Sub-Sahara African Academic Research Publications
September, 2020, Editions

JECM
Journal of Environmental Design and Construction Mgt.
Vol.16, No.4, ISSN 2292-7733

ASSESSMENT OF SOIL AND GROUNDWATER QUALITY AROUND MAJOR DUMPSITES IN RIVERS STATE USING INDEX MODELS APPROACH

***OZOEKWE, V. E.; **GOBO, A. E.; **ABAM, T. K. S.; & **NGAH, S. A.**
**Environmental Management and Control, Institute of Geosciences and Space Technology. Rivers State University, Port Harcourt. Nigeria. **Institute of Geosciences and Space Technology. Rivers State University, Port Harcourt. Nigeria.*

ABSTRACT

Soil and groundwater quality assessment was conducted in order to determine the level and extent of contamination imposed from surface dumpsites cited within residential areas in Rivers State, Nigeria. Thirty soil and groundwater samples were obtained from dumpsite centers and surrounding residential areas for physico-chemical, heavy metals and petroleum hydrocarbons analysis. Sampling was carried out in the wet and dry seasons to reflect seasonal variations in soil and groundwater quality. The samples were analyzed using AAS and standard laboratory procedural guidelines. Pollution load index and water quality index were used to address soil and groundwater quality status in the area. The results of soil heavy metal pollution load ranged from 0.65 to 1.45 in the wet season and 0.74 to 1.55 in the dry season. Soil metal pollution load revealed all dump centres have deteriorated soil quality, while 20% and 87% of soils in residential areas have deteriorated quality for wet and dry seasons respectively. Groundwater across the entire area is very acidic in both wet and dry season with pH values < 5.0. Water quality index revealed only a single borehole in Igwuruta has unsuitable water quality, all other boreholes showed good to excellent quality across both wet and dry seasons. The study recommends groundwater in the area is treated with lime or carbonates to reduce its acidity before subsequent consumption.

Keywords: *Water Quality Index, Pollution Load Index, Groundwater, Soil, Contamination.*

BACKGROUND OF STUDY

Groundwater is very important to man-kind as it has become a major source for drinking, especially in the Niger Delta region where most of the surface water resources are contaminated from industrial and urban activities including gas flaring, waste water discharge, oil spillage, inadequately engineered solid waste disposal sites, vehicular exhaust, poorly constructed latrines, etc. All these activities have significantly altered the chemistry of surface water resources, rendering it generally unfit for drinking purposes, especially in Port-Harcourt, which is host to most oil and gas companies in Nigeria. Management of municipal solid waste is of major environmental interest across the world and has been identified as one of the major threats to groundwater resources especially in Rivers State where there are inefficient and inadequate legislations guiding disposal methods practiced in the region. Currently, world cities generate about 1.3 billion tonnes of solid waste per year. This volume is expected to increase to 2.2 billion tonnes by 2025. Waste generation rates will more than double over the next twenty years in lower income countries like Nigeria. Globally, solid waste management costs will increase from today's annual $205.4 billion to about $375.5 billion in 2025 (Okoli *et al.,* 2020). In developing countries as Nigeria, dumpsites are located near residential housing (Ubong, *et al.,* 2015) and therefore represent a threat to human health and the environment (Aderemi & Falade, 2012). Mangizvo (2010) and Aderemi *et al.,* (2012) identified several associated health issues with dumpsites including; water borne diseases from leachates percolating into drinking water supplies, spread of diseases by vermins and insects, landfill gas emissions causing odor, landfill fires polluting air quality, etc. Based on the above, it is pertinent that these waste dumpsites may have some consequences on soils, surface and ground water quality with attendant health implications. These must be tackled head on before an epidemic occurs (Ladele & Ogundele, 2017). Hence, the aim of this study is to appraise the status of soil and groundwater quality around major dumpsites in Rivers State using soil and groundwater quality assessment index models.

DESCRIPTION OF STUDY AREA

The study area is located in Rivers State, Southern Nigeria. Generally, the area lies along the Nigeria coastal zone and experiences a tropical climate characterized by two distinct seasons; the rainy season (April to mid-August, September to mid-November) and dry season (November till March) usually with sparse rainfall in-between. The rainfall exhibits a double maxima regime with peaks in July and September, with a little dry season in August. In the dry season, high evapotranspiration rate induced by dry conditions helps to increase water losses in the region (Etu-Efeotor and Odigi, 1983). Geologically, the soil type consists mainly of poorly-drained silt clays mixed with sand, which is classified under the Benin formation (Ayotamuno and Gobo, 2004). The aquifers in the area occurs within the Benin Formation. The formation has been identified as fresh water bearing sand (Short and Stauble 1967; Amajor and Ofoegbu 1988) and all aquifers in the deltaic region occurs within this lithostratigraphic unit. Generally, the depth to the water table in the Delta increases northwards from <1 m at the coast to 16 m at the northeast section (Giadom *et al.,* 2015). The regional groundwater flow direction in deep aquifers is generally southwards towards the Atlantic Ocean whilst the local flow direction in shallow aquifers is generally towards the nearest river or stream. A total of six major dumpsites were selected across the state and utilized for this study.

METHODOLOGY

Field Data Acquisition

Soil and groundwater samples were collected randomly within and around the vicinity of major active dumpsites in Rivers State (Figure 1.0). A total of thirty (30) soil and groundwater samples were obtained from six dumpsites centres and into surrounding residential areas which included; Chinda dumpsite (Plate 1), Igwuruta dumpsite (Plate 2), Aluu dumpsite, Chinda dumpsite, Eliozu dumpsite, Oyigbo and Iwofe dumpsites. Soil samples were collected from the dumpsite centres and into surrounding residential areas where groundwater samples were also collected from boreholes. At each soil sampling station, the soil samples were collected at depths from 0 to 30 cm and homogenized before collecting about 50g of soil samples into well labelled polyethene bags. Groundwater samples were collected from shallow residential boreholes as close as possible to the well head in order to prevent any form of sample contamination. The samples were collected in duplicates in pre-cleaned bottles. Samples for physicochemical and heavy metal analysis were collected in plastic bottles, while samples for polycyclic aromatic hydrocarbons determination were collected in glass bottles. Unstable groundwater parameters such as pH, temperature, total dissolved solids and electrical conductivity were analyzed in-situ in order to preserve the integrity of the water samples. Table 1.0 shows the geographic reference locations and distances from dumpsite centres for the sampling stations.

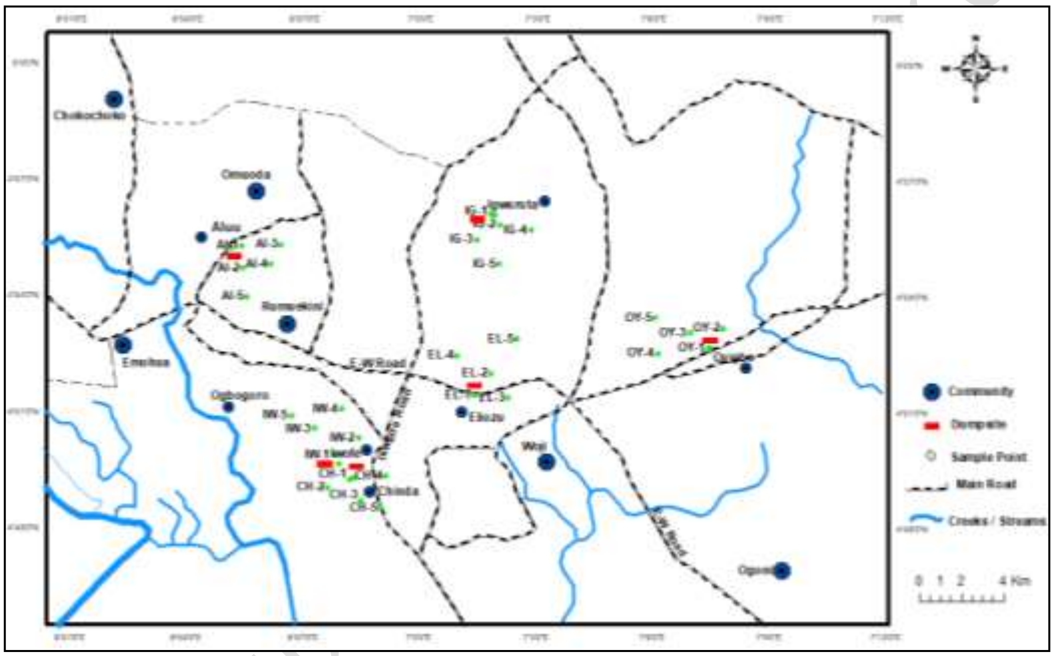

Figure 1.0: Map of PortHarcourt Metropolis showing major dumpsites utilized for this study

Laboratory Analysis

The soil samples were spread out on a plastic sheet and allowed to air dry for 2-3 days. Afterwards, the soils were sorted manually to remove sticks, shells, organic matter and stones from the air-dried samples. The samples were further homogenized and gently crushed repeatedly using a mortar and pestle, and then passed through a 0.125 mm sieve prior to analysis. The digested soil sample solution and groundwater samples were analyzed using the atomic absorption spectrometer (Buck Scientific 210 VGP Atomic

Absorption Spectrophotometer, AAS) using standard laboratory procedures. Table 2.0 shows laboratory procedures utilized for samples analysis.

Plate 1: Dumpsite at Chinda community

Plate 2: Dumpsite at Igwuruta community

Table 1.0: Soil, leachate and groundwater sampling locations within the study area

Sample ID	Media	Easting (m)	Northing (m)	Distance to dump (m)	Sample ID	Media	Easting (m)	Northing (m)	Distance to dump (m)
CH	L	275071	533301	0	OY-3	G	291054	540186	1288
IW	L	274355	533973	0	OY-4	G	289532	539221	2903
OY	L	292035	539477	0	OY-5	G	289423	540901	2932
IG	L	281783	545837	0	EL-1	G	280772	537228	18
EL	L	280833	537251	0	EL-2	G	281605	538270	1100
AL	L	269212	544266	0	EL-3	G	282406	537086	1200
CH-1	G	274860	533189	1012	EL-4	G	279980	539123	2201
CH-2	G	273817	532833	1595	EL-5	G	282834	539913	3300
CH-3	G	275410	532199	80	IG-1	G	281609	545887	16
CH-4	G	276571	533381	1682	IG-2	G	282025	545364	334
CH-5	G	276325	531848	1122	IG-3	G	280929	544655	966
IW-1	G	274104	534377	2036	IG-4	G	283492	545114	1780
IW-2	G	275275	535184	1553	IG-5	G	281985	543483	2334
IW-3	G	273189	535653	1210	AL-1	G	269725	544367	1232
IW-4	G	274474	536588	40	AL-2	G	269778	543294	1556
IW-5	G	272082	536266	2100	AL-3	G	271586	544420	13

OY-1	G	291945	539457	980	AL-4	G	271112	543502	389
OY-2	G	292659	540412	25	AL-5	G	269960	541943	2800

G- Groundwater; L – Dumpsite Leachate; CH -Chinda; IW – Iwofe; IG – Igwuruta; OY – Oyigbo; EL – Eliozu; AL – Aluu;

Table 2.0: Analytical methods used for groundwater samples analysis

Parameter	Unit	Laboratory Standard	Parameter	Unit	Laboratory Standard
pH		APHA 4500-H^+B	Iron	mg/L	APHA 3111B
Total Dissolved Solids	mg/L	APHA 2540C	Zinc	mg/L	APHA 3111B
Electrical Conductivity	uS/cm	APHA 2510B	Manganese	mg/L	APHA 3111B
Temperature	°C		Chromium	mg/L	APHA 3111B
Calcium	mg/L	APHA 3111D	Lead	mg/L	APHA 3111B
Magnesium	mg/L	APHA 3111B	Nickel	mg/L	APHA 3111B
Dissolved Oxygen	mg/L	APHA 4500-O G	Cadmium	mg/L	APHA 3111B
Sulphate	mg/L	APHA 4500/SO_4-E	Copper	mg/L	APHA 3111B
Nitrate	mg/L	APHA 4500/NO_3-E	Polycyclic Aromatic Hydrocarbons	ug/L	USEPA 8270

Soil Pollution Index

Soil pollution assessment models are indicators used to assess the presence and intensity of anthropogenic contaminant (from dumpsite) deposition on soils. In this study, soil contamination Index (CI) and soil pollution Load Index (PLI) were determined to evaluate the impact of dumpsites on the soils in the area.

The contamination factors were derived by using the CI equation as defined by Lacutusu (2000):

$$CF = \frac{Cn}{Bn} \qquad (1)$$

Where Cn = measured metal concentration and Bn = background concentration (from DPR 2002 regulatory guidelines). The contamination factors were used as inputs for determining the soil pollution load index. The PLI gives a generalized assessment on the level of heavy metal contamination in soil. The PLI is obtained using Tomlinson's (1980) approach as follows;

$$PLI = [CF_1 \times CF_2 \times CF_3 \times \ldots\ldots \times CF_n]^{1/n} \qquad (2)$$

where, CF= contamination factor; and n = number of metals.

The PLI classification scheme according to Thomilson (1980) is as follows; 0 (background concentration in soil), >0 PLI ≤1 (unpolluted to moderately polluted soil), >1 PLI ≤2 (moderately polluted soil), >2 PLI ≤3 (moderately to highly polluted soil), >3 PLI ≤4 (Highly polluted soil) and ≥5 (very highly polluted soil).

Water quality index

Water quality index (WQI) gives an overall assessment of the water quality in any given area. It does not recognise and incorporate specific water functions such as drinking water supply, agriculture, industry, etc. Ten parameters (pH, EC, Zn, Ni, Mn, Fe, Cr, Pb, Cd and Cu) were utilized in calculating WQI for the study area. Each parameter was assigned a given weight (wi) based on the perceived health effect or the importance of the parameter on the overall water quality for drinking purposes (Vasanthavigar et al., 2010). Parameter that were considered not to be harmful to health were assigned a value of 1 while parameters that had the most impact on health were assigned a value of 5. Based on overall impact, other parameters were assigned values between 1-5. The method adopted for WQI determination in this study was based on Dhakad et al., (2008). The method involves first calculating the quality of the water parameters (qi) as follows;

$$qi = \frac{v_a}{v_s} \times 100 \quad (3)$$

Where; qi – quality rating of each parameter for n number of samples

v_a – value of parameter as obtained from laboratory analysis

v_s – value of parameter obtained from WHO water quality 2006 standard reference table.

The relative weight (Wi) was calculating as follows;

$$Wi = \frac{w_i}{\sum w_i} \quad (4)$$

Water Quality Index was determined as follows;

$$WQI = \sum(q_i w_i) \quad (5)$$

The WQI was then used to classify water quality in the area based on data from Vasanthavigar et al., (2010) as follows; 0-25 (Excellent), >25 – 50 (Good), >50 – 75 (Poor), >75 – 100 (Very poor), > 100 (Unsuitable for drinking purposes).

RESULTS AND DISCUSSION

The results of soil and groundwater quality assessment are summarized in Table 3.0 and 4.0 respectively. Soil pH ranges from 7.4 to 8.8 at dumpsite centres and from 6.8 to 8.10 in the surrounding residential areas in the dry season. Similarly, in the wet season, soil pH ranged from 7.8 to 9.1 at dumpsite centres and 7.3 to 8.4 in the surrounding residential area in the wet season.

This shows that there is no significant difference in soil pH across all sampled stations and across both seasons.

Table 5.0 shows the results of soil pollution load index for the study area. The results of soil pollution load index ranges from 0.65 at Chinda residential area to 1.45 at Aluu residential area in the wet season and from 0.74 at Chinda residential area to 1.55 at Aluu residential area. Generally, the soil quality at all dumpsite centres (Chinda, Iwofe, Oyigbo, Igwuruta and Aluu) revealed deteriorated soil quality for both wet and dry seasons, having pollution load index values exceeding unity. Only OY-1, IG-2 and Al-3 residential areas showed deteriorated soil quality in the wet season while in the dry season, CH-3, IW-5, OY-1, EL-1, EL-2, EL-3, EL-4, IG-1, IG-2, IG-4, IG-5, Al-2 and Al-3 residential station revealed deteriorated soil quality. All other residential sample station showed unpolluted soil quality, having pollution index values less than unity. In a general sense, 100% of the dumpsite centres revealed deteriorated soil quality for both wet and dry seasons, while 20% and 87% of residential sampling stations revealed deteriorated soil quality for wet and dry seasons respectively. This occurs as chemical constituents are leached from the dumpsites.

Table 3.0: Comparison of average soil chemistry for dumpsite soil and surrounding residential areas for the rainy and dry seasons along with global regulations.

Sample ID	**Sample Season**	**Media**	**PH**	**EC**	**Temp**	**Zn**	**Ni**	**Mn**	**Fe**	**Cr**	**Pb**	**Cd**	**Cu**
				ʊs/cm	°C	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg
Chinda	Dry Season	Dumpsite Soil	7.8	505	26.6	32.01	5.38	58.3	1861.6	<0.001	15.2	0.45	13.27
Iwofe			8.8	214	26.9	34.92	**94.86**	103.43	1920.9	**100.3**	48.18	0.66	**60.72**
Oyigbo			7.9	160	26.9	42.74	14.43	96.12	1879.5	32.18	84.32	**10.34**	**75.08**
Eliozu			7.4	344	26.8	29.6	20.49	90.39	1817.6	26.92	22.72	0.79	**36.64**
Igwuruta			7.8	451	27	27.83	6.76	82.61	1683.6	2.65	26.94	0.45	17.97
Chinda		Residential area	7.72	133.8	27.12	12.876	3.278	39.376	1624.96	3.765	5.248	0.33	4.848
Iwofe			7.12	285.6	27.22	16.646	3.198	39.462	1779	6.88	6.488	0.356	6.284

Oyigbo			7.5	90.2	27.36	12.634	2.804	67.408	1682.58	2.3	8.816	0.324	5.618
Eliozu			7.9	171.8	26.5	18.75	3.332	55.29	1605.32	2.335	8.066	0.296	6.786
Igwuruta			7.26	813	27.38	22.314	8.614	88.172	1788.02	10.258	20.928	0.71	31.558
Aluu			7.9	119.2	27.34	13.958	3.466	55.122	1553.14	<0.001	22.414	3.376	9.74
Chinda	Rainy Season	Dumpsite Soil	8.3	342	26	23.38	3.92	39.15	1542.3	<0.001	9.88	0.38	8.56
Iwofe			9.1	126	25.8	24.59	**55.94**	76.42	1617.4	48.69	31.65	0.44	**41.11**
Oyigbo			8.1	97	26.1	29.6	8.78	68.83	1488.6	19.81	50.13	**7.25**	**52.28**
Eliozu			7.8	218	26	18.11	12.5	67.15	1509.2	16.3	13.22	0.49	22.34
Igwuruta			8.5	299	25.9	19.53	4.14	55.35	1295.6	1.42	15.6	0.3	11.49
Chinda		Residential area	8.2	86.4	26.26	7.404	1.838	24.702	1129.82	2.575	2.928	0.2525	2.616
Iwofe			7.54	182.4	26.32	7.728	1.808	25.244	1313.42	4.66	4.702	0.224	3.25
Oyigbo			7.8	57.8	26.28	7.27	1.59	39.66	1224.6	1.37	5.486	0.218	3.634
Eliozu			8.22	112.6	26.16	11.548	2.062	33.994	1209.36	3.04	5.564	0.2225	4.222
Igwuruta			7.56	450.8	26.16	12.712	5.118	54.992	1327.92	7.202	13.904	0.418	19.222
Aluu			8.24	80.6	26.3	8.974	1.726	32.616	1128.58	<0.001	13.074	2.068	5.28
DPR (2002)						140.00	35.00	437.00	47000.00	100.00	85.00	0.80	36.00
US EPA (2002)						1100.00	72.00			11.00	200.00	0.48	270.00

into the surrounding soils which are in turn transported into the soil media by surface runoff and infiltration. Soil pollution maps revealed that the soil quality significantly deteriorates away from the dumpsite centres into the surrounding residential areas for both wet and dry seasons (Figure 2.0 and 3.0). Aluu area situated at the northwestern part of the study area shows the most deteriorated soil quality while Chinda area shows the least deteriorated soil quality for both wet and dry seasons respectively.

Water-quality index aims at giving a single value to the water quality of a source on the basis of one or the other system which translates the list of constituents and their concentrations present in a sample into a single value. The results of WQI is presented in Table 6.0 for groundwater samples in the area. The values range from 14.28 in Oyigbo to in Igwuruta in the dry season, and from 11.55 in Oyigbo to 27.41 in Oyigbo. Apart from Igwuruta (IG-1) borehole with unsuitable water quality, these result show that all other boreholes in both dry and wet seasons had good to excellent water quality based on Vasanthavigar et al., (2010) water quality classification scheme. Water quality

Table 4.0: Comparison of average groundwater chemistry for leachate and surrounding residential areas for the rainy and dry seasons along with WHO regulatory limits

Sample ID	Sample Season	Sample Media	pH	EC	TDS	Temp	DO	Salinity	NO^{3-}	$SO4^{2-}$	Ca	Mg	PAH	Zn	Ni	Mn	Fe	Cr	Pb	Cd	Cu
				µs/cm	mg/L	°C	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
Chinda	Dry Season	Residential area	4.28	87.80	48.40	28.38	4.68	22.44	0.55	1.80	2.88	0.64	0.003	0.03	<0.001	0.0342	<0.001	<0.001	<0.001	<0.001	<0.001
Iwofe			3.66	115.40	63.40	28.44	4.64	25.06	0.56	2.00	2.72	1.15	0.002	0.02	<0.001	0.1462	<0.001	<0.001	<0.001	<0.001	<0.001
Oyigbo			4.82	101.40	55.80	28.28	4.74	17.82	0.76	1.60	2.78	0.75	0.003	0.01	<0.001	0.0452	<0.001	<0.001	<0.001	<0.001	<0.001
Eliozu			3.78	127.60	70.00	27.56	5.86	29.04	0.47	2.00	0.93	0.91	0.001	0.06	<0.001	0.0982	<0.001	<0.001	<0.001	<0.001	<0.001
Igwuruta			5.70	1788	983.6	27.40	4.76	634.12	0.52	177.33	13.47	7.68	0.018	0.22	<0.001	0.0994	7.783	<0.001	0.299	0.038	0.057
Alua			4.14	30.20	16.40	27.16	5.86	8.58	0.44	1.00	0.42	0.63	0.002	0.01	<0.001	0.0668	<0.001	<0.001	<0.001	<0.001	<0.001
Chinda		Dumpsite Leachate	6.30	876.00	482.0	27.70	1.40	36.29	0.88	29.00	30.08	5.05	0.020	0.22	0.14	0.17	3.60	<0.001	0.15	0.02	0.03
Igwuruta			7.10	191.00	105.0	27.30	2.90	16.49	0.76	50.00	21.37	5.83	0.002	<0.001	0.05	0.003	0.09	<0.001	0.13	<0.001	<0.001
Iwofe			7.50	1844	1014	27.70	2.60	742.30	1.15	34.00	65.59	35.33	0.020	1.75	0.31	2.02	15.50	<0.001	0.40	0.06	0.75
Oyigbo			7.10	1264	695	27.60	4.20	448.50	2.48	5.00	48.78	18.69	0.002	0.14	0.18	0.56	11.17	<0.001	0.38	0.03	<0.001
Chinda	Wet Season	Residential area	5.20	114.40	62.94	27.80	4.28	44.88	0.20	2.00	0.92	0.20	0.007	<0.001	<0.001	0.011	<0.001	<0.001	<0.001	<0.001	<0.001
Iwofe			4.14	139.40	76.70	29.88	4.44	28.38	0.22	1.33	0.90	0.23	<0.001	0.22	<0.001	0.0792	<0.001	<0.001	<0.001	<0.001	<0.001
Oyigbo			5.64	162.40	89.33	28.98	4.30	29.00	0.29	2.50	0.74	0.35	0.015	1.20	<0.001	0.0522	<0.001	<0.001	<0.001	<0.001	<0.001
Eliozu			4.12	128.40	70.64	31.30	5.16	21.78	0.18	2.00	0.41	0.25	<0.001	0.21	<0.001	0.0736	<0.001	<0.001	<0.001	<0.001	<0.001
Igwuruta			5.88	28.80	15.86	29.64	5.02	8.04	0.19	1.00	1.06	<0.001	0.061	<0.001	<0.001	0.0135	<0.001	<0.001	<0.001	<0.001	<0.001
Alua			4.66	37.40	20.62	29.84	5.20	17.16	0.10	1.00	0.15	0.20	<0.001	0.02	<0.001	0.0453	<0.001	<0.001	<0.001	<0.001	<0.001
Chinda		Dumpsite Leachate	8.60	693	381.00	29.00	2.80	122.10	0.21	2.00	14.40	2.99	0.080	<0.001	<0.001	0.08	0.87	<0.001	<0.001	<0.001	<0.001
Eliozu			9.40	138	76.00	28.80	1.80	62.70	0.25	4.00	7.85	1.25	0.240	<0.001	<0.001	0.04	0.12	<0.001	<0.001	<0.001	<0.001
Igwuruta			9.70	9800	5390	28.90	3.50	164.90	0.18	12.00	27.01	47.68	0.020	<0.001	<0.001	0.31	1.68	<0.001	0.352	<0.001	0.012
Iwofe			8.80	1269	698	29.00	1.50	230.90	0.30	8.00	20.30	31.32	0.060	<0.001	<0.001	0.14	0.81	<0.001	<0.001	<0.001	<0.001
Oyigbo			9.6	12400	6820	28.80	1.50	2969.00	1.21	15.00	20.91	48.86	1.380	0.318	<0.001	0.13	5.3	<0.001	0.48	<0.001	0.267
WHO (2006)			6.5-8.5	1000	500		5.00	600.00	5.00	500.00	75.00	50.00	0.15	5.00	0.02	0.20	0.30	0.05	0.01	0.003	1.00

Table 5.0: Pollution Load Index interpretation for soils in the study area

Sample ID	Media	Pollution Load Index	Interpretation	Pollution Load Index	Interpretation
		Wet Season		Dry Season	
Chinda	Dumpsite Soil	1.03	Polluted Soil Quality	1.08	Polluted Soil Quality
Iwofe	Dumpsite Soil	1.24	Polluted Soil Quality	1.33	Polluted Soil Quality
Oyigbo	Dumpsite Soil	1.43	Polluted Soil Quality	1.50	Polluted Soil Quality
Igwuruta	Dumpsite Soil	1.12	Polluted Soil Quality	1.20	Polluted Soil Quality
Aluu	Dumpsite Soil	1.04	Polluted Soil Quality	1.11	Polluted Soil Quality
CH-1	Residential Soil	0.93	Unpolluted	0.99	Unpolluted
CH-2	Residential Soil	0.65	Unpolluted	0.74	Unpolluted
CH-3	Residential Soil	1.00	Unpolluted	1.06	Polluted Soil Quality
CH-4	Residential Soil	0.92	Unpolluted	0.99	Unpolluted
CH-5	Residential Soil	0.92	Unpolluted	0.98	Unpolluted
IW-1	Residential Soil	0.95	Unpolluted	1.00	Unpolluted
IW-2	Residential Soil	0.95	Unpolluted	1.00	Unpolluted
IW-3	Residential Soil	0.94	Unpolluted	1.00	Unpolluted
IW-4	Residential Soil	0.95	Unpolluted	1.00	Unpolluted
IW-5	Residential Soil	0.97	Unpolluted	1.04	Polluted Soil Quality
OY-1	Residential Soil	1.02	Polluted Soil Quality	1.08	Polluted Soil Quality
OY-2	Residential Soil	0.92	Unpolluted	0.97	Unpolluted
OY-3	Residential Soil	0.93	Unpolluted	0.98	Unpolluted
OY-4	Residential Soil	0.94	Unpolluted	1.00	Unpolluted
OY-5	Residential Soil	0.88	Unpolluted	0.95	Unpolluted
EL-1	Residential Soil	0.98	Unpolluted	1.04	Polluted Soil Quality
EL-2	Residential Soil	0.96	Unpolluted	1.02	Polluted Soil Quality
EL-3	Residential Soil	0.96	Unpolluted	1.02	Polluted Soil Quality
EL-4	Residential Soil	0.94	Unpolluted	1.01	Polluted Soil Quality
EL-5	Residential Soil	0.81	Unpolluted	0.88	Unpolluted
IG-1	Residential Soil	1.10	Unpolluted	1.17	Polluted Soil Quality
IG-2	Residential Soil	1.19	Polluted Soil Quality	1.26	Polluted Soil Quality
IG-3	Residential Soil	0.93	Unpolluted	1.00	Unpolluted
IG-4	Residential Soil	0.97	Unpolluted	1.04	Polluted Soil Quality
IG-5	Residential Soil	0.97	Unpolluted	1.04	Polluted Soil Quality
Al-1	Residential Soil	0.86	Unpolluted	0.95	Unpolluted
Al-2	Residential Soil	0.98	Unpolluted	1.06	Polluted Soil Quality
Al-3	Residential Soil	1.45	Polluted Soil Quality	1.55	Polluted Soil Quality
Al-4	Residential Soil	0.93	Unpolluted	0.99	Unpolluted
Al-5	Residential Soil	0.89	Unpolluted	0.97	Unpolluted

index map for the dry season revealed the most deteriorated water quality (IG-1) lies in the northern part of the study area very close to Igwuruta dumpsite centre (16.0 m from centre of dumpsite) (Figure 4.0). In the wet season, only Oyigbo located towards the eastern part of the study area revealed good water quality, all other area revealed excellent water quality (Figure 5.0). Abraham and Udom (2018) also reported

Table 6.0: Summary of water quality indices determination for groundwater in the area

Sample ID	WQI	Interpretation	WQI	Interpretation
	Dry Season		**Wet Season**	
CH-1	16.53	Excellent	14.9	Excellent
CH-2	16.35	Excellent	12.34	Excellent
CH-3	14.56	Excellent	16.27	Excellent
CH-4	15.26	Excellent	13.93	Excellent
CH-5	16.93	Excellent	16.02	Excellent
IW-1	27.04	Good	21.96	Excellent
IW-2	15.48	Excellent	15.93	Excellent
IW-3	29.82	Good	20.95	Excellent
IW-4	18.35	Excellent	23.45	Excellent
IW-5	26.81	Good	11.65	Excellent
OY-1	17.84	Excellent	18.48	Excellent
OY-2	22	Excellent	27.41	Excellent
OY-3	17.39	Excellent	15.42	Excellent
OY-4	14.28	Excellent	15.34	Excellent
OY-5	17.77	Excellent	11.55	Excellent
EL-1	20.78	Excellent	25.37	Good
EL-2	19.46	Excellent	17.97	Excellent
EL-3	16.71	Excellent	17.89	Excellent
EL-4	28.47	Good	15.54	Excellent
EL-5	23.43	Excellent	17.02	Excellent
IG-1	**272.35**	**Unsuitable**	12.93	Excellent
IG-2	16.49	Excellent	13.65	Excellent
IG-3	16.63	Excellent	12.2	Excellent
IG-4	17.61	Excellent	16.65	Excellent
IG-5	14.88	Excellent	14.41	Excellent
Al-1	17.7	Excellent	16.73	Excellent
Al-2	14.58	Excellent	12.78	Excellent
Al-3	22.65	Excellent	14.6	Excellent
Al-4	17.14	Excellent	16.38	Excellent
Al-5	16.14	Excellent	14.46	Excellent

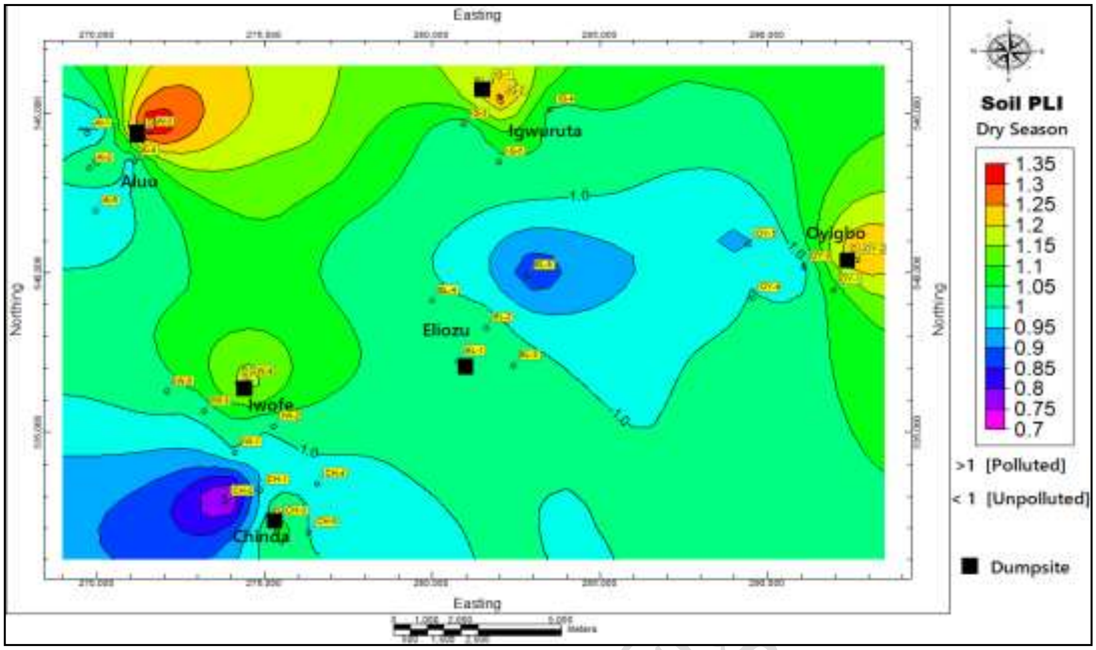

Figure 2.0: Pollution load index showing the heavy metal pollution status in the area during the dry season excellent water quality for Oyibo community in Port-Harcourt. These results suggest that the dumpsites are not significantly deteriorating water quality in the area.

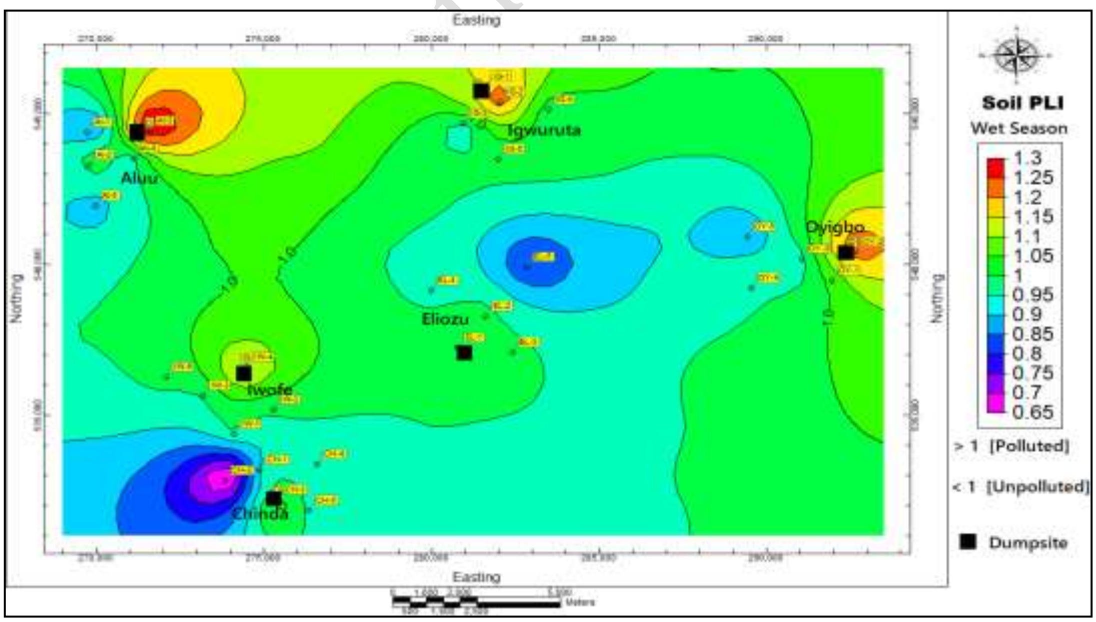

Figure 3.0: Pollution load index showing the heavy metal pollution status in the area during the wet season

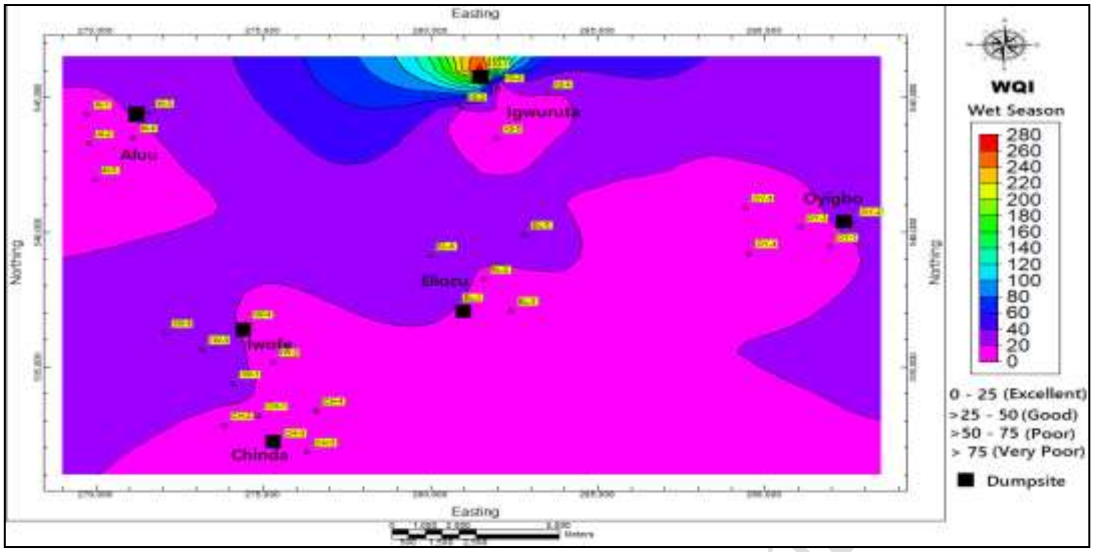

Figure 4.0: Water quality index showing the overall groundwater quality in the area during the wet season

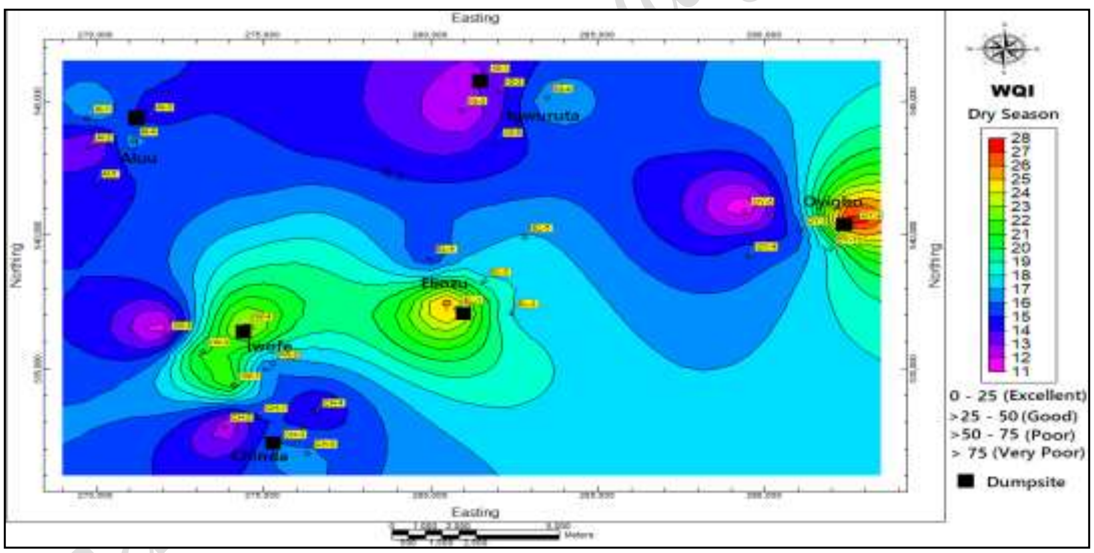

Figure 5.0: Water quality index showing the overall groundwater quality in the area during the dry season

CONCLUSION AND RECOMMENDATION

Dumpsite soils revealed alkaline composition as opposed to acidic groundwater composition, which suggest groundwater acidity is predominantly from acid rain. Ni, Cr, Cu and Cd had concentrations that exceeded DPR limits in some dumpsite centres compared with all other metals analyzed in soils (Zn, Ni, Mn, Fe, Cr, Pb, Cd and Cu). Overall soil heavy metal pollution analyzed using pollution load index revealed all dumpsite centres have deteriorated soil quality for both wet and dry seasons, while 20% and 87% of residential areas revealed deteriorated soil quality for wet and dry seasons respectively. Groundwater across the entire area is very acidic in both wet and dry season and exceeds WHO limit for potable water. Water quality index revealed most of the water samples in the dry season and all the water samples in the wet season are having good to excellent quality. Only IG-1 borehole in Igwuruta showed unsuitable water quality situated towards the northern part of the study area.

Generally, groundwater quality during dry season is more deteriorated compared with the wet season across the area. The study therefore recommends that groundwater in the area be treated with lime or carbonates to reduce its acidity before subsequent consumption.

REFERENCES

Abraham, N.C., and Udom, G.J. (2018). Characterization of Groundwater Quality Using Water Quality Index in Umuebulu IV Oyigbo, Rivers State. Journal of Geography, Environment and Earth Science International, 14(2): 1-16.

Aderemi, O. A., and Falade, T. C. (2012). Environmental and Health Concerns Associated with Open Dumping of Municipal Solid Waste: A Lagos, Nigeria Experience. *American Journal of Environmental Engineering 2012,* 2(6): 160 – 165.

APHA (2005). American Public Health Association *Standard Methods for the Examination of Water and Wastewater (21st edn.)*American Public Health Association: Washington DC.

Amajor, L. C. and Ofoegbu C. O. (1988). Determination of Polluted Aquifers by Stratigraphically Controlled Biochemical Mapping; Example from the Eastern Niger Delta, Nigeria. Groundwater and Mineral Resources of Nigeria, pp. 62-73.

Ayotamuno, J. M., and Gobo, A. E. (2004). Municipal solid waste management in Port Harcourt, Nigeria: Obstacles and Prospects.*Management ofEnvironmental Quality: An International Journal,* 15 (4), 389 – 398. DOI: 10.1108/14777830410540135 URL: http://www.emeraldinsight.com/1477-7835.htmEmerald Group Publishing Limited

DPR (2002). Department of Petroleum Resources. Environmental guidelines and standards for the petroleum industry in Nigeria, revised edn. Department of Petroleum Resources, Ministry of Petroleum and Mineral Resources, Abuja, Nigeria.

Dhakad, N.K., Deepak, S., and Choudhary, P. (2008). Water quality index of ground water (GWQI) of Jhabua Town, M.P (India). J. Environ. Res. Dev., 2:443–446.

Etu – Efeotor, J.O and Odigi, M.I (1983).Water Supply Problems in the Eastern Niger Delta. *Journal of Mining and Geology.* 20: 183-193

Groundwater Contamination and Environmental Risk Assessment of a Hydrocarbon Contaminated Site in Eastern Niger Delta, Nigeria.

Groundwater Contamination and Environmental Risk Assessment of a Hydrocarbon Contaminated Site in Eastern Niger Delta, Nigeria.

Giadom, FD, Akpokodje EG, Tse AC (2015) Determination of migration rates of contaminants in a hydrocarbon-polluted site using non-reactive tracer test in the Niger Delta, Nigeria. Environmental Earth Sciences. DOI 10.1007/s12665-015-4094-3

Giadom, FD, Akpokodje EG, Tse AC (2015) Determination of migration rates of contaminants in a hydrocarbon-polluted site using non-reactive tracer test in the Niger Delta, Nigeria. Environmental Earth Sciences. DOI 10.1007/s12665-015-4094-3

Giadom, FD, Akpokodje EG, Tse AC (2015) Determination of migration rates of contaminants in a hydrocarbon-polluted site using non-reactive tracer test in the Niger Delta, Nigeria. Environmental Earth Sciences. DOI 10.1007/s12665-015-4094-3
Giadom, FD, Akpokodje EG, Tse AC (2015) Determination of migration rates of contaminants in a hydrocarbon-polluted site using non-reactive tracer test in the Niger Delta, Nigeria. Environmental Earth Sciences. DOI 10.1007/s12665-015-4094-3
Giadom, F. D. and Tse, A. C. (2015). Groundwater Contamination and Environmental Risk Assessment of a Hydrocarbon Contaminated Site in Eastern Niger Delta Nigeria. Journal of Environment and Earth Science. ISSN 2224-3216 (Paper) ISSN 2225-0948 (Online). 5 (14)

Isirimah, M. O. (2000). *Soils and Environmental Pollution Management.* Owerri: Nichdano Publishers. p. 15-17

Lacutusu, R. (2000). Appraising levels of soil contamination and pollution with heavy metals In Heinike H. J., Eckselman W., Thomasson A.J., Jones R.J.A, Montanarella L. and Buckeley B. (eds.). Land information systems for planning the sustainable use of land resources. European Soil Bureau Research Report No. 4. Office of Official Publication of the European Communities, Luxembourg, 393-402.

Ladele, S. I., and Ogundele, M. (2017). Municipal Waste Management for Environmental Sustainability: A Case Study of University of Ibadan. *Journal of Nigerian Environmental Society (JNES),*11 (1), 160-174. Online: http://www.jnes-nes.org

Mangizvo, R. V. (2008). An Overview of the Management Practices at Solid Waste Disposal Sites in African Cities and Towns. *Journal of Sustainable Development in Africa,* 12(7) (2010): 233-239.

Okoli, N, C. and Egobueze, A. (2020). Waste Management Policy Implementation in Nigeria: A study of Rivers State waste management agency. International Journal of Advanced Research, 8. 755-765.

Patil, C., Narayankar, S., and Virupakshi, A. (2013). Assessment of Groundwater Quality around Solid Waste Landfill Area – A Case Study. *International Journal of Innovative Research, Engineering and Technology.* 2(7):3131-3136

Short, K.C. and Stauble, A.J. (1967). Outline Geology of the Niger Delta. AAPG Bull 51; 761-779.

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. Mar. Res., 33(1–4): 566–575.

Ubong, I. U., Ngah, S. A., and Ozoekwe, V. E. (2015). Polycyclic Aromatic Hydrocarbons (PAHS) and Heavy Metals in Fish Tissues of Rumuola Borrow Pit, Port Harcourt. Rivers State, Nigeria. *Journal of Geo and Environmental Science Research* 3(3) 01-21. Online: http//www.professionaljournals.org/JGESR

Vasanthavigar, M., Srinivasamoorthy, K., Vijayaragavan, K. (2010). Application of water quality index for groundwater quality assessment: Thirumanimuttar sub-basin, Tamilnadu, India. Environ. Monit. Assess., 171:595–609.

W.H.O. (2006). World Health Organisation *Guidelines for Drinking Water Quality.* Vol. Recommendations, World Health Organization. Geneva, pp: 130