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Assessment of Physiochemical Parameters of Water from Hand Dug Wells of Igbo-Ora, Ibarapa Central Local Government Area, Oyo State, South-western Nigeria

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Abstract : *Groundwater is water that occupies voids, cracks or other spaces between particles of clay, silt, sand, gravel or rock within the saturated zone of a geologic formation. This study assesses the direction of groundwater flow from hand-dug wells and their physio-chemical parameters of Igbo-Ora, Ibarapa Central Local Government Area Oyo State, Nigeria. The assessment covered both the wet (June - July, 2010) seasons and dry (December, 2009 - January, 2010) for evaluation of extremes. Physical and chemical parameters analyzed for included (pH), (EC), Alkality, hardness, (Cl^-), (SO_4^{2-}), (Mg^{2+}), (Ca^{2+}), ($HCO3^-$), (Na^+), (K^+) and temperature. Fifty samples were collected in hand dug wells along different direction with 50 units of Sterilised 1 Litre plastic bottles. The spatial location of each sample collected was determined with the use of handheld Global Positioning System (Garmin GPS) in which the geographic coordinates (x, y) and their height above mean sea level (z) were determined. Using SON standard for drinking water quality, the results of pH values reveal the mean value of 7.79 for wet season and 6.53 for dry season and EC with mean value of 524.9 for wet season and 449.64 for dry season which are below the SON standard limits. Higher mean values of SO_4^{2-} were found for both seasons with 291.65 and 165.90 which were above the SON limits, while NO_3^- has lower mean value of 23.30 and 0.81for both seasons which are lower than the SON standard limits. The t-test analysis carried out showed the inter-relationship between chemical elements/parameters and at 98% and 99% confidence level, the significant differences exist for the parameters for wet, dry and between both seasons. It can be concluded that the qualities of the well water samples were not suitable for human consumption without adequate treatment.*

Keywords: *Chemical Parameters, Groundwater, significant level, spatial location*

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I. Introduction

Groundwater has globally been considered and accepted as an agent of development. Today in Nigeria, households, industries and commercial houses now build alternative, independent and supplementary sources of water supplies into their development plans due to inadequacy of government supplies [1]. The most considered of all available alternatives is groundwater, exploited through the construction of boreholes and hand dug wells. The consideration of groundwater as an alternative source is due to a number of factors. Firstly, with adequate aquifer protection, groundwater has an excellent microbial and chemical quality and it therefore requires minimal or no treatment. Secondly, the capital cost of groundwater development when compared to surface water development is modest and groundwater lends itself to flexible development [2]. Thirdly, it is available everywhere, though the quantity derivable differ from place to place.

Groundwater is an important water resource in both the urban and rural areas of Nigeria, though in cities, pipe-borne water is majorly provided. However rural dwellers rely basically on hand-dug wells as the streams usually dry up in the dry season [3]. In Igbo-Ora, the study area of this study, groundwater from hand dug wells tapping the regolith portion of the geologic formation is mainly relied on because the public water supply system provided to service the town has been inadequate, the understanding of which is reflected in her history of water supply. A number of water quality investigations have been carried out in Nigeria, though these are usually on local scales and consider a limited number of chemical constituents. Asubiojo et al, [4] carried out a survey of tap water and groundwater quality taken from various sources in southern Nigeria. The locations, source aquifers and well details (depth etc) for the samples are unknown but the data illustrate the ranges of a number of trace elements in Nigerian groundwater that are assumed to be typically used for human consumption. The data indicate that most elements investigated are present at concentrations below the respective WHO health-based guideline values. The exceptions are barium (Ba), lead (Pb), nickel (Ni) and selenium (Se). Concentrations of nitrate and ammonium related to pollution inputs may be high in some shallow groundwater samples, particularly from hand dug wells, if pollution sources exist nearby. Malomo et al. [5] reported concentrations of nitrate-NO_3 up to 124 mg/l and nitrite-NO_2 up to 1.2 mg/l in shallow groundwater samples from dug wells in weathered basement rocks of south-west Nigeria.

It is worthy of that the total alkalinity value of water is an indication of the acid – neutralizing ability and is determined by how much carbonate, bicarbonate and hydroxide is present. Excessive alkalinity values may cause scale formation, the water may also have a distinctly flat, unpleasant taste [6]. Ca and Mg are essential elements needed in good quantity by the human body while Ca is used in teeth and bone formation; it also plays an important role in neuromuscular extractability, and for good functioning of the contractibility and also for blood coagulability [7]. Although Ca alongside Mg is a major contributor to water hardness, however calcium is important for strong teeth and healthy bones. It also plays an important role in neuromuscular extractability and for good functioning of the conducting myocardial system, heart and muscle contractibility and also for blood coagulability [7]. High chloride content in drinking water may indicate possible pollution from human sewage, animal manure or industrial wastes while high sulphate concentrations though not a significant health hazard, can cause scale formation and may be associated with a bitter taste in water that can have a laxative effect on humans and young livestock [6]. Ion exchange systems use ion exchange resin- or zeolite-packed columns to replace unwanted ions. The most common case is water softening consisting of removal of Ca^{2+} and Mg^{2+} ions replacing them with benign (soap friendly) Na^+ or K^+ ions. Ion exchange resins also used to remove toxic ions such as nitrate, nitrite, lead, mercury, arsenic and many others. [8-11].

Adekunle et al. [3] assessed the levels of some physical, chemical, biochemical and microbial water quality parameters in twelve hand dug wells in a typical rural area of southwest region of the country. Seasonal variations and proximity to pollution sources (municipal waste dumps and defecation sites) were also examined. All parameters were detected up to 200 m from pollution source and most of them increased in concentration during the rainy season over the dry periods, pointing to infiltrations from storm water, coliform population, Pb; NO_3^- and Cd in most cases, exceeded the World Health Organisation recommended thresholds for potable water. Trace elements in groundwater are defined as chemical elements dissolved in water in minute quantities, always or almost always in concentration of less than 1 mg of trace element in one liter of water [12]. The study of quantity of water alone is not sufficient to solve the water management problems because its uses for various purposes depend on its quality. Hence, the hydrogeochemical character of groundwater and groundwater quality in different aquifers over space and time has proven to be important in solving the problems [13-16]. Similar studies were done by [17-22]. Therefore, this study employed the set limits of SON, [27] to assess the physical, chemical quality of water samples of Igbo-Ora, Ibarapa Central Local Government Area of Oyo State, Southwestern Nigeria.

II. Materials and Method

2.1. Description/ Location of the Study Area: The study area, Igbo-Ora, is the headquarters of Ibarapa Central Local Government Area of Oyo State, Southwest Nigeria. The town is located between longitudes 3°13`E and 3°19`E and latitudes 7°22`N and 7°28`N. Approximately, as the crow flies, Igbo-Ora is 66km north-west of Ibadan, the Oyo State capital and about 32km north of Abeokuta, the capital of Ogun State. Igbo-Ora share boundary with Ogun state to the South and West, Ibarapa North Local Government Area to the North-West, Iseyin Local Government Area to the North-East and Ibarapa East Local Government to the East (Fig. 1).

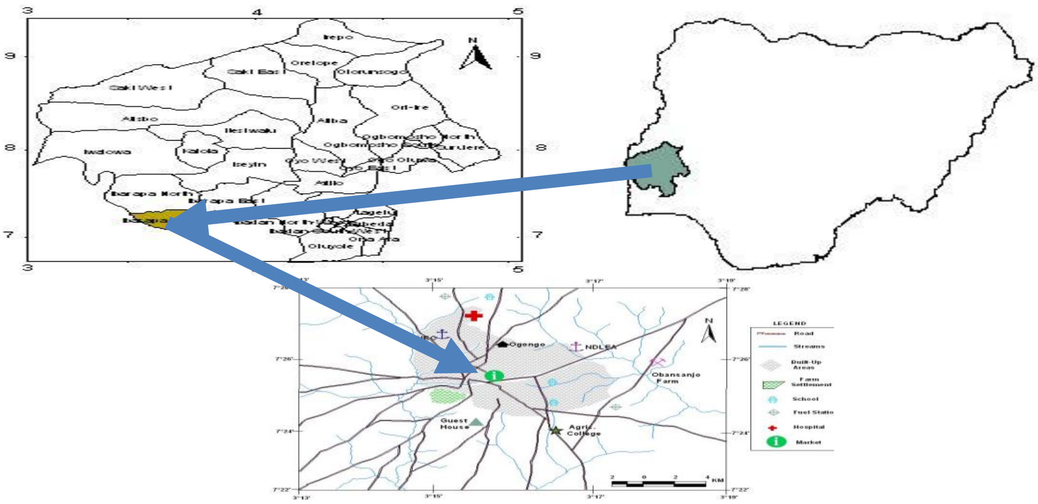


Figure 1: Map of the study area (Insert show location within Oyo State and Nigeria)

2.2 Material used: The materials used for data acquisition in this study are as listed below:

- Handheld Global Positioning System (Garmin GPS 60 Carnigatia) 2
- Sterilised 1 Litre plastic bottles 50 units
- Topographic map (for study area location)
- Cab/ Taxi (for movement from location to location) 1

2.3 Methods/Procedures: The field work started out by first sourcing maps covering the study area. The topographic map sheet 260, Abeokuta North-East was used to determine the position of Igbo-Ora. Data was acquired to determine the spatial location of each the water sampled and the results were shown in (table 1). Handheld Global positioning system; (Garmin GPS 60 Carnigatia) was used to determine the positions of selected hand dug wells and their geographical coordinates Longitude/Eastings (Em), Latitude/Northings (Nm) and height (Zm) above the sea levels. The significance of the correlation between parameters was calculated and as well as correlation that exist between both the wet and dry season using the critical value of Pearson's r for a two-tailed test as follows;
The degree of freedom for all hand dug well = total sampled (N) – 2 for a two tailed, since the total sample is fifteen (50) for both season, then the degree of freedom (d.f) = 50 - 2 = 48 and from the Pearson r statistical table, the degree of freedom for 48 at 1% (0.010), 2% (0.020) were (0.361, 0.328). These values were used to compare the result of the r statistics from the correlation coefficient matrix table which was used to show the level of significance between parameters/chemical elements studied.

2.4 Water sample collection/Laboratory analysis: Water samples for physical and chemical analysis were collected in sterilized 1-liter sample bottles while 50ml sterilized samplers were used to collect water for the physiochemical analysis. Samples were labelled against their respective sample locations and were deposited in respective laboratories within hours of collection. Physical and chemical characteristics analyzed for included Hydrogen concentrated ion (pH), Electrical conductivity (EC), Alkality, hardness, chloride ion (Cl^-), Sulphate ion (SO_4^{2-}), magnesium ion (Mg^{2+}), calcium ion (Ca^{2+}), Hydrogen carbonate ion ($HCO3^-$), sodium ion (Na^+), and potassium ion (K^+) and temperature. Digital Water Analyzer (Systronic-371) was used to determine Temperature, pH, and Electrical Conductivity (EC) on site. Further analyses on other samples were done in the laboratory using the standard method of APHA. [23]

2.5 Statistical Analysis: EVIEWS (11 version) statistical analysis software package was used in correlation analysis. All data sampled were tested for correlation analysis and significance level to determine associations among various parameters/elements measured in the study. Correlation coefficient being a common tool used to assess the relationship that exists between two variables and how well one predicts the other. The Pearson r statistics for the t-test analysis showed coefficient of their correlation and their significance level (Table 4, 5, 6).

III. Results

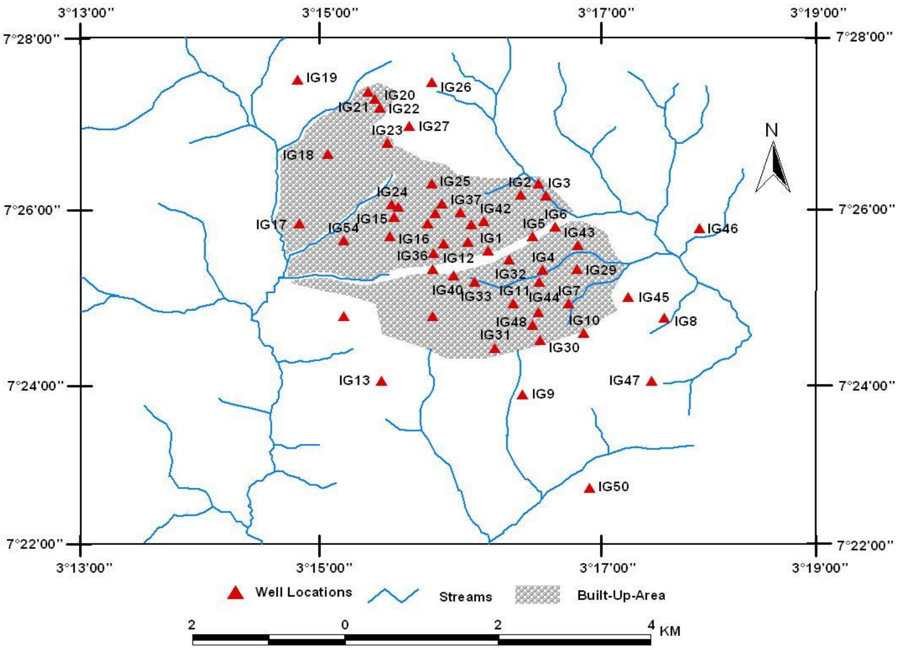
The results presented here showed the results of the water sampled in the laboratory and the Pearson r correlation coefficient matrix analysis. The laboratory test showed the value of each chemical parameter studied for the wet and dry seasons as presented in Table 2 & 3. Table 4, 5, 6 presented the result of the correlation coefficient matrix for wet season, dry season and the combined seasons. Fig. 2 presented the well locations and height above mean sea level in three dimensions (3D). Fig. 3 showed Quartiles Quartiles (QQ) Scattered plot and the relationship between the strength of their linear association. Fig. 4, 5, 6, 7, 8 presented variations in pH, electrical conductivity (EC), Sulphate (SO_4^{2+}), Nitrate (NO_3^-), and water hardness between wet and dry season in comparison with the Standard Organization of Nigeria (SON) standard limits. Table 1 presented the well locations, spatial locations values and their height above the mean sea level.

Table 1: Location, Geographical coordinates and height of studied wells in the study area

S/NO	Well Location	Latitude	Longitude	Height above mean sea level (m)
01	Owotutu (HQ)	7.4386389	3.2963333	173
02	resort center	7.4460000	3.3000000	194
03	NDLEA office	7.4458333	3.3028611	156
04	Adegoke NPS	7.4360833	3.3024444	162
05	Akin-Akintola	7.4405278	3.3013611	182
06	Ogboja	7.4418056	3.3038611	163
07	Kastad Igbole	7.4316944	3.3054167	167
08	Owotutu Igbole	7.4298611	3.3162222	172
09	College of Agric.	7.4197778	3.3001944	141
10	Moore fuel station.	7.4278333	3.3070833	158
11	Okunrin-Rodo	7.4316667	3.2991944	167
12	Adebisi-Idofin	7.4395833	3.2912778	166

13	lga guest House	7.4215556	3.2842500	160
14	Agbaakin-idofin	7.4421111	3.3243889	169
15	Afonja-Idofin	7.4430278	3.2856667	172
16	Isale-Oba(R.A)	7.4404722	3.2851944	156
17	Oke-ayin Grammar School	7.4421944	3.2750000	154
18	INEC Office	7.4513333	3.2782222	155
19	Owotutu (Idere RD)	7.4611389	3.2747778	154
20	Olugbon Med.	7.4585556	3.2835278	158
21	General Hospital	7.4594722	3.2827222	175
22	Owotutu Farm	7.4574167	3.2840556	162
23	Mechanic WS Ajegule	7.4528056	3.2849444	156
24	The blood Church. Ajegule	7.4447222	3.2853611	155
25	Ogongo Oke Iserin	7.4474167	3.3020278	177
26	Lagorun (H.S)	7.4607778	3.2899722	182
27	Igbo- Tapa	7.4550000	3.2873611	170
28	Veterinary Clinic	7.4421667	3.2894722	160
29	Ajibade's House	7.4362500	3.3063611	175
30	Methodist School II	7.4269167	3.3021389	164
31	RCCG IB Erekodo	7.4258611	3.2970278	160
32	Oduremi Pako	7.4375278	3.2986944	178
33	Elejire Iberekodo	7.4345556	3.2948056	176
34	Olu-asho Iberekodo	7.4436111	3.2903333	175
35	Towobowo Market	7.4397778	3.2940278	173
36	Sagaun (Ojenike)	7.4362500	3.2900000	168
37	Onikeke (Oke- Isimin)	7.4436667	3.2931667	170
38	Baptist Pry School	7.4448056	3.2910833	170
39	Ile-Elegun	7.4383333	3.2901667	163
40	Ile-Arinsanyan	7.4353889	3.2924444	155
41	Ile-Agbagbatele	7.4444167	3.2861667	172
42	Aborikura (IBKD)	7.4425000	3.2958333	179
43	Odeyale Pako	7.4393333	3.3064167	170
44	Adedokun	7.4345278	3.3021111	170
45	Bambeke Igbole	7.4316111	3.3125833	173
46	Obasanjo Farm	7.4415556	3.3201667	139
47	Express Igbole	7.4214722	3.3147778	159
48	Sawmill	7.4288889	3.3013611	160
49	Gbotikale	7.4305556	3.3020278	174
50	Ahamans Pet.	7.4075000	3.3077778	174

Source: AUthors field survey



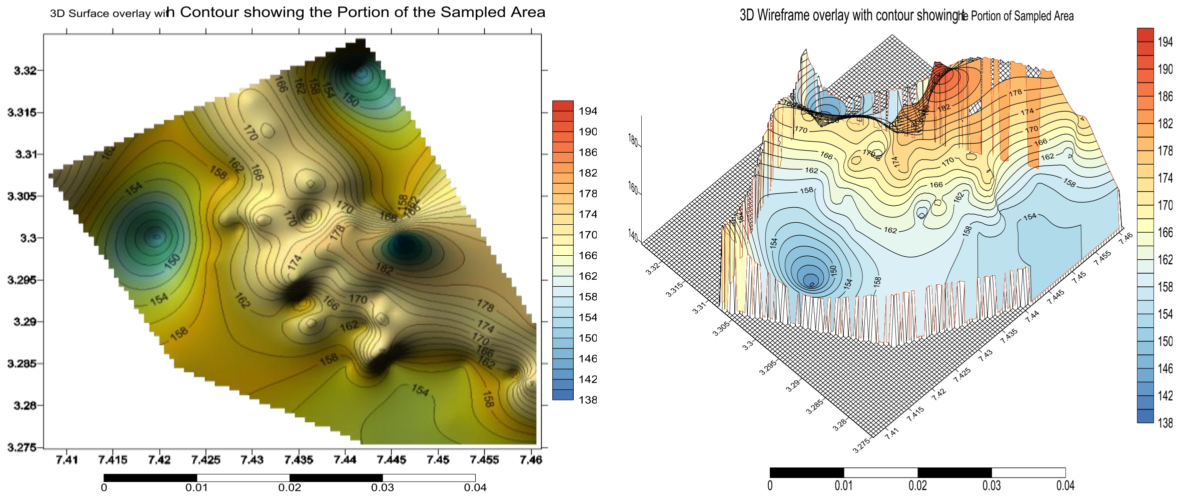


Figure 2: Map of the study area showing well locations, height above mean sea level.

Table 2: Laboratory Results of Physio-chemical parameters of water samples for wet season (June - July 2010)

S/No	Well Location	Ph	EC µS/cm (@ 25^0 C)	Temp °C	Hardness ppm	Alkalinity ppm	Cl^- ppm	SO_4^{2-} ppm	Mg^{2+} ppm	Ca^{2+} ppm	HCO_3^- ppm	NO_3^- Ppm	Na^+ ppm	K^+ ppm
1	Owotutu Hq.	7.21	812	25.1	54	3	18	112.47	32	22	0	13.38	8	3
2	Resort Center	6.95	393	25.4	72	2	45	98.35	43	29	0	17.45	16	12
3	NDLEA	7.82	255	25.3	54	4	20	87.14	21	33	0	28.54	4	3
4	Adegoke N/PS	6.42	193	26.2	51	1	28	146.31	33	18	0	22.43	32	12
5	Akin Akintola	812	603	25.9	184	4.0	74	172.43	54	130	0	34.15	15	5
6	Ogboja	8.20	93	25.4	74	1	14	235.46	45	29	0	31.30	13	5
7	KSTD-Igbole	6.95	501	26.1	91	2	43	214.36	36	55	0	23.74	22	14
8	Owotutu-Igbole	8.50	817	26.2	272	4.1	143	209.81	96	176	0	19.78	14	2
9	College of Agric.	8.45	249	26.1	83	3	14	98.49	29	54	0	16.89	3	1
10	Moore	7.64	269	26	48	3	12	87.32	28	20	0	18.76	12	8
11	Okunrin-Rodo	8.12	543	26	63	1	64	246.93	37	26	0	27.34	8	5
12	Adebisi-Idofin	7.24	583	25.8	58	2	58	483.82	43	15	0	25.95	32	17
13	I.G.A.-Guest House	7.95	172	25.4	103	10	48	234.18	58	45	0	18.27	28	9
14	Agba-Akin idofin	8.32	764	25.3	116	2	79	218.24	78	38	0	17.62	12	7
15	Afonja	8.43	486	26.2	86	6	17	131.71	47	39	0	15.28	13	1
16	Isale Oba (R.A)	8.21	426	25.4	121	12	162	513.42	59	62	0	22.41	19	21
17	Oke-Ayin Gramm. Sch.	7.34	110	25.6	38	2	19	326.11	24	14	0	29.74	4	1
18	INEC	7.43	126	26.2	45	1	11	139.48	28	17	0	24.43	5	2
19	Owotutu Idere Rd.	7.80	133	25.2	31	2	72	912.13	19	12	0	23.45	3	4
20	Olugbonm.C.	7.43	407	26	80	1	45	235.94	46	34	0	26.48	12	9
21	General Hospital	7.03	599	26.1	86	5	38	613.74	52	34	0	28.86	32	8
22	Owotutu Farm	8.43	282	25.4	63	4	13	104.23	39	24	0	27.62	14	2
23	Mechanic W.S.	8.50	954	26.1	326	8	67	714.48	192	154	0	23.82	18	5
24	Isale-Ajegunle (the blod)	8.34	630	26	87	6	49	328.12	29	58	0	19.64	21	11
25	Ogongo Oke-Iserin	7.25	607	26	94	1	74	117.13	38	56	0	18.36	30	15
26	Lajorun H.S. Oke-Iserin	7.68	226	25.4	56	3	89	248.38	40	16	0	29.82	7	2
27	Igbo-Tapa	8.31	314	25.8	38	2	23	123.98	23	15	0	28.47	6	1
28	VET-Clinic	8.27	606	25.9	106	3	32	128.50	22	84	0	22.92	8	3
29	Ajibade's HS	7.76	786	25.7	222	9	71	289.25	46	176	0	21.12	19	14
30	Methodist Sch.11	7.89	275	25.6	53	4	16	221.71	28	25	0	24.13	11	5

31	RCCG Iberekodo	7.42	257	26.1	83	3	52	103.18	40	43	0	26.18	4	1
32	Oduremi Pako	7.25	790	25.3	133	6	65	238.42	49	84	0	27.93	27	8
33	Elejire Iberekodo	7.26	560	26.2	118	4	38	301.36	51	67	0	21.16	10	7
34	Olu-Asho Iberekodo	6.95	791	26	112	3	87	236.19	36	76	0	24.31	21	13
35	Towobowo Market	8.45	836	25.4	110	2	64	333.74	57	53	0	23.54	11	6
36	Ojenike Sagan-un	7.95	919	25.9	68	4	61	475.68	33	35	0	22.14	14	5
37	Onikeke	7.43	819	25.7	138	2	32	309.12	70	68	0	18.72	11	7
38	Baptist Pry-Sch	8.50	672	26.1	72	4	51	113.79	39	33	0	31.46	17	6
39	Ile-Elegun	7.64	618	25.1	74	3	64	416.13	36	38	0	22.34	13	6
40	Ile Arisanyan	7.25	821	25.8	117	7	66	521.15	53	64	0	17.54	21	11
41	Ile Agbagbatele	8.27	73	25.7	99	6	61	513.11	40	59	0	17.45	31	14
42	Agborikura Iberekodo	7.89	782	26	77	1	59	198.57	38	39	0	26.84	19	13
43	Odeyale Pako	6.95	651	26.2	93	1	82	213.68	57	36	0	16.96	12	9
44	Adedokun	8.43	593	25.3	98	7	73	417.36	51	47	0	29.47	11	6
45	Bambeke Igbole	8.27	894	25.7	128	6	28	831.19	58	70	0	28.92	7	3
46	Obasanjo Farms	7.42	531	25.6	94	5	21	738.75	58	36	0	23.41	22	14
47	Express Igbole	7.82	470	25.4	94	5	29	138.26	60	34	0	28.16	16	9
48	Sawmill	7.68	620	26.1	101	4	63	174.85	29	72	0	17.62	8	4
49	Gbotikale	8.32	876	26.2	120	2	97	216.93	54	66	0	18.76	18	7
50	Shammans	8.50	458	25.1	36	3	15	297.43	22	14	0	19.87	16	9
Maximum		8.5	954	26.2	326	12	162	912.13	192	176	0	34.15	32	21
Minimum		6.42	73	25.1	31	1	11	87.14	19	12	0	13.38	3	1
Mean		7.7928	524.9	25.754	96.4	3.782	51.32	291.650	45.92	50.88	0	23.2986	15	7.3
SON Standard Limit		6.5-8.5	1000	-	150	-	250	100	0.20	-	-	50	200	-
Health Implication (SON, 2003)		None	None		None		None	None	Consumer acceptability			Cyanosis, and asphyxia	None	

Source: Federal University of Agriculture Abeokuta Laboratory, Ogun State Nigeria

Table 3: Laboratory Results of Physio-chemical parameters of water samples for dry season (Dec.2009 – Jan. 2010)

S/No	Well Location	Ph	EC µS/cm (@ 25^0C)	Temp °C	Hardness ppm	Alkalinity ppm	Cl^- ppm	SO_4^{2-} ppm	Mg^{2+} ppm	Ca^{2+} ppm	HCO_3^- ppm	NO_3^- Ppm	Na^+ ppm	K^+ ppm
1	owotutu hq.	6.94	737	27.9	98	4	16	45.962	72	26	0	0.525	11	**1**
2	resort center	6.47	334	27.5	166	2	49	21.574	106	60	0	1.088	22	**14**
3	NDLEA	7.06	167	27.4	82	5	18	29.078	16	66	0	0.128	6	**2**
4	adegoke n/ps	5.55	125	27.4	76	2	31	50.652	62	14	0	0.448	40	**15**
5	akin akintola	6.64	560	27.5	240	6	79	66.598	140	100	0	0.947	38	**6**
6	Ogboja	6.4	72	27.3	136	2	16	187.6	114	22	0	0.447	7	**1**
7	KSTD-igbole	6.07	454	27.4	208	2	55	135.072	142	66	0	0.729	26	**8**
8	Owotutu-Igbole	6.21	813	27.4	332	9	155	183.848	144	188	0	0.972	32	**3**
9	College of Agric.	7.34	170	27.4	130	5	17	105.994	48	82	0	0.397	5	**2**
10	Moore	6.39	210	27.4	92	4	17	27.202	58	34	0	3.71	19	**4**
11	okunrin-rodo	6.77	475	27.5	158	4	75	197.918	44	114	0	1.100	11	**1**
12	Adebisi-Idofin	6.18	506	27.3	124	3	73	230.748	62	62	0	0.179	38	**22**
13	l.G.A.-Guest House	6.14	132	27.7	232	14	59	92.962	86	146	0	0.806	44	**14**
14	Agba-Akin Idofin	6.69	645	26.6	268	4	96	93.8	156	112	0	0.985	11	**18**
15	Afonja	7.05	429	26.6	192	8	26	71.288	48	144	0	1.190	19	**4**
16	Isale Oba (R.A)	7.31	1159	26.9	264	15	200	343.308	74	90	0	0.166	23	**45**

17	Oke-Ayin Gramm. Sch.	6.08	73	26.5	70	3	18	130.382	44	26	0	0.448	8	**3**
18	INEC	6.45	78	26.8	80	2	13	94.738	55	26	0	0.397	6	**1**
19	Owotutu Idere Rd.	6.6	116	26.6	40	3	90	750.4	20	20	0	0.307	2	**2**
20	Olugbon M.C.	6.53	445	26.8	240	4	51	105.056	90	150	0	0.461	19	**17**
21	General Hospital	6.64	577	26.7	132	6	43	459.62	132	70	0	0.090	60	**12**
22	Owotutu Farm	6.60	231	26.8	100	6	11	39.396	44	56	0	0.614	17	**3**
23	Mechanic W.S.	6.75	918	26.9	440	15	59	685.678	356	84	0	0.870	22	**13**
24	Isale-ajegunle (The Blod)	6.55	596	26.8	196	8	57	153.832	48	144	0	0.870	30	**21**
25	Ogongo Oke-Iserin	5.5	581	27	190	2	86	40.334	106	84	0	1.535	40	**20**
26	Lajorun H.S. Oke-Iserin	6.37	153	26.8	102	4	110	86.296	74	28	0	0.320	10	**3**
27	Igbo-Tapa	6.66	263	26.8	72	3	35	32.83	24	48	0	0.486	11	**2**
28	VET-Clinic	6.89	512	26.8	204	6	65	271.082	104	100	0	0.793	23	**24**
29	Ajibade's House	7.35	696	26.8	324	10	60	195.104	154	170	0	1.152	35	**33**
30	Methodist Sch.11	7.07	246	26.5	130	5	23	77.854	34	96	0	0.307	19	**7**
31	RCCG Iberekodo	7.18	204	26.5	144	6	66	66.598	90	84	0	0.461	5	**3**
32	Oduremi Pako	6.74	683	26.6	270	8	87	135.072	102	168	0	0.691	15	**14**
33	Elejire Iberekodo	6.88	430	26.7	196	5	46	152.894	100	96	0	0.910	11	**3**
34	Olu-Asho Iberekodo	6.45	645	26.8	196	7	103	147.266	62	134	0	1.049	19	**17**
35	Towobowo Market	7.14	625	26.6	230	4	95	135.072	118	112	0	0.998	17	**12**
36	Ojenike Sagan-un	6.45	665	26.8	112	8	95	263.578	50	62	0	0.537	48	**21**
37	Onikeke	5.82	690	26.9	244	3	47	151.018	104	140	0	0.985	14	**7**
38	Baptist Pry-Sch	6.07	413	26.7	140	5	60	46.9	68	72	0	0.486	7	**4**
39	Ile-Elegun	6.81	551	26.7	140	6	85	169.778	66	74	0	0.729	60	**22**
40	Ile Arisanyan	6.87	688	26.8	240	10	84	295.47	86	154	0	0.832	50	**28**
41	Ile Agbagbatele	6.19	17	26.7	230	8	78	255.136	104	126	0	1.216	21	**24**
42	Agborikura Iberekodo	5.54	606	26.8	156	1	106	69.412	78	78	0	0.921	14	**13**
43	Odeyale Pako	5.74	548	26.8	272	2	91	106.932	188	84	0	0.896	30	**6**
44	Adedokun	6.85	431	26.8	182	8	35	186.662	76	106	0	0.704	12	**9**
45	Bambeke Igbole	6.15	695	26.9	322	7	62	422.1	182	140	0	1.356	23	**10**
46	Obasanjo Farms	6.62	324	26.9	154	6	26	390.208	98	56	0	0.294	20	**3**
47	Express Igbole	6.02	251	26.9	162	4	37	56.28	110	52	0	0.525	14	**4**
48	Sawmill	6.06	489	26.9	192	5	79	23.45	48	144	0	0.550	19	**10**
49	Gbotikale	6.31	753	27	234	3	124	114.436	102	132	0	0.934	19	**16**
50	Shammans	7.36	301	27	44	3	18	100.366	34	10	8	0.345	13	**27**
Max		7.06	1159	27.9	440	15	200	750.4	356	188	8	3.71	60	45
Min		5.5	17	26.5	40	1	11	21.574	16	10	0	0.09	2	1
Mean		6.53	449.64	26.952	179.56	5.5	62.54	165.896	90.46	89.04	0.16	0.810	21.7	11.48
SON Standard Limit		6.5-8.5	1000	-	150	-	250	100	0.20	-	-	50	200	-
Health Implication (SON, 2003)		None	None		None		None	None	Consumer acceptability			Cyanosis, and asphyxia	None	

Source: Federal University of Agriculture Abeokuta Laboratory, Ogun State, Nigeria

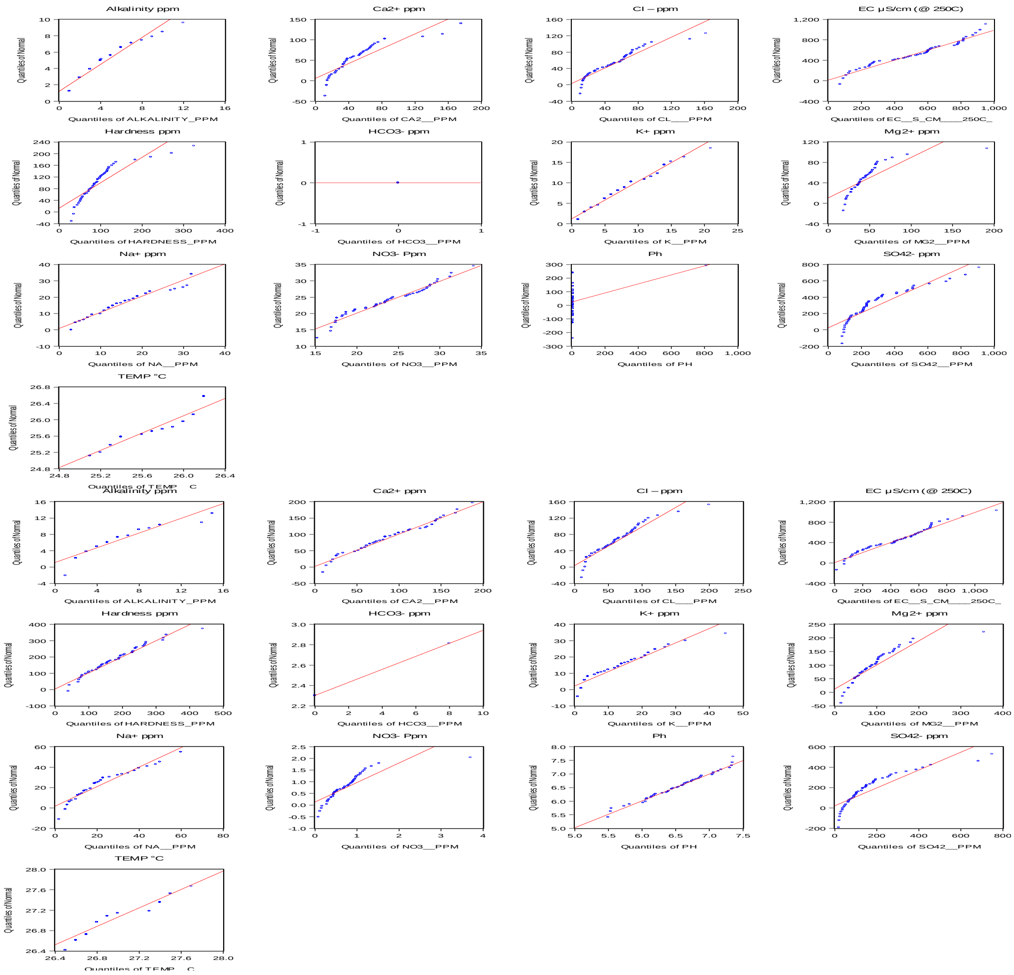


Figure 3: Quartiles Quartiles (QQ) Scattered plot showing relationship between the strength of their linear association for the wet and dry season

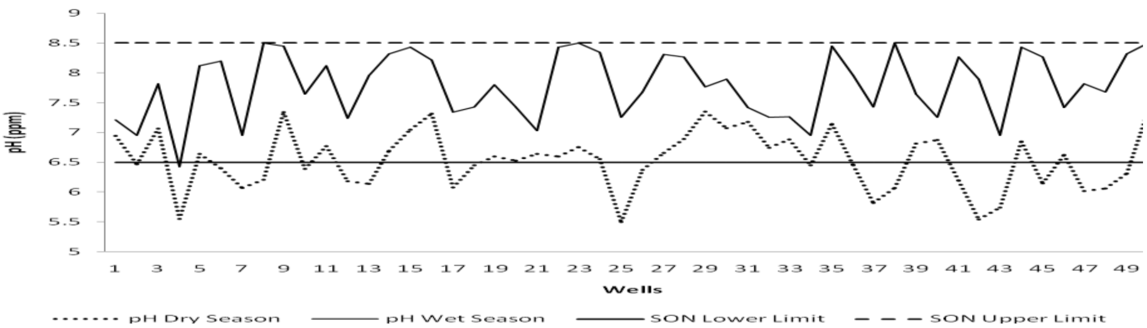


Figure 4: Variation of pH in water for dry and wet season in comparism with SON limits

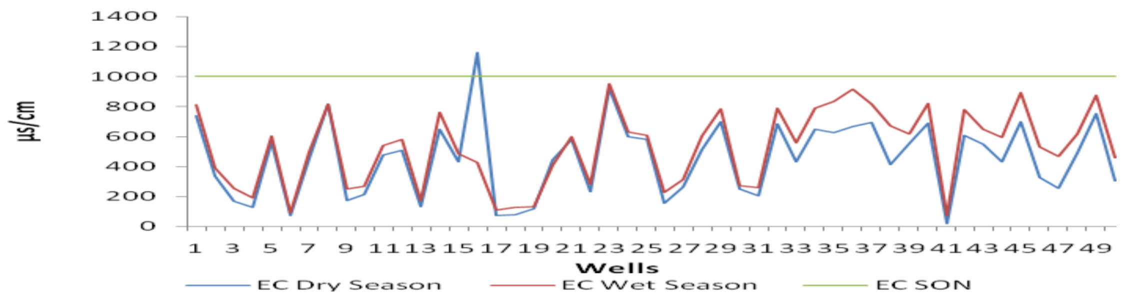


Figure 5: Variation of Electrical conductivity in water for dry and wet season in comparism with SON limits

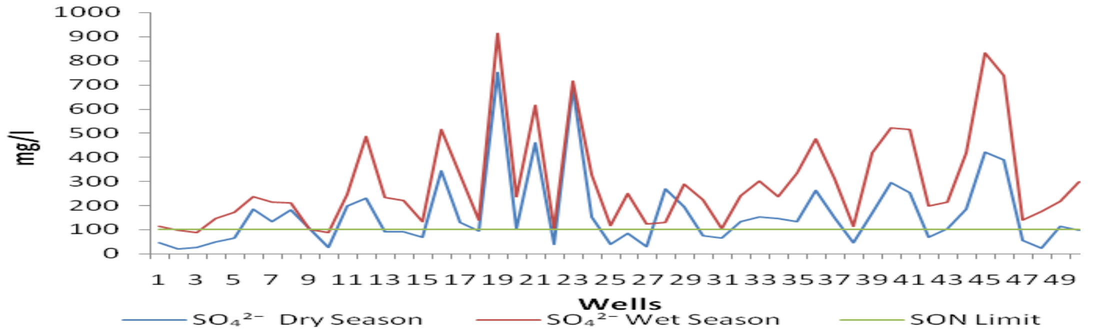


Figure 6: Variation of SO_4^{2-} in water for dry and wet season in comparism with SON limit

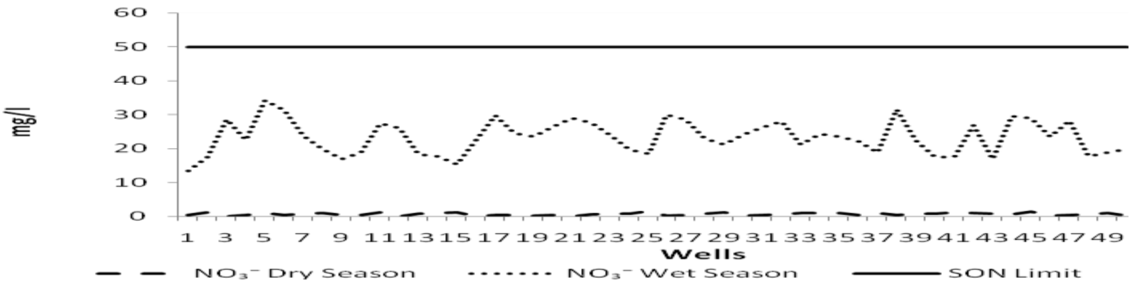


Figure 7: Variation of NO_3^- in water for dry and wet season in comparism with SON limits.

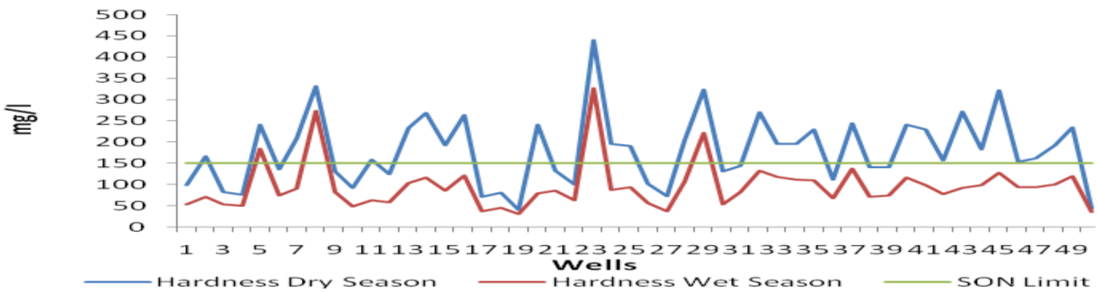


Figure 8: Variation of water hardness for dry and wet seasons in comparism with SON limits

Table 4: Correlation co-efficient of Wet season

Parameters	Alkalinity _ppm	CA^2 _ppm	Cl _ppm	EC µs/cm 250c	Hardness _ppm	HCO_3 _ppm	K^+_ppm	Mg^2 _ppm	Na _ppm	NO_3 _ppm	ph	SO_4^2 _ppm	Temp °c
Alkalinity _ppm	1												
Ca^2 ppm	0.437*	1											
Cl ppm	0.293	0.469*	1										
EC µs/cm	0.153	0.551*	0.410*	1									
Hardness _ppm	0.452*	0.937*	0.479*	0.588*	1								
HCO_3 _ppm	NA	NA	NA	NA	NA	NA							
K^+ _ppm	0.237	0.060	0.339**	0.166	0.061		1						
Mg^2 _ppm	0.349**	0.575*	0.342**	0.472*	0.824*		0.034	1					
Na_ppm	0.261	0.127	0.189	0.182	0.165		0.740*	0.171	1				
NO_3 _ppm	-0.095	-0.121	-0.126	-0.124	-0.117		-0.240	-0.071	-0.152	1			
PH	0.013	0.300	0.101	0.049	0.228		-0.075	0.044	-0.004	0.327	1		
SO_4^2 _ppm	0.350**	0.089	0.188	0.221	0.197		0.194	0.323	0.148	0.057	-0.089	1	
Temp °c	-0.199	0.246	0.018	0.202	0.217		-0.044	0.117	0.092	-0.189	0.055	-0.223	1

Table 5: Correlation co-efficient of Dry season

Parameters	Alkalinit(ppm)	Ca^2(ppm)	Cl(ppm)	EC µs/cm 250c	Hardness(ppm)	HCO_3(ppm)	K^+(ppm)	Mg^2(ppm)	Na(ppm)	NO_3(ppm)	pH	SO_4^{-2} (ppm)	Temp (°c)
Alkalinity	1												
Ca^{+2} (ppm)	0.493*	1											
Cl (ppm)	0.316	0.391*	1										
Ec µs/cm 250c	0.443*	0.557*	0.671*	1									
Hardness(ppm)	0.565*	0.739*	0.453*	0.706*	1								
HCO_3 (ppm)	-0.113	-0.255	-0.172	-0.083	-0.242	1							
K^+ (ppm)	0.430*	0.282	0.473*	0.537*	0.322	0.228	1						
Mg^{2+} (ppm)	0.323	0.253	0.200	0.477*	0.804*	-0.147	0.105	1					
Na (ppm)	0.309	0.220	0.231	0.368*	0.225	-0.091	0.494*	0.202	1				
NO_3 (ppm)	0.002	0.206	-0.001	0.107	0.236	-0.111	-0.004	0.180	0.071	1			
pH	0.393*	0.104	-0.080	0.086	0.006	0.255	0.184	-0.115	-0.155	-0.173	1		
SO_4^{2+} ppm	0.402*	-0.008	0.205	0.286	0.269	-0.064	0.173	0.400*	0.143	-0.161	0.161	1	
Temp (°c)	-0.035	-0.076	-0.073	-0.113	-0.006	0.031	-0.104	0.023	0.166	0.192	-0.190	-0.192	1

*and ** represents 1% (0.01) and 2% (0.02) at 2 tail level of significance

Table 6: Correlation between wet and dry season

Parameters	Alkalinity (d)	Alkalinity (w)	ca2 (w)	ca2 (d)	Cl (d)	Cl (w)	Ec µs/cm (d)	Ec µs/cm (w)	Hardness (d)	Hardness (w)	K (d)	K (w)	mg2 (w)	mg2 (d)	Na (d)	Na (w)	no3 (w)	no3 (d)	Ph (d)	Ph (w)	so42 (d)	so42 (w)	Temp (d)	Temp (w)
Alkalinity (d)	1																							
Alkalinity (w)	0.814*	1																						
ca2 (w)	0.244*	0.437*	1																					
ca2 (d)	0.493*	0.414*	0.631*	1																				
Cl (d)	0.316	0.209	0.370*	0.391*	1																			
Cl (w)	0.398*	0.393	0.468*	0.411*	0.848*	1																		
Ec µs/cm (d)	0.443*	0.332**	0.392*	0.557*	0.671*	0.627*	1																	
Ec µs/cm (w)	0.240	0.133	0.337*	0.336*	0.431*	0.418*	0.836*	1																
Hardness (d)	0.565*	0.400*	0.784*	0.739*	0.453*	0.388*	0.706*	0.632*	1															
Hardness (w)	0.390*	0.432*	0.837*	0.575*	0.368*	0.478*	0.603*	0.888*	0.872*	1														
K (d)	0.430*	0.444*	0.249	0.282	0.473*	0.441*	0.537*	0.333	0.322	0.193	1													
K (wet)	0.121	0.237	0.060	0.087	0.336**	0.338**	0.332**	0.166	0.209	0.081	0.606*	1												
mg2 (wet)	0.267*	0.349*	0.373*	0.283	0.241	0.342**	0.313*	0.472*	0.731*	0.824*	0.020	0.034	1											
mg2 (dry)	0.323	0.222	0.617*	0.253	0.200	0.207	0.477*	0.487*	0.804*	0.780*	0.105	0.113	0.337*	1										
Na (d)	0.309*	0.220	0.233	0.220	0.231	0.226	0.368*	0.336**	0.225	0.217	0.494*	0.373*	0.121	0.202	1									
Na (w)	0.213	0.261	0.127	0.138	0.173	0.189	0.233	0.182	0.214	0.162	0.481*	0.749*	0.171	0.204	0.667*	1								
NO_3 (wet)	-0.130	-0.092	-0.121	-0.316	-0.130	-0.128	-0.128	-0.124	-0.230	-0.117	-0.338	-0.260	-0.071	-0.038	-0.230	-0.122	1							
NO_3 (d)	0.002	-0.023	0.191	0.206	-0.001	-0.016	0.107	0.174	0.236	0.180	-0.004	0.080	0.078	0.180	0.071	0.041	-0.240	1						
Ph (d)	0.393*	0.373*	0.139	0.104	-0.080	-0.023	0.086	-0.037	0.006	0.083	0.184	-0.206	-0.019	-0.115	-0.155	-0.222	-0.087	-0.173	1					
Ph (wet)	0.022	0.013	0.309	0.032	0.039	0.101	0.068	0.049	0.102	0.233	-0.082	-0.072	0.044	0.127	0.163	-0.004	0.327	0.049	0.038	1				
SO_4^{-2} (d)	0.402*	0.323	0.227	-0.008	0.205	0.211	0.286	0.197	0.269	0.333**	0.173	0.081	0.430*	0.400*	0.143	0.074	0.020	-0.161	0.161	-0.082	1			
SO_4^{-2} (w)	0.333**	0.330**	0.089	0.014	0.201	0.188	0.203	0.221	0.212	0.197	0.232	0.184	0.322	0.289	0.232	0.148	0.037	-0.187	0.082	-0.089	0.560*	1		
Temp (d)	-0.032	-0.026	0.093	-0.076	-0.073	-0.017	-0.113	-0.101	-0.006	0.079	-0.104	0.160	0.029	0.023	0.166	0.182	-0.080	0.192	-0.190	0.282	-0.192	-0.222	1	
Temp (w)	-0.078	-0.199	0.248	0.204	0.031	0.018	0.103	0.202	0.194	0.217	-0.173	-0.066	0.117	0.181	0.117	0.092	-0.180	0.207	-0.230	0.022	-0.087	-0.222	0.094	1

Source: Authors Computation

w = wet, d = dry

3.1 Analysis of Results

Tables 2 & 3 showed the results and summaries of physical and chemical parameters of water samples from wells during the field survey. The pH ranged between 5.5 and 7.06 with a mean of 6.53 (± 0.48) for dry season, while it ranged between 6.42 and 8.5 for wet season with a mean of 7.79 (±0.55). The electrical conductivity in µs/cm at 25^0C for dry season was between (7 and 1159) µs/cm, with mean 449.64 (±251.60) for dry season and ranges between (73 to 954) µs/cm with a mean of 524.9(±254.49) for wet season. Water hardness in ppm was from 40 to 440 with a mean of 179.36 (±82.55) and 31 to 326 with a mean of 96.4 (±55.53) for dry and wet season respectively while Alkalinity was between 1 and 15 with a mean of 4 (±3.25) and 1 to 12, mean 3.78 (±2.47) for dry and wet season. Cl^- in ppm for dry season ranged from 11 to 200, mean 62.54(±38.66) and from 11 to 162, mean 51.32 (±31.91) for wet season, while SO_4^{2-} in ppm for dry season ranged from 21.574 to 750.4, with mean 165.89 (±154.58) and 87.14 to 912.13 with mean 291.65 (±200.91) for wet season. Mg^{2+} (ppm) ranged 16 to 356, with mean 90.46 (±55.94) and 19 to 192, with mean 45.92 (±26.09) for dry and wet seasons respectively, while Ca^{2+} (ppm) ranged from 10 to 188, with mean 89.04 (±46.32) and 12 to 176 with mean 50.88 (±38.07) for dry and wet season respectively. HCO_3^- had 8ppm recorded for a location in the dry season while others were zeros just as obtained in the wet season. For NO3-, Na+, and K+, analysis showed 0.09 to 371 with mean 8.10 (±52.3), 2 to 60 with mean 21.7 (±14.16) and 1 to 45 with mean 11.48 (±9.79) respectively for dry season, while 13.38 to 34.15 with mean 23.29 (±4.91), 3 to 32 with mean 15 (±4.77) correspondingly for wet season, with all values in ppm.

Using t-test statistics, at (98 & 99) % confidence level, seasonal variations were analyzed and significant differences were found to exist for physical and chemical parameters of water samples analyses between both season. (Table 4) showed the result of the Pearson correlation coefficient analysis carried out on all samples in wet season. Ca^2 showed a positive and strong significant relationship with Alkalinity (r = .0.437) , Cl^- with ca^2 (r = .469), EC with Ca^{2+} and Cl^- (r = .551, .543 and .410). Hardness showed strong relationship with Alkalinity, Ca^{2+}, Cl^-, and EC with (r = .452, .973, .479 and .588), K with Cl^- with (r = .339) .Mg^2 and Alkalinity, Ca^{2+}, Cl^-, EC and Hardness with (r = .349, .575, .342, .472 and 824), Na^+ showed a positive and strong correlation with K^+ (r = .740), $N0_3$ showed negative correlation with all other chemical elements. pH with weak correlation with all other chemical elements. SO_4 showed a strong correlation with only alkalinity with (r = .350), temperature with negative and weak correlation.

(Table 5) showed the result of the Pearson correlation coefficient analysis carried out on all samples in dry season. Ca^{2+} showed a positive and strong significant relationship with Alkalinity (r = .0.493) , Cl^- with Ca^{2+} (r = .391), EC with alkalinity, Ca^{2+} and Cl^- with (r = .443, .557 and .671). Hardness showed strong relationship with Alkalinity, Ca^{2+}, Cl^-, and EC with (r = .477, .739, .453 and .706), K^+ with alkalinity, Cl^- and EC with (r = .430, .473 and .537). Mg^2 with EC and Hardness with (r = .477 and 804), Na^+ showed a positive and strong correlation with EC and K^+ (r = .368 and .494). $N0_3$ showed negative and weak correlation with all other chemical elements. pH showed positive correlation with alkalinity and low/negative correlation to other chemical elements. SO_4^{2-} showed a strong correlation with mg^{2+} and alkalinity with (r = .402 and .400). Temperature showed negative and weak correlation to other chemical elements.

(Table 6) showed the results of the correlation analysis between both the wet and dry seasons. Alkalinity of wet season showed strong correlation with alkalinity of dry season with (r = .914). Ca^{2+} in the wet season showed correlation with Alkalinity (dry & wet) seasons with (r = .544, .437). Also, Ca^{2+} in dry season showed correlation with alkalinity of (wet & dry) season, and Ca^{2+} wet season with (r = .493, .414, .639). Cl^- (dry) showed correlation of Ca^{2+} (wet &dry) seasons with (r = .370, 391). Cl^- (wet) showed correlation with alkalinity dry, Ca^2 (wet & dry) season, and Cl^- (dry) with (r = .396, .469, .411, .940). EC showed correlation with Alkalinity (dry & wet), ca2 (wet &dry), Cl^- (dry &wet) with (r = .443, .352, .592, .557, .671, .657). Also, EC in wet season showed correlation with ca^2 (wet &dry), Cl (dry &wet), and EC dry with (r = .551, .554, .451, .418, .856). Hardness (dry) showed correlation with Alkalinity (dry & wet), ca^{2+} (wet &dry), Cl^- (dry &wet), EC (dry & wet with (r = .565, .460, .794, .739, .453, .506, .706, .635).

Hardness (wet) showed correlation with Alkalinity (dry & wet), ca^{2+} (wet &dry), Cl^- (dry & wet), EC (dry & wet) and hardness (dry) with (r = .590, .452, .937, .573, .368, 479, .635, .588, .875). K^+ (dry) showed correlation with Alkalinity (dry & wet), Cl^- (dry &wet), EC dry with (r = .430, .444, .473, .441, .537). K^+ (wet) showed correlation with Cl^- (dry &wet) and EC (dry) with (r = .334, .339, .335). Mg^2 (wet) showed correlation with Alkalinity (dry & wet), ca^{2+} (wet & dry), Cl^- (dry & wet), EC (dry & wet), Hardness (dry & wet) with (r = .507, .349, .575, .342, .515, .472, .751, .842). Mg^2 (dry) showed correlation with Ca^{2+} (wet), EC (dry & wet), Hardness (dry & wet) and Mg^{2+} (wet) with (r = .617, .447, .487, .804, .790, .852). Na^+ (dry) showed correlation with alkalinity (dry), EC (dry & wet), K (dry & wet) with (r = .309, .368, .334, .494, .371). Na^+ (wet) showed correlation with K (dry & wet), Na^+ (dry) with (r = .491, .740, .607). No correlation between No_3^- (dry & wet) with other chemical elements. pH (dry) showed correlation with only alkalinity (dry & wet) with (r = .393, .378). So_4 (dry) showed correlation with alkalinity (dry), hardness (wet), mg^2 (wet & dry) with (r = .402, .333,

.430, .400). So_4^{2-} (wet) showed correlation with alkalinity (dry & wet), So_4 (dry) with (r = .353, .350, .900). Temperature has no correlation with all the chemical elements both in wet and dry seasons.

The results of pH values reveal the mean value of 7.79 for wet season and 6.53 for dry season and EC with mean value of 524.9 for wet season and 449.64 for dry season which are below the SON standard limits. Higher mean values of SO_4^{2-} were found for both seasons with 291.65 and 165.90 which were above the SON limits, while NO_3^- has lower mean value of 23.30 and 0.81for both seasons which are lower than the SON standard limits. The t-test analysis was carried out show the inter-relationship between chemical elements/parameters. At 98% and 99% confidence level, the significant differences exist for the parameters studied between both seasons.

3.2 Discussion of Results

In the dry season, pH values of water samples ranges between 5.5 and 7.06, with an average of 6.53. In the wet season, pH values ranges between 6.42 and 8.5, with an average of 7.79. In the dry season, pH values of water samples suggests that they tend towards acidity, while in the wet season, they tend towards alkalinity. However, this does not give effects since pH as a primary standard parameter has no health implication [24]. The recommended maximum allowable limit of electrical conductivity in potable water is 1000µS/cm. Though, an health implication of exceeding this limit is not known. In the study, all values fall below the recommended limit, except one; (Isale-Oba R.A.), which was freshly dug as at the time of sampling. Total hardness is normally expressed as the total concentration of Ca^{2+} in milligrams per litre equivalent of $CaCO_3$ (Freeze and Cherry, 1979). Water with total hardness value greater than 150mg/1 is designated as being hard; soft water have values less than 60ml/l [25]. Although Mg^{+2} alongside Ca are major contributors to water hardness, Mg^{+2} is an essential element needed in good quantity by the human body [7], therefore this does not show forth any effects. Ca^{2+} had values that were within the acceptable limit of 50mg/l set by WHO [6], however there is no health-based drinking standards for K^+ [26]. The recommended maximum limit of hardness is 150mg/l [27]. No health implication of higher value is known. Higher number of samples taken in the dry season appears to be harder than that of the wet season. Hard water has the characteristics of obtainable reducing the cleansing action of soaps, and cause excessive scale formation in water carrying pipes. Sulphate (So_4^{2-}) was found in the range of 21.57ppm to 750.40ppm with a mean of 165.89ppm in the dry season and 87.14ppm to 912.13ppm with mean 291.65ppm in the wet season.

Graphical variation showed that 34% of the samples had their sulphate content below the limit of Standard Organization of Nigeria for drinking water while 68% were found above it in the dry season and just 2% existed below this limit in the wet season. No health implication of higher sulphate content above SON limit is known as suggested in (Table 2 & 3). For Nitrate, it ranges for the dry season was 0.09ppm to 3.71ppm with mean 0.81ppm while wet season ranged from 13.38 to 34.15ppm with mean 23.29ppm. The recommended allowable limit by SON is 50mg/l(ppm), the violation of which could result into cyanosis and asphyxia (blue baby syndrome) in infants under 3 months. Though none of the tested sample for both season exceeded the set limit, however, the content was obviously enhanced in the wet season as shown by the seasonal variation graph. Then, there is no health impacts recorded for high sulphate intake [24]. High sulphate concentrations though not a significant health hazard, can cause scale formation and may be associated with a bitter taste in water that can have a laxative effect of humans and young livestock [6]. NO_3^- and Cl^- both had values that were within the acceptable limits of 50mg/l and 250mg/l by SON and WHO respectively.

The health implication associated with high concentrations of NO_3^- especially in young children is the blue baby syndrome also known as Metamoglobinemia which can cause death in the children while high chloride content in drinking water may indicate possible pollution from human sewage, animal manure or industrial wastes [6]. HCO_3^- has no effect as both the wet and the dry season showed no correlation effects and no health-based guidelines were indicated for HCO_3^- by SON [27]. The qualities of the well water samples were therefore not suitable for human consumption without adequate treatment. Regular monitoring of groundwater quality, abolishment of unhealthy waste disposal practices and introduction of modern techniques are recommended. Quantiles Quantiles (QQ) scatter plot for both seasons signifies how the correlation relates to the strength of their linear association. From the QQ plots, it can be seen that the points are closely scattered about an underlying straight lines as opposed to a curves. It can be said that there is a strong linear relationship between the chemical elements/parameters. The quantile quantile (QQ) scattered plot showed that increase in quantiles of normal leads to increase in quantiles of the chemical element. The trend that occurred between these parameters showed an indication that the pollutant present in the water and the parameter tested is strongly interrelated and interdependent on one another with common variable values that was observed. Thus, high correlations show that the parameters are derived from the same source [28].

IV. Conclusion

Generally, physico-chemical constituents of water samples increased in value from dry to wet season, except hardness that was lowered and pH that shifted from acidity towards basicity, thus it could be concluded that increased water volume in the regolith aquifer of the study area enhanced the value of physico-chemical constituents. Wells with high coliform count were indicators of high organic loads and indices of pollution from leachates, seepages from waste disposal system within well vicinity and infiltration into storage from run-off which was more evident in the wet season.

V. Recommendation

Following the research findings, it is recommended that;

i. The redesign of reservoir and waterworks on Opeki River be done by Oyo State Government from where public water supply can once again be provided for Igbo-Ora as most hand-dug wells tested in this research can only serve supplementary roles. Moreover, the population of the area is on the increase, thus, water from hand dug wells cannot provide enough for the future.

ii. Also, it is recommended that test holes (boreholes) be constructed in Igbo-Ora for a more effective study of groundwater both in the regolith and the fractured zones of the study area. This will not just give a broader knowledge of groundwater occurrence in Igbo-Ora, but provide a platform on which groundwater development plan can be built for municipal water supply, while periodic appraisal will give knowledge of changes that might occur in the future.

iii. Igbo-Ora has no central sewage system, thus individual houses construct one or more of latrines, soak-away and septic tanks for sewage disposal while open dump sites receive solid wastes from the public. These waste disposal systems are probable sources of pollution, thus it is recommended that adequate solid waste disposal system be adopted, waste deposit or discharge on identified recharge points be avoided. Finally, it is recommended that water drawn from hand dug wells be boiled before consumption, since conventional water treatment plants may be too expensive for individual families.

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