Constant of proportionality

For this study, the heavy metals used for the computation of the HPI are Na, K, Ca, Mg, Fe, Mn, Zn, Cu, Cr, Cd, Ni, and Pb. Since the intended use of the HPI is to ascertain the suitability of the groundwater for drinking and the pollution potentials of the leachate in relation to the groundwater, the critical pollution index value is 100 (Prasad and Kumari, 2008; Kwaya *et al*., 2019) and when this value is exceeded, the pollution level should be regarded as unacceptable.

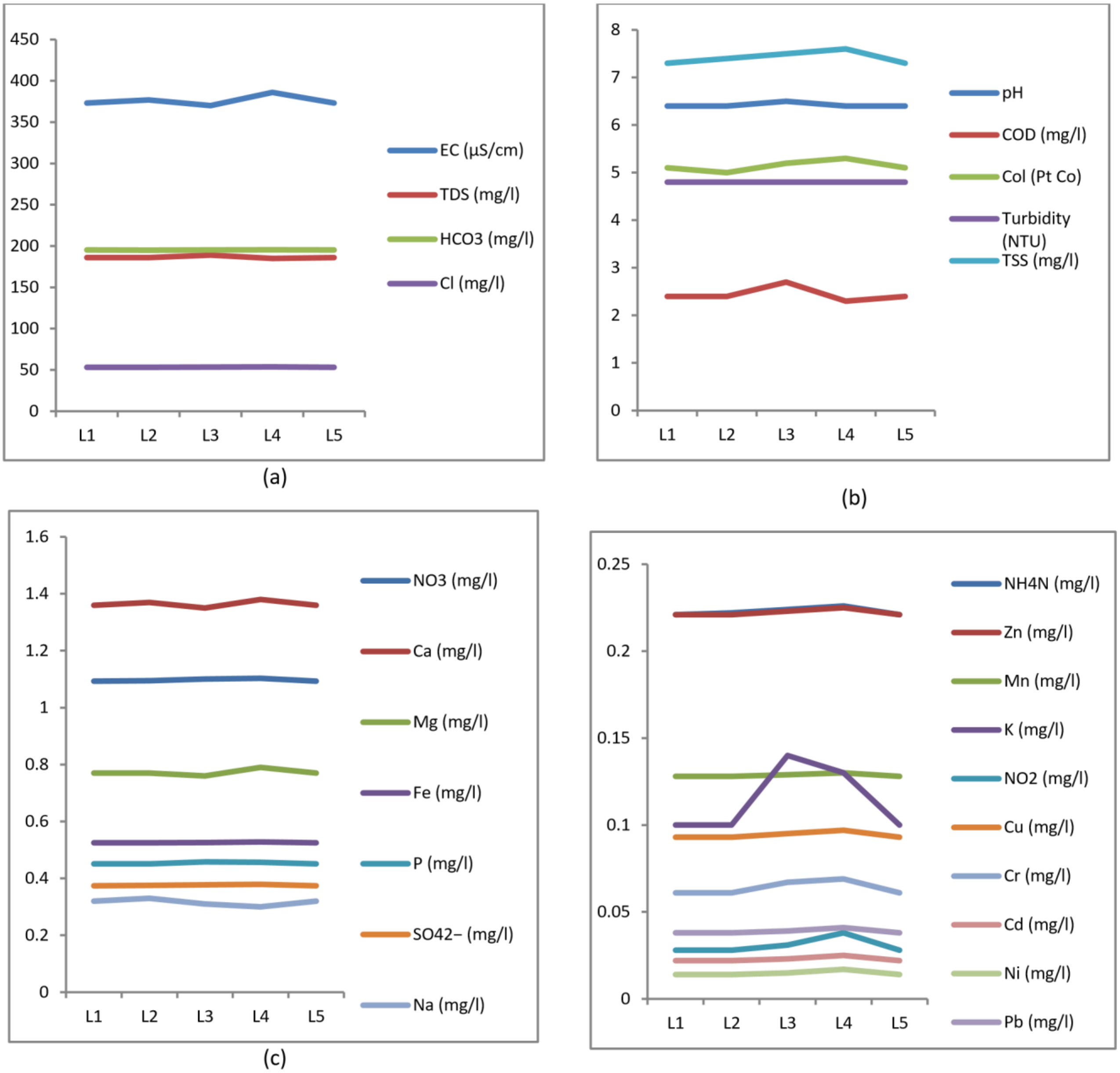
3.0 RESULTS AND DISCUSSION

Results from both physiochemical and HPI analyses are presented in Figures 3, 4 and Tables 3, 4, 5 and 6.The comparison of physiochemical properties of the leachate and groundwater with standards (Nigerian Standard for Drinking Water Quality-NSDWQ, 2015 and World Health Organisation-WHO, 2011) are presented in Tables 3 and 4. Figure 3 and 4 shows variations of the physiochemical properties of leachate at different points around the dump site and groundwater at different locations from the dump site. Also, results of HPI for both leachate and groundwater are presented in Tables 5 and 6.

Table 3: Comparison of Physiochemical Analysis of the Leachate Samples with Standards

Parameters	**Minimum**	**Maximum**	**Mean**	**Std. Deviation**	**Variance**	**Standards WHO (2011)**	**NSDWQ (2015)**
Ph	6.4	6.5	6.42	0.04472	0.002	6.5-8.5	6.5 -8.5
EC (µS/cm)	370	386	375.8	6.22093	38.7	1500	1500
Col. (Pt. Co)	5	5.3	5.14	0.114018	0.013	0	0
Turbidity (NTU)	4.8	4.8	4.8	0	0	5	5
TSS (mg/l)	7.3	7.6	7.42	0.130384	0.017	N/A	N/A

TDS (mg/l)	185	189	186.4	1.516575	2.3	N/A	500
COD (mg/l)	2.3	2.7	2.44	0.151658	0.023	<50	75
HCO_3 (mg/l)	195	195.4	195.22	0.148324	0.022	500	500
NO_2^- (mg/l)	0.028	0.038	0.0306	0.004336	0	3	0.2
NO_3^- (mg/l)	1.093	1.103	1.0968	0.004494	0	50	50
NH_4N (mg/l)	0.221	0.226	0.2228	0.002168	0	N/A	0.5
SO_4^{2-} (mg/l)	0.374	0.379	0.3758	0.002168	0	N/A	N/A
Na (mg/l)	0.3	0.33	0.316	0.011402	0	N/A	200
K (mg/l)	0.1	0.14	0.114	0.019494	0	N/A	20
Ca (mg/l)	1.35	1.38	1.364	0.011402	0	200	200
Mg (mg/l)	0.76	0.79	0.772	0.010954	0	50	20
Cl (mg/l)	53.2	53.7	53.34	0.219089	0.048	250	250
P (mg/l)	0.451	0.458	0.4534	0.003362	0	N/A	N/A
Fe (mg/l)	0.525	0.528	0.5258	0.001304	0	0.3	0.3
Mn (mg/l)	0.128	0.13	0.1286	0.000894	0	N/A	0.2
Zn (mg/l)	0.221	0.225	0.2222	0.001789	0	N/A	3
Cu (mg/l)	0.093	0.097	0.0942	0.001789	0	2	1
Cr (mg/l)	0.061	0.069	0.0638	0.003899	0	0.05	0.05
Cd (mg/l)	0.022	0.025	0.0228	0.001304	0	0.003	0.003
Ni (mg/l)	0.014	0.017	0.0148	0.001304	0	0.07	0.02
Pb (mg/l)	0.038	0.041	0.0388	0.001304	0	0.01	0.01



(d)

Figure 3: Variations of the Physiochemical Properties of Leachate Samples at Different Points around the Dump Site

Results from Table 3 and Figure 3 shows that all parameters examined were within WHO and NDSWQ acceptable limits for drinking water quality standards except for pH, coliform bacteria (Col.), Fe, Cr, Cd, Pb and that there were slight variations in parameters at different leachate points. According to Vasanthi *et al*. (2008) the amount and production rates of contaminants depend on the type of waste and moisture content. Hence, the slight variation observed in parameters might be due to the type of waste and moisture content at different leachate points and this is implying that the waste dumped at different points in the dump site might not have much effect on the leachate at different points. The mean pH value (6.42) of the leachate was below the acceptable limits of 6.5-8.5 (WHO, 2011 and NSDWQ, 2015) and it indicates slightly acidic leachate. From Figure 3b, the pH of leachate from L3 (6.5) was within acceptable limits while the pH of leachate from L1, L2, L4 and L5 (6.4 respectively) were not within acceptable limits. The acidic pH observed may be attributed to the carbon dioxide produced from the dump site which is as a result of the decomposition of the Organic matter contained in the refuse under aerobic conditions. It is an indication that the leachate might also be affecting the quality of the groundwater around the dump site. In contrast, Ugwu and Nwosu (2009), Achadu *et al*. (2018) show an alkaline pH in the leachate from an open dump site in Nigeria, this might be attributed to the different waste materials in the dump site together with the hydrogeological properties of the area (presence of calcareous material in soils). The mean coliform count (5.14pt.co) was above the acceptable limit of 0pt.co (WHO, 2011 and NSDWQ, 2015). Results from Figure 3b indicates that the highest count (5.3pt.co) was recorded in leachate from L4, left side of the dumpsite while the lowest count (5.0pt.co) was recorded in L2, right side of the dumpsite. Other researchers (Achadu *et al*., 2018) have also reported the presence of coliform bacteria in the leachate from an open dump site in Nigeria. The presence of coliform bacteria in the leachate implies that the dump site consist of both animal and human waste (particularly from waste pickers who defecate at the site). And this poses a threat to the groundwater quality around the dump site as the leachate might contaminate the groundwater with time, thus making it unsafe and unfit for human use.

The mean values of Fe (0.5258 mg/l), Cr (0.0638 mg/l), Cd (0.0228 mg/l) and Pb (0.0388 mg/l) were all above the acceptable limits of 0.3 mg/l, 0.05 mg/l, 0.003 mg/l and 0.01 mg/l (WHO, 2011 and NSDWQ, 2015). From Figure 3c and 3d, the highest Fe, Cr, Cd and Pb values (0.528 mg/l, 0.069 mg/l, 0.025 mg/l and 0.041 mg/l) were recorded in leachate from L4. High levels of heavy metals (Fe, Cr, Cd and Pb) observed in the leachate is in accordance with those of Achadu *et al*. (2018). Their presence may originate from the different waste materials dumped at the site (Aderemi *et al*., 2011). The presence of high concentrations of Fe, Cr, Cd and Pb may be greatly influenced by the disposal of scrap metals (such as iron metals, stainless steel etc.), PVC plastics and lead pipes at the site. High levels of Cd and Pb may also be an indication of battery wastes at the dump site. The high concentrations of heavy metals (Fe, Cr, Cd and Pb) in the leachate calls for concerns as it might contaminate the groundwater around the dump site with time.

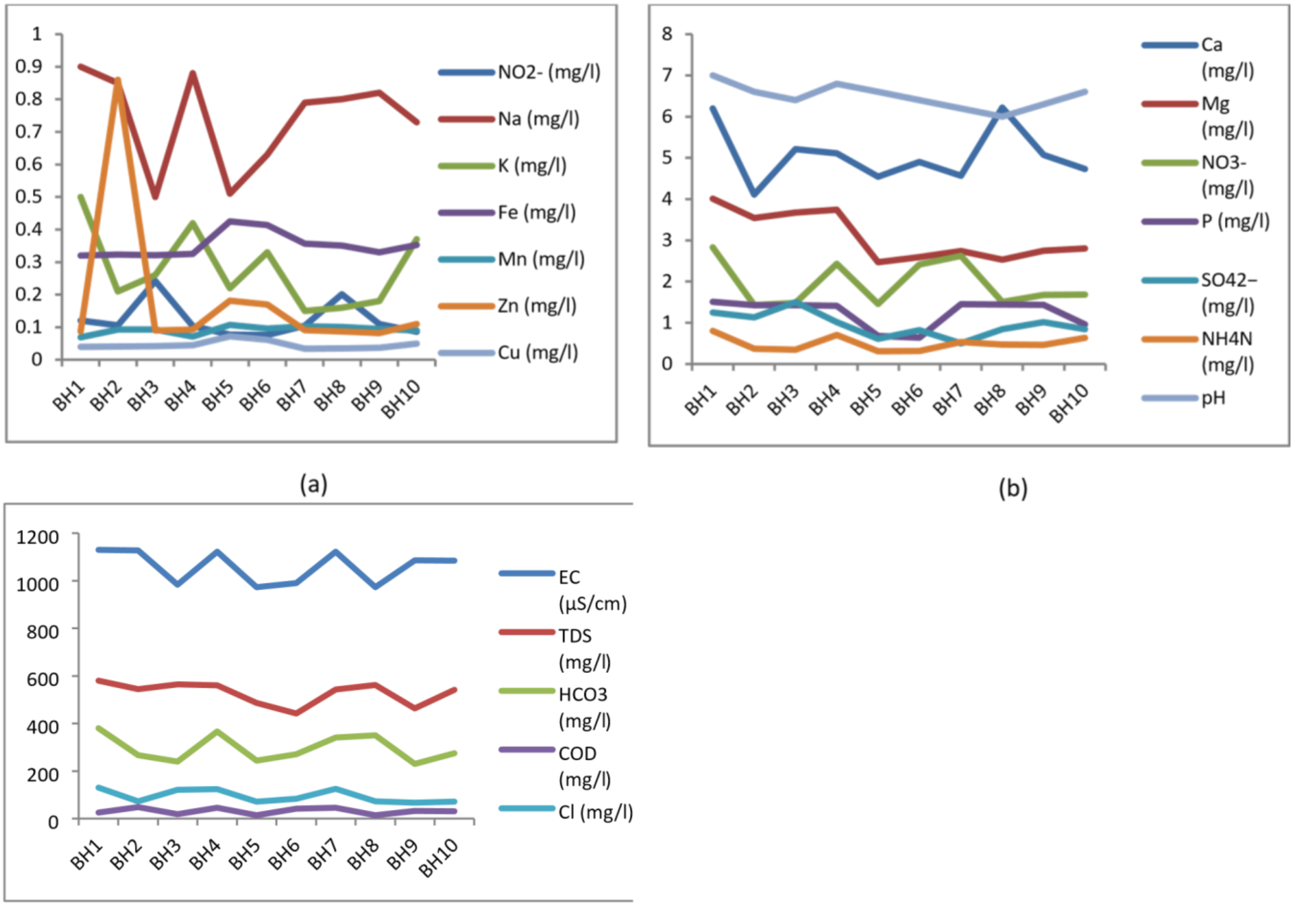
Results from Table 4 and Figure 4 shows that all parameters examined were within WHO and NSDWQ acceptable limits for drinking water quality standards except for pH, TDS, NH_4N and Fe and that there were variations in parameters at different groundwater locations. The mean pH value (6.49) was not within acceptable limits of 6.5-8.5 (WHO, 2011 and NSDWQ, 2015) and it indicates slightly acidic water. However, the pH of the groundwater at different locations from the dump site (Figure 4b) revealed moderately acidic to neutral water, as pH of water from locations BH1, BH2, BH4, BH5 and BH10 (7.0, 6.6, 6.8, 6.6 and 6.6 respectively) were within acceptable limits while the pH of water from locations BH3, BH6, BH7, BH8 and BH9 (6.4, 6.4, 6.2, 6.0.and 6.3 respectively) were not within acceptable limits. Water from BH1 at 60m from the dump site has the highest pH of 7.0 (neutral water) while water from BH8 at 200m from the dump site has the lowest pH of 6.0 (moderately acidic). The acidic nature of Nigerian groundwater at distances from an open dump site had been noted by various researchers (Akudo *et al*., 2010; Aderemi *et al*., 2011; Kola-Olusanya, 2012 and Achadu *et al*., 2018). Acidity in ground water may be as a result of the presence of free carbon dioxide. Hence, the moderately acidic to neutral nature of the groundwater observed in this study might be attributed to the methanogenic activity in the dump site leachate (as it permeates into the underground) together with the hydrogeological condition of the area (presence of calcareous material in soils and rocks). Acidity enhances the corrosive characteristics of water which may result in deterioration of distribution system and thus affect the taste and appearance of drinking water (WHO, 2007; Egun, and Ogiesoba-Eguakun, 2018). Acidic water may also pose a potential health hazard as it might result in serious health complications such as irritation in the eyes, skin and mucous membrane (Karunakaran, 2008; Rawlings and Ikediashi, 2020).

Table 4: Comparison of Physiochemical Properties of the Groundwater Samples with Standards

Parameter	**Minimum**	**Maximum**	**Mean**	**Std. Deviation**	**Variance**	**Standards WHO (2011)**	**NSDWQ**
pH	6	7	6.49	0.29231	0.085		

(2015)
6.5-8.5

EC (µS/cm)	973.1	1130	1059.22	70.04357	4906.102	1500	1500	6.5-8.5
Col. (Pt. Co)	ND	ND	-	-	-	0	0	
Turbidity (NTU)	ND	ND	-	-	-	5	5	
TSS (mg/l)	ND	ND	-	-	-	N/A	N/A	
TDS (mg/l)	442	580	528.7	47.495146	2255.789	N/A	500	
COD (mg/l)	14.4	48.4	31.95	13.467842	181.383	<50	75	
HCO_3 (mg/l)	230.1	380.1	296.33	56.874483	3234.707	500	500	
NO_2^- (mg/l)	0.076	0.242	0.1227	0.054864	0.003	3	0.2	
NO3- (mg/l)	1.43	2.83	1.9501	0.547367	0.3	50	50	
NH_4N (mg/l)	0.31	0.803	0.4949	0.171038	0.029	N/A	0.5	
SO42− (mg/l)	0.501	1.502	0.9532	0.297201	0.088	N/A	N/A	
Na (mg/l)	0.5	0.9	0.741	0.146246	0.021	N/A	200	
K (mg/l)	0.15	0.5	0.28	0.119629	0.014	N/A	20	
Ca (mg/l)	4.11	6.22	5.066	0.684547	0.469	200	200	
Mg (mg/l)	2.47	4.01	3.084	0.584773	0.342	50	20	
Cl (mg/l)	70.9	130.3	94.01	27.374175	749.345	250	250	
P (mg/l)	0.64	1.509	1.2381	0.340219	0.116	N/A	N/A	
Fe (mg/l)	0.32	0.425	0.3519	0.038353	0.001	0.3	0.3	
Mn (mg/l)	0.069	0.107	0.0918	0.012595	0	N/A	0.2	
Zn (mg/l)	0.082	0.17	0.1851	0.239822	0.058	N/A	3	
Cu (mg/l)	0.034	0.072	0.0457	0.012202	0	2	1	
Cr (mg/l)	ND	ND	-	-	-	0.05	0.05	
Cd (mg/l)	ND	ND	-	-	-	0.003	0.003	
Ni (mg/l)	ND	ND	-	-	-	0.07	0.02	
Pb (mg/l)	ND	ND	-	-	-	0.01	0.01	



(c)

Figure 4: Variations of Physiochemical Properties of Groundwater Samples at Different Locations from the Dump Site

The mean TDS value (528.7 mg/l) was above the acceptable limit of 500 mg/l (NSDWQ, 2015), however TDS were below and above acceptable limit at different groundwater locations (Figure 4c). The TDS in water from location BH5, BH6 and BH9 (486 mg/l, 442 mg/l and 463 mg/l respectively) were below acceptable limits while TDS in water from location BH1, BH2, BH3, BH4, BH7, BH8 and BH10 (580 mg/l, 544 mg/l, 564 mg/l, 561 mg/l, 543 mg/l, 562 mg/l and 542 mg/l respectively) were above acceptable limits. The highest concentrations of TDS were observed at BH1 (580 mg/l), BH3 (564 mg/l) and BH8 (562 mg/l) which are 60 m, 100 m and 200 m from the dump site respectively. Higher levels of TDS in groundwater around dump sites in Warri town have also been noted by Akudo *et al*. (2010). Although, the TDS in the leachates were all below acceptable limit, however, the higher levels of TDS observed may be attributed to the permeation of leachate from the dump site together with effluents from the industries around the areas (Ibe-Sr *et al*., 1999). It also implies a downward transfer of leachate into the groundwater (Mor *et al*., 2006; Longe and Enekwechi, 2007; Srigirisetty *et al*., 2017). Higher levels of TDS in water decrease its palatability and may possibly cause gastrointestinal irritation in human and laxative effects particularly upon transits (WHO, 1997; Srigirisetty *et al*., 2017). Although the mean NH_4N value (0.4949) was below the acceptable limit of 0.5 mg/l (NSDWQ, 2015), however NH_4N were below and above acceptable limit at different groundwater locations (Figure 4b). The NH_4N in water from locations BH2, BH3, BH5, BH6, BH8 and BH9 (0.370 mg/l, 0.345 mg/l, 0.310 mg/l, 0.320 mg/l, 0.475 mg/l and 0.460 mg/l respectively) were all below acceptable limits while the NH_4N in water from locations BH1, BH4, BH7 and BH10 (0.803 mg/l, 0.705 mg/l, 0.530 mg/l and 0.631 mg/l respectively) were above acceptable limits. The highest NH_4N value (0.803 mg/l) was recorded in water from BH1. Izeze and Konboye (2018) have also reported higher levels of NH_4N in groundwater in Warri town. Higher levels of NH_4N observed in this study are an indication of faecal contamination. Although, the NH_4N in the leachates were all below acceptable limit, however the high content of NH_4N in the groundwater might be attributed to the leachate from the dump site (due to the presence of coliform bacteria in the leachate) together with possible septic tank leakage within the areas (Izeze and Konboye, 2018). Ammonia in water is an indicator of possible bacterial, sewage and animal waste pollution (WHO, 2011), thus rendering the water unsafe and unfit for human use as it may result in serious health issues such as water borne diseases (typhoid fever, cholera, and dysentery etc.).

The mean Fe value (0.351 mg/l) was above the acceptable limit of 0.3 mg/l (WHO, 2011 and NSDWQ, 2015). From Figure 4a, It was observed that the Fe content in the groundwater at all locations were all above the acceptable limits (BH1-0.32 mg/l; BH2-0.323 mg/l; BH3-0.321 mg/l; BH4-0.325 mg/l; BH5-0.425 mg/l; BH60.414 mg/l; BH7-0.357 mg/l; BH8-0.351 mg/l; BH9-0.33 mg/l; BH10-0.353). The highest concentrations of Fe were observed at BH5 (0.425 mg/l) and BH6 (0.414 mg/l) which are at 150 m and 220 m from the dump site. Similarly, high Fe content in groundwater within and around the vicinity of a dump site has also been reported (Akudo *et al*., 2010; Ugwu and Nwosu, 2009; Aderemi *et al*., 2011). The high content of Fe in this study may be attributed to the permeation of leachate from the dump site together with the soil geology of the study area (Oghenero *et al.*, 2014). Higher concentrations of Fe in water can result to hemochromatosis, heart diseases, liver problems and diabetes (Garvin 2017; Egun and Ogiesoba-Eguakun, 2018). It also results in aesthetic, taste and odour problems.

Parameters such as coliform bacteria, Turbidity, TSS, Cr, Cd, Ni and Pb were not detected in all the groundwater samples. The presence of these parameters in the leachates and their absence in all the groundwater samples can be attributed to the sub-surface geology of the study area which consists of clay (Oghenero *et al*., 2014). It has been reported that some metals (such as Cr, Cd, Ni and Pb) have the affinity to be absorbed by clayey soil (Mor *et al*., 2006; Longe and Enekwehi, 2007; Aderemi Adeolu *et al*., 2011) and thus other parameters may also have possessed this property.

Results from Figure 3 and 4 further indicated that all the parameters analysed were higher in concentrations in the groundwater than the leachate, except for coliform bacteria, Fe, Mn, Zn, Cu, Cr, Cd, Ni and Pb which were higher in the leachate than the groundwater. It implies that the leachate is a potential threat of faecal and heavy metal contamination to the groundwater with time. Hence, the dump site has impact on the groundwater quality in the study area.

Table 5: Heavy metals Pollution Index (HPI) for Leachate at Different Points in the Dump Site

Leachate	Heavy metal Pollution Index (HPI)
L1	27.21
L2	30.75
L3	43.22
L4	45.97
L5	27.05
Mean	34.85

Results from Table 5 shows that the HPI for leachate at different point in the dump site is below the critical index value (100), it ranges from 27.05 to 45.97 and had a mean of 34.85. The highest HPI value (45.97) was at point L4 while the lowest HPI value (27.05) was at point L1, front side of the dump site. This low value might be attributed to the low concentration of waste (such as scrap metals, PVC plastics, lead pipes, batteries etc.) at this point in the dump site.

Table 6: Heavy metals Pollution Index (HPI) for Groundwater at Different Locations from the Dump

Site

Borehole Locations	**Heavy metals Pollution Index (HPI)**
BH1	29.917
BH2	39.547
BH3	38.319
BH4	44.522
BH5	44.522
BH6	40.427
BH7	42.318
BH8	41.522
BH9	1.193
BH10	37.484
Mean	35.977

Results from Table 6 shows that the HPI for the groundwater at different locations from the dump site is below the critical index value (100), it ranges from 1.193 to 44.522 and had a mean of 35.977. The highest HPI value was found at locations BH4 and BH5 (44.522 respectively) while the lowest HPI value was found at locations BH9 (1.193) which is at 230m away from the dump site, hence the low levels of heavy metals in this location might indicate dilution effect due to seepage or percolation of rainwater (Reza *et al*., 2011; Abdullah, 2013). The critical pollution index value, above which the overall pollution level should be considered unacceptable, is 100 (Prasad and Kumari, 2008). Hence, the results from this study indicate that the water is not critically polluted with respect to heavy metals. This result correlates with that of the physiochemical analysis which shows that some heavy metals were not detected in the groundwater while the ones that were detected were below acceptable limit except for Fe.

The Mean HPI value for leachate (34.85) and groundwater (35.977) further indicates that the concentrations of heavy metals detected in the groundwater may not have originated from the dump site alone and that other anthropogenic activities might also have contributed.

4.0 CONCLUSION

The groundwater at distances from a dump site and the leachate at different points around the same dump site in Ekurede-Itesekiri, Warri South LGA, Delta State, Nigeria were analysed for their physiochemical properties and evaluated for their heavy metal pollution status. Results of physiochemical analysis revealed that all parameters examined in the groundwater samples were within WHO and NDSWQ acceptable limits except for pH, TDS, NH_4N and Fe and that for the leachate, all parameters examined were within WHO and NDSWQ acceptable limits except for pH, coliform bacteria, Fe, Cr, Cd and Pb. All parameters analysed were detected in the leachate while some parameters (coliform bacteria, Turbidity, TSS, Cr, Cd, Ni and Pb) were not detected in the groundwater. The clayey soil in the study area seems to have significantly influenced the absence of these contaminants from the groundwater. The observation of high levels of coliform bacteria, Fe, Cr, Cd and Pb in the leachate and the presence of TDS, NH_4N and Fe above WHO and NDSWQ acceptable limits in groundwater samples implies that the dump site has impact on the groundwater quality around it and that the leachate is a possible potential threat to the groundwater quality in the entire study area with time. Hence, there is need for an improved waste management practice in Ekurede-Itesekiri community. The collected solid waste must be segregated, treated and disposed in an environmentally acceptable manner. The mean HPI value of the groundwater (35.977) and the leachate (34.85) were below the critical index value (100), thus indicating that they are not critically polluted with heavy metals. It was observed that the mean HPI of the groundwater was slightly higher than that of the leachate). This is implying that the concentrations of heavy metals detected in the groundwater may not have originated from the dump site alone and that other anthropogenic activities might also have contributed. Although, the HPI has indicated that the groundwater is not critically polluted with heavy metals, but results of the physiochemical analysis has revealed that the groundwater around the dump site has deteriorated and as such it is unsafe and unfit for human use.

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