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ASSESSMENT OF WATER QUALITY INDEX OF GROUNDWATER RESOURCES IN IWO LOCAL GOVERNMENT AREA, OSUN STATE, SOUTHWESTERN NIGERIA

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Abstract

This study assessed the groundwater quality of 30 selected wells and boreholes in Iwo Local Government Area, Osun State, Nigeria. Groundwater sources were randomly stratified and identified according to the 15 political wards using hand-held GPS equipment. The selected sources were sampled during rainy season (October) and dry season (January) to determine water quality. The physico-chemical and microbiological parameters of the water samples such as temperature, turbidity, total suspended solids, pH, electrical conductivity, total dissolved solids, total alkalinity, total hardness, chloride, sulphate, nitrate, phosphate, magnesium, calcium, iron, zinc, lead, manganese, cadmium, chromium and total coliform were determined using standard methods. The results showed that total hardness, calcium, cadmium, sulphate and phosphate had mean values above the acceptable values for rainy and dry seasons; their mean values in mg/l for rainy season were 252.933, 98.267, 0.018, 305.119 and 1.762, respectively, while their values for dry season were 299.633, 115.831, 0.020, 285.695 and 1.705, respectively. The Water Quality Index (WQI) values showed that 30% of the selected groundwater sources were fit for consumption while 60% were poor and 10% were unfit for drinking during rainy season. During the dry season, 50% of the groundwater sources were fit for consumption, 40% were poor and 10% were unfit for consumption.

Key words

Contamination, groundwater, water supply, quality, treatment

INTRODUCTION

Water is basic for the survival of every living thing. It is also vital for the world's economic and industrial developments. The world's population grows quickly in both developed and developing countries. This makes water an essential and valuable asset. It is needed domestically for drinking, agriculturally for irrigation and industrially for the production of goods. It is essential to check the quantity and quality of water aimed at residential, agricultural and industrial purposes. WHO, (2017) stated that the provision of potable water is part of the Sustainable Development Goals (SDGs).

There are two major sources of water supply. These include both groundwater and surface water. The groundwater plays a very significant role in meeting the ever-increasing water demands from the residential, agricultural and industrial regions. This role necessitates technological efforts, particularly through the erection of wells and boreholes, both of which are derived from underground water. Surface water requires more treatment operations for its portability because it gets contaminated easily due to increasing urbanization (Dohare *et al.*, 2014). Nas (2009) reported that a shortage of supply of quality surface water due to rapid industrialization and population has amplified groundwater usage.

Recently, these groundwater sources are under the risk of degradation in both quantity and quality in many parts of the world, especially Nigeria. Large quantities of human and industrial wastes are discharged into the environment, which causes a serious threat to the groundwater (Adegbola and Adewoye, 2012). These wastes infiltrate into the groundwater gradually and their concentrations are enhanced with continuous discharge, coupled with some other environmental factors. Munna *et al.*, (2015) reported that excessive pumping and unscientific management of aquifers are also accountable for the deterioration of groundwater quality.

Generally, contaminations in built-up areas of Nigeria are anthropogenic. This is as a result of discharged effluents and untreated wastes, especially in Osun State, Nigeria (Atobatele and Olutona, 2013; Jeje and Oladepo, 2014). Menaces from water-borne diseases are obviously public health distress in Iwo Local Government Area (Ogunbode *et al*., 2016). Water supply for domestic and industrial use should be free from disease-causing organisms and other matters which are unacceptable to the final consumers. This is because contaminated groundwater makes a negative impact on public health (Sharma and Chhipa, 2013). In order to safeguard the public health, rigorous sampling and analysis of groundwater samples to assess water quality represent the major purpose of a monitoring program (Ahmed, 2017). The measurement of the type and level of contaminants present in a sample is generally referred to as water quality assessment.

Water quality index is an essential tool used to derive information about the quality of any source of water supply (Herojeet *et al.*, 2016). It is a technique which derives a simple index by summarizing various groundwater quality parameters and serves as a useful tool in water quality management and control. The highly recommended water quality index established by various agencies and departments are the Washington State Water Quality Index, Taiwan Water Quality Index, Canadian Water Quality Index, Colombia Water Quality Index, Florida Stream Water Quality Index, French Creek Quality Index, France Water Quality Index, Malaysian Water Quality Index, Oregon Water Quality Index and British Colombia Water Act Quality Index (Mahapatra *et al.,* 2012).

Materials and Methods

Study Area

Iwo Local Government Area is one of the 30 Local Government Areas in Osun State, Nigeria. It is divided into five quarters namely; Isale Oba, Molete, Oke Adan, Gidigbo and Oke Oba (Ogunbode *et al.*, 2016). These are further subdivided into 15 political wards. The local government encompasses rural, agricultural and urban regions. The urban region forms Iwo town, which is located on Latitude 07o38′ N to 07040′ N and Longitude 004009′ E to 004o11′ E.

Iwo is the administrative headquarter town of Iwo Local Government Area of Osun State in the Southwestern geopolitical zone of Nigeria. The town has an area of 245 km2 with a population of 191,348 of Yoruba descent and predominantly Muslims (National Population Commission, 2006). It is a nodal town from which towns such as Ibadan, Ile-Ogbo and Ede can readily be accessed. However, the study area shares boundaries with Aiyedire and Ola Oluwa in Osun State. It also shares boundaries with Lagelu, Akinyele, Afijio and Oyo East in Oyo State as shown in Figure 1. The study area is endowed with two rivers namely river Oba and river Aiba. River Aiba can be located at the north-eastern part of the study area, which was dammed and named Aiba reservoir for public water supply.

Aiba reservoir can be located between longitude 4o11′ to 4o 13′ East of the Greenwich and latitude 7o 38′ to 7o 39′ North of the Equator. It is a man-made lake located in Iwo city in the southwestern part of Nigeria. Aiba water reservoir located within government forest reservation area in the town serves as the major source of potable water in Iwo. Unfortunately, there is an inadequate supply of potable water from the waterworks, due to poor management and an increase in the population of the area. This led to the exploitation of underground water sources in the town.

The mean annual rainfall varies from 150 cm in the southern part of Nigeria to 300 cm (Ogunbode *et al.,* 2016; Olutona *et al.*, 2012). Mean maximum ambient temperature values range between 33.84 oC in February and 28.8 oC in August, while mean minimum temperatures range between 25.18 oC in March and 23.0 oC in August. Higher temperatures are mostly recorded at the peak of the dry season, while lower temperatures are recorded in the rainy season.

Collection of Samples

Water samples were collected for water quality and bacteriological studies from 30 locations including boreholes, hand pump and shallow wells within Iwo Local Government Area as shown in Table 1. The sampling was designed to target the population demanding groundwater majorly for domestic purpose.

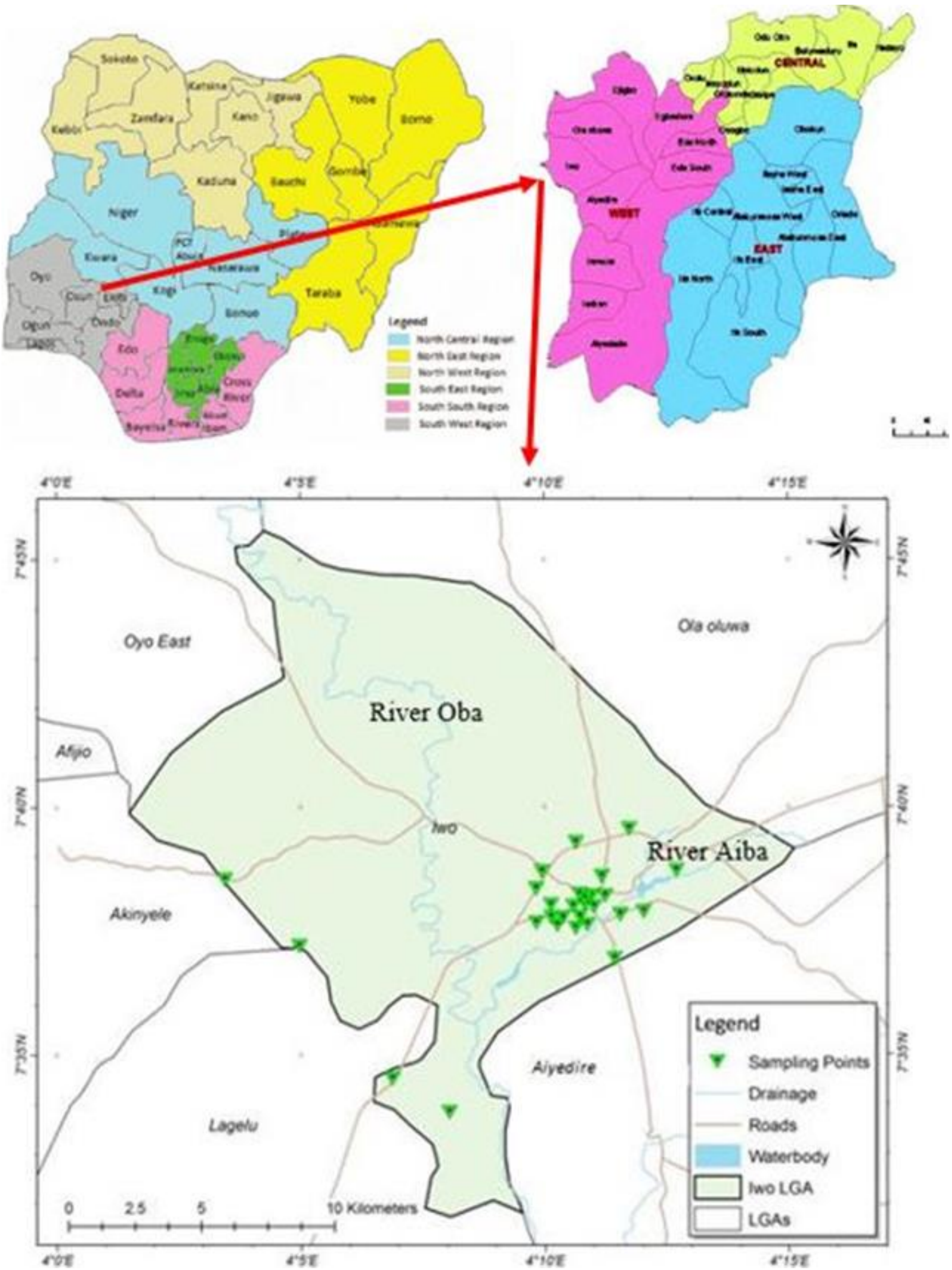

Figure 1: Map of the Study Area

Table 1: Locations of selected hand pump boreholes, boreholes and shallow wells within Iwo Local Government Area

S/N	Political ward	Latitude	Longitude	GL(m)
1	Isale Oba Ward 01A	$07^{0}\ 37^{1}\ 32.6^{11}$	$04^{0}\ 10^{1}\ 38.7^{11}$	237
2	Isale Oba Ward 01B	$07^{0}\ 37^{1}\ 46.6^{11}$	$04^{0}\ 10^{1}\ 43.9^{11}$	249
3	Isale Oba Ward 02A	$07^{0}\ 37^{1}\ 37.2^{11}$	$04^{0}\ 10^{1}\ 52.7^{11}$	237
4	Isale Oba Ward 02B	$07^{0}\ 37^{1}\ 45.5^{11}$	$04^{0}\ 10^{1}\ 22.5^{11}$	249
5	Isale Oba Ward 03A	$07^{0}\ 37^{1}\ 52.7^{11}$	$04^{0}\ 12^{1}\ 02.2^{11}$	245
6	Isale Oba Ward 03B	$07^{0}\ 37^{1}\ 49.2^{11}$	$04^{0}\ 11^{1}\ 33.4^{11}$	242
7	Isale Oba Ward 04A	$07^{0}\ 37^{1}\ 36.5^{11}$	$04^{0}\ 10^{1}\ 15.8^{11}$	241
8	Isale Oba Ward 04B	$07^{0}\ 36^{1}\ 55.6^{11}$	$04^{0}\ 11^{1}\ 26.4^{11}$	242
9	Molete Ward 05A	$07^{0}\ 37^{1}\ 58.8^{11}$	$04^{0}\ 11^{1}\ 01.3^{11}$	250
10	Molete Ward 05B	$07^{0}\ 38^{1}\ 02.4^{11}$	$04^{0}\ 10^{1}\ 49.6^{11}$	259
11	Molete Ward 06A	$07^{0}\ 38^{1}\ 11.7^{11}$	$04^{0}\ 11^{1}\ 14.8^{11}$	246
12	Molete Ward 06B	$07^{0}\ 38^{1}\ 42.5^{11}$	$04^{0}\ 12^{1}\ 42.5^{11}$	254
13	Molete Ward 07A	07° 38′ 35.0″	04° 11′ 10.9″	260
14	Molete Ward 07B	$07^{0}\ 38^{1}\ 35.1^{11}$	$04^{0}\ 11^{1}\ 10.8^{11}$	260
15	Oke Adan Ward 08A	$07^{0}\ 38^{1}\ 10.6^{11}$	$04^{0}\ 10^{1}\ 54.7^{11}$	249
16	Oke Adan Ward 08B	$07^{0}\ 38^{1}\ 12.0^{11}$	$04^{0}\ 10^{1}\ 57.5^{11}$	255
17	Oke Adan Ward 09A	$07^{0}\ 38^{1}\ 08.7^{11}$	$04^{0}\ 10^{1}\ 50.2^{11}$	253
18	Oke Adan Ward 09B	$07^{0}\ 38^{1}\ 13.9^{11}$	$04^{0}\ 10^{1}\ 43.3^{11}$	252
19	Oke Adan Ward 10A	$07^{0}\ 39^{1}\ 16.4^{11}$	$04^{0}\ 10^{1}\ 38.9^{11}$	269
20	Oke Adan Ward 10B	$07^{0}\ 39^{1}\ 32.9^{11}$	$04^{0}\ 11^{1}\ 44.3^{11}$	255
21	Gidigbo Ward 11A	$07^{0}\ 37^{1}\ 45.7^{11}$	$04^{0}\ 10^{1}\ 08.3^{11}$	243

Therefore groundwater sources were randomly stratified and identified according to the 15 political wards using hand-held Global Positioning System (GPS) equipment. Most of the wells were covered in the urban region, while those located in rural regions were unlined and hand pump wells. The location of each well was recorded using a handheld GPS. Sampling was done once during the rainy season (October) and also once during the dry season (January).

Analysis of Water Samples

The 21 physical, chemical and microbiological parameters such as temperature, turbidity, pH, electrical conductivity, total suspended solids, total dissolved solids, total alkalinity, total hardness, chloride, sulphate, nitrate, phosphate, magnesium, calcium, iron, zinc, lead, manganese, cadmium, chromium and total coliform were selected in line with researches carried out by Ogunbode *et al.*, (2016) and Olutona *et al.*, (2012).

The pH of water samples were measured in-situ, using a pH meter. Temperature was measured at the sampling points using a mercury thermometer with an accuracy of 0.1 ºC, at 25 ºC. Electrical conductivities of the water samples were determined using platinum electrode conductivity meter. Total dissolve solid was determined by using total dissolved solid meter. The quantity of chloride present in the water samples was determined by titration using standard silver nitrate. Hardness was determined by standard Ethylene Diamine Tetra-acetic Acid (EDTA) titration method.

Sulphate, nitrate and phosphate concentrations of the water samples were determined using UV-Spectrophotometer. Complexometric titration method was used to find the quantity of calcium of the hardness of water by titrating the water sample with a standard EDTA of known concentration and volume. Magnesium was determined by calculating the difference between total hardness and calcium hardness as $CaCO_3$ equivalent. The result was multiplied by mass ratio of magnesium (0.243).

The alkalinity of the water samples were determined by titrating 100 ml of the samples with 0.2 N solution of sulphuric acid using phenolphthalein and mixed indicators as indicators. Total suspended solid was measured gravimetrically after drying in an oven at 105 ºC and cooled to room temperature in a desiccator. Electronic turbid meter with scattered-light detectors was used for turbidity measurement after calibrating the instrument with distilled water.

The total coliform in the water samples were obtained using the membrane-filtration method. The heavy metals in the samples were analyzed using Atomic Absorption Spectrophotometer (AAS) which makes use of flame as the atomizer. In order to obtain accurate result, 100 ml of sampled water were digested with 10 ml concentrated nitric acid. The solution was heated for a period of 30 minutes, cooled and transferred to a 100 ml beaker which was filled up to 100 ml mark with distilled water.

Calculation of Water Quality Index

According to Verma et al., (2013), water quality index of a source of water supply is mostly calculated using the following equations:

$$WQI = \sum_{i=1}^{n} W_i \times Q_i \quad (1)$$

$$W_i = \frac{K}{S_i} \quad (2)$$

$$K = \left[\frac{1}{\sum_{n=i}^{n} \frac{1}{S_i}} \right] \quad (3)$$

$$Q_i = \left[\frac{(V_a - V_i)}{(V_s - V_i)} \times 100 \right] \quad (4)$$

Where,

WQI = Water Quality Index
Q_i = Quality rating
W_n = Unit weight
V_a = Measured value of water quality parameter
V_i = Ideal value of the parameter. (pH = 7, other parameters = 0)
V_s = Standard value of the water quality parameter
S_n = Acceptable value of water quality parameter from standards.
K = Proportionality constant
S_i = Individual standard value for water quality parameter
N = number of parameters

Based on the water quality index, quality of groundwater supply from sampling points were categorized into unfit for drinking (> 100), very poor (76 – 100), poor (51 – 75), good (26 – 50) and excellent (0 – 25) (Oko *et al.*, 2014). Turbidity, chloride, nitrate, pH, hardness, total dissolved solids and electrical conductivity were the seven selected parameters used for water quality index.

RESULTS

Rainy Season

The mean temperature for the sampled wells during the rainy season was 27.48 oC, clearly above the guideline value of 25 oC. The pH of the water samples ranged from 5.6 to 8.5 and had a mean of 7.07 which was within the World Health Organization (WHO) guideline value of 6.5 – 8.5. The mean electrical conductivity (568.60 µS/cm) was below the guideline value of 1,000 µS/cm. The mean total dissolved solid (330.57 mg/l) was below the guideline value of 500 mg/l. The mean value of chloride (67.13 mg/l) was below the guideline value of 250 mg/l.

The mean total alkalinity (120.57 mg/l) was below the guideline value of 200 mg/l. The mean total suspended solid (180 mg/l) was below the guideline value of 250 mg/l. The mean turbidity (3.90 NTU) was below the guideline value of 5 NTU. The mean total hardness (252.93 mg/l) was above the guideline value of 150 mg/l. The mean calcium (98.27 mg/l) was above the guideline value of 75 mg/l. The mean magnesium (1.91 mg/l) was below the guideline value of 50 mg/l.

The mean value of nitrate (52.16 mg/l) was above the standard value of 50 mg/L. The mean value of sulphate (305.12 mg/l) was above the guideline value of 250 mg/l. The mean value of phosphate (1.76 mg/l) was above the guideline value of 0.05 mg/l. The mean value of iron (0.16 mg/l) was below the guideline value of 0.3 mg/l.

The mean of lead (0.01 mg/l) was below the guideline value of 0.01 mg/l as shown in Table 2a. The mean manganese (0.03 mg/l) was below the guideline value of 0.4 mg/l. The mean value of zinc (0.03 mg/l) was below the guideline value of 3.0 mg/l. The mean cadmium (0.02 mg/l) was above the guideline value of 0.003 mg/l. The mean chromium (0.03 mg/l) was below the guideline value of 0.05 mg/l. The mean value of total coliform (22.67 x 10-4 CFU/ml) was above the guideline value of 10 CFU/ml.

Dry season

The pH of the water samples had a mean value of 7.16 which was within the WHO guideline value of 6.5 – 8.5 as shown in Table 2b. The mean temperature of the water samples (16.20 oC) was below the guideline value of 25 oC. The mean electrical conductivity (504.97 µS/cm) was below the guideline value of 1,000 µS/cm. The mean value of total dissolved solids (308.3 mg/l) was below the guideline value of 500 mg/l as shown in Table 2b.

The mean value of chloride (68.44 mg/l) was below the guideline value of 250 mg/l. The mean total alkalinity (141.43 mg/l) was below the guideline value of 200 mg/l. The mean total suspended solid (190 mg/l) was below the guideline value of 250 mg/l. The mean turbidity (3.03 NTU) was below the guideline value of 5 NTU. The mean total hardness (299.63 mg/l) was above the guideline value of 150 mg/l. The mean calcium (115.83 mg/l) was above the guideline value of 75 mg/l.

Table 2a: Groundwater parameters mean against WHO values for rainy season

SN	Parameter	WHO	Mean	Standard Error	Standard Dev.	Coefficient of Variation (%)
1	pH (-)	6.5 – 8.5	7.07	±0.114	±0.625	8.84
2	Temp (°C)	25	27.48	±0.261	±1.429	5.20
3	EC (µS/cm)	1000	568.60	±94.059	±515.180	90.61
4	TDS (mg/l)	500	330.57	±54.352	±297.701	90.06
5	T. Al. (mg/l)	200	120.57	±15.927	±87.234	72.35
6	TSS (mg/l)	250	180.00	±22.565	±123.596	68.66
7	Turb. (NTU)	5	3.90	±0.379	±2.074	53.17
8	TH (mg/l)	150	252.93	±32.553	±178.298	70.49
9	Ca (mg/l)	75	98.27	±13.057	±71.518	72.78
10	Mg (mg/l)	50	1.91	±0.225	±1.230	64.51
11	Cl (mg/l)	250	67.13	±13.681	±74.936	111.63
12	NO_3^- (mg/l)	50	52.16	±4.162	±22.796	43.70
13	SO_4^{2-} (mg/l)	250	305.12	±17.511	±95.910	31.43
14	PO_4^{3-} (mg/l)	0.05	1.76	±0.178	±0.972	55.17
15	Fe (mg/l)	0.3	0.16	±0.006	±0.035	22.41
16	Pb (mg/l)	0.01	0.01	±0.000	±0.002	23.14
17	Mn (mg/l)	0.05	0.03	±0.001	±0.007	23.60
18	Zn (mg/l)	3.0	0.03	±0.002	±0.009	27.62
19	Cd (mg/l)	0.003	0.02	±0.001	±0.004	19.45
20	Cr (mg/l)	0.05	0.03	±0.002	±0.012	41.52
21	TCC(cfu/ml)x 10^{-4}	10	22.67	±4.555	±24.951	110.08

Table 2b: Groundwater parameters mean against WHO values for dry season

SN	Parameter	WHO	Mean	Standard Error	Standard Dev.	Coefficient of Variation (%)
1	pH (-)	6.5 – 8.5	7.16	±0.210	±1.148	16.03
2	Temp (°C)	25	16.20	±0.471	±2.578	15.91
3	EC (µS/cm)	1000	504.97	±80.224	±439.403	87.02
4	TDS (mg/l)	500	308.30	±49.234	±269.666	87.47
5	T. Al. (mg/l)	200	141.43	±13.442	±73.626	52.06
6	TSS (mg/l)	250	190.00	±24.377	±133.520	70.27
7	Turb. (NTU)	5	3.03	±0.373	±2.042	67.33
8	TH (mg/l)	150	299.63	±37.694	±206.458	68.90
9	Ca (mg/l)	75	115.83	±14.970	±81.996	70.79
10	Mg (mg/l)	50	2.32	±0.281	±1.540	66.43
11	Cl (mg/l)	250	68.44	±13.324	±72.981	106.63
12	NO_3^- (mg/l)	50	48.29	±3.739	±20.481	42.41
13	SO_4^{2-} (mg/l)	250	285.70	±17.540	±96.068	33.63
14	PO_4^{3-} (mg/l)	0.05	1.71	±0.174	±0.954	55.95
15	Fe (mg/l)	0.3	0.19	±0.009	±0.048	25.18
16	Pb (mg/l)	0.01	0.01	±0.000	±0.002	27.06

17	Mn (mg/l)	0.05	0.03	±0.001	±0.008	23.02
18	Zn (mg/l)	3.0	0.03	±0.002	±0.008	24.83
19	Cd (mg/l)	0.003	0.02	±0.001	±0.004	19.95
20	Cr (mg/l)	0.05	0.03	±0.002	±0.012	39.49
21	TCC(cfu/ml)x10^{-4}	10	6.63	±1.221	±6.688	100.82

The mean magnesium (2.32 mg/l) was below the guideline value of 50 mg/l. The mean value of Nitrate (48.29 mg/l) was below the standard value of 50 mg/l. The mean value of sulphate (285.70 mg/l) was above the guideline value of 250 mg/l. The mean value of phosphate (1.71 mg/l) was above the guideline value of 0.05 mg/l. The mean value of iron (0.19 mg/l) was below the guideline value of 0.3 mg/l. The mean of lead (0.01 mg/l) was within the guideline value of 0.01 mg/l. The mean manganese (0.03 mg/l) was below the guideline value of 0.05 mg/l.

The mean value of zinc (0.03 mg/l) was below the guideline value of 3.0 mg/l. The mean cadmium (0.02 mg/l) was above the guideline value of 0.003 mg/l. The mean chromium (0.03 mg/l) was below the guideline value of 0.05 mg/l. The mean value of total coliform (6.63 x 10-4 CFU/ml) was below the guideline value of 10 CFU/ml.

Discussion

Results were compared with the acceptable limits of WHO and a few of the parameters were above the acceptable limits during the rainy and dry seasons. Total hardness, calcium, cadmium, sulphate and phosphate were the groundwater quality parameters having mean values above the standard values for both seasons. It can be observed that the groundwater in the study area is generally hard. This is beneficial in the aspect of health (Olutona et al., 2012). Although not economical, since hard water results in excessive use of soap for washing (Oko et al., 2014).

The application of water quality index was able to reveal the quality status of the sampled wells. Equations 2 and 3 were used to obtain the values for unit weight and the proportionality constant as shown in Table 3. Subsequently, standard values and the measured values of the water quality parameters were used to obtain the quality rating values applying equation 4. These values for rainy and dry seasons were as shown in Tables 4 and 6 respectively.

Table 3: Water quality index independent variables

S/N	Parameter	Standard Value (Si)	Proportionality constant (K)	Unit Weight (Wi)
1	Chloride	250	2.838	0.0114
2	Turbidity	5	2.838	0.5676
3	Nitrate	50	2.838	0.0568
4	pH	8.5	2.838	0.3334
5	Hardness	150	2.838	0.0189
6	Total Dissolved Solids	500	2.838	0.0057
7	Electrical Conductivity	1000	2.838	0.0028

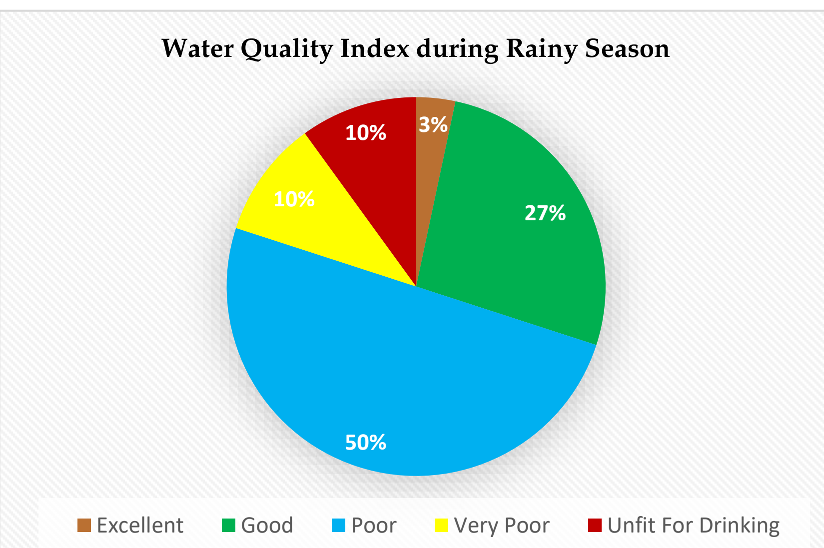

Figure 2: Water Quality Index for the Study Area during Rainy Season

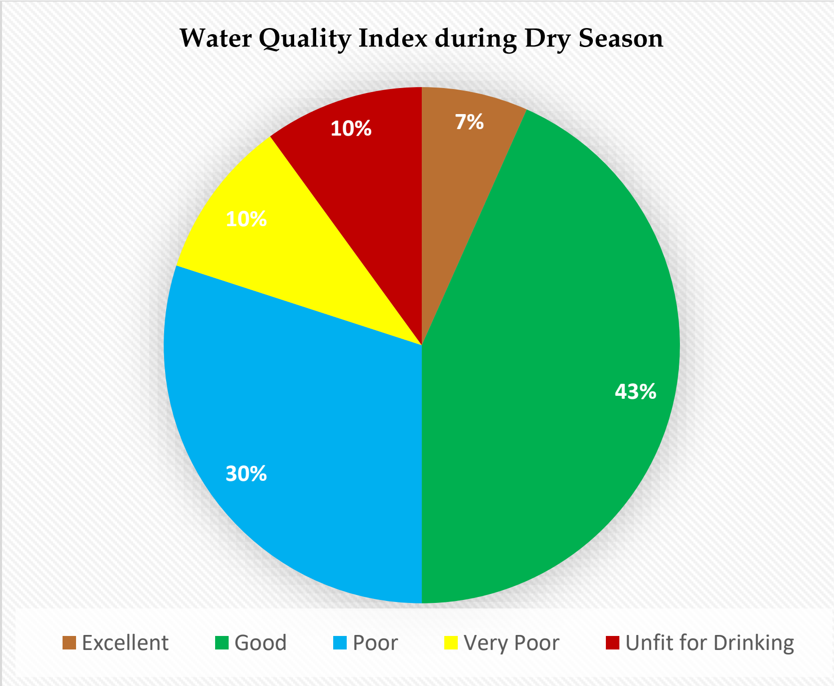

Figure 3: Water Quality Index for the Study Area during Dry Season

Table 4: Quality Rating Values for Seven Water Quality Parameters during Rainy Season

Sample	Cl^-	Turb.	NO_3^-	pH	Hardness	TDS	EC
1A	0.16	0.6	0.9736	0.2	3.313	0.14	0.12
1B	0.3696	0.2	0.8618	0.0	0.893	0.9	1.36
2A	0.16	1.4	0.5576	0.4	0.740	0.12	0.086
2B	0.19	0.8	1.0344	0.33	5.307	1.206	1.095
3A	0.1260	0.8	0.9534	0.47	1.547	0.4	0.311
3B	0.0820	0.2	1.2276	0.133	2.50	0.146	0.103
4A	0.1220	1.0	1.2884	0.0	1.913	0.106	0.096
4B	0.1520	0.8	1.8866	0.2	0.50	0.24	0.219
5A	0.1220	0.8	1.1462	0.27	1.333	1.274	0.994
5B	0.3619	0.2	0.4358	0.333	0.293	0.45	0.322
6A	0.0820	0.4	1.024	0.066	2.387	1.120	1.020
6B	1.1316	1.4	1.3084	0.333	1.913	0.480	1.036
7A	0.5818	0.6	0.8924	0.933	0.3	1.22	0.957
7B	0.4119	0.8	1.7852	0.333	0.360	0.958	0.684
8A	0.1860	1.4	1.7344	1.000	1.573	1.688	1.319
8B	0.5518	1.0	0.3344	0.0	0.747	2.020	1.430
9A	0.0560	0.6	1.0144	0.867	4.287	2.026	1.843
9B	0.5458	1.4	0.9428	0.267	1.027	0.116	0.090
10A	0.1360	0.8	1.4404	0.533	1.78	0.63	0.45
10B	0.0900	1.0	0.3242	0.2	2.26	0.28	0.219
11A	0.0820	0.4	0.4664	0.267	0.54	0.382	0.273
11B	0.0560	0.6	0.3648	0.40	0.52	0.30	0.196
12A	0.0900	0.2	1.0444	0.2	2.14	0.28	0.257
12B	1.2556	1.8	0.2838	0.533	1.167	1.66	1.284
13A	0.0960	1.2	1.572	0.40	0.54	0.42	0.299
13B	0.0820	0.8	1.359	0.333	3.007	0.22	0.195
14A	0.1620	0.6	1.041	0.067	1.807	0.4	0.295
14B	0.0720	0.4	1.2698	0.267	1.513	0.28	0.215
15A	0.0620	0.8	1.0152	0.267	1.993	0.148	0.115
15B	0.4798	0.4	1.7144	0.333	2.387	0.224	0.175

The Water Quality Index (WQI) values showed that 30% of the selected groundwater sources were adequate for consumption while 50% were poor, 10% were very poor and 10% were unfit for drinking during rainy season as shown in Figure 2. The Water Quality Index (WQI) values showed that 50% of the selected groundwater sources were adequate for consumption while 30% were poor, 10% were very poor and 10% were unfit for drinking during the dry season as shown in Figure 3. It can be observed that the water quality was better during the dry season than the rainy season.

Table 5: Water Quality Index for Seven Water Quality Parameters during Rainy Season

Sample	**Cl^- 1**	**Turb. 2**	**NO_3^- 3**	**pH 4**	**Hardness 5**	**TDS 6**	**EC 7**	**Total (1+2+3+4+5+6+7)**
1A	0.1824	34.056	5.530	6.668	5.262	0.0798	0.1736	51.95
1B	0.4213	11.352	4.395	0.0	1.688	0.513	0.3808	18.75
2A	0.1824	79.464	3.167	13.336	1.3986	0.0684	0.0241	97.6405
2B	0.2166	45.408	5.375	11.002	10.030	0.6874	0.3066	73.026
3A	0.1436	45.408	5.415	15.670	2.924	0.228	0.087	59.876
3B	0.0935	11.352	6.3728	4.434	4.725	0.0832	0.0288	27.0893
4A	0.1391	56.76	7.3181	0.0	3.6156	0.06042	0.02688	57.9201
4B	0.1733	45.408	10.7159	6.668	0.945	0.1368	0.06132	64.108
5A	0.1391	45.408	6.5104	9.0018	2.5194	0.7262	0.27832	64.583
5B	0.4126	11.352	2.4753	11.102	0.5538	0.2565	0.0902	26.2424
6A	0.0935	22.704	5.8163	2.2004	4.5114	0.6384	0.2556	36.2496
6B	1.29	79.464	7.432	11.102	3.6156	0.2736	0.2901	**103.467**
7A	0.5633	34.056	5.0688	31.126	0.567	0.6954	0.2680	72.345
7B	0.4696	45.408	10.140	11.102	0.6804	0.5461	0.1915	58.5376
8A	0.21204	79.464	9.3514	33.34	2.973	0.9622	0.3693	**125.67**
8B	0.5291	56.76	1.3994	0.000	1.4118	1.1514	0.4004	61.6521
9A	0.0638	34.056	5.7618	23.9058	3.1024	1.1548	0.5160	63.5607
9B	0.5222	79.4640	5.3551	3.9018	1.9410	0.0661	0.0252	91.2754
10A	0.1550	45.408	8.1815	17.770	3.3642	0.3591	0.126	75.3638
10B	0.1026	56.76	1.3415	6.668	4.2714	0.1596	0.0613	63.364
11A	0.0935	32.704	2.5492	3.9018	1.0206	0.2177	0.0764	30.563
11B	0.0638	34.056	2.0721	13.3360	0.9828	0.171	0.0549	50.7366
12A	0.1026	11.352	5.3322	6.668	4.0446	0.1596	0.0720	27.731
12B	1.4314	102.168	1.5120	12.7702	2.2056	0.9462	0.3595	**121.393**
13A	0.1094	68.112	3.929	13.336	1.0206	0.2394	0.0837	86.5271
13B	0.0935	45.408	0.7191	11.102	5.6832	0.1254	0.0546	53.1858
14A	0.1847	34.056	5.9129	2.2338	3.4152	0.228	0.0826	45.113
14B	0.0821	22.704	7.2125	3.9018	2.8596	0.1596	0.0602	35.9798
15A	0.0707	45.408	5.7663	3.9018	3.7668	0.0844	0.0322	53.0302
15B	0.5470	22.7040	9.7378	11.102	4.5114	0.1277	0.049	43.779

For the rainy season, samples 6B, 8A and 12B had water quality index greater than 100 as shown in Table 5. For the dry season, samples 8A, 9A and 13A had water quality index greater than 100 as shown in Table 7. It can be observed that the water sample labelled 8A was unfit for drinking throughout the season. Groundwater from these five locations in the study area should be subjected to conventional treatment in order to safeguard the health of the populace that demand water from such wells (Ogunbode et al., 2016).

Table 6: Quality Rating Values for Seven Water Quality Parameters during Dry Season

Sample	Cl^-	Turb.	NO_3^-	pH	Hardness	TDS	EC
1A	0.1700	0.4000	0.9444	0.3333	3.5667	0.1540	0.1400
1B	0.3898	0.4000	0.8188	0.7333	0.6667	1.2100	1.008
2A	0.1500	1.2000	0.5520	0.6000	1.1000	0.0760	0.0590
2B	0.1900	0.6000	1.0138	0.5333	6.4267	1.3520	0.9650
3A	0.1660	0.4000	0.9152	0.0000	1.9400	0.3000	0.2720
3B	0.0800	0.4000	1.1908	0.8660	2.6733	0.1320	0.1100
4A	0.1200	0.2000	1.2240	0.9333	2.1067	0.0660	0.0510
4B	0.1500	0.4000	1.6678	0.1333	0.7533	0.2520	0.1800
5A	0.1220	1.0000	1.0086	0.4000	1.6200	0.9840	0.8940
5B	0.3399	0.2000	0.4270	0.2000	0.3667	0.2720	0.2260
6A	0.0860	0.2000	0.9830	0.4667	2.5533	1.2480	0.9600
6B	1.1616	0.2000	1.2430	0.3333	2.1000	1.0820	0.7730
7A	0.6858	0.6000	0.8032	1.0000	0.4467	0.9360	0.8500
7B	0.4199	1.0000	1.6602	0.4667	0.4333	0.6860	0.5920
8A	0.1979	1.4000	1.4742	2.3333	1.9733	1.5500	1.2760
8B	0.5617	1.2000	0.2942	0.7333	0.8000	1.4700	1.1300
9A	0.0500	0.4000	0.9840	2.0000	4.7200	1.7760	1.6150
9B	0.5018	1.0000	0.8956	1.0000	1.5133	0.0960	0.0820
10A	0.1260	0.4000	1.3684	0.2667	2.4867	0.5120	0.4190
10B	0.0860	0.2000	0.3210	0.0000	2.4933	0.2540	0.1960
11A	0.0780	1.0000	0.4570	0.2000	0.5733	0.2420	0.2190
11B	0.0600	0.4000	0.3502	0.6667	0.5800	0.1880	0.1620
12A	0.0920	0.2000	1.0130	0.8000	3.2000	0.3080	0.2530
12B	0.9277	0.8000	0.2554	0.2667	1.4200	1.5060	1.1590
13A	0.0980	1.6000	1.4934	0.1333	0.5267	0.3960	0.3600
13B	0.0560	0.2000	1.0454	0.2000	3.2267	0.4300	0.3700
14A	0.1660	0.6000	0.9682	0.2000	1.9933	0.1980	0.1630
14B	0.0620	1.0000	1.0794	0.2667	2.2667	0.5460	0.4200
15A	0.0740	0.4000	0.8934	0.0000	2.4067	0.1420	0.1290
15B	0.8457	0.2000	1.6286	0.4667	2.9933	0.1340	0.1160

Table 7: Water Quality Index for Seven Water Quality Parameters during Dry Season

Sample	Cl^-	Turb.	NO_3^-	pH	Hardness	TDS	EC	Total
	1	2	3	4	5	6	7	(1+2+3+4+5+6+7)
1A	0.1938	22.7040	5.3642	11.1122	6.7411	0.0878	0.0392	46.2423
1B	0.4444	22.7040	4.5508	24.4482	1.2601	0.6897	0.2822	54.3794
2A	0.1710	68.1120	3.1354	20.0040	2.0790	0.0433	0.0165	93.5612
2B	0.2166	34.0560	5.7584	17.7802	12.1465	0.7706	0.2702	70.9985
3A	0.1892	22.7040	5.1983	0.0000	3.6666	0.1710	0.0762	32.0053
3B	0.0912	22.7040	1.0837	23.8724	5.0525	0.0752	0.0308	52.9098
4A	0.1368	11.3520	5.9523	31.1162	3.3817	0.0376	0.0143	51.9909
4B	0.1710	22.7040	9.4731	4.4442	1.4237	0.1436	0.0504	38.4100
5A	0.1391	56.7600	5.7289	13.3360	3.0618	0.5609	0.2503	79.8370
5B	0.3875	11.3520	2.4254	6.6680	0.5931	0.1550	0.0633	14.3037
6A	0.0980	11.3520	5.5834	15.5598	4.3257	0.7114	0.2688	37.8991
6B	1.3242	11.3520	7.0602	11.1122	3.9790	0.6167	0.2164	35.6507
7A	0.7818	34.0560	4.5622	33.3400	0.3443	0.5335	0.2380	73.8558
7B	0.4787	56.7600	9.4299	15.5598	0.3189	0.3910	0.1658	33.1041
8A	0.2256	79.4640	8.3735	77.7900	3.7295	0.8835	0.3573	**170.8234**
8B	0.5403	68.1120	1.5711	24.4482	1.5120	0.8379	0.3164	37.3379
9A	0.0570	22.7040	5.5891	66.6800	8.9208	1.0123	0.4522	**105.4154**
9B	0.5721	56.7600	5.0870	33.3400	2.3601	0.0547	0.0230	38.1969
10A	0.1436	22.7040	7.7725	8.3918	4.5999	0.2918	0.1173	44.0209
10B	0.0980	11.3520	1.8233	0.0000	4.7123	0.1448	0.0549	18.1853

11A	0.0889	56.7600	2.5958	6.6680	1.0835	0.1379	0.0613	57.3954
11B	0.0684	22.7040	1.9890	22.2278	1.0962	0.1072	0.0454	48.2380
12A	0.1049	11.3520	5.7538	26.6720	6.0480	0.1756	0.0708	50.1771
12B	1.0576	45.4080	1.4507	8.3918	2.6838	0.8584	0.3245	50.1748
13A	0.1117	90.8160	8.4825	4.4442	0.3955	0.2257	0.1008	**104.5764**
13B	0.0638	11.3520	5.3379	6.6680	6.0985	0.2451	0.1036	29.8689
14A	0.1892	34.0560	5.4994	6.6680	3.7673	0.1129	0.0456	50.3384
14B	0.0707	56.7600	6.1310	8.3918	4.2841	0.3112	0.1176	76.0664
15A	0.0844	22.7040	5.0745	0.0000	4.5487	0.0809	0.0361	32.5286
15B	0.3641	11.3520	9.2505	15.5598	5.5573	0.0764	0.0325	42.1926

Conclusion

Five out of the thirty sampled groundwater sources were confirmed unfit for drinking during both rainy and dry seasons. These were based on the results from the water quality index, which is useful for effective management by the societal policymakers (Acharya et al., 2018). These wells had water quality index greater than 100 (Oko et al., 2014). These wells should be subjected to water treatment processes, such as that used in Obafemi Awolowo University ozonized bottled water production system (Oladepo *et al.*, 2012). While others were either poor or good for drinking, which can be subjected to slight or no conventional treatment respectively.

Water supply for domestic and industrial use should be free from disease-causing organisms and other matters which are unacceptable to the final consumers (Ayodele and Olufunmilayo, 2012a). Therefore, periodical assessment of physical, chemical and microbial analysis of groundwater in Iwo Local Government Area is recommended. This assessment will aid early identification of any potential future degradation of the groundwater parameters which were below and within the acceptable limits. There should be frequent public awareness by the local government officials about the role of individuals to protect groundwater from residential, agricultural and industrial waste contaminations.

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