Assessment of Deep Well Water Quality In Owena Osun Market

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Abstract— Water isa vital resource for human survival and economic development, sourcesincluderivers, streams, springs, boreholes and deep wells.Geometric population increase and economic growth, increases water demand while the availability remain sunstable both in quantity and quality.These callformonitoring,management and maintenance of the available ones. This study examined well waterquality in Owena Ijesa market using Remote Sensing and Geographic Information Science. Landsat8 was acquired from http://glovis.usgs.gov/. Stratified Systematic Random method wasused in the selection of sample area / location. A total of fifteen water samples were collected around ten dump sites in Owena market. Water quality assessment and Risk map/contamination index for nitrates,chloride, hardness, bicarbonatesandcalcium were done using kriging interpolation method.The calculated WQI revealed that the ground water from the study areaissuitableforhumanuseexcept some wells need to besituatedawayfrom waste disposal sites that is, 100m or moreinaccordancewiththeW.H.Ostandard. WQI for all the wells are GOOD while DWI and DW3 are FAIR.Themean value of physicchemical parameters are pH (6.58) T (27.13^{0}C),Chloride (49.35mg/l),HCO_3^-(49.35mg/l),Hardness (86.63), $N0_3^-$(1.12mg/l) and Ca (15.94mg/l).It was discovered that the effect of human activities were becoming pronounced on the potability of the deep well. Water quality index has been recommended for composite parameters. However there is the need for routine monitoring of the various human activities within the area especially in order to avoid the deterioration in quality of the groundwater.

Index Terms— Remote sensing-GIS, physicochemical parameters, Monitoring status, Sustainable water management.

1.0 INTRODUCTION

Water is life, the availability of good quality water is an indispensable feature for preventing diseases and improving quality of life. Water also play a vital role in Earth's ecosystem [5]. The potential sources of water contamination are geological conditions, industrial and agricultural activities and water treatment plants.These contaminants are further categorized as micro-organisms, inorganics, organics, radionuclides, and disinfectants [14]. It is necessary to know-details about the physical, chemical and biological parameters in order to accurately assess the quality of water. Physico-chemical parameters such as color, temperature, acidity, hardness, pH, sulphate, chloride, DO, Biological Oxygen Demand (BOD), Chemical Oxygen Demand (COD), alkalinity are used testing water quality. Heavy metals such as Pb, Cr, Fe, Hg etc.are of special concern for because they produce water or chronic poisoning inaquatic animals. People on globe are under tremendous threat due to undesired changes in the physical, chemical and biological characteristics of air,water and soil.Increasing human population,industrialization,use of fertilizers, solid waste disposal and other man-made activities have had a negative impact on the quality of groundwater [6]. Pollutants from some of these sources can percolate through the subsurface into groundwater [13].The use of this contaminated water could lead the local inhabitants of the area suffering from water borne diseases.Hence, it is necessary that the quality of drinking water should be checked at regular time interval.

2.0 STUDY AREA

The study area, Owena lies about 7°11'38"North and 5°01'21" of the equator. Owena market in Ondo East Local Government Area, Ondo State is located in the western part of Nigeria about 213 miles (342km) south-west of Abuja (Figure 1). The area lies within the tropics, characterized by two seasons: raining and dry seasons. The raining season commences from April to October while the dry season starts from November and ends in March. Annual rainfall average is about 780mm. The relative humidity never exceed 20-25%, the highest humidity occurs in the months of August and September, while the lowest occur in the month of February and March [9].The soil inthe study area fall underTropical ferruginous soil and weakly developed soil of the majorstreams.This soil is called alfisols according to USDA soil taxonomy orluvisols based on FAO/UNESCO soil taxonomy.The exact character of this soil is dependent on such factor as topographical relation, and anthropogenic modification.The color ranges from dark grey or grayish brown in the top soil to yellowish red or yellowish brown in the subsoil, rarely becoming reddish yellow.Land use in the study area is dominated by urban activities, such as residential, administrative, commercial, social landuses, and small area for livestock. Residential areas cover almost over 70%part of the studyarea.

2.1 GEOLOGY OF THE AREA

The study area is underlain by the crystalline rocks (Figure 2). The crystalline rocks in Nigeria are divided into four main groups:

(i) The Precambrian Basement Complex;
(ii) The Jurassic Younger Granites;
(iii) Cretaceous , intermediate to basic hypabyssal rocks;
(iv) The Tertiary – Recent Volcanic rocks.

These crystalline rocks are part of the Basement complex rocks of south western Nigeria. These rocks are Precambrian in age and lie between the West African craton to the west and the Congo craton to the southeast within the African continent.The Nigeria basement complex are polycyclic in nature as they have been affected by at least four orogenies, namely, Liberian (c. 2800 Ma), Eburnean (2000 Ma), Kibaran (c. 1100 Ma) and Pan African (c. 600 Ma) [3], [4]. Adekoya and Adekoya et al.,[1], [2] gave a four-fold tectono-stratigraphic division of the Nigerian Basement into: Migmatite-gneiss-quartzite complex; the supracrustal low to medium metasedimentary and meta-igneous rock referred to as the Schist Belt; the Older granite; and the minor felsic to mafic intrusive[12]. The Owena area is underlain by rocks which include quartzite and granite gneiss. These rocks have undergone polycyclic deformation as evident in some structures such as folds, fault etc. displayed by the rocks.

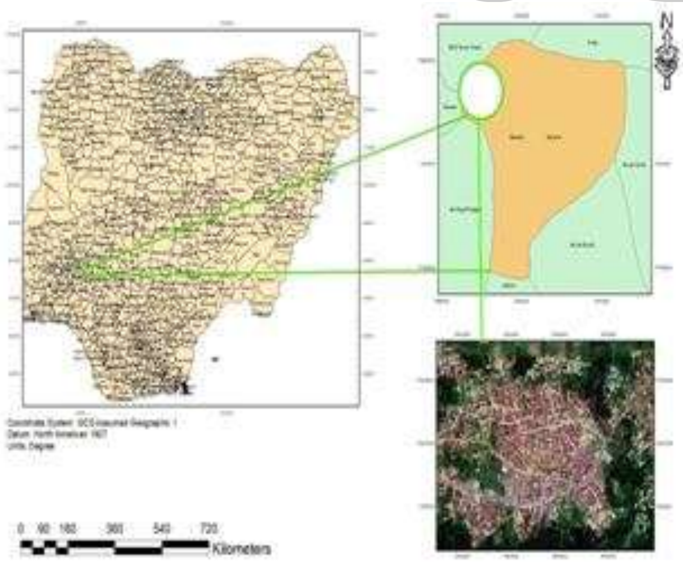


Figure 1: Location Map of the Study Area.

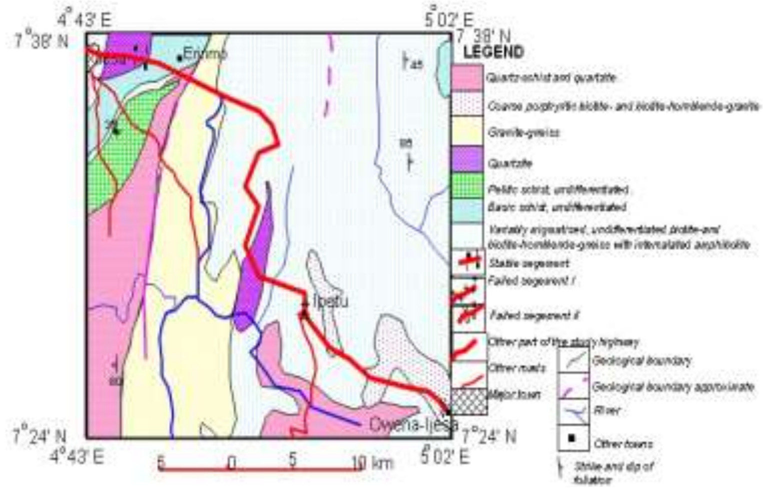


Figure 2: Geological Map of the area (Adapted from Momoh et al., 2008)

3.0. MATERIALS AND METHODS

Landsat8, which has a spatial resolution of 30 meters, was acquired in January 2019 from http://glovis.usgs.gov/. The Landsat8 data was pre-processed. The pre-processing involved atmospheric and radiometric corrections, image enhancement and resampling. The Landsat8 data were, then, converted to surface reflectance by top-of-atmosphere (TOA) method Using ENVI. The enhancement technique used is the creation of a Colour Composite bands.To carry out this analysis, Band 7 (SWIR2), Band4 (Red) and Band3 (Green) of the Landsat 8 OLI were used.The purpose of carrying out the image enhancement is to enable better visualization of the area to aid proper classification of the imagery. Image filtering and sharpening was carried out on the imagery in other to modify or enhance the image.The image filtering techniques used for the analysis is known as linear filtering, while that of sharpening is known as HSV sharpening. The image classificationwas carried out using ENVI 5.3 classification workflow.The classification workflow used was the Supervised Classificationonthe enhanced sub-scenes covering the study area.Supervised classification locates the known land cover types on a satellite image that have been identified from Google earth image and personal experience.

3.1 DEVELOPING WATER QUALITY INDEX (WQI)

Water quality index was developed using [8] method. The following subsections describe the steps leading to the formulation of the WQI, all the steps below were done using ESRI-ArcMap 10.3.

3.1.1 The Primary Map

Concentration maps representing the "primary mapI" were-constructed for each parameter from the point data using mainly Kriging interpolation. The parameters used were also accompanied with the WHO guideline (Table 1).

Kriging is an advanced geostatistical procedure that generates an estimated surface from a scattered set of pionts with-values. Kriging assumes that the distance or direction between sample points reflects a spatial correlation that can be used to explain variation in the surface.

Kriging is similar to IDW in that it weighs the surrounding measured values to derive a prediction for an unmeasured location. The general formula for both interpolators is formed as a weighted sum of the data:

Weighted sum formula

$$\hat{Z}(s_0) = \sum_{i=1}^{N} \lambda_i Z(s_i)$$

Where:

Z (S_i) =the measured value at the ith location

λi = an unknownweightforthe measured value at the ith location

S_0=the prediction location

N =the number of measured values

Table 1: World Health Organization (WHO) standard

Parameter	WHOguideline/Standard
Temperature	30^0C
PH	6.5 – 8.5
Nitrates	≤ 50mg/l
Hardness	500mg/l
Chloride	≤ 250mg/l
Bicarbonate	200mg/l
Calcium	75mg/l

3.1.2 Transforming The Data Into Universal Norm

In order to relate the datato universal norm, the measured concentration, X', of every pixel in the "primary mapI"was related to its desired WHO standard value X using a normalized difference index:

C = (x1– x) / (x1+ x)

The resultant "primary mapII" thus displays for each pixels a contamination index values ranging between -1 and 1. This is close to the contamination index approach which is calculated as the ratio between the measured concentration of contaminant and the prescribed maximum acceptable contaminant level. However, the normalized difference index used here provides fixed upper and lower limits for the contamination level. Table 1 shows the WHO guideline for the parameters used in the index.This step is done using Raster Calculator in Arc Map application.

3.1.3 The Rank Map

The contamination index (primary mapII) was then rated between 1 and 10 to generate the "rank map". The rate1 indicates minimum impacton groundwater quality while the rate10 indicates maximum impact. The minimum contamination index level (-1) was set equal to 1, the median level (0) was set equal to 5 and the maximum level (1) was set equal to 10. The following polynomial function can thus be used to rank the contamination level (C) of every pixel between 1 and 10:

r = 0.5* C+4.5 * C+5

Where;

C stands for the contamination index value for each pixel.
r stands for the corresponding rank value.
This step was done using Raster Calculator in ArcMap application

3.1.4 Buffering of Deep Wells from Waste Dump Sites

A buffer is a reclassification based on distance- classification of within /without a given proximity. Buffering involves measuring distance outward in directions from an object. Buffering can be done on all three types of vector data: point, line and area.The resulting buffer is a polygon file. Most buffers are often measured in uniform distance. For example, creating a 50m buffer around all rivers. A buffer based on different distances is called avariable buffer. According to World Health Organization (WHO), the safe distance of waste disposal site to any water source should not be less than 100m.

3.1.5 Generation of Near – DistanceTable

It calculates distances and other proximity information between features in one or more feature class or layer.Unlike the near tool, which modifies the input, Generate Near-Table writes results to a new stand-alone table and supports finding more than one near feature.

3.2 Sampling and Analytical Procedure

Groundwater samples were collected from fifteen wells (Table 2) around ten selected waste disposal sites (Table 3) within the study area. The samples, after collection, were stored in iced

box and were immediately transported to the laboratory. At the laboratory, the samples were refrigerated, in order to prevent loss of ion, before analysis using standard methods.
Physico-chemical parameters of the groundwater such as pH, temperature, chloride (Cl^-), bicarbonate (HCO^{3-}), hardness, nitrate (NO_3^-) and calcium (Ca^{2+}) were determined in the laboratory. Physical parameters such as appearance, colour, taste and odour were determined as well.

The temperature and the pH of the groundwater were determined using mercury in bulb thermometer and pH meter respectively. Total hardness was determined by complexometric method; chloride by titrimetry; nitrate by phenoldisulphonic acid method and Ca determined by atomic absorption spectrophotometry (Buck scientific 210VGP model).

Table 2: Geographic Location of Selected Deep Wells

NAME	LATITUDEN(^{0})	LONGITUDE E(^{0})
DW1	7.399985610	5.008544390
DW2	7.399690564	5.007457810
DW3	7.400151512	5.007218310
DW4	7.399446422	5.008895833
DW5	7.399817818	5.010172415
DW6	7.400197827	5.011090136
DW7	7.400572756	5.011722215
DW8	7.401139218	5.011663491
DW9	7.401641500	5.011211134
DW10	7.400911656	5.010724732
DW11	7.401442259	5.010323245
DW12	7.401136493	5.009879092
DW13	7.401826185	5.009603119
DW14	7.400986533	5.008819955
DW15	7.400646373	5.009524944

Table 3: Geographic Location of Selected Waste Disposal Sites from the Study Area

NAME	LATITUDE	LONGITUDE
WDS 1	7.399949384	5.007421739
WDS 2	7.399942246	5.008278345
WDS 3	7.399635295	5.009284857
WDS 4	7.399585326	5.010269954
WDS 5	7.400156397	5.011412095
WDS 6	7.401105802	5.012104518
WDS 7	7.40159835	5.011547724
WDS 8	7.401441306	5.010569766
WDS 9	7.401555520	5.009648915
WDS 10	7.400556146	5.009920173

3.3 Data Analysis

The data generated from the laboratory were subjected to descriptive statistical analysis. Maximun, minimum, range and standard deviation values of the data were determined by using Statistical Package for Social Sciences (SPSS) version 16.0 software. The physico-chemical parameters were compared with World Health Organization (WHO), United States Environmental Protection Agency (USEPA) and NDWQS acceptable limits. The Water Quality Index (WQI) rating of each of the deep wells was computed. pH, temperature, chloride (Cl^-), bicarbonate (HCO_3^-) values etc. were displayed in form of charts using Microsoft Excel. Spatial analysis of the parameters were also done by kriging interpolation method using ArcGIS software.

4.0. RESULTS AND DISCUSSION

4.1 Physico-Chemical Parameters

The descriptive statistics of the physico-chemical data are presented in Table 4. The temperature ranges from 26.9 – 27.4^{0}C with a mean of 27.13^{0}C. When the mean value is compared to the WHO, USEPA and NDWQS (Table 5) standards values for temperature (30^{0}C), it is clearly in accordance with the standards. The maximum value of temperature recorded was 27.4 for DW11and DW2, while the minimum value was 26.9 for DW1 (Figure 3). These values are still less than the WHO, USEPA and NDWQS standards values for temperature (30^{0}C). The mean Chloride content was 49.35mg/l, the values range from 12.76 to 152.44 mg/l. These values are lower than the WHO, USEPA and NDWQS standards values for Chloride and are clearly in accordance with the standards.The maximum and minimum values of chloride recorded was 152.44mg/l for DW5 and 12.76mg/l for DW 11(Figure 4) respectively. These values are clearly in accordance with the set standard.

The mean as well as the maximum and minimum values of the pH recorded from the deep water wells from the study area are within the ranges of pH values for WHO, USEPA and NDWQS standards. The minimum value of pH recorded was 5.45 for DW5 while the maximum value recorded was 7.45 for DW8 (Figure 5). It could be inferred that the pH of the ground water in the study area is neutral and are, therefore, good for drinking. A lot of factors could have been responsible for the low pH (5.45) recorded at DW5. The factors could be as a result of high levels of CO_2, SO_2, H_2S and NO present in the water. The mean bicarbonate content was 0.64mg/l, which is below the standard set by WHO for bicarbonate (200mg/l). The maximumvalue of bicarbonate was 1.5mg/l for DW8 while the minimum value was 0.1 for DW1, DW5, DW6 and DW7 (Figure 6). These values are below the WHO, USEPA and NDWQS standard values for bicarbonate.

The mean Hardness for the sampled groundwater was 86.63mg/l while the minimum and maximum values were 60.5 mg/l for DW10 and 165.88 mg/l for DW5 respectively (Figure 7). These values are less than the WHO (500 mg/l), USEPA (450 mg/l).

Table 4: Raw data and descriptive statistics of the Physico-chemical Parameters of the Groundwater from the Study Area.

S/N	pH	Temperature	Chloride (mg/l)	Bicarbonate (mg/l)	Hardness	Nitrate	Calcium
DW1	6.28	26.9	51.76	0.1	66.34	1.23	16.13
DW2	6.3	27.4	75.15	0.35	95.52	1.3	15.13
DW3	6.3	27	95.72	0.35	67.18	1.03	14.53
DW4	6.85	27.2	48.21	1.15	101.02	1.05	16.93
DW5	5.45	27	152.44	0.1	165.88	1.25	15.67
DW6	6.1	27.2	51.76	0.1	73.15	1.22	14.6
DW7	6.25	27	17.02	0.1	88.68	1.19	13.47
DW8	7.45	27.1	29.07	1.5	92.11	1.13	16.93
DW9	7.15	27.3	26.94	1.1	75.5	1.35	16.87
DW10	6.75	27.1	45.38	0.8	60.5	1.16	15.7
DW11	6.35	27.4	12.76	0.25	74.89	1.19	20.26
DW12	6.95	27.1	39.7	0.9	77.9	0.95	16.4
DW13	7	27.1	36.16	0.95	105.5	1.06	15.97
DW14	6.45	27	14.89	0.4	90.86	0.76	14.4
DW15	7.05	27.2	43.25	1.4	64.44	0.91	16.11
Mean	6.58	27.13	49.35	0.64	86.63	1.12	15.94
Minimum	5.45	26.9	12.76	0.1	60.5	0.76	13.47
Maximum	7.45	27.4	152.44	1.5	165.88	1.35	20.26
Range	2	0.5	139.68	1.4	105.38	0.59	6.79
Standard Deviation	0.51	0.15	36.12	0.05	25.99	0.16	1.58

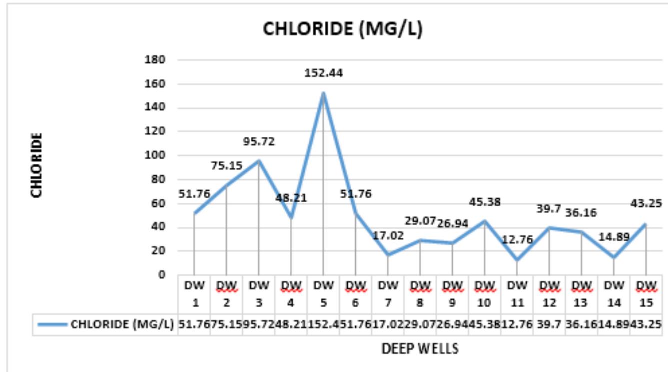


Figure 4: Line graph showing variationin chloride content of the well water from the study area.

Table 5: Various Drinking Water Standards by Different Organizations

Parameter	WHOstandards	USEPA standards	NDWQS
Temperature	30°C	30°C	30°C
pH	6.5–8.5	6.5–8.5	6.5–9.5
Nitrates	≤50mg/l	45mg/l	45mg/l
Hardness	500mg/l	450mg/l	600mg/l
Chloride	≤250mg/l	250mg/l	250mg/l
Carbonate	200mg/l	150mg/l	200mg/l
Calcium	75mg/l	N/A	N/A

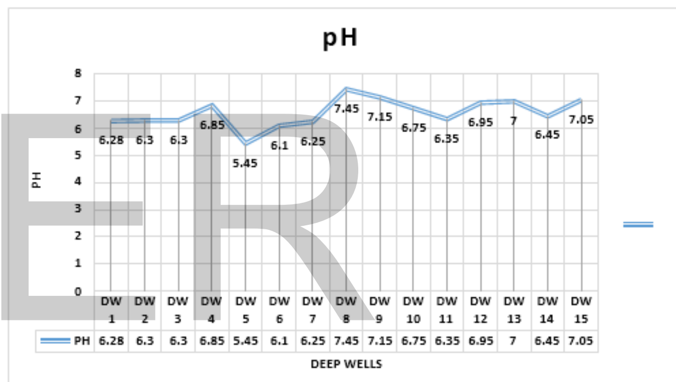


Figure5: Line graph showing variationin pH of the well water from the study area.

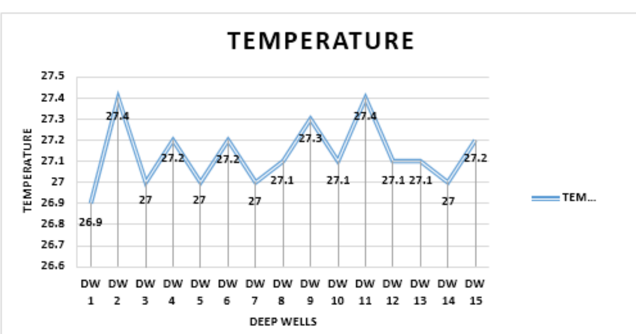


Figure 3: Line graph showing variationin temperature of the well water from the study area.

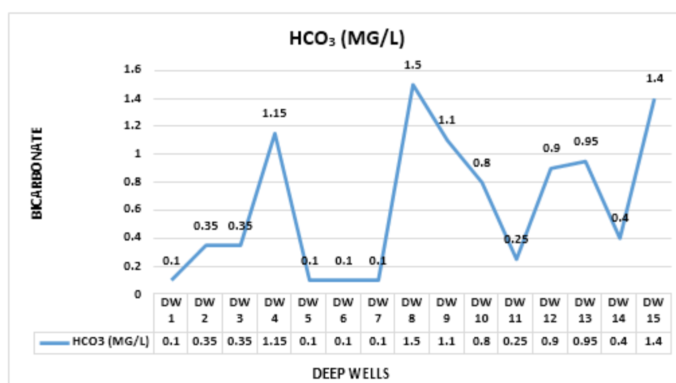


Figure 6: Line graph showing variation in bicarbonate content of the well water from the study area.

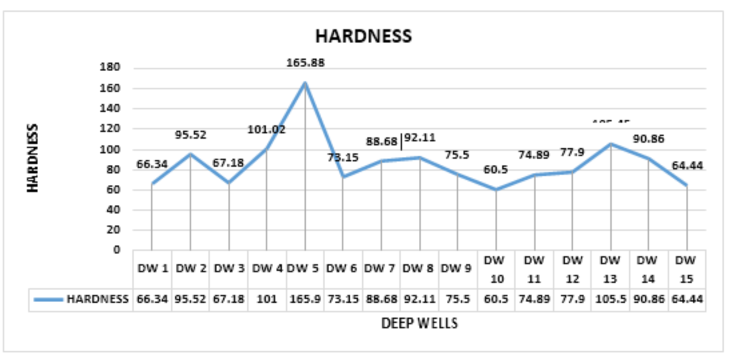


Figure 7: Line graph showing variationin hardness of the well water from the study area.

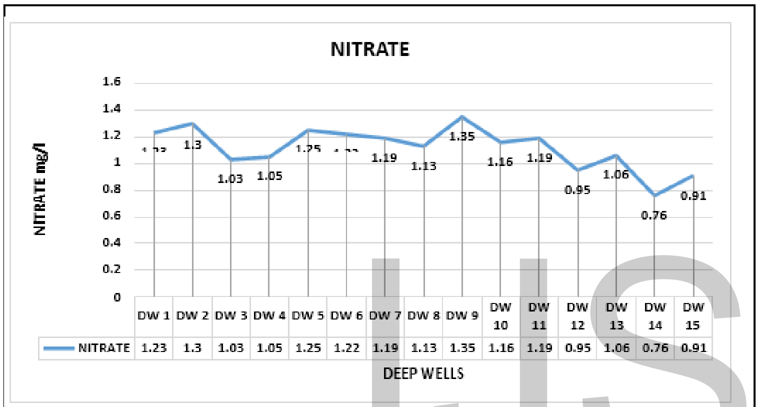


Figure 8: Line graph showing variationin nitrate content of the well water from the study area.

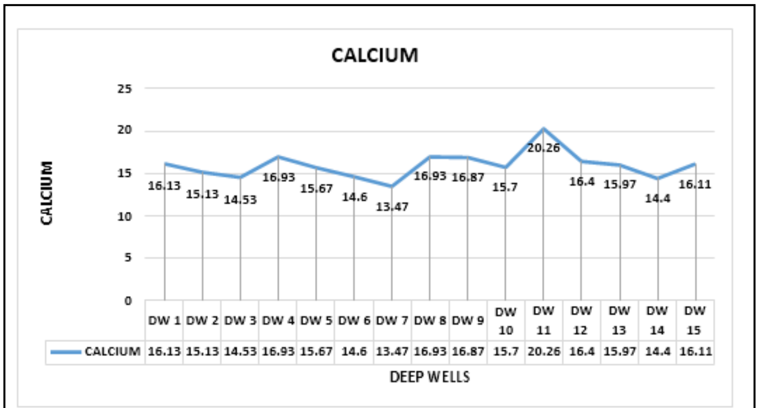


Figure 9: Line graph showing variationin calcium content of the well water from the study area.

And NDWQS (500 mg/l) standards values for Hardness.The 165.88 mg/l value for DW5 is, however, higher than the other Hardness values for the remaining deep wells within the study area.

The mean Nitrate content of the sampled deep wells in the study area was 1.12mg/l. This value is within the range of WHO, USEPA and NDWQS standard values for nitrate. Finally, the minimum and maximum nitrate values are less than the corresponding standard values for nitrate (Figure 8).Therefore, the groundwater is not polluted with respect to NO^{3-}. Increase in NO^{3-} concentration of groundwater could be as a result of some anthropogenic activities such as the overuse of nitrogenous fertilizers during farming, nitrification. It could also be from the decomposition of domestic and industrial waste.The mean, minimum and maximum (Figure 9) Ca^{2+} content of the groundwater also fall within the range specified by WHO, USEPA and NDWQS. The Ca^{2+} content of the groundwater in the study area could probably have been from water-rock interaction. Sources of Ca^{2+} could be from the weathering of rocks and minerals such as calcite, aragonite, gypsum, plagioclase etc. [7], [11], [10].These rocks and minerals contain calcium.

4.2 Physical Parameters

The Physical parameters of the sampled deep wells are shown in Table 6. A critical look at the table revealed that DW1, DW6, DW 7, DW 10, DW 11, DW 12 and DW 13 are fit for drinking. This is as a result of the fact that the groundwater samples are clear, colourless, and odourless. The other deep wells are not fit for drinking with respect to the appearance, colour, taste and odour. Furthermore, DW 4, DW5 and DW 8are totally unfit for drinking because none of the aforementioned wells pass the physical appearance test.

4.3 Water Quality Index

Tables 7 and 8 represent the Standard Water Quality Index and Water Quality Index ratings of the fifteen sampled deepwells respectively. The WQIs were calculated based on the results of the physicochemical analysis and also the assigned weight. A lot of factors can affect the Water quality which includes the distances of deep wells from waste disposal sites, the physical appearances and also the results of the physicochemical analysis. The table revealed that only DW12 is potable and can, therefore, be recommended for drinking without health hazards, DW1 and DW3 are unfit for drinking because of their low ratings while other remaining deep wells cannot be highly trusted but can be fetched for domestic use.

Ten waste disposal sites were located around various watersource. In order to calculate the distance between each deep well and the dumpsites.The multiple ring buffering was employed, The WHO standard for safe distance of waste disposal sites from water source is 100m (Table 9). From Table 9, only DW14 is the farthest (more than 100m) from any waste disposal site. This could be a hint that the water source is potable. DW1, DW2, DW3, DW5, DW11 and DW13 have distances from waste disposal sites less than 30m which is far below the standards set by WHO. Therefore, those deep well water area thigh risk of not being potable. DW7 and DW8 are the only deep wells that are above the 50m mark away.

Table 6: Physical Parameters of the Analyzed Groundwater Samples

S/N	Appearance	Colour	Taste	Odour
DW1	Clear	Colourless	Insipid	Odourless
DW2	Clear	Colourless	Sipid	Odourless
DW3	Clear	Colourless	Sipid	Odourless
DW4	Turbid	Slightly Coloured	Sipid	Odourless
DW5	Turbid	Slightly Coloured	Sipid	Odourless
DW6	Clear	Colourless	Insipid	Odourless
DW7	Clear	Colourless	Insipid	Odourless
DW8	Turbid	Slightly Coloured	Sipid	Odorous
DW9	Clear	Colourless	Sipid	Odourless
DW10	Clear	Colourless	Insipid	Odourless
DW11	Clear	Colourless	Insipid	Odourless
DW12	Clear	Colourless	Insipid	Odourless
DW13	Clear	Colourless	Insipid	Odourless
DW14	Clear	Colourless	Sipid	Odourless
DW15	Clear	Colourless	Sipid	Odorous

Table 7: Standard Water Quality Index

WATER QUALITY	WQIRANGE
EXCELLENT	90 – 100
VERY GOOD	75 – 89
GOOD	60 – 74
FAIR	40 – 59
POOR	0 – 39

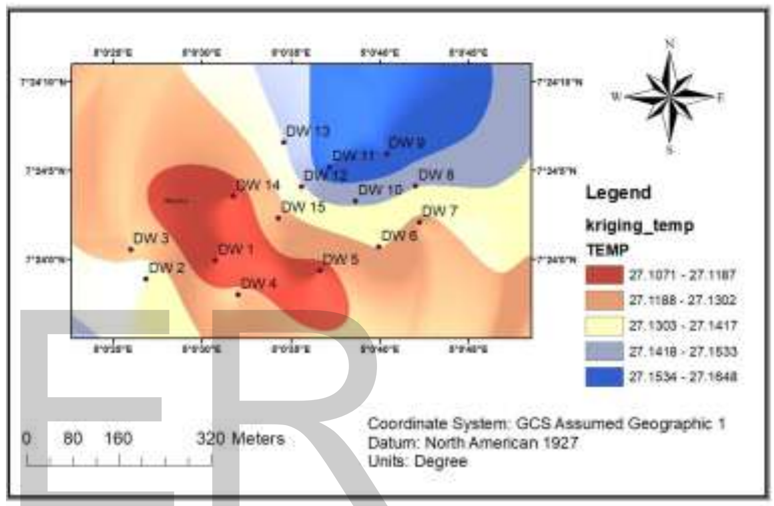
Table 8: Water Quality Index (WQI) Rating of the Selected deep wells

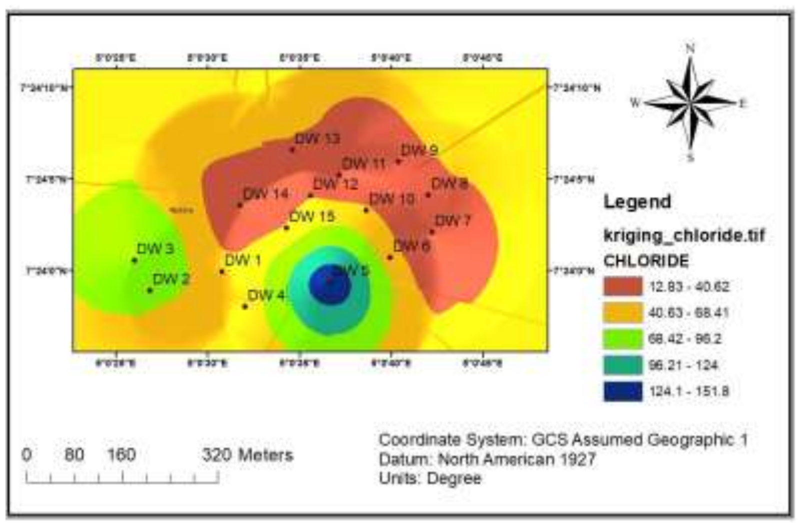
DEEP WELLS	WQI(%)	WQIRATINGS
DW1	58	FAIR
DW2	63	GOOD
DW3	59	FAIR
DW4	60	GOOD
DW5	61	GOOD
DW6	66	GOOD
DW7	68	GOOD
DW8	63	GOOD
DW9	64	GOOD
DW10	64	GOOD
DW11	61	GOOD
DW12	75	VERY GOOD
DW13	67	GOOD
DW14	68	GOOD
DW15	66	GOOD

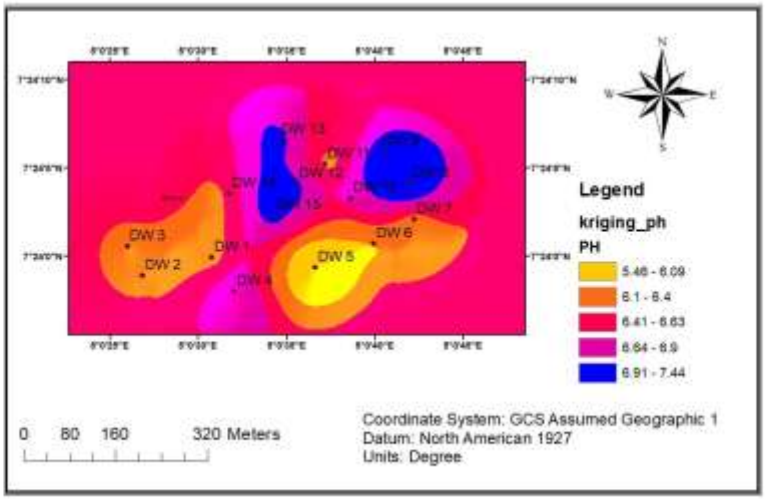
From the nearest waste disposal site, they can still be considered to fall below the standard set but they are quite better than those below the 50m mark downwards.

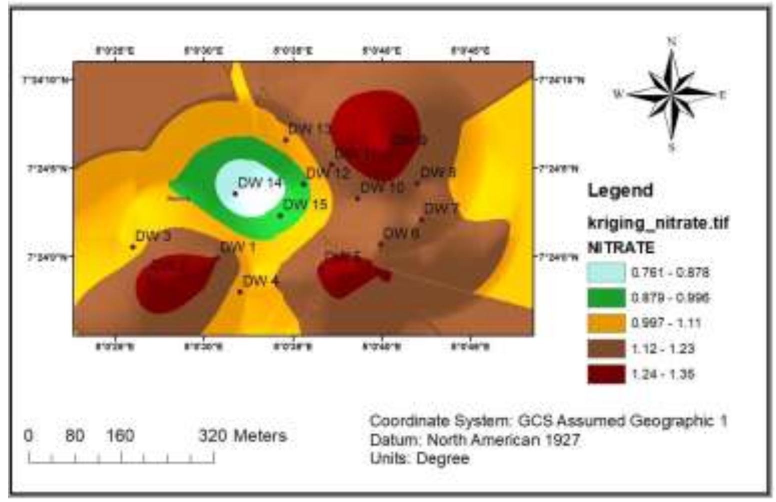
4.4 Spatial Analysis

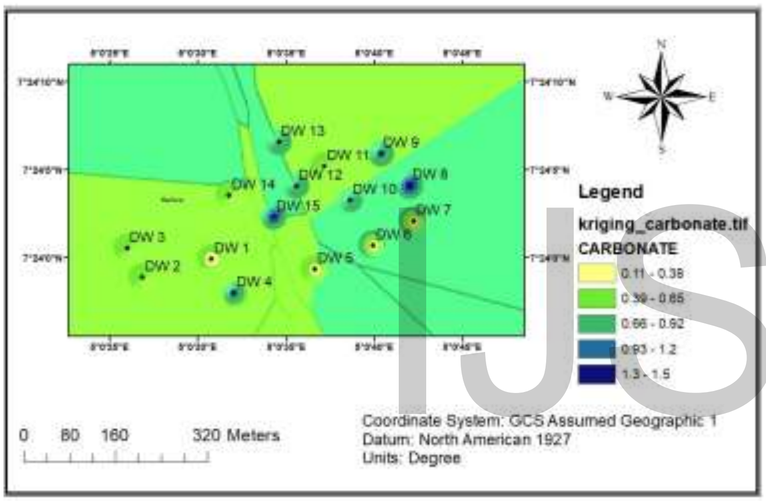
Kriging interpolation technique is used to predict, or estimate the values around the area of the assigned physicochemical parameters analyzed. Areas of deep wells that have almost the same physicochemical properties or common values for each physicochemical parameter have the same trend (Figure 10).

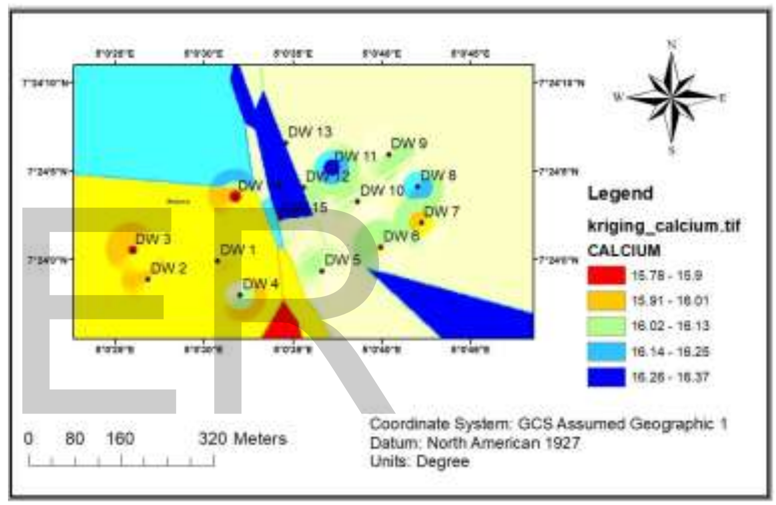












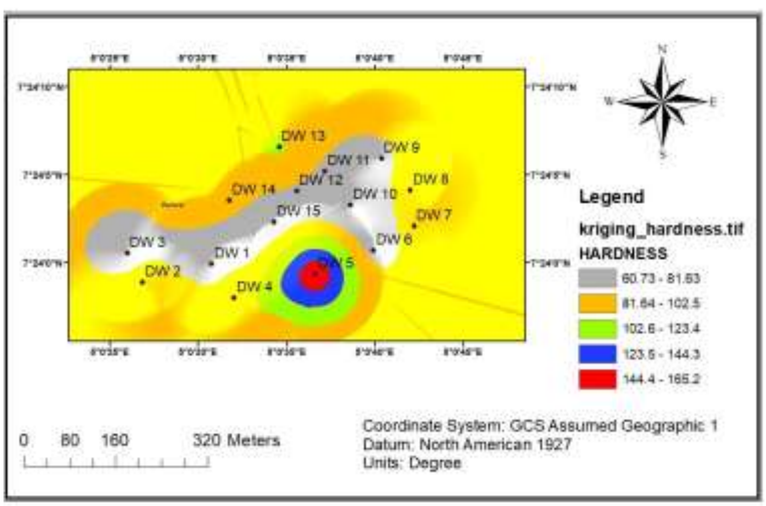


Figure 10: Kriging interpolation technique predicting the values around the physic-chemical parameters.

4.0 CONCLUSION

The study revealed that, all the deep well water samples examined are within the W.H.O standards for drinking water quality. Also, it was discovered that the effect of human activities were becoming pronounced on the potability of the deepwell water.
Therefore, the monitoring programs using remote sensing and GIS are needed to treat all contamination occurs and provides the effective action at all levels. Therefore, remote sensing and GIS techniques are the effective, cheaper and valuable tools in monitoring groundwater quality.
Further, the calculated WQI revealed that the groundwater from the study area is suitable for human use except that some deep wells need to be situated abit faraway from waste disposal sites that is, 100m or more in accordance with the W.H.O standard. It was concluded that the water supply groundwater in Owena market and its surroundings is suitable for drinking. However, there is need for routine monitoring of the various

human activities within the area especially in order to avoid the deterioration in quality of the groundwater.

The proximity krigging techniques such as multiple ring-buffer analysis and near distancetable and also, interpolation of parameters, has been approved in this study to an intelligent methods in analysis of water quality data for drawing meaningful information. Water quality index has been approved in this study to be user friendly, easy communication tool and more trustful as it express about the water quality for composite of parameters.

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