

## Hydrogeology and Water Quality Assessment (WQA) of Ikhueniro and Okhuahe Using Water Quality Index (WQI)

O. M. Omorogieva<sup>1\*</sup>, O. I. Imasuen<sup>1</sup>, M. I. Isikhueme<sup>1</sup>, O. A. Ehinlaye<sup>1</sup>,  
B. Anegebe<sup>2</sup> and M. O. Ikponmwen<sup>3</sup>

<sup>1</sup>Department of Geology, University of Benin, P.M.B 1154 Benin City, Nigeria.

<sup>2</sup>Department of Chemistry, Western Delta University, Oghara, Delta State, Nigeria.

<sup>3</sup>Department of Physics, University of Benin, Benin City, Nigeria.

### Authors' contributions

*This work was carried out in collaboration between all authors. All authors read and approved the final manuscript.*

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### ABSTRACT

About half of the people that live in developing countries do not have access to safe drinking water and 73% have no sanitation, thus some of their wastes contaminate their drinking water supply leading to a high level of suffering. In view of the foregoing, this study was carried out in two suburbs in Benin City, Edo state Nigeria in order to examine the hydrogeology and water quality of these communities. Three boreholes were drilled to the depth of 57.60, 60.35 and 45.68 meters respectively while soil samples were taken at 4.57 meter intervals in order to determine the soil properties, aquifer geometry and subsurface geology. Water samples from these wells were collected including two other existing boreholes and a sample from a nearby river in order to

\*Corresponding author: E-mail: [osakpolor.omorogieva@physci.uniben.edu](mailto:osakpolor.omorogieva@physci.uniben.edu);

evaluate the water quality, using water quality index (WQI). The water samples were analysed for physico-chemical parameters such as TDS, pH, TH, EC,  $\text{NO}_3^-$ ,  $\text{SO}_4^{2-}$ ,  $\text{Cl}^-$ ,  $\text{Mg}^{2+}$  using standard laboratory procedures while the heavy metals were analysed using Atomic Absorption Spectrometer (AAS) model 969 unicam series with air acetylene flame. The results obtained from physico-chemical analysis were used to compute the values for water quality index and the results revealed that three of the wells were extremely contaminated, two were of good quality and the other poor. The hydrogeological study revealed that the aquifer geometry is unconfined basically of fine to coarse sands grains with high porosity and permeability which enhance water percolation. The groundwater flows from North West towards South East; and it was observed that water quality increases from adjacent landfill towards the river in the study area which suggest that the leachate emanating from the unprotected landfill coupled with the geography and geology of the terrain is a major factor contributing to the poor water quality. The authors advise a proper legislature and enforcement of existing environmental laws to arrest the situation.

*Keywords: Borehole; water quality index; hydrogeology; landfill and government.*

## 1. INTRODUCTION

Fifty decades ago, Ikhueniro and environs was a replica of a typical rural setting but have gained popularity in recent times due to its strategic location and expansion of Benin metropolis coupled with the influx of land speculators. The only source of fresh and clean water for both domestic and commercial use within the study area is groundwater. Since landfill have been identify as a major source of groundwater contamination; the study was initiated in order to examine the quality of groundwater by applying WQI technique, and report any negative observations if any, this will help to inform global arena and policy maker to addressed the situation; because one reason the provision of safe drinking water is of paramount concern is that 75% of all diseases in developing countries arise from polluted drinking water [1-3]. It has been reported by WHO-UNICEF and TWAS that each day, about 25,000 people die from use of contaminated water and several more suffer from water borne illnesses [1,2] this is alarming because more than half of the people that live in developing countries do not have access to safe drinking water and 73% have no sanitation, thus some of their wastes eventually contaminate their drinking water supply leading to a high level of suffering [2]. In developing countries like Nigeria, land filling is a major concern with respect to existing circumstances [4-7]. The uncontrolled dumping of solid waste on the outskirts of cities is creating serious environment and public health problems since the waste contain hazardous materials such as heavy metals [8-12]. The improper management results in high possibility of leachate leakage with subsequent impact on soils, plants, groundwater,

aquatic organisms and human beings [4,13,10-12]; it is therefore imperative to monitor the quality of water resources for drinking purpose [1,2,4,10,14,15] in order to advise government and concerned authorities as well as meeting the target of the millennium development goals (MDGs) which is aimed at having access to safe drinking water and basic sanitation [16]. The present study is aimed at evaluating the hydrogeology and water quality of Ikhueniro and Okhuahe suburbs using water quality index as proposed by Horton, Srinivas and Nageswarao [7,17-22]. Understanding the hydrogeology and aquifer geometry of a terrain is an intricate aspect of groundwater pollution studies [13,10-12]. The concept of Water Quality Index (WQI) to represent gradation in water quality was first proposed by Horton [7,23,24]. It is a well known method for assessing water quality that offers a simple stable, reproductive unit of measurement and communicate information of water quality to policy makers concerned citizens just as the application of geographic information system in the evaluation and mapping of water wells for irrigation, Omran et al. [25]. Srinivas and Negeswararao, Li et al. Sudhakar et al. as well as Horton and several others have applied the concept of WQI in groundwater pollution studies [7,23,18,19] hence its application in this study.

### 1.1 Location, Climate and the Geology of the Study Areas

Ikhueniro and Okhuahe are suburbs located in south senatorial district of Edo state (Fig. 1). Edo State is one of the thirty six states in Nigeria with the population of 3,233,366 and total land area of 19,794 sq.km [3,26]. The state is subdivided into

three senatorial district and lies approximately on latitudes 5°44'N and 7°37'N and on longitudes 5°44' and 6°43'E and share common boundaries with Kogi in the north, Ondo to the west, Delta and Anambra to the east and north east respectively. Both communities are in Uhumwode Local Government Area of the state with the administrative headquarter at Ehor. Uhumwode has an area of 2,033 km<sup>2</sup> and a population of 121,749 with a population density of 59.89 km<sup>2</sup> [3,26,27], both communities share common boundaries with one another and their neighbouring communities. The topography of the terrain is characterized by a gentle slope plunging towards the south eastern portion of the study area and gradually increases steepness towards Okhuahe community. The distance of the study sites from the city center is about 14 and 16 km respectively; due to urbanization and anthropogenic activities, the vegetation has been reduced to the barest minimum with visible urban development. The vegetation favours agricultural products such as cassava, pawpaw, palm fruits and plantain. The inhabitants of the communities depend largely on groundwater resources for domestic and commercial use. Groundwater is recharged naturally in the study area through rainfall and snow. Natural discharge often occurs at springs and seeps, and can form oases or wetlands. In this study, groundwater discharge is through river Okhuahe, private, public and industrial boreholes, also often withdrawn for agricultural and municipal use by constructing

and operating extraction wells [10,20]. Ikhueni and Okhuahe are on the coordinates of 06°19'38.1" N and 005°44'5.2" E, 06°19'21.9" N and 005°46'02.9" E respectively (Fig. 1). Ikhueni landfill which belongs to Edo state government is now at the center of the community; constitutes an important aspect of this study because the aquifer geometry in the area is shallow and unconfined as a result, leachates from the adjacent landfill have a high probability of seeping into the groundwater system thereby contaminating the aquifer.

The study area falls under tropical equatorial climate which is characterized by heavy annual rainfall throughout the year with an average monthly rainfall and temperature of 50 mm (2 inches) and 27°C (80°F) respectively [28]. The Geology belongs to the Benin Formation (FM) which is the youngest of the Tertiary Niger Delta [29,30]; it consists of massive, highly porous, fresh water bearing sandstone with local thin shale inter-beds which are thought to be of braided stream origin [29]. The shale inter-beds usually contain plant remains and lignite streak. It is thicker in the central onshore part where it is about 1970 m (1.97 km) and thin towards the delta margins. Short and Stauble [30], carried out studies on the Benin Formation in Elele1 well 39km Northwest of Port Harcourt and define the base of the Benin Formation by the first marine foraminifera within the shale and assigned the age of Recent to Miocene.

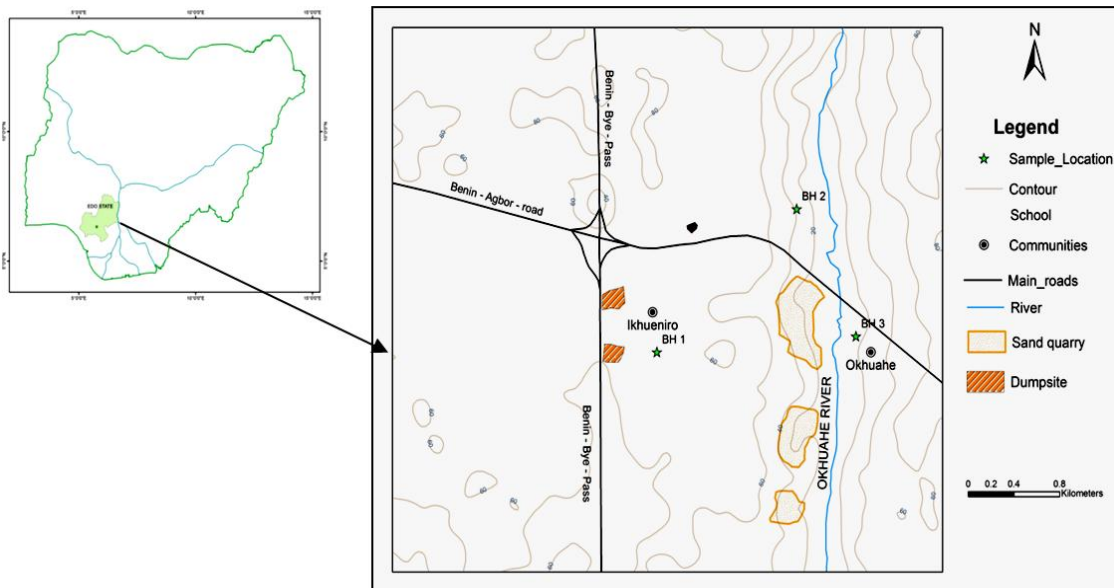


Fig. 1. Map of Nigeria and Edo state indicating Ikhueni and Neighbouring communities

## 2. METHODOLOGY

Ikhueniro and Okhuahe communities are in Uhumwode Local Government Area of Edo State (Fig. 1). In order to properly understand the hydrogeology of the areas, three boreholes were drilled by the application of rotary method and the depth to water table as well as the flow direction were determine. Water Quality Assessment (WQA) based on Water Quality Index (WQI) proposed by Horton, Srinivas and Nageswararao, Sudhakar et al. with slight modification was employed in this study [7,17,31,18,19]. Six water samples were collected from five borholes including the drilled boreholes and river Okhuahe in Okhuahe community being the only river present in the study area. The procedures for water sample collection as specify by America Public Health Association and Allen et al. [31,32] were adopted. The water samples were analyzed for physico-chemical parameters such as pH, Total Hardness (TH), Calcium ( $Ca^{2+}$ ), Maganessium ( $Mg^{2+}$ ), Total Dissoved Solid (TDS), Nitrate ( $NO_3^-$ ), Chloride ( $Cl^-$ ), Lead ( $Pb^{2+}$ ), Hexavalent Chromium ( $Cr^{6+}$ ), Sulphate ( $SO_4^{2-}$ ), Alkalinity (Alk.) and Electrical Conductivity (EC). Temperature, Electrical conductivity (EC) and pH were recorded in situ while on field with the appropriate instruments. TDS were determined using gravimetric method, APHA [31] in which the sample was vigorously shaken and a measured volume was transferred into 100 ml graduated cylinder by means of a funnel. The sample was filtered through a glass fibre filter and vacuum applied for 3 minutes to ensure that water was removed as much as possible. The sample was washed with deionised water and suction continued for at least three (3) minutes. The total filtrate was transferred to a weighted evaporating dish and evaporated to dryness on a water bath. The evaporated sample was dried for at least one (1) hour at 1800°C. The dried sample was cooled in desiccators and weighed. Drying and weighing process was repeated until a constant weight was obtained. Total Alkalinity, TH and  $Cl^-$  concentrations were determined using titrimetric methods. Alkalinity was determined by titration of 50 ml water sample with 0.1 M hydrochloric acid to pH 4.5 using methyl orange as indicator while TH was analysed by titration of 50 ml water sample with standard EDTA at pH10 using Erichrome black T as indicator. The  $Cl^-$  content was determine by argentometric method. The sample was titrated with standard silver nitrate using potassium chromate indicator [33]. The heavy metal

content were determined using Atomic Absorption Spectrometer (AAS) uncam series model 969 with air acetylen flame after digestion with perchloric, nitric and HCl. The parameters were selected based on their known impact, the geology of the study environment and their general contribution to water quality [34].

### 2.1 Water Quality Index (WQI)

The calculation of WQI involve the application of the three (3) fundamental steps as proposed by Hortin, Srinivas and Negeswararao, Sudhakar, Li et al. [7,17,18,19]. The first step is the assignment of weight ( $w_i$ ) to each parameter measured in the water samples according to their relative importance in the overall quality of water for drinking purpose as propose by Srinivas and Horton [7,23,34]. In this study, a maximum weight of five (5) was assigned to  $NO_3^-$ , four (4) to pH, TDS, and EC respectively. Others include  $Cl^-$ , Pb,  $Cr^{6+}$ ,  $SO_4^{2-}$  which has been assigned a weight of three (3) while TH,  $Ca^{2+}$ ,  $Mg^{2+}$  and Alkalinity has been assigned a weight of two (2), Table 1. The second step involves the determination of the relative weight ( $W_i$ ) using the formulae;

$$W_i = \sum_{i=1}^{wi/n} w_i$$

Where  $W_i$  is the relative weight,  $w_i$  is the weight assigned to each parameter and  $n$  is the number of parameters (Table 1). The third step is the calculation of the quantity rating scale ( $q_i$ ) for each parameter by applying the equation;  $q_i = (M_i - M_{i0}) / (Z_i - M_{i0}) * 100$ . In this equation,  $M_i$  is the concentration in mg/L of each parameter measured in the laboratory for each water sample,  $M_{i0}$  is the ideal value of the parameter in pure water whereas  $Z_i$  is the Nigeria drinking water standard specified by Standard Organization of Nigeria [14,15]. The ideal value of pH was taken to be 7 because at pH 7 water is neither acid nor basic. On the other hand, the values for the other parameters is taken to be zero (0) because pure water is assumed to be free from impurities.

The final stage of the experiment is the calculation of WQI by applying the formulae;

$$WQI = \sum_{i=1}^n S1i$$

Where  $S1i$  is the product of  $W_i$  and  $q_i$  (Table 4). Table 5 shows the WQI calculated and their corresponding remarks.

### 3. RESULTS AND DISCUSSION

The results obtained from the borehole logs during drilling show that the area is dominated with sands and thin lenses of clay (Figs. 2-4). The aquifer is shallow and unconfined ranging from 57.60 m to 60.35 m. Static water level of 50.35 m, 47.60 m and 42.60 m, and elevation of 85.34 m, 34 m, and 84.82 m respectively were recorded. The coordinate and the lithologic description of the boreholes were determine and summarize in Figs. 2-4. The rock units is composed of fine to coarse sands with intercalation of clay; it is porous and highly permeable and enhance the percolation of water from recharge source to the aquifer bearing unit [20]. The area is subject to high rainfall [3,26] which enhances the mobility and percolation of contaminants such as heavy metal into the aquifer. The data obtained from the hydrological study, revealed that the groundwater flows from Northwest (NW) to Southeast (SE).

The overall Water Quality Index (WQI) of all the six sampling stations were calculated according to the procedure outline by Srinivas and Negaswararao, Horten [7,23] and the results are presented in Table 4. Table 1 represent Nigeria Standard for drinking water and the values calculated for  $w_i$  and  $W_i$  respectively while Table 2 represents physico-chemical values obtained for water samples analysis. Physico-chemical result for each parameter in the six sampling stations revealed that the pH was fairly acidic with a range of 5.71 – 6.8 and a mean value of 6.16; this value is above the permissible limit specify by SON and WHO-UNICEF for drinking water [2,14]. Table 2 also show that magnesium exceed the specified value of 0.2 mg/L, the

values obtained in this study range between 1.14 mg/L in sample station 4 (GW4) to 160 mg/L in station 1 (GW1). Other parameters that were observed to have high values above permissible limit include  $Cl^-$  and  $Pb^{2+}$  and hexavalent chromium ( $Cr^{6+}$ ), Table 2. In station 1 and 2 (GW1 and GW2) 400 mg/L and 130 mg/L of  $Cl^-$  were recorded respectively. In Table 3 and 4, the values obtained from  $q_i$  and  $S_{li}$  for the overall computation of WQI was presented. WQI in this study range from good to extremely poor (Table 5). It was observed that GW1- GW3 fall under extremely poor WQI with a value of 4436.22 mg/L, 1019.30 mg/L and 103679.10 mg/L respectively (Table 4 and 5); GW4 and RW (station 4 and 5) were classified under good WQI with a value of 78.38 mg/L and 95.58 mg/L respectively, whereas GW5 (station 5) was classified under poor WQI with a value of 112.27 mg/L (Tables 4 and 5) respectively. The parameters observed to have contributed to the poor water quality in the study area include TDS, EC,  $Mg^{2+}$ ,  $Pb^{2+}$ ,  $Cl^-$ , Alkalinity,  $NO_3^-$ ,  $Cr^{6+}$  and  $SO_4^{2-}$  (Table 4). Correlation between these parameters show a strong positive relationship with a coefficient range ( $r$ ) of 0.96 – 0.99 indicating a similar source. The source of these parameters could be traced to unprotected landfill which is now at the center of the study site as it was observed that concentration of the parameters decrease in values away from the landfill with increase in water quality (hydrodynamic dispersion). pH plays a major role in the dissolution of substance in water, this could also be another factor for the abundance of the chemical species present in the water samples (Table 1) with respect to pH values recorded in the study.

Table 1. The valus for  $W_i$ ,  $w_i$  and SON

S/N	Parameters measured (mg/L)	Nigeria standard used (SON)	Weight assigned ( $w_i$ )	Relative weight ( $W_i$ )
1	pH	7.5	4	0.1081
2	TH	150	2	0.0540
3	$Ca^{2+}$	75	2	0.0540
4	$Mg^{2+}$	0.2	2	0.0540
5	TDS	500	4	0.1081
6	$NO_3^-$	50	5	0.1351
7	$Cl^-$	100	3	0.0810
8	$Pb^{2+}$	0.01	3	0.0810
9	$Cr^{6+}$	0.05	3	0.0810
10	$SO_4^{2-}$	100	3	0.0810
11	Alkalinity	100	2	0.0540
12	EC	1000	4	0.1081

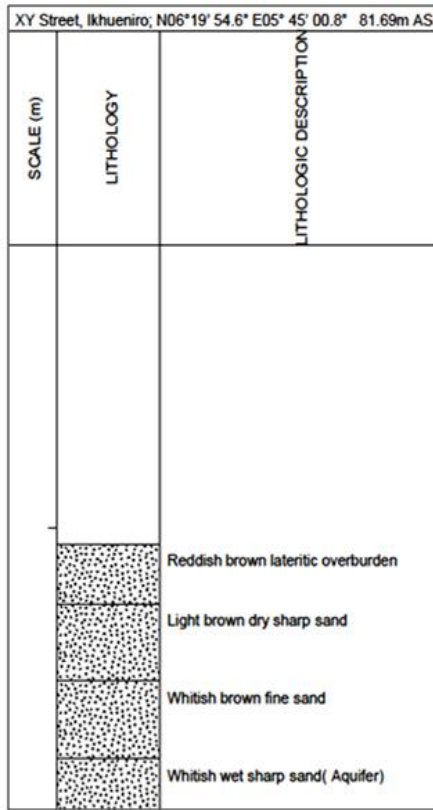


Fig. 2

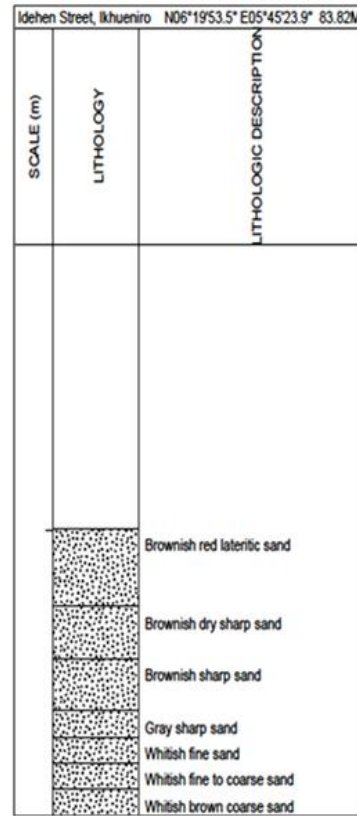


Fig. 3

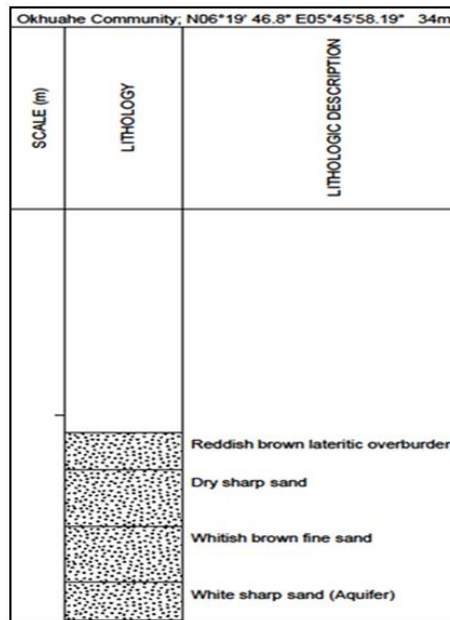


Fig. 4.

Figs. 2-4. Coordinates and Lithologic description of the boreholes [11]

**Table 2. Physico-chemical result for measured parameters**

S/N	Code (mg/L)	Parameters measured (mg/L)											
		pH	TH	Ca <sup>2+</sup>	Mg <sup>2+</sup>	TDS	NO <sub>3</sub> <sup>-</sup>	Cl <sup>-</sup>	Pb	Cr <sup>6+</sup>	SO <sub>4</sub> <sup>2-</sup>	Alk	EC
1	GW <sub>1</sub>	6.80	12.00	121.00	160.00	200.00	0.30	400.00	0.04	ND	280.00	200.00	400.00
2	GW <sub>2</sub>	6.33	7.00	29.00	45.00	35.00	2.94	18.90	0.03	0.03	124.00	75.00	70.00
3	GW <sub>3</sub>	5.71	10.00	0.81	2.86	42.00	5.47	39.06	0.01	0.12	794.00	69.40	84.00
4	GW <sub>4</sub>	5.78	8.50	0.76	1.14	47.50	2.09	30.40	0.001	0.00	1.33	3.46	95.00
5	GW <sub>5</sub>	6.20	5.00	1.81	4.04	29.26	0.36	130.00	0.05	ND	109.79	26.92	58.53
6	RW	6.11	7.50	2.59	6.76	41.71	3.50	22.53	0.07	0.02	0.92	38.38	83.43

Note: GW and RW represents groundwater and river water respectively

**Table 3. Values for q<sub>1</sub> in each parameter measured in water samples**

S/N	Sample code (mg/L)	q <sub>1</sub> for parameter measured (mg/L)											
		pH	TH	Ca <sup>2+</sup>	Mg <sup>2+</sup>	TDS	NO <sub>3</sub> <sup>-</sup>	Cl <sup>-</sup>	Pb	Cr <sup>6+</sup>	SO <sub>4</sub> <sup>2-</sup>	Alk	EC
1	GW <sub>1</sub>	-40	8.00	161.33	80000.00	40.00	0.60	400.00	400.00	0.00	280.00	200.00	40.00
2	GW <sub>2</sub>	-134	4.67	38.67	2250.00	875.00	58.80	630.00	300.00	60.00	4133.33	3750.00	1750.00
3	GW <sub>3</sub>	-258	6.67	1.08	5291.00	38850.00	4047.80	48174.00	100.00	240	979266.70	128390	77700.00
4	GW <sub>4</sub>	-244	70.83	1.01	0.71	23.75	696.67	7.60	10.00	0.00	0.48	1.73	23.75
5	GW <sub>5</sub>	-160	71.42	2.41	8.98	83.60	12.24	687.83	500.00	0.00	88.54	35.89	83.61
6	RW	-178	75.00	3.45	236.24	99.31	63.98	57.68	700.00	40.00	0.12	55.30	99.32

**Table 4. S<sub>1i</sub> calculated for each parameter for the six samples (mg/L)**

S/N	Parameters	GW1	GW2	GW3	GW4	GW5	RW
1	pH	-4.32	-14.49	-27.89	-26.38	-17.29	-19.24
2	TH	0.43	0.25	0.36	3.83	3.86	4.05
3	Ca <sup>2+</sup>	8.72	2.09	0.06	0.05	0.13	0.19
4	Mg <sup>2+</sup>	4324.32	121.62	286	0.04	0.49	12.78
5	TDS	4.32	94.59	4200	2.57	9.04	10.73
6	NO <sub>3</sub> <sup>-</sup>	0.08	7.95	547	94.14	1.65	8.65
7	Cl <sup>-</sup>	32.43	51.08	3906	0.62	55.77	4.68
8	Pb <sup>2+</sup>	32.43	24.32	8.11	0.81	40.54	56.76
9	Cr <sup>6+</sup>	0	4.86	19.46	0	0	3.24

S/N	Parameters	GW1	GW2	GW3	GW4	GW5	RW
10	SO <sub>4</sub> <sup>2-</sup>	22.70	335.14	79400	0.04	7.19	0.01
11	Alk	10.81	202.70	6940	0.09	1.94	2.99
12	EC	4.32	189.19	8400	2.57	9.04	10.74
13	WQI	4436.22	1019.30	103679.10	78.38	112.27	95.58

**Table 5. Water quality index and remarks**

WQI	Water quality remark	GW1	GW2	GW3	GW4	GW5	RW
< 50	Excellent	-	-	-	-	-	-
50-100	Good	-	-	-	✓	-	✓
100-200	Poor	-	-	-	-	✓	-
200-500	Very poor	-	-	-	-	-	-
>500	Extremely poor	✓	✓	✓	-	-	-

**Table 6. Corelation matrix of parameter measured**

	pH	TH	Ca <sup>2+</sup>	Mg <sup>2+</sup>	TDS	NO <sub>3</sub> <sup>-</sup>	Cl <sup>-</sup>	Pb	Cr	SO <sub>4</sub> <sup>2-</sup>	Alk	EC
pH	1											
TH	0.4436	1										
Ca <sup>2+</sup>	0.2580	-0.5391	1									
Mg <sup>2+</sup>	0.1426	-0.4750	0.9731	1								
TDS	-0.9997	-0.4548	-0.2590	-0.1478	1							
NO <sub>3</sub> <sup>-</sup>	-0.9861	-0.3789	-0.3151	-0.1931	0.9851	1						
Cl <sup>-</sup>	-0.9999	-0.4498	-0.2552	-0.1413	0.9998	0.9845	1					
Pb	0.4503	0.3228	0.1252	0.0967	-0.4521	-0.5620	-0.4482	1				
Cr	-0.9625	-0.5052	-0.3047	-0.2378	0.9669	0.9351	0.9629	-0.3681	1			
SO <sub>4</sub> <sup>2-</sup>	-0.9999	-0.4461	-0.2578	-0.1432	0.9998	0.9860	0.9999	-0.4509	0.9634	1		
Alk	0.1967	-0.4726	0.0299	-0.1896	-0.1764	-0.2268	-0.1898	-0.0686	0.0208	-0.1927	1	
EC	-0.9998	-0.4555	-0.2587	-0.1476	0.9999	0.9851	0.9998	-0.4529	0.9670	0.9998	-0.1757	1

Note: Corelation is highly significant at 0.99, significant at 0.5-0.8 and not significant at < 0.5



#### 4. CONCLUSION

To understand the hydrogeology and water quality at Ikhueni and Okhuahe, three boreholes were drilled and evaluated while water samples were collected from six stations tagged GW1 – 5 and RW respectively. The result obtained from the hydrological studies revealed that groundwater flow from NW to SE while the aquifer is unconfined, dominated with high proportion of fine to coarse sand grains with thin lenses of clay. WQI was calculated from the result obtained from physico-chemical analysis following already established procedure and the results obtained revealed WQI range of good to extremely poor. TDS, EC,  $Mg^{2+}$ ,  $Pb^{2+}$ ,  $Cl^-$ ,  $Alk^-$ , and  $SO_4^{2-}$  were identified as the major parameters contributing to the poor water quality; these parameters were suggested to have percolated into the aquifer from adjacent unprotected landfill which was confirmed by the linear regression with correlation coefficient range of  $r = 0.69 - 0.99$  between TDS, EC,  $NO_3^-$ ,  $Cl^-$ ,  $Cr^{+6}$  and  $SO_4^{2-}$ . The authors suggest that the landfill should be closed immediately in order to safeguard the environment and public health, and enhance sustainable water resource development.

#### 5. RECOMMENDATION

The authors recommend that;

1. A more detailed groundwater geology of study areas and neighbouring communities should be carried out in order to have an in depth knowledge of the stratigraphy.
2. Speciation study should be carried out to investigate the mobility and bioavailability of heavy metals in the soil

#### COMPETING INTERESTS

Authors have declared that no competing interests exist.

#### REFERENCES

1. The World Academy of Science (TWAS). Safe drinking water the need, the problem, solutions and an action plan. Report of the Third World Academy of Sciences. Third World Academy of Sciences (TWAS), Trieste, Italy; 2002.
2. WHO-UNICEF. Global water supply and sanitation assessment Report; 2000. Available:[http://www.who.int/watersanitation\\_health/Globassessment/GlobalTOC.htm](http://www.who.int/watersanitation_health/Globassessment/GlobalTOC.htm)
3. Omorogieva OM. Geoenvironmental characterization of leachate and hydro-geochemical properties of Ikhueni landfill and environs in Benin City. Unpublished Master of Philosophy Thesis Submitted to the Department of Geology, University of Benin, Benin City Nigeria. 2016;120.
4. Merwan R, Harshit M, Subhankar K. Leachate characterization and assessment of water pollution near municipal solid waste landfill site. International Journal of Chemical and Physical Sciences IJPCS. 2013;2(Special Issue).
5. Agrawa A, Pandey R, Agrawal ML. Municipal waste management. International Journal of Chemical and Environmental Engineering. 2011;2:113-118
6. Imasuen OI, Omorogieva OM. Waste management as a practical approach to sustainable development: A case study of the University of Benin, Faculty of Physical Sciences. J. Appl. Sci. Environ. Manage. 2015;19(3):487–493. Available:[www.ajol.info](http://www.ajol.info) Available:[www.bioline.org.br/ja](http://www.bioline.org.br/ja)
7. Srinivas Rao G, Nageswararao G. Assessment of groundwater quality using water quality index. Arch. Environ. Sci. 2013;7:1-5.
8. Imeokparia EG, Onyeobi TUS, Abodunde FL. Heavy metals concentration in the soils from a mechanic village, Uvwie Local Government Area of Delta State. Nigeria Journal of Applied Science. 2009;27:137-143.
9. Imasuen OI, Omorogieva OM. Sources and environmental implication of heavy metal pollution in plants grown around contaminated site in Edo State, Nigeria. Resource Journal in Engineering and Applied Sciences: USA. 2013a;2(5):385-391.
10. Isikhuemen MI, Omorogieva OM. Hydrogeology and water quality assessment of the middle aquiferous horizon of Onitsha and environs in Anambra Basin, Eastern Nigeria. British Journal of Applied Science & Technology. 2015a; 9(5):475-483.
11. Onyeobi TUS, Akujize CN. Characteristics of soil and sediment parameter of Jisik-Izombe upper aquifer system for assessment of the potential of groundwater pollution. J. Appl. Sci. Environ. Manage. 2014;18(4):677-683.

12. Akujieze CN, Idehai IM. Physiochemical assessment of landfill generated leachates in Lagos, Nigeria. *Internat. J. Sci. Engr.* 2014;7(2):113-123.
13. Akujieze CN, Oteze GE. Deteriorating quality of groundwater in Benin City, Edo State, Nigeria. *Journal of Nigeria Association of Hydrogeologists.* 2007;1: 192-196.
14. SON. Standard Organization of Nigeria. *Nigeria Standard for Drinking Water Quality.* 2007;15-16.
15. WHO, *Guidelines for drinking water quality: Health criteria and other support information Vol. 1 2<sup>nd</sup> (Ed).* World Health Organization, Geneva; 2006.
16. Millennium Project Report; 2002-2006.
17. Sudhakar G, Swarnalatha G, Venkataratnamma Z, Vishnuvardhan. Determination of water quality index for groundwater of Bapatla Mandal, Guntur District, Andhra Pradesh, India. *International Journal of Engineering Research and Technology.* 2014;3(3):77-80.
18. Li P, Qian H, Wu J. Groundwater quality assessment based on improved water quality index in Pengyang County, Ningxia, Northwest China. *E-Journal of Chemistry.* 2010;7(S1):S209-S216. DOI: 10.1155/2010/451304
19. Li P, Qian H, Wu J. Origin and assessment of groundwater pollution and associated health risk: A case study in an industrial park, northwest China. *Environmental Geochemistry and Health.* 2014;6(4):693-712. DOI: 10.1007/s10653-013-9590-3
20. Montgomery CW. *Environmental geology, Sixth Edition.* McGraw-Hill Higher Education, Internal Edition ISBN 0-07-119941-1. 2003;553.
21. Tiwari TN, Mishra MA. A preliminary assignment of water quality index of major Indian rivers. *Indian J. Environ. Prot.* 1985;5(4):276-279.
22. Sinha DK, Shilpi S, Ritesh S. Water quality index for Range Gange River at Mordabad. *Poll. Res.* 2004;23(3):527-531.
23. Horten RK. An index number for rating water quality. *J. Water Poll. Cont. Fed.* 1965;37(3):300-306.
24. Kakati SS, Sarma HP. Water quality index of drinking water of Lakhimpur District. *Indian J. Environ. Prot.* 2007;27(5):425-428.
25. Omran EIE, Ghallab A, Selmy S, Gad A. Evaluation and mapping water wells suitability for irrigation using GIS in Darb El-Arbaein, South Western Desert, Egypt. *International Journal of Water Resources and Arid Environments.* 2014;3(1):63-76.
26. Edo State Bureau of Statistics. *The Edo State Statistical Year Book.* Fourth edition produced by the Edo State Central Office of Research and Statistics. 2013;131.
27. National Population Commission. *National Head Count (Census).* National Office Abuja, Nigeria; 2006.
28. Ojo SO, Ologe KO, Ezechukwu FC. *Countdown to senior secondary school certificate examination, Geography.* Evans Brothers Nigeria Publisher Limited. 1999;421.
29. Rayment RA. *Aspects of the Geology of Nigeria.* Ibadan University Press; 1965.
30. Short KC, Stauble AJ. *Outline of Geology of Niger-Delta.* AAPG Bu. 1967;51:761-779.
31. APHA, America Public Health Association. *Standard Methods for the Examination of Water and Waste Water.* 18th Edition, Washington D.C. 1985;4-17.
32. Allen SE, Grinshaw HW, Parkinson JA, Quarmby C. *Chemical methods of analysing ecological materials.* London, UK, Blackwell Scientific Publication. 1974;565.
33. Adetunde LA, Glover RLK, Oguntola GO. Assessment of groundwater quality in Ogbomosho township of Oyo state of Nigeria. *IJRRAS.* 2011;8(1).
34. Poonam T, Tanushree B, Sukalyan C. Water quality indices-important tools for water quality assessment: A review. *Intern. Journal of Advances in Chemistry.* 2013;1(1):15-28.

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