GEOPHYSICAL AND WATER QUALITY INDEX SURVEYS OF GROUNDWATER QUALITY AROUND UGBOR DUMPSITE IN BENIN CITY, EDO STATE, NIGERIA, WEST AFRICA.

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ABSTRACT

This study takes a look into groundwater quality at Ugbor Dumpsite area using water quality index (WQI), 2-Dimensional (2-D) geophysical resistivity tomography and vertical electric sounding (VES).The geophysical resistivity methods employed revealed the depth to aquifer, the geoelectric layers being made up of lateritic topsoil, clayed sand and sand. Along the trasverse line in the third geoelectric layer of lateral distance of 76 m to 100 m is a very low resistivity of 0.9 to 13 m from a depth range o f about 3 to 25 m beneath the surface- indicating contamination. Water samples were collected and analyzed at the same site during the raining season and during the dry season. The value of water quality index during the raining season was 115.92 and during the dry season was 147.43. Since values at both seasons were more than 100, it implies that the water is contaminated to some extent and therefore poor for drinking purpose. The Water Quality Index was established from important analyses of biological and physico-chemical parameters with significant health importance. These values computed for dumpsite area at Ugbor were mostly contributed by the seasonal variations in the concentrations of some parameters, such as, conductivity, total dissolved solids, hardness, alkalinity, chlorides, nitrates, calcium, phosphates, zinc, which showed significant differences ($P<0.01$ and $P<0.05$) in seasonal variation.

KEY WORDS

Groundwater, contamination, dumpsites, Ugbor, WQI.

INTRODUCTION

Water is a prime solvent and its properties determine many natural phenomena. Water is the most known and most abundant of all known chemical substances, which occur naturally on the surface of the earth. It is an essential natural resource for sustainability of life on earth. Water covers about three quarter of the total earth crust (Nelson, 2002; Mbagwu, 2003). Approximately 2.4% of water on earth crust is fresh, this occurs in form of ice in glacier and liquid in streams, river, lake and aquifer (groundwater). Groundwater is one of our important freshwater resources. Originating as precipitation that percolates into the layers of soil, groundwater makes up the largest compartment of liquid freshwater (Cunningham and Cunningham, 2006). In terms of storage capacity, groundwater worldwide contains over 90 % of the total fresh water available for human use (Oluyemi et al, 2009).

Wastes placed in landfills are subject to either groundwater underflow or infiltration from precipitation and as water percolates through the waste, it picks up a variety of inorganic and organic compounds, flowing out of the wastes to accumulate at the bottom of the landfill. The resulting contaminated water is termed 'leachate' and can percolate through the soil (Mor et al, 2006). Municipal landfill leachate are highly concentrated complex effluents which contain pathogenic organisms, dissolved organic matters; inorganic compounds such as ammonium, calcium, magnesium, sodium, potassium, iron, sulphates, chlorides and heavy metals such as cadmium, chromium, copper, lead, zinc, nickel; and xenobiotic organic substances (Lee and Jones-Lee, 1993; Christensen et al, 2001).

An electrical resistivity method is one of the most useful techniques in ground water hydrology exploration. This is because the resistivity of rock is very sensitive to its content, while the resistivity of water is also very sensitive to its ionic content. The common practice in resistivity surveying techniques is to pass current into the ground by means of two electrodes called current electrodes and to measure potential drop through pair of electrodes called potential electrodes (Osemeikhian and Asokhia, 1994).

AIMS OF THE STUDY

The aims of the study are to:

1. Find out the status of water quality around Ugbor Dumpsite,

2. Find out if there is significant difference between the data collected on the water samples analyses in Ugbor Dumpsite at raining season and dry season.

3. Find out if there is significant difference between the values of the Water Quality Index of the same dumpsite but at different seasons (rainy and dry).

STUDY AREA:

This study was conducted in Benin City located in South South geopolitical zone of Nigeria. Benin City is the capital of Edo State, bounded by latitudes 06° 06' N, 06° 30' N and longitudes 005° 30' E, 005° 45' E and an area of about 500 square kilometres. The sampling site Ugbor Dumpsite (Figure.1) - latitude 06° 17' 01.8'' and longitude 005° 37' 05.1'' (Figure. 1).
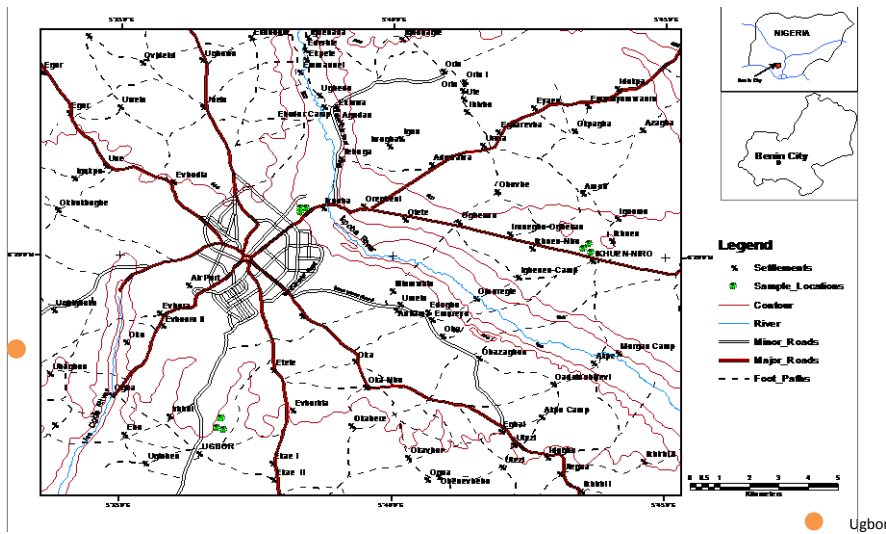

Figure1: Benin City falls within the tropical equatorial zone dominated by dry season (November – March) and wet seasons (April – October). The City is underlain by sedimentary formation described by Short and Stauble, (1967). The formation is made up of top reddish clayey sand, sandstone with local thin clays and shale interbeds.

Ugbor Dumpsite

Ugbor Dumpsite is located at Ugbor community closed to Benson Idahosa University (BIU) (Plate1, Plate 2) show Ugbor Dumpsite from different views.

Plate 1: Ugbor Dumpsite   **Plate 2: Ugbor Dumpsite**

\MATERIALS AND METHODS.

The geophysical technique employed for this study is the 2-Dimensional Resistivity Imaging using the Wenner-Schlumberger array conFigureuration (Figure. 2) which is moderately sensitive to both horizontal and vertical structures (Loke M. H. 2014).
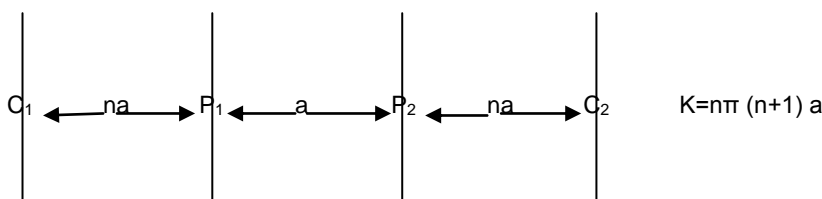

$$K = n\pi (n+1) a$$

Figure 2: Electrodes arrangement in Wenner-Schlumberger array

The data were processed with DIPRO Software and presented as 2-D resistivity imaging. In order to determine the water quality index and further ascertain suitability of these groundwater sources located near the study areas, the laboratory analyses of the microbial and physico-chemical parameters using standard methods adopted from Hutton (1983); Radojevic and Bashkin (1999) were employed. Results were presented as mean and standard deviation. Paired t-test was used for the statistical analyses of results obtained at 95% confidence level. This analysis was computed using the computer application SPSS 16.0 and Microsoft Excel - 2007 for window.

For this study, Water Quality Index (WQI) was calculated by using the Weighted Arithmetic Index method as described by Cude, (2001). Calculation of water quality index is to turn complex water quality data into information that is understandable and useable by the public. In this study the WQI was considered for human consumption or uses and the maximum permissible WQI for the drinking water was taken as 100 score (Table 1).

Table 1: Grades Water Quality Index (WQI) and status of water quality

Water Quality Index Levels	Description
< 50	Excellent
50 – 100	Good
100 – 200	Poor
200 – 300	Very poor (bad) water
> 300	Unsuitable (unfit)for drinking

 (Ramakrishniah et al., 2009)

PRESENTATION OF RESULTS/DATA:

The presentation of both Vertical Electric Sounding and 2-Dimensional Tomography using DIPRO is shown below.

FIELD DATA

TABLE 2: SITE DESCRIPTION: UGBOR DUMPSITE [DUMPSITE GROUND] BESIDE B.I.U

ELECTRODE CONFIGURATION: SCHLUMBEGER

INSTRUMENT: ABEM TERRAMETER SAS 1000

DATA ACQUIRED BY: IDEHEN OSABUOHIEN

VES

S/N	AB/2[m],L	MN/2[m], l	Geometric factor $K = \pi L^2 / l$	Apparent Resistivity[Ω m]
1	1.0	0.5	6.28	800
2	2.0	0.5	25.13	192
3	3.0	0.5	56.55	62
4	4.0	0.5	100.53	32
5	6.0	0.5	226.19	27
6	6.0	1.0	113.10	29
7	9.0	1.0	254.47	25
8	12.0	1.0	452.39	24
9	15.0	1.0	706.86	23
10	15.0	2.0	353.45	25
11	25.0	2.0	981.75	21
12	32.0	2.0	1608.05	22
13	40.0	2.0	2513.37	22
14	40.0	5.0	1605.31	26
15	65.0	5.0	2654.65	24

16	100.0	5.0	6283.19	27
17	100.0	10.0	3141.59	29
18	150.0	10.0	7068.59	31
19	200.0	10.0	12566.37	29
20	200.0	20.0	6283.19	32
21	250.0	20.0	9817.48	28
22	300.0	20.0	14137.17	26

Figure. 3: GRAPHICAL ILLUSTRATION OF VES IN UGBOR DUMPSITE

| 17 Points | 5 Layers | 2.76% RMS | | |
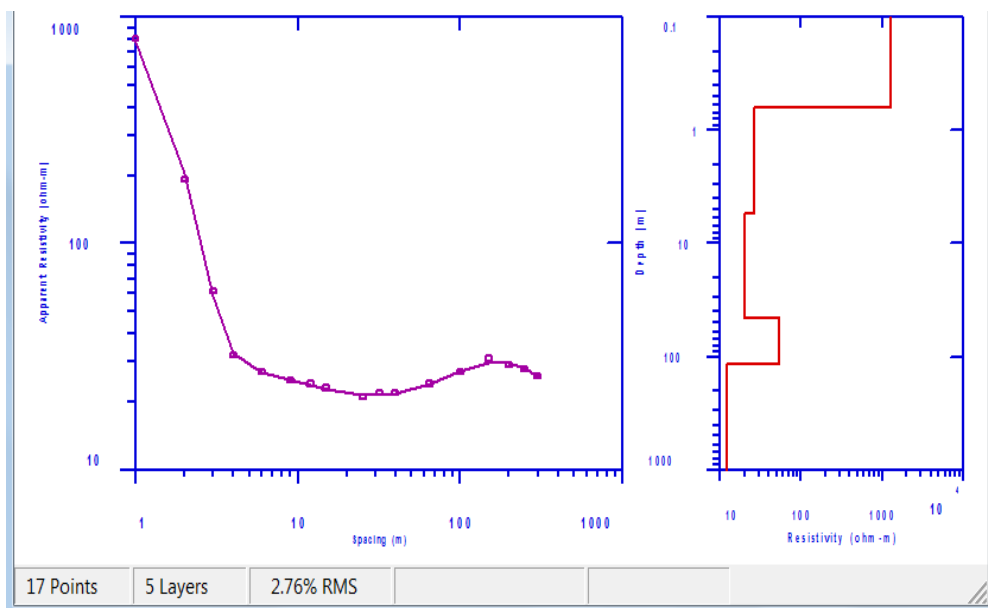
Table 3: Layer model of VES.

Surface Elevation: 0.0000   Fitting Error: 2.7607

☐ Use Depth Instead of Thickness   Units: (meters)

#	Rho	Fix?	Thick	Depth	Elev	Fix?
1	1259.7	☐	0.63587	0.63587	-0.63587	☐
2	26.993	☐	4.8650	5.5008	-5.5008	☐
3	20.159	☐	39.881	45.382	-45.382	☐
4	54.732	☐	71.635	117.02	-117.02	☐
5	12.212	☐				☐

Figure.4 : 2-D Electrical Resistivity Imaging along Traverse at Ugbor.
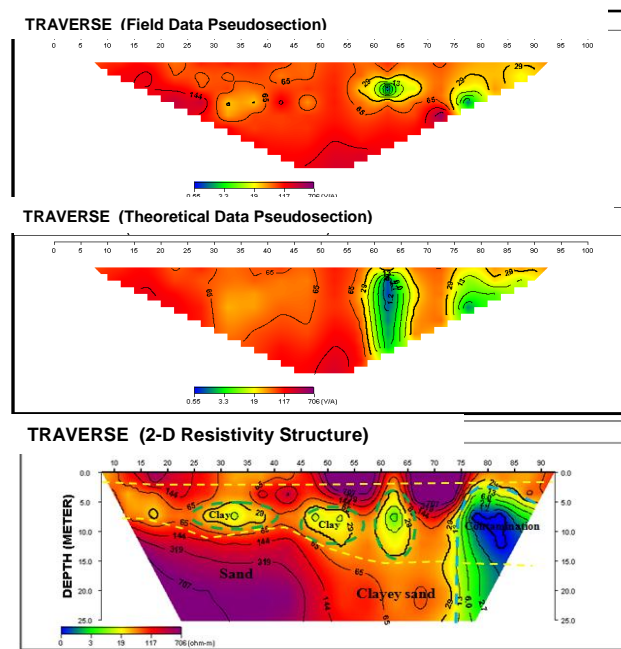

Figure. 5: 2D Electrical Resistivity Section along Traverse at Ugbor Dumpsite.

Table 4: Physico-chemical analysis of water at Ugbor

Parameters (Units)	Rainy season	Dry season	p-Value
pH (potential of hydrogen)	6.20	6.30	p>0.05
Colour (CTU)	0.00	9.00	p<0.01
Turbidity (NTU)	0.00	1.00	p>0.05
Conductivity (µS/cm)	8.34	206.00	p<0.01
Total Dissolved Solid (mg/l)	4.00	102.40	p<0.01
Hardness (mg/l)	4.00	48.00	p<0.01
Alkalinity (mg/l)	16.00	30.50	p<0.05
Chloride (mg/l)	14.20	40.10	p<0.01
Sulphate (mg/l)	4.00	9.00	p>0.05
Nitrate (mg/l)	1.57	0.10	p<0.01
Phosphate (mg/l)	0.19	18.30	p<0.01
Calcium (mg/l)	0.80	10.80	p<0.01
Magnesium (mg/l)	0.47	5.10	p<0.01
Cadmium (mg/l)	0.00	0.00	p>0.05
Iron (mg/l)	0.04	0.02	p>0.05
Lead (mg/l)	0.03	0.00	p<0.01
Chromium (mg/l)	0.00	0.00	p>0.05
Zinc (mg/l)	0.03	0.00	p<0.01
Total Coliform (cfu/ml)	0.00	130.00	p<0.01
Escharichia. coli (cfu/ml)	0.00	0.00	p>0.05
Entrococcus facecalis (cfu/ml)	0.00	0.00	p>0.05

Mesophilic count (cfu/ml)	1.70×10^4	1.60×10^2	$p < 0.01$
Fungi/Yeast (cfu/ml)	0.00	0.00	$p > 0.05$

$p < 0.01$ – Highly Significant Difference

$p < 0.05$ – Significant Difference

$p > 0.05$ – No Significant Difference

Table 5: Summary of the Selected Physicochemical and Biological Characteristics of the Groundwater

	Ugbor		
Parameters (Units)	Rainy season	Dry season	NIS (2007)
pH (potential of hydrogen)	6.200	6.300	6.50-8.50
Colour (CTU)	0.000	9.000	15.00
Turbidity (NTU)	0.000	1.000	5.00
Conductivity (µS/cm)	8.340	206.000	1000.00
Total Dissolved Solid (mg/l)	4.000	102.400	500.00
Hardness (mg/l)	4.000	48.000	150.00
Alkalinity (mg/l)	16.000	30.500	N/A
Chloride (mg/l)	14.200	40.100	250.00
Sulphate (mg/l)	4.000	9.000	100.00
Nitrate (mg/l)	1.570	0.100	50.00
Phosphate (mg/l)	0.190	18.300	N/A
Calcium (mg/l)	0.800	10.800	N/A
Magnesium (mg/l)	0.470	5.100	0.20
Cadmium (mg/l)	0.002	0.002	N/A
Iron (mg/l)	0.040	0.020	0.30
Lead (mg/l)	0.030	0.000	0.01
Chromium (mg/l)	0.004	0.001	0.05
Zinc (mg/l)	0.032	0.000	3.00
Total Coliform (cfu/ml)	0.000	130.000	10.00
Escharichia coli (cfu/ml)	0.000	0.000	0.00

CTU – Coding Tree Units.

NTU – Nephelometric Turbidity Units (the units of turbidity from a calibrated phenelometer).

CFU/ml – Colony Forming Units (the number of viable cells per milliliter).

pH – Potential of hydrogen

Table 6: Computed water quality index values for Ugbor dumpsite (rainy season)

Parameters	V (actual)	V (ideal)	V (standard)	Quality rating (Qi)	Relative weight (Wi)	WiQi
Colour	0.000	0.000	15.000	0.000	0.067	0.000
Turbidity	0.000	0.000	5.000	0.000	0.200	0.000
Conductivity	8.340	0.000	1000.000	0.834	0.001	0.001
Total Dissolved Solid	4.000	0.000	500.000	0.800	0.002	0.002
Hardness	4.000	0.000	150.000	2.667	0.007	0.018
Chloride	14.200	0.000	250.000	5.680	0.004	0.023
Sulphate	4.000	0.000	100.000	4.000	0.010	0.040
Nitrate	1.570	0.000	50.000	3.140	0.020	0.063
Magnesium	0.470	0.000	0.200	235.000	5.000	1175.000
Cadmium	0.002	0.000	0.003	66.667	333.333	22222.222
Iron	0.040	0.000	0.300	13.333	3.333	44.444
Lead	0.030	0.000	0.010	300.000	100.000	30000.000
Chromium	0.004	0.000	0.050	8.000	20.000	160.000
Zinc	0.032	0.000	3.000	1.067	0.333	0.356
Total Coliform	0.000	0.000	10.000	0.000	0.100	0.000
Escharichia coli	0.000	0.000	0.000	0.000	0.000	0.000
Σ					462.410	53602.170
WQI=ΣWiQi/Σwi						115.919

Table 7: Computed water quality index values for Ugbor dumpsite (dry season)

Parameters	V (actual)	V (ideal)	V (standard)	Quality rating (Qi)	Relative weight (Wi)	WiQi
Colour	9.000	0.000	15.000	60.000	0.067	4.000
Turbidity	1.000	0.000	5.000	20.000	0.200	4.000
Conductivity	206.000	0.000	1000.000	20.600	0.001	0.021
Total Dissolved Solid	102.400	0.000	500.000	20.480	0.002	0.041
Hardness	48.000	0.000	150.000	32.000	0.007	0.213
Chloride	40.100	0.000	250.000	16.040	0.004	0.064
Sulphate	9.000	0.000	100.000	9.000	0.010	0.090
Nitrate	0.100	0.000	50.000	0.200	0.020	0.004
Magnesium	18.300	0.000	0.200	9150.000	5.000	45750.000
Cadmium	0.002	0.000	0.003	66.667	333.333	22222.222
Iron	0.020	0.000	0.300	6.667	3.333	22.222
Lead	0.000	0.000	0.010	0.000	100.000	0.000
Chromium	0.001	0.000	0.050	2.000	20.000	40.000
Zinc	0.000	0.000	3.000	0.000	0.333	0.000
Total Coliform	130.000	0.000	10.000	1300.000	0.100	130.000
Escharichia coli	0.000	0.000	0.000	0.000	0.000	0.000
Σ					462.41	68172.88
WQI=ΣWiQi/Σwi						147.43
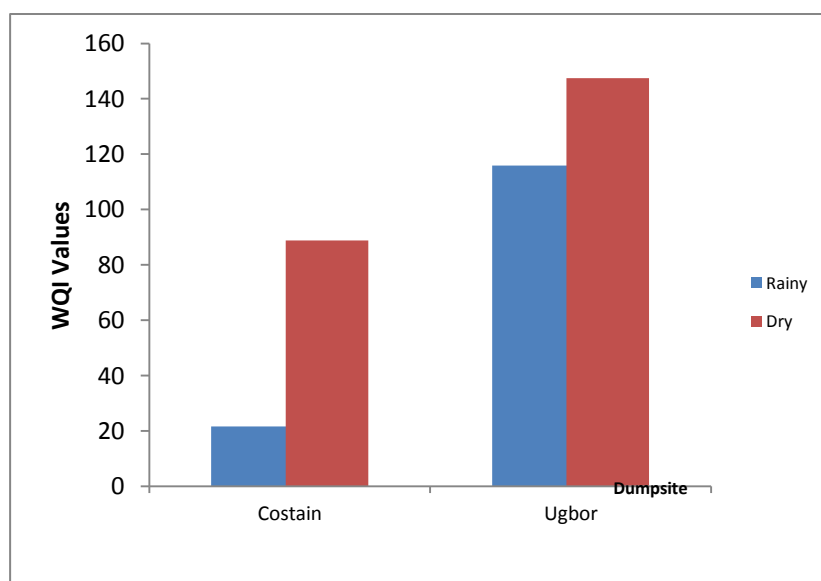
Figure. 6: Variations in WQI values across the seasons at Ugbor dumpsite.

DISCUSSION OF RESULTS

2-D Resistivity Section along Profile at Ugbor Dumpsite

Figure. 4 and Figure. 5 represent the 2-D resistivity section along profile conducted at Ugbor Dumpsite. A maximum spread of 100 m was taken using the Wenner-Schlumberger array conFigureuration along this profile and maximum depth of 25 m was investigated. The first geoelectric layer represents the topsoil which is composed of clayey sand and sand with resistivity value that ranges from 65 to 797 Ωm and extends from the surface to depth of about 2 m. Beneath this topsoil is the second geoelectric layer with resistivity value that ranges from 29 to 144 Ωm within the depth range of about 2 to 14 m beneath the surface. This layer is composed of clayey sand.

However, a very low resisitive material indicative of the leachate effect from the dumpsite was delineated at lateral distance of 76 to 100 m with resistivity value ranging from 0.9 to 13 Ωm and depth range from about 3 to 25 m beneath the surface. The third geoelectric layer has resistivity value that ranges from 65 to 707 Ωm at lateral distance of 10 to 75 m and depth range of about 7 to 25 m beneath the surface. This layer is free from contamination from the dumpsite and represents the first hydrogeologic unit (aquifer unit) for groundwater exploration within the study area. Along this traverse line, the contamination from the dumpsite is more pronounced at lateral distance of 76 to 100 m with resistivity value range from 0.9 to 13 Ωm and depth range from about 3 to 25 m beneath the surface. In addition, the VES results showed the depth to aquifer and layers models.

The results of the selected Physico Chemical and Microbial parameters analyses.

In order to determine the impact of leachate percolation on groundwater quality and seasonal variation of microbial and physico chemical parameters in the vicinity of an unlined municipal solid waste (MSW) landfill at Ugbor, Benin City, equal sets of water samples were collected from boreholes located close to this site. The WQI values computed for groundwater samples obtained at Ugbor environs were 115.92 and 147.43 in rainy and dry seasons respectively. The computed values for WQI were significantly lower in rainy season than the dry season. These seasonal variations are in consonant with the physico-chemical parameters which form the basis for the computation of WQI. These variations are possibly due to dilution - during the rainy season, the volume of water in the aquifer increases due to more inflow through the aquifer recharge zone which in most cases is not commensurate with water extraction at this time. Thus the concentrations of ions in the aquifer get diluted but during the dry season the reverse is the case. This change in respect to season can also be attributed to microbial activities which tend to reduce during the rainy season due to reduction in water temperature; during dry season, the water quality deteriorated on account of the increase in microbial activity as well as increase in pollutants concentration (Yisa and Jimoh, 2010). According to Ramakrishniah et al, (2009) the quality of groundwater at Ugbor environs indicated that the quality of the groundwater is poor for human consumption since the WQI values were above 100 in both raining and dry seasons. This is an indicator that the activities within this environs influence the quality of the groundwater. Furthermore the groundwater at Ugbor environs may either get contaminated from its recharge zones or being impacted by the dumpsites. The values computed for WQI at Ugbor environs in rainy and dry seasons were contributed mostly by magnesium and lead and magnesium, cadmium and lead respectively

CONCLUSION

The 2-D electrical resistivity technique has been applied in Ugbor Dumpsite area of Benin City, Edo State, South-South Nigeria with the aim of investigating groundwater contamination within the study area. The Wenner-Schlumberger array was used for the survey with a minimum and maximum spread of 100 m and 25 m depth of investigation. The subsurface was characterized based on its electrical resistivity distribution into three geoelectric layers composed of topsoil, clayey sand/clay and sand. However, the contamination is pronounced along Traverse (in Ugbor Dumpsite) towards the end of the profile (at lateral distance of 76 to 100 m)

Water quality index is a useful tool for communicating water quality information to the public and to decision makers. This study clearly revealed that the status of the groundwater at Ugbor showed that the WQI values were relatively high in both rainy and dry seasons. Health safety of the consumers depends upon proper treatment of the water before drinking. . The WQI values computed for groundwater samples obtained from the vicinity of Ugbor Dumpsite were 115.92 during the rainy season and 147.43 during the dry season. These values computed for dumpsite were mostly contributed seasonal variations in the concentrations of some parameters, such as, conductivity, total dissolved solids, hardness, alkalinity, chlorides, nitrates, calcium, phosphates, zinc, which showed significant differences (P<0.01 and P<0.05) in seasonal variations. Application of WQI in this study has been found functional in assessing the overall quality of water. This method appears to be more systematic and gives comparative evaluation of the water quality at sampled sites. As exemplified in this study, periodic monitoring of water sources for domestic purposes using WQI is essential in safeguarding the health of the populace.

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