ISSN No:-2456-2165

Physico-Chemical and Water Quality Assessment of Borehole Water Sources in Ishiagu South-eastern Region of Ebonyi State, Nigeria.

[1]OGBEIDE Osareme Mercy
Department of Science Laboratory Technology,
Federal College of Agriculture, P.M.B. 7008,
Ishiagu, Ebonyi State, Nigeria

[2]UKAH Victor Ifeanyichukwu
Department of Science Laboratory Technology,
Federal College of Agriculture, P.M.B. 7008,
Ishiagu, Ebonyi State, Nigeria

[3]OKORO Chioma Catherine
Department of Science Laboratory Technology,
Federal College of Agriculture, P.M.B. 7008,
Ishiagu, Ebonyi State, Nigeria

[4]NJOKU Chukwunweolu
Department of Animal Health and Production Technology,
Federal College of Agriculture, P.M.B. 7008,
Ishiagu, Ebonyi State, Nigeria

[5]AGBOM Chukwuka
Department of Science Laboratory Technology,
Federal College of Agriculture, P.M.B. 7008,
Ishiagu, Ebonyi State, Nigeria

Abstract:- The physicochemical and water quality assessment of borehole water sources of Ishiagu, south-estern region of Nigeria was investigated to ascertain the portability, suitability and quality of the water used for drinking and other domestic purposes. Sampling was done twice every month in each of the selected nine stations which lasted for six months. Some experiments were carried out in-situ for Temperature, pH, Electrical conductivity (EC), Total dissolved solid (TDS), and Dissolved Oxygen (DO), while rest of the other parameters were carried out in the laboratory. From the analysis results, the borehole water sources selected recorded the average pH values that is within the WHO/SON acceptable limits. The results obtained for the mean WQI of the nine different stations ranges from 41.78 to 67.37, which further revealed that 44% of the stations had good water quality for drinking while 56% of the stations uses poor water quality which may require pre-treatment before drinking. The high WQI values in some stations signifies high level of deterioration which mainly could be due to higher values of turbidity, EC and TH in (S3), TDS in (S5, S3), K^+ in (S7, S9), NO_3^- in (S5), PO_5^{3-} in (S7, S4, S3) and Fe^{2+} in (S3, S7) within some months. In conclusion, the status of the borehole water in the selected stations were properly ranked based on suitability and goodness, in the following order: S1 > S8 > S2 > S6, > S9 > S5 > S7 > S4 > S3. This electronic document is a "live" template and already defines the components of your paper [title, text, heads, etc.] in its style sheet.

Keywords:- *Water quality index (WQI), physicochemical parameters, borehole water, drinking, Ishiagu.*

I. INTRODUCTION

Water is an essential universal solvent for life support of every living organisms in an ecosystem. It is the most essential component of biodiversity with versatile applications. If properly managed or conserved would give a better access to portable water, extreme growth and socio-economic development of a nation, especially, in various sectors of economy like in agriculture, industrial processes, health sector, forestry, hydropower generation, fisheries and livestock production [1].

In the developing countries of the world, the demand for clean water has been a major challenge as many still depend on public boreholes for water supply, coupled with the government failures in providing the necessary infrastructural services especially in the rural areas.

Ishiagu, a town in south-esthern region of Nigeria, well known for her rich mineral resources, mining and quarrying sites, with tropical weather, depended mostly on alternative water sources like; wells, rivers, streams, reservoirs and boreholes. Some of these sources dries up during dry season, some got contaminated due to anthropogenic and farming activities around the areas. Thus, the dwellers in the areas now resort in digging boreholes which they have increasingly commercialized as a major source of water for drinking and for domestic purpose without considering the effects of consuming without treatment. Although, groundwater as a reliable water source with natural infiltration through soil and rocks is less polluted, as about 55% of it pollutants are been restricted down the soil profile [2]. But, the amount of mineral salts been dissolved down the aquifer is enough to cause water hardness, which associates with metals and heavy metal deposits from quarrying activities. Moreover, the need to assess the quality of the borehole waters consumes in the region is very important to monitor when it exceed permissible limit. Several articles had been published previously on the assessment of groundwater quality in Ishiagu by [3],[4],[5] and [6], but none was elaborated. From the result of our recent work [6], we tend to expand the scope of study to cover more stations in both dry and rainy season (from January to July), as study have revealed that water quality of groundwater (borehole) varies seasonally with climate changes [7], [8] and [9]. More work will be done using water quality index (WQI) techniques, I which the information generated will be disseminated to the public, which will serve as yardstick for policymaking and for future checks and balances in the region and anywhere in the world. In this case, the aim of this study is to assess the Physico-chemical parameters and Water quality index of the borehole water sources in Ishiagu South-eastern region of Nigeria.

II. MATERIALS AND METHODS

A. Materials and Instruments

a) Description of the study area

Ishiagu town is located in southeast region in Ebonyi State. The inhabitants of the area and the surroundings are mostly farmers, stone dealers, students and public servants. The area falls between longitude 7^{o}34’32” to 7^{o}34’57”E and latitude 5^{o}56’56” to 5^{o}57’1”N, and experiences a tropical climate with rainfall all year round. The rainy season lasts from April to October, while dry season last between November to March of every year. The range of the mean annual rainfall for the area is 1750-2000 mm, while that of temperature is 26.5-27.5^{o}C [10] and [11]. Solid mineral mining is also an important activity going on in the area. Lead and zinc mines including stone quarrying activities attracts people to the area, and further increase the demand for potable water since water sources are polluted.

b) Sampling stations/location

Three sample stations were mapped out in each of the three locations (Amaeze, Ngwogwo and Amaokwo) in the areas where they have functional boreholes. Their descriptions, the distance between two stations and the Global Positioning System (GPS) co-ordinates where also recorded in Table 1.0.

Sample station Codes	Location	Coordinate		Description	Distance
		Latitude	Longitude		
S1	Ogorji Amaeze (I)	5^{o}57'25" N	7^{o}33'26" E	The station is situated along the street concrete road, surrounded by houses, nearby restaurants, shops and hotels	1 km between S1 & S3
S2	Ogorji Amaeze (II)	5^{o}57'20" N	7^{o}33'25" E	Situated along the major tarred road with side gutters, surrounded by buildings, shops, car wash spot, business centers, automobiles repairing workshops, and building materials shops.	
S3	Amuzu Amaeze	5^{o}58'10" N	7^{o}33'7" E	Situated in residential building along the major road, close to fuel stations, bushes, welder shops and heavy duty vehicle garage	
S4	Ngwogwo Amachara	5^{o}57'33" N	7^{o}34'46" E	Situated at the health center close to newly opened quarry site.	800m between S4 & S6
S5	Ngwogwo Amaedim (I)	5^{o}57'25" N	7^{o}34'23" E	This area is public arena very close to refuge dump and bushes, people houses and commercial grinding machine. It is very close to drainage curvet where wastewaters from the surrounding homes and grinding machine are channeled. It also has predominant rock known as “Elu mkpume”.	
S6	Ngwogwo Amaedim (II)	5^{o}57'17" N	7^{o}34'10" E	The station is situated at the residential building surrounded by houses and close to Elu mkpume.	
S7	Egbe Amaokwo	5^{o}57'17" N	7^{o}34'11" E	The station is situated along the community road surrounded by houses, with nearby farms, shops, bars and approximately 1km away from old Amaokwo General Hospital.	550m between S7 & S9
S8	Ihuogwu Amaokwo (I)	5^{o}57'17" N	7^{o}33'51" E	Situated at the residential building along busy street road, houses, nearby shops, bars, business center and close to the old General Hospital.	
S9	Ihuogwu Amaokwo (II)	5^{o}57'17" N	7^{o}33'40" E	The station is situated along minor road at residential building, close to Amaokwo power generator house.	

Table 1 : Locations, Codes and GPS Co-ordinates of the sample stations

c) Sample collection/Preservation

Three water samples from each stations were collected twice a month at the designated stations; S1, S2, S3, S4, S5, S6, S7, S8 and S9 for six months, starting from January to July 2020, covering both the dry (January-March) and wet (May-July) seasons. The month of April was excluded as transition month between dry and rainy season in Ishiagu. Meanwhile, the plastic containers and glass wares were soaked in nitric acid for 24 hours before sampling. They were thoroughly washed with detergent and rinsed with distilled water before air-dried.

ISSN No:-2456-2165

The average sampling time was 9:30 am daily. At each sampling point, the sample containers (1.5 liters) were rinsed with the representative water sample three times, and then filled with the sample and corked tightly. The BOD bottle and 1-liter container was used to collect samples for DO and BOD analysis, taking precaution not allow air bubbles into the bottle nor container. The containers were labeled (coded) and properly packed into a cooler of ice blocks at 4 oC, and later convey to the laboratory where it was freshly preserved in the refrigerator.

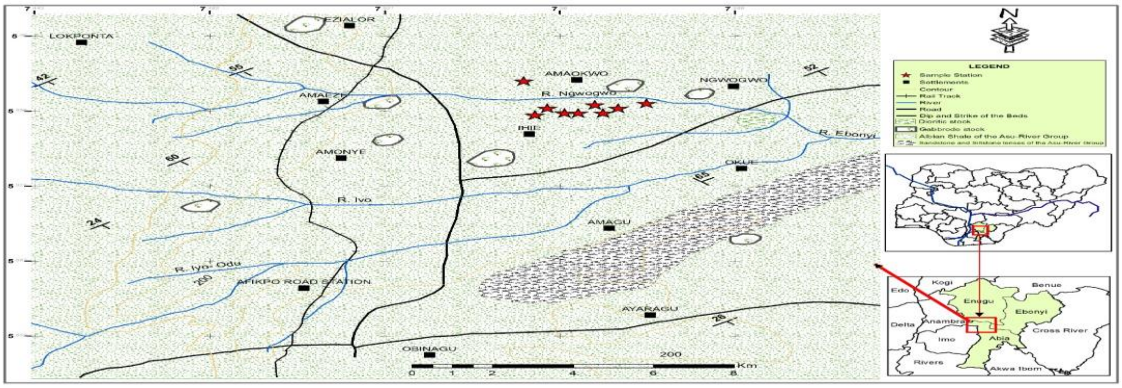


Fig 1: Maps of Ishiagu showing the nine sampling stations

B. Methods

a) Physicochemical analysis of the borehole water sample:

Nineteen physicochemical parameters were analyzed in the samples collected using standard methods recommended by America Public Health Association [12]. All measurements were done in triplicate, the results were expressed in average of the two samples in each month.

b) On site analysis:

In-situ measurements were carried out at the sampling stations for some parameters such as; Temperature, pH, Total dissolved solid (TDS), Electrical conductivity (EC) and Dissolved Oxygen (DO), with aid of a portable digital HANNA multi-purpose meter (Model: HI9813-6) immediately after calibration. Dissolved oxygen (DO) was determined by Winkler titration method.

c) Laboratory analysis:

Using standard methods in Table 2.0, some analysis were carried out in the Laboratory as follows;

Parameter	Method
Turbidity	Nephelometric method with the aid of Hach's turbidmeter (Model2100A)
Biochemical oxygen demand (BOD)	5 days incubation of the sample at 20°C and titration of initial and final DO (Winkler method).
Total Suspended Solids (TSS)	Gravimetric method
Total Alkalinity (TA)	Titrimetric method
Total Hardness (TH)	EDTA-Titrimetric method
Calcium, (Ca^{2+})	EDTA-Titrimetric method and calculation
Magnesium, (Mg^{2+})	EDTA-Titrimetric method and calculation
Chloride ion (Cl^-)	Argentometric method
Sodium (Na^+) and potassium (K^+)	Flame photometric method [13]
Phosphate ion (PO_4^{3-})	Spectrophotometric method [14]
Nitrate nitrogen ($NO_3^- N$)	UV-spectrophotometric method [15]
Sulphate ion (SO_4^{2-})	UV spectrophotometric method
Iron concentration (F^{2+})	Spectrophotometric method using Apel 3000UV-VIS spectrophotometer

Table 2: Methods of analysis of water quality parameters

d) Water quality index (WQI)

This is an index number that describes overall water quality at a particular location or region based on composite parameters of water quality obtained in comparison with their respective regulatory standard values [16]. The technique is employed to simplify or rate the overall water quality status of water resources, and properly pass the information to the management teams, policymakers and to general public [6]. In the United States, WQI was initially proposed by [17], and was further developed by [18] as widely used National Sanitation Foundation's Water Quality Index (WQI-NSF). Moreover, [19] and [20] reported various methods of WQI determination, as described by different national and international bodies. In this study, the weighted arithmetic water quality index (WAWQI) method was applied to assess the water quality parameters. This method has been widely applied by scientists as reported by; [21], [22], [23], [24], [25], [26], [27], [28] and [29] in their various research. Thus, the concept can be generalized in five steps as follows:

- Determination of the unit weight (wi) of each water quality parameters using the equation:

  $$W_i = k/S_i \quad (1)$$

  Where, S_i = the recommended standard value of ith parameter, and k = proportionality constant which can be calculated using the equation: = $[1/(\Sigma^n_{i=1}(1/S_i))]$, while n = the number of parameters.

- Computation of the Relative weight (W_i) of the parameters: Here, we compute the relative weight of the parameters using a weighted arithmetic index method [30][17] given by dividing the unit weight (w_i) by it summation as follow:

  $$W_i = w_i/\Sigma^n_{i=1}(w_i) \quad (2)$$

- Calculation of quality rating scale (q_i) for each ith parameter: We calculated this by dividing each of the water sample parameter obtained by its respective standard, and then multiplied by 100 as follows:

  $$q_i = [(V_o – V_i)/(V_{Si} - V_i)] \times 100\% \quad (3)$$

  Where, V_{Si} = the recommended standard value concentration of ith parameter, V_o = the observed concentration of ith parameter in the analyzed water sample, V_i = the ideal value of this parameter in pure water, which is zero '0' for all ideal value parameter for drinking water except for pH = 7.0 and DO = 14.6 mg/L.

- Determination of Sub-index (SI_i) of the ith parameter: This can be determined by finding the product of q_i and W_i using equation (2) and (3) above, as follows:

  $$SI_i = q_i \times W_i \quad (4)$$

- Summation of each sub-index values gotten gives the overall water quality index (WQI) as follows:

  $$WQI = \Sigma^n_{i=1}SI_i = \Sigma^n_{i=1} (q_iW_i) \quad (5)$$

  WQI values are usually classified into five categories: Excellent, good, poor, very poor and unsuitable water as shown in Table 3.0, while WQI parameter constants; unit weight (wi), relative weight (Wi) and Standard values (Si) are summarized in Table 4.0

WQI	Rating of water quality	Grading
0-25	Excellent water quality	A
26-50	Good water quality	B
51-75	Poor water quality	C
76-100	Very poor water quality	D
Above 100	Unsuitable for drinking purpose	E

Table 3 : Weighted Arithmetic Water Quality Index Rating

PARAMETERS	Standard Value (Si)	Recommended Agency	1/Si	Unit weight (wi)	Relative Weight (Wi)
pH	6.5 - 8.5	WHO/SON	0.11765	0.00487	0.0048683
Temperature (ºC)	30 - 35	WHO	0.02857	0.00118	0.0011823
Turbidity (NTU)	< 5	WHO/SON	0.20000	0.00828	0.0082761
EC (µs/cm)	1200	WHO/SON	0.00100	0.00004	0.0000414
TDS (mgL^{-1})	500 - 1000	WHO/SON	0.00200	0.00008	0.0000828
TSS (mgL^{-1})	250 - 500	WHO	0.00200	0.00008	0.0000828
Total alkalinity (mgL^{-1})	<120	WHO/SON	0.00833	0.00035	0.0003448
Total hardness (mgL^{-1})	100 - 300	WHO/SON	0.00667	0.00028	0.0002759
DO (mgL^{-1})	6 - 8	WHO/FEPA	0.20000	0.00828	0.0082761
BOD (mgL^{-1})	≤ 5	WHO/SON	0.20000	0.00828	0.0082761
Chloride, Cl^- (mgL^{-1})	200 - 250	WHO/SON	0.00400	0.00017	0.0001655
Sodium, Na^+ (mgL^{-1})	200	WHO/SON	0.00500	0.00021	0.0002069
Potassium, K^+ (mgL^{-1})	12	WHO/(SON, 2007)	0.08333	0.00345	0.0034484
Calcium, Ca^{2+} (mgL^{-1})	75	WHO	0.01333	0.00055	0.0005517
Magnessium, Mg^{2+} (mgL^{-1})	50	WHO	0.02000	0.00083	0.0008276
Nitrate, NO_3^- (mgL^{-1})	50	WHO	0.02000	0.00083	0.0008276
Sulphate, SO_4^{2-} (mgL^{-1})	250	WHO	0.00400	0.00017	0.0001655
Phosphate, PO_5^{3-} (mgL^{-1})	0.05	WHO	20.0000	0.82762	0.8276134
Iron (mgL^{-1})	< 0.3	WHO/SON	3.33333	0.13794	0.1379356

Table 4 : Water standards, recommending Agencies, Unit weights (wi) and Relative weight (Wi)

ISSN No:-2456-2165

a) Statistical analysis**:** Mean, Standard deviation (SD), Maximum (Max) and Minimum (Min) values of the obtained data was descriptively analyzed using Microsoft Excel 2019, as well as WAWQI method of the water quality index (WQI) evaluation.

III. RESULTS AND DISCUSSION

a) Physicochemical results of the borehole water

The analysis results of the various physicochemical parameters of the water samples from January to July, including their standard values were used to run the arithmetic data analysis. In this case, the statistical descriptions of the data values obtained for each of the water samples were carried out taken into account the average values for the six months (Jan-Jul) as shown in Table 4.0, 5.0 and 6.0.

PARAMETERS	S1				S2				S3			
	Min	Max	Mean	Std. Dev	Min	Max	Mean	Std. Dev	Min	Max	Mean	Std. Dev
pH	6.87	7.44	7.07	0.20	6.68	7.93	7.23	0.45	7.1	8.01	7.373	0.353
Temperature (ºC)	27.75	29.72	28.49	0.73	27.41	28.68	27.86	0.46	26.6	28.45	27.85	0.807
Turbidity (NTU)	1.65	3.76	2.45	0.74	1.41	4.22	2.41	1.10	4.22	7.45	5.651	1.263
EC (µs/cm)	320.4	407.3	355.0	30.3	311.6	397.8	350.1	32.6	363.9	463.2	413.5	39.35
TDS (mgL^{-1})	142.2	188.4	164.8	17.64	139.5	182.5	160.9	15.73	203.5	254.2	238.4	19.54
TSS (mgL^{-1})	1.92	4.89	2.90	1.14	1.45	4.04	2.46	0.93	2.11	3.43	2.870	0.472
Total alkalinity (mgL^{-1})	41.08	73.47	52.96	11.67	38.06	63.14	50.68	8.21	42.31	56.34	53.61	5.569
Total hardness (mgL^{-1})	118.9	181.3	143.7	23.00	119.6	185.1	141.7	24.16	170.5	189.5	177.9	7.644
DO (mgL^{-1})	2.61	5.95	4.24	1.11	2.41	5.35	3.90	1.17	4.25	5.02	4.563	0.295
BOD (mgL^{-1})	2.21	4.01	3.02	0.61	1.77	4.51	3.18	1.08	2.43	3.35	2.952	0.383
Chloride, Cl^- (mgL^{-1})	31.94	74.61	50.37	13.76	33.03	72.10	49.21	17.07	40.91	51.37	47.00	4.202
Sodium, Na^+ (mgL^{-1})	8.21	21.80	12.91	4.72	0.71	15.47	10.26	5.03	10.3	21.92	15.05	5.367
Potassium, K^+ (mgL^{-1})	7.47	9.06	8.18	0.62	8.12	10.60	8.85	0.92	7.65	9.33	8.502	0.682
Calcium, Ca^{2+} (mgL^{-1})	34.26	44.28	38.27	3.30	34.39	51.59	40.30	5.87	38.21	54.23	47.05	6.565
Magnesium, Mg^{2+} (mgL^{-1})	5.39	21.34	11.66	5.42	5.18	13.92	9.94	4.13	10.92	18.89	14.64	3.284
Nitrate, NO_3^- (mgL^{-1})	11.74	47.57	21.49	13.29	8.54	27.11	15.51	6.69	10.63	18.07	13.34	3.496
Sulphate, SO_4^{2-} (mgL^{-1})	11.18	22.72	16.13	4.61	6.37	17.38	11.43	4.22	11.02	21.11	16.82	3.767
Phosphate, PO_5^{3-} (mgL-1)	0.01	0.02	0.02	0.00	0.01	0.03	0.02	0.01	0.022	0.039	0.032	0.007
Iron (mgL^{-1})	0.01	0.52	0.18	0.20	0.02	0.40	0.22	0.14	0.01	0.438	0.247	0.140

Table 5: Descriptive statistics of the borehole water (S1, S2, S3) samples from Jan to Jul 2020

PARAMETERS	S4				S5				S6			
	Min	Max	Mean	Std. Dev	Min	Max	Mean	Std. Dev	Min	Max	Mean	Std. Dev
pH	6.97	7.53	7.20	0.23	7.44	7.76	7.53	0.12	7.15	8.38	7.56	0.55
Temperature (ºC)	26.50	27.96	27.20	0.63	27.25	28.75	27.94	0.50	26.64	29.57	27.76	1.12
Turbidity (NTU)	1.69	3.44	2.43	0.81	1.41	3.93	2.66	0.82	1.43	3.87	2.35	0.97
EC (µs/cm)	232.7	360.9	309.6	44.0	231.3	380.2	316.4	48.1	311.6	345.2	327.7	14.71
TDS (mgL^{-1})	124.7	221.9	160.9	34.2	132.8	266.9	174.4	47.5	160.4	180.4	172.5	7.07
TSS (mgL-1)	2.39	4.47	3.22	0.79	2.37	16.14	5.13	5.40	1.21	3.12	2.19	0.62
Total alkalinity (mgL^{-1})	23.59	76.21	49.61	17.66	33.24	74.03	52.80	15.98	26.53	75.42	51.40	18.48
Total hardness (mgL^{-1})	123.9	176.5	157.6	18.97	118.0	180.3	151.3	25.31	146.5	174.3	155.9	10.72
DO (mgL^{-1})	1.73	5.17	3.42	1.42	2.50	5.90	4.08	1.26	1.78	6.23	3.56	1.82
BOD (mgL^{-1})	2.44	4.31	3.16	0.78	2.11	4.54	3.33	1.01	2.23	3.46	2.73	0.44
Chloride, Cl^- (mgL^{-1})	18.52	60.79	34.47	15.42	29.67	58.74	43.54	11.52	43.16	72.01	59.98	10.59
Sodium, Na^+ (mgL^{-1})	9.17	20.09	12.55	4.08	1.26	11.78	8.21	4.23	4.32	11.33	8.16	2.88
Potassium, K^+ (mgL^{-1})	7.29	13.75	9.45	2.48	1.26	11.52	7.64	3.71	7.51	10.44	9.14	1.29
Calcium, Ca^{2+} (mgL^{-1})	26.76	46.76	37.44	8.40	22.07	51.82	37.39	9.72	39.23	47.46	43.87	3.46
Magnessium, Mg^{2+} (mgL^{-1})	10.96	22.05	15.53	3.72	4.75	23.59	14.04	7.10	8.02	14.30	11.23	2.19
Nitrate, NO_3^- (mgL^{-1})	8.57	12.23	10.04	1.59	1.58	47.99	25.13	8.17	5.54	19.45	12.31	4.57
Sulphate, SO_4^{2-} (mgL^{-1})	20.01	23.77	21.84	1.48	10.46	19.39	14.30	3.67	8.22	19.30	14.04	4.12
Phosphate, PO_5^{3-} (mgL^{-1})	0.024	0.037	0.030	0.005	0.022	0.033	0.027	0.004	0.010	0.033	0.026	0.009
Iron (mgL^{-1})	0.028	0.273	0.118	0.097	0.025	0.425	0.171	0.142	0.024	0.110	0.063	0.035

Table 6 : Descriptive statistics of the borehole water (S4, S5, S6) samples from Jan to Jul 2020

ISSN No:-2456-2165

PARAMETERS	S7				S8				S9			
	Min	Max	Mean	Std. Dev	Min	Max	Mean	Std. Dev	Min	Max	Mean	Std. Dev
pH	7.00	8.04	7.47	0.47	7.19	7.97	7.56	0.31	6.59	7.63	7.31	0.37
Temperature (ºC)	26.88	29.58	28.33	0.92	27.29	30.37	28.73	1.15	25.8	29.14	27.53	1.14
Turbidity (NTU)	1.54	2.70	2.18	0.40	1.49	3.55	2.42	0.73	1.46	2.77	2.22	0.46
EC (µs/cm)	317.3	372.0	349.8	18.7	311.6	408.3	349.0	33.4	218.3	380.4	275.0	68.2
TDS (mgL^{-1})	161.1	171.8	166.0	4.3	156.0	207.8	174.8	18.6	138.2	168.3	153.3	10.0
TSS (mgL^{-1})	1.66	2.72	2.02	0.43	2.31	3.26	2.56	0.36	2.44	3.880	2.898	0.518
Total alkalinity (mgL^{-1})	31.28	60.81	43.50	9.96	30.43	64.59	55.05	12.84	43.32	66.52	55.53	9.351
Total hardness (mgL^{-1})	147.5	174.5	158.5	11.17	142.4	178.3	161.5	14.52	142.1	160.3	153.5	6.537
DO (mgL^{-1})	2.04	4.31	3.13	1.00	2.16	5.78	4.14	1.56	2.29	3.600	2.840	0.545
BOD (mgL^{-1})	1.94	4.79	3.06	0.97	1.67	3.22	2.33	0.57	2.22	4.500	3.587	0.782
Chloride, Cl^- (mgL^{-1})	29.84	65.73	45.82	12.61	26.29	70.02	51.62	17.19	29.75	52.40	40.37	9.210
Sodium, Na^+ (mgL^{-1})	6.06	15.31	10.21	3.87	4.93	13.18	10.14	2.84	11.33	20.15	15.20	3.903
Potassium, K^+ (mgL^{-1})	7.53	10.32	8.76	0.92	8.75	10.32	9.40	0.52	6.17	12.43	9.737	2.387
Calcium, Ca^{2+} (mgL^{-1})	38.77	45.28	42.48	2.74	34.76	46.12	41.54	4.99	20.17	43.83	30.29	9.549
Magnessium, Mg^{2+} (mgL^{-1})	8.73	14.99	12.70	2.81	10.89	16.47	13.99	1.94	10.05	25.23	18.87	6.361
Nitrate, NO_3^- (mgL^{-1})	7.88	42.42	17.88	12.78	8.65	69.13	21.58	23.40	8.41	21.87	14.03	5.578
Sulphate, SO_4^{2-} (mgL^{-1})	10.84	24.57	15.03	4.89	9.49	28.26	15.45	6.71	13.32	24.00	19.12	4.626
Phosphate, PO_5^{3-} (mgL^{-1})	0.02	0.04	0.03	0.01	0.01	0.03	0.02	0.00	0.016	0.034	0.026	0.007
Iron (mgL^{-1})	0.03	0.45	0.14	0.16	0.02	0.20	0.10	0.08	0.043	0.282	0.161	0.106

Table 7 : Descriptive statistics of the borehole water (S7, S8, S9) samples from Jan to Jul 2020

b) Physicochemical parameters assessment

The water quality physicochemical variables were analyzed, and the outcome of the nine stations were assessed in different months as shown in Fig 3.0(a-s). The concentration of each parameter varies from one sample point to the other. This is then compared to the WHO, SON or FEPA acceptable values in order to assess the health status of water consumes in the study area. To further explain this, the individual parameters were discussed as follows:

The pH: pH is an important quantity that reflects the chemical composition of a solution [31]. The pH of water can change due to contaminants which in turn can harm animals, plants, other living organisms and human. Therefore, monitoring the pH of water is important to keep it in check for a wide variety of applications. From the results, the pH values of borehole water in the various sampling stations ranges from 6.37 to 8.38. The highest pH values (8.13 and 8.38) was recorded in station S6 in January and May respectively, as shown in Fig 3.0(a), with mean value of 7.56±0.55 mgL^{-1} in Table 5.0. This higher pH values could be due to dissolution of rocky minerals in the form of ionic salts of some carbonates and bicarbonates as it move down aquifer and leaching of rocks down the groundwater seepage during the rainy season. Likewise, the lowest pH of 6.37 and 6.41 were recorded in stations S5 and S1 in February and May respectively, as shown in Fig 3.0(a). Despite the variation in pH of the analyzed borehole stations (from S1 to S9) throughout the inclusive months, the values still lie within the WHO and SON standard permissible range of 6.5 to 8.5 for drinking water, except in February and May when station S5 and S1 gave slightly acidic pH values less than the recommended desirable standards. This could be caused by the wastewaters from drainages, leachates from refuse dump, carbondioxide concentration and organic matters decomposition [32] especially at station S5.

Tempearatue (ºC): The temperature of drinking water is of important because it influences the physical, chemical and biochemical properties of water. Warm or high water temperature between 4ºC to 60ºC enhances the growth of micro-organisms by increasing it enzyme activities [33], but higher temperature above 60ºC can destroy pathogens. From the analysis results, the temperature of the sampled borehole waters in all the stations ranges from 25.8°C to 30.4°C. The highest value (level) of the samples was recorded in station S8 as 30.37 °C in the month of May as shown in Fig 3.0(b), with the mean value of 28.73±1.15°C in Table 6.0. Likewise, the lowest level (25.8 °C) was found in station S9 in January. These values are all within the WHO standard permissible limit (25-40ºC) for drinking water, and are similar to those reported by [5] and [4]. Though at higher temperature, metal corrosion problem may increase which in turn increases the conductivity especially when the pH of the water is slightly or more acidic as we had at station S5 in February. From Fig 3.0(i), the lower levels of dissolved oxygen (DO) observed at same station S5 throughout the selected months also suggested the effect of the high temperature in the area as shown in Fig 3.0(b). However, the higher temperature values recorded at station S1 and S8 could be influenced by the sunlight intensity through the rocky ground surface of the areas.

Turbidity (NTU): This is the measure of water clarity whether transparent, translucent or muddy. High turbid water could be as a result of total dissolved solid (TDS) and total suspended solid (TSS) in water, while low turbidity happens as the TDS and TSS decreases. High turbidity water absorbs more heat from sunlight and becomes warmer and so reducing the oxygen concentration [34]. Groundwater normally has very low turbidity due to natural filtration that occurs as the water penetrates through the soil [35]. From the analysis results, turbidity values of the boreholes in all the stations ranges from 1.41 to 7.45 NTU. The highest turbid value of 7.45 NTU was recorded in station S3 in January, with mean value of 5.65±1.26 NTU in Table 4.0. Station S3 also exhibited higher turbid values (level) in all the months, though higher turbid values in dry season than in rainy season as shown in Fig 2.0(c). These higher turbid values exceeded the WHO and SON standard permissible limit (5 NTU) for drinking water, meaning that consuming the borehole water at station S3 exposes human and aquatic life to health issues, because pathogens and harmful microorganisms are been protected or shield (by the particulates that made up the high turbidity) from effects of disinfectants, and through that, their growth are been facilitated while chlorine demand in the cause of treatment would increase [36] and [37]. Meanwhile, the lowest turbidity value of 1.41 NTU was obtained in both water samples collected in station S2 and S5 in March and May respectively, and are in close range with the values of 1.49 NTU, 1.46 NTU and 1.43 NTU obtained at stations S8, S9, and S6 respectively, in the month of January and February.

Electrical Conductivity (EC): Electrical Conductivity is the measure of ionic pollutants or salinity that affects the taste of drinking water. It also serves as an indicator of the presence of dissolved and suspended solids to water quality. Water with high mineral content or inorganic dissolved solids such as Chloride, nitrate, sulfate and phosphate, sodium, magnesium, calcium, iron, and aluminum ions tends to have higher conductivity. The analysis results showed that the electrical Conductivity (EC) of water samples in all the stations ranges from 218.3 to 463.2 μScm^{-1}. EC was recorded higher in station S3 throughout the inclusive months with mean value of 413.5±39.35 μScm^{-1} and highest point of 463.4 μScm^{-1} as shown in Fig 3.0(d). Station S9 maintained lower values (levels) throughout the inclusive months with lowest point of 218.3 μScm^{-1} in the month of May. According to [38] in reference to report by [39], Conductivity values below 50 μScm^{-1} are regarded as low, those between 50-600 μScm^{-1} are said to be medium while values above 600 μScm^{-1} are considered to be high [39]. Also, the WHO and SON recommended standard limit is 1200 μScm^{-1}, which means that both the highest and least values of EC obtained are medium and within the standard limit.

Total Dissolved Solids (TDS): This composed of mainly inorganic salts like; carbonates, bicarbonates, chlorides, phosphates and nitrates of calcium, magnesium, sodium, potassium and manganese, as well as organic matter and other particles [38]. From the analysis results, the TDS value of water samples ranges from 132.8 to 266.9 mgL^{-1}. The highest TDS value of 266.9 mgL^{-1} was recorded in station S5 in January with mean value of 174.4±47.5 mgL^{-1} in Table 5.0. Higher TDS levels was also observed at station S3 throughout the inclusive months as shown in Fig 3.0(e), suggesting high salts and minerals which must have contributed to the higher levels of EC and turbidity observed in the station. On the other hand, the lowest TDS value (132.8 mgL^{-1}) was recorded in water samples collected from station S5 in the month of March, then followed by the least values obtained at other stations like; S1, S2, S7 and S9. However, the WHO and SON desirable limit for TDS is 500 mgL^{-1} and maximum permissible limit is 1000 mgL^{-1} prescribed for drinking water. Hence, both highest and lowest values obtained in all the samples are medium and within the standards for drinking water.

Total suspended solids (TSS): These are suspended particulate matter or particles undissolved in water sample, it may either settle slowly or be trapped by a filter, and contributes to water turbidity. From the analysis results, the TSS value of water samples ranges from 1.21 to 4.47 mgL^{-1}. The highest TSS value of 4.47 mgL^{-1} was recorded in station S4 in the month of June with mean value of 3.22±0.79 mgL^{-1} in Table 5.0, while the lowest value (level) of 1.21 mgL^{-1} was found in the water sample at station S6 in February as shown in Fig 3.0(f). The reduced TSS values observed in all the stations could be due to the underground water flow rate adhering to infiltration through the seepage. Thus, both the highest and lowest TSS values obtained in all the sample stations throughout the inclusive months are within the maximum recommended TSS limit set by WHO for drinking water which is 500 mgL^{-1}.

Total alkalinity (TA): This is a measure of all dissolved carbonates, bicarbonates and hydroxide in water. It is also a measure of the capacity of the water to neutralize acids [40]. Alkalinity in the studied samples ranged from 23.59-76.21 mgL^{-1}. The highest value of 76.21 mgL^{-1} was recorded in station S4 in February with mean value of 49.61±17.66 mgL^{-1}, then followed by the values; 75.42 mgL^{-1} and 74.03 mgL^{-1} obtained in water samples in station S6 and S5 in May and June respectively, as shown in Fig 3.0(g). However, these values are within the maximum standard limit of 120 mgL^{-1} for drinking water. Meanwhile, the lowest TA value was recorded as 26.59 mgL^{-1} and 28.82 mgL^{-1} in station S6 in June and July respectively, implying that S6 had more TA value in dry season than in rainy season.

Total Hardness (TH): Total Hardness is a measure of the mineral content and ability of water to cause precipitation of insoluble Calcium and magnesium salts of higher fatty acids from soap solution [41]. It is classified in terms of $CaCO_3$ mgL^{-1} with respect to water quality by [42], in the range of; 0-75 mgL^{-1} (soft), 75-150 mgL^{-1} (moderately hard), 150-300 mgL^{-1} (hard), and above 300 mgL^{-1} (very hard). From the analysis results, the borehole water samples had hardness ranges from 118.0-189.5 mgL^{-1}. The highest TH value of 189.5 mgL^{-1} was recorded in station S3 in the month of January with mean value of 177.9±7.64 mgL^{-1}, then followed by the value of 185.1 mgL^{-1} obtained in June at station S2 as shown in Fig 3.0(h). However, the lowest TH value (level) was recorded in station S5 as 118.0 mgL^{-1} in July, followed by the value of 118.9 mgL^{-1} gotten from station S1 in same month of July as shown in Fig 3.0(h). Nevertheless, all TH results obtained in all the stations at every given month are within the permissible limit of 100-300 mgL^{-1} prescribed by WHO and SON for drinking water. Also, the water samples ranges from "moderately hard" to "hard" category, and could be safer and suitable for drinking than soft water, since it contains the required essential minerals like calcium and magnesium which we need to prevent heart disease and for our healthy teeth and bones.

Dissolved oxygen (DO): This is an important indicator of water quality that measures the amount of oxygen freely available in borehole water for human consumption and for the survival of fish and other aquatic organisms. The higher the concentration of dissolved oxygen, the better the water quality. The current study revealed that the borehole water samples from all the stations had DO values ranges from 1.46-6.23 mgL^{-1}. From Fig 3.0(i), the highest DO value of 6.23 mgL^{-1} was recorded in station S6 in May, with mean value of 3.56±1.82 mgL^{-1}, then followed by the higher values obtained in some other stations which varies with temperature throughout the months of dry and rainy seasons. The lowest DO values were recorded in station S5 as 1.46 mgL^{-1} and 1.54 mgL^{-1} in June and July, and continued throughout the other months as displayed in Fig 3.0(i). These higher values recorded in some stations are within the WHO and FEPA maximum permissible limit of 8 mgL^{-1} [43], while the lower DO values recorded in station S5 and other stations (S7, S6, S9, S2, S6, S4) in January, February, March, May, June and July respectively were lower than the WHO and FEPA minimum desirable limit of 6 mgL^{-1}. Further, the lower DO levels reflects the richness of organic matter and warm temperature at station S5, which consumes large amount of dissolved oxygen in the process of decomposition as similarly reported by [43]. Low dissolved oxygen in other stations could be attributed to wastewater pollution, dissolved salts and other oxidizable substances.

Biochemical oxygen demand (BOD): Biochemical Oxygen Demand is a measure of the oxygen in the water that is required by the aerobic organisms. The higher the BOD, the lower the DO levels and vice versa. The BOD in the studied sample ranges from 1.67-4.79 mgL^{-1}. And according to [38], the unpolluted water should have a BOD of 5mg/L or less. The highest BOD value of 4.79 mgL^{-1} was recorded in station S7 in January with mean value of 3.06±0.97 mgL^{-1}, while station S9 and S5 recorded higher BOD values (levels) in all the inclusive months compare to other stations as shown in Fig 3.0(j). This could be attributed to organic matter or waste and bacterial present area. However, these values are within the WHO and SON standard permissible limit of 5mgL^{-1} for portable water. Though, the least BOD values varies in most of the stations suggesting less organic pollution. The lowest value was recorded as 1.67 mgL^{-1} in station S8 in the month of June.

Chloride (Cl-): Chloride is one of the anions that occurs naturally in varying concentrations in most natural waters and is often found as salt component of sodium, and in some cases, in combination with potassium, calcium or magnesium. It usually occurs in greater concentration in groundwater than in surface water especially in salt mineral deposits areas [44], and is less harmful on public health [35]. Chloride increases levels of metals in water by reacting with them to form soluble salt, thereby increasing the electrical conductivity of the water and thus increases its corrosivity [36]. In the present study, chloride ion concentration fluctuated at various sampling stations throughout the inclusive months. These chloride ions concentration in all the sampling stations ranges from 18.52 to 74.61 mgL^{-1}. The highest Cl^- value (level) was recorded in station S1 as 74.61 mgL^{-1} in June with mean value of 50.37±13.8 mgL^{-1}, followed by the values 72.10 mgL^{-1} and 72.01 mgL^{-1} obtained in water samples at station S2 and S6 in same June and July, as shown in Fig 3.0(k). These values are within the WHO and SON permissible limit of 250 mgL^{-1} for drinking water, exceeding this level could lead to salty tastes, undesirable odors of water, and could lead to hyperchloremia, a health problem [45]. However, the lowest Cl^{-1} level (value) was recorded in station S4 as 18.52 mgL^{-1} in July.

Sodium (Na^+): Sodium is an essential mineral in our diet for normal functioning of the human body. It is released naturally into water from rocks or through mineral deposits in groundwater, and can be found in the form of sodium carbonate, sodium nitrate, sodium sulfate and also commonly found in the form of sodium chloride [36]. Excessive sodium salt intake above the desirable limit can aggravate high blood pressure, heart disease, cardiovascular disease and kidney problems. From the analysis results, sodium concentration ranges from 1.26 to 21.92 mgL^{-1}. The highest Na^+ value of 21.92 mgL^{-1} was recorded in station S3 in February, with mean value of 15.05±5.37 mgL^{-1} in Table 4.0, followed by the values 21.80 mgL^{-1} and 21.68 mgL^{-1} recorded in station S1 and S3 in months of February and January, as shown in Fig 3.0(l). These values are very low and within the WHO and SON permissible limit of 200 mgL^{-1}, exceeding this could be harmful. However, the lowest Na^+ value was recorded in station S5 as 1.26 mgL^{-1} in the month of July, which could be due to mobility of sodium ions and saline extrusion through the aquifer during dry season.

Potassium (K^+): Potassium and sodium are electrolytes needed for body to function normally and help maintain fluid and blood volume in the body. However, consuming little potassium and too much sodium in the body could lead to higher blood pressure. But, increasing potassium intake can reduce risk of heart diseases, stroke and blood pressure in hypertensive person [46] and [47]. The current results revealed that the concentration of potassium in study areas ranges from 6.02 to 12.43 mgL^{-1}. The highest K^+ values of 12.19 mgL^{-1} and 12.43 mgL^{-1} was recorded in station S9 in the month of February and May respectively, with mean value of 9.73±2.39 mgL^{-1}. These higher potassium values in S9 exceeded the WHO and SON standard permissible limit of 12 mgL^{-1}, could be attributed to saline intrusion in the aquifer sediment through which seepage of groundwater drainage [48], especially during rainy season. Likewise, the lowest K^+ value (level) was recorded in station S5 as 6.02 mgL^{-1} in the month of June as shown in Fig 3.0(m).

Calcium (Ca^{2+}): Calcium is the most abundant mineral that plays an important role in the body. It helps to maintain healthy teeth, bones, and proper functioning of the cardiovascular and muscle [49]. From the analysis results, the concentration of calcium in study areas ranges from 20.17 to 54.23 mgL^{-1}. The highest Ca^{2+} values of 54.23 mgL^{-1} and 52.64 mgL^{-1} were recorded in station S3 in January and February respectively, with mean value of 47.05±6.57 mgL^{-1}. These values are all within the WHO standard permissible limit of 75 mgL^{-1} for drinking water, and the presence of Ca^{2+} in the study areas may be due to the intense dissolution and leaching of calcium-rich rocks underlying the areas and also from acidic rains (which can dissolve nutrients like calcium and magnesium) during rainy season. However, station S9 recorded lower calcium levels throughout the months of dry season, with lowest point of 20.17 mgL^{-1} in May, and increases in June and July as shown in Fig 3.0(n).

Magnesium (Mg^{2+}): Magnesium is an 8th most abundant element on earth crust and natural constituent of water [50]. It is an essential nutrient just like sodium, potassium and calcium needed for proper functioning of living organisms. According to WHO standards, the permissible limit of magnesium in water is 50 mgL^{-1}. The analysis results showed that magnesium ranges from 4.75 to 25.23 mgL^{-1}. Station S9 recorded higher magnesium levels throughout the months of dry season, with highest point of 25.23 mgL^{-1} in May, and decreases in June and July with mean value of 18.87±6.36 mgL^{-1} as shown in Fig 3.0(o). The presence of magnesium concentrations in these study areas could be due to intense dissolution and leaching of magnesium-rich rocks underlying the areas. Thus, all the values recorded in all the stations are within the WHO standard permissible limit of 50 mgL^{-1}. Further, the lowest Mg^{2+} value (level) was recorded in station S5 as 4.75 mgL^{-1} in the month of July as also shown in Fig 3.0(o).

Nitrate (NO_3^-) Nitrate has adverse effect on the health of human and animals. It is one of the most common groundwater contaminants that has been mostly reported in rural areas. The presence in water indicates possible pollution, and regulating it in drinking water supply is very important because excess levels can cause oxygen reduction (just as it affected the dissolved oxygen levels of station S5 in Fig 3.0i) and health problems especially to infants [50]. The analysis result revealed that the concentration of nitrate ion is generally low in most of the study areas except in station S5 as displayed in Fig 3.0(p). The concentration in all the stations ranges from 5.45 to 44.04 mgL^{-1}. Station S5 recorded the most nitrate values (level) throughout the inclusive months, and still recorded the highest values of 40.34 mgL^{-1} and 44.04 mgL^{-1} in the month of June and July respectively, with mean value of 25.13±8.17 mgL^{-1} in Table 5.0. This implies therefore, that the sources of the nitrate to the borehole water in station S5 could be from the groundwater seepage through soil containing nitrate-bearing minerals, fertilizer use and leachates from waste dumps and waste waters from residential buildings [51]. And according to [52], water with nitrate value between 21-40 mgL^{-1} should not be used as a drinking water source but short-term use is acceptable for adults. Likewise, WHO also gave the Maximum Contaminant Level (MCL) standards for drinking water as 50 mgL^{-1}, which is approximately equivalent to 11.3 mgL^{-1} as NO_3^-N (gotten by multiplying NO_3^- mgL^{-1} by 0.2258) [53]. Thus, borehole water from station S5 should be monitored periodically for nitrate changes to prevent exceeding limit. Station S4 recorded the least calcium values throughout the inclusive months, while the lowest nitrate values of 6.54 mgL^{-1} and 5.45 mgL^{-1} were recorded in station S6 in January and May respectively, as shown in Fig 3.0(p), which indicates little or no source of household waste in the area.

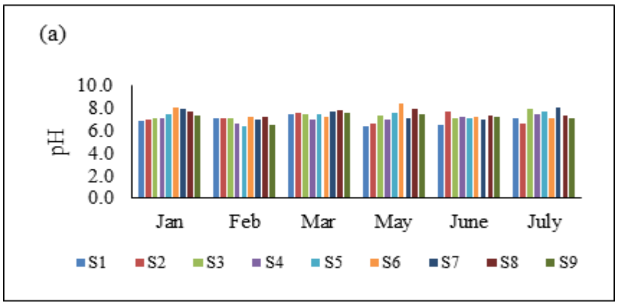
Sulphate ion (SO_4^{2-}): Sulphate is an oxidized form of sulfur that is found at high concentrations in aquifers of underlying soils rich in gypsum. Sulfate occurs as a dissolved ion, and is mobile in ground water [54]. High concentrations of sulfate in the water we drink can expose our body systems to health problems, and can as well have a laxative effect when combined with calcium and magnesium [55]. The concentration of sulphate ion in study areas ranges from 6.37 to 28.26 mgL^{-1}. The highest value was recorded in station S8 as 28.26 mgL^{-1} in June, with mean value of 15.45±6.71 mgL^{-1} in Table 6.0 and Fig 3.0(q). This implies that the source of sulphate in borehole water (S8) environment could be seasonal, as the month of June and July (rainy season) yield more sulphate, perhaps through leached wastewaters on the groundwater quality around the area. Meanwhile, the lowest sulphate values of 6.37 mgL^{-1} and 6.68 mgL^{-1} were recorded in station S2 in January and May, which was similar months the lowest level concentration of nitrate was recorded. The low values recorded could be due to sulphate removal from the water by bacteria [56]. However, the WHO has established 250 mgL^{-l} as the Maximum permissible limit of sulphate for drinking water. Therefore, the results showed that concentration of sulfate in most of the study areas was lower than the standard limit and it may not be harmful for human health.

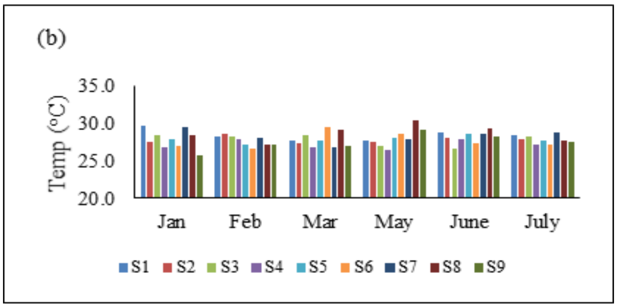
Phosphate ion (PO_4^{3-}): Phosphate is an essential element in desirable limit for human health. However, it is considered a pollutant if it concentration exceeds the recommended permissible limit. Moreover, the discharge of phosphate ion causes serious environmental hazards to the ecosystems by influencing excessive growth of algae, which in turn leads to decrease in the levels of dissolved oxygen due to eutrophication in water [57]. In the present study, the concentration of phosphate ion ranges from 0.01 to 0.04 mgL^{-1}. The same highest value of 0.04 mgL^{-1} was recorded in three other different stations like station S7, S4 and S3 in January, February and March (dry season), while the most recorded values (level) of phosphate was in station S3 throughout the inclusive months as shown in Fig 3.0(r). According to WHO standards, the permissible range of phosphate in water is 0.05 mgL^{-1}. But, the presence in higher concentrations very close to this recommended limit calls for attention to avoid rising beyond limit. The lowest phosphate values of 0.01 mgL^{-1} was recorded in station S8 and S6 in January and June. However, all the values are within the WHO permissible standard limit of 0.05 mgL^{-1}.

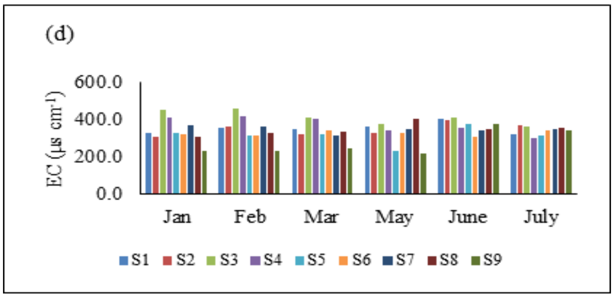
Iron: Just like manganese, iron occurs naturally in soils, rocks and minerals. In groundwater, iron occurs in a reduced soluble oxidation state of Fe^{2+}, but when the groundwater comes in contact with atmospheric oxygen, the iron is oxidized to the ferric state (Fe^{3+}) and precipitated as iron mineral. In the present study, the iron concentration in the study areas ranges from 0.01 to 0.45 mgL^{-1}. Station S3 recorded the most iron values (levels) throughout the months except in July, while the highest point (level) was recorded in station S7 in February with mean value of 0.14±0.16 mgL^{-1}. From Fig 3.0(s), there is variation in level concentration of iron in all the stations with respect to month. The higher concentration recorded in some months could be traced to

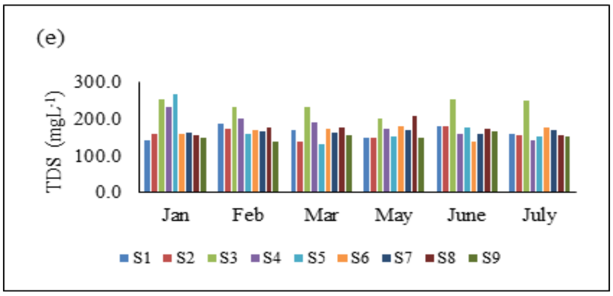
ISSN No:-2456-2165

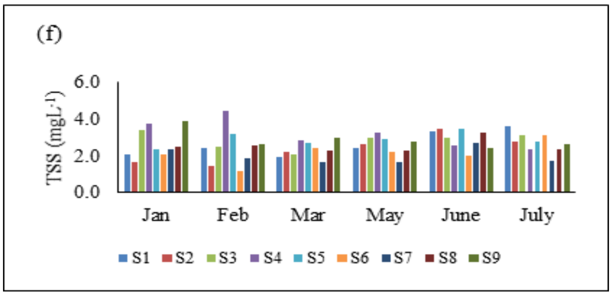
changes in underlying geologic formations in the aquifer during dissolution of iron minerals from rocks. According to WHO and SON standards, maximum permissible limit for iron in drinking water is 0.3 mgL^{-1}, and the recorded concentration exceeded the recommended standard in some months especially in dry season with respect to some stations as observed in Fig 3.0(s). Thus, prolong consumption of this waters overtime without proper balance may raise health issues.

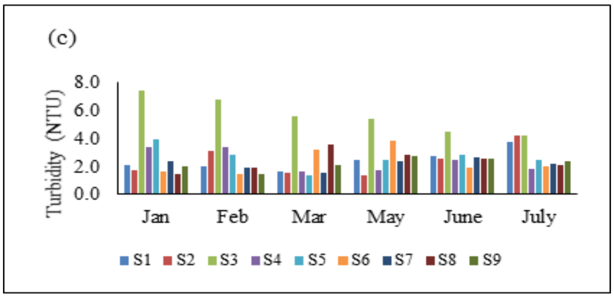


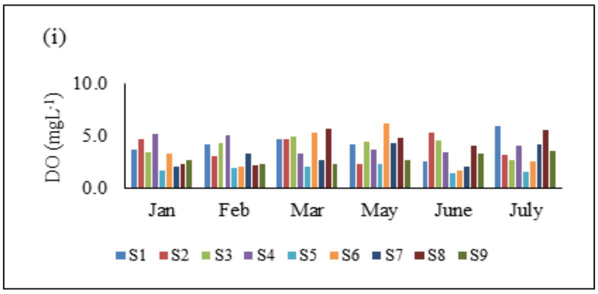


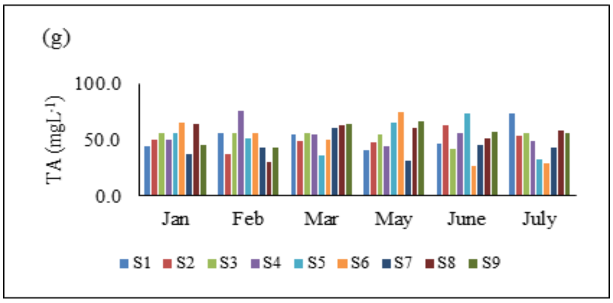


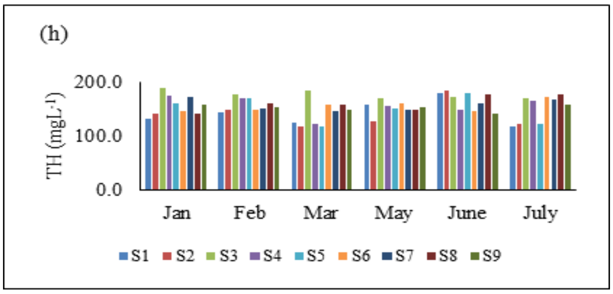


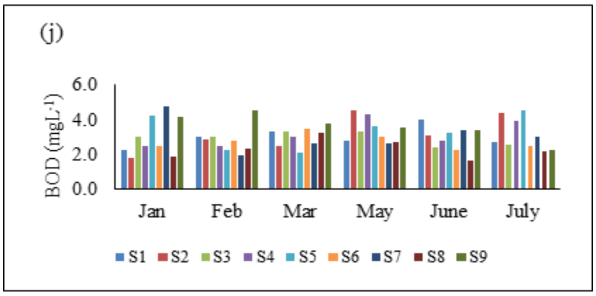


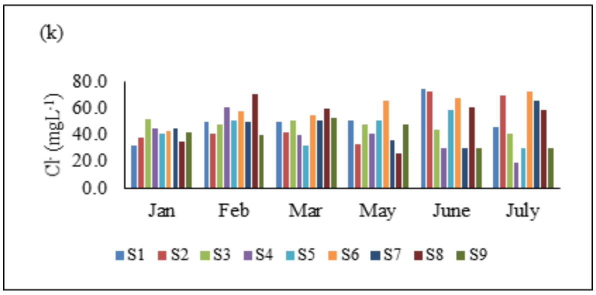


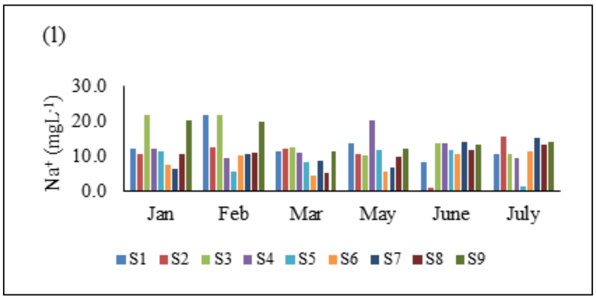


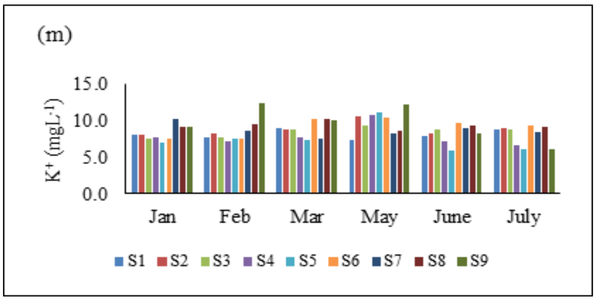


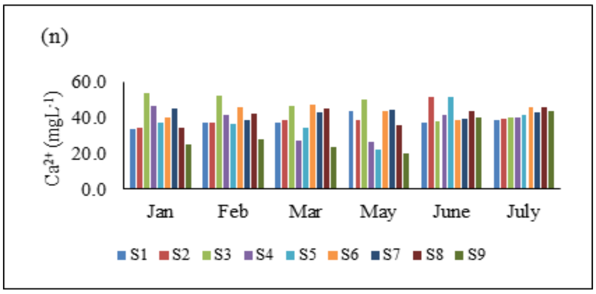


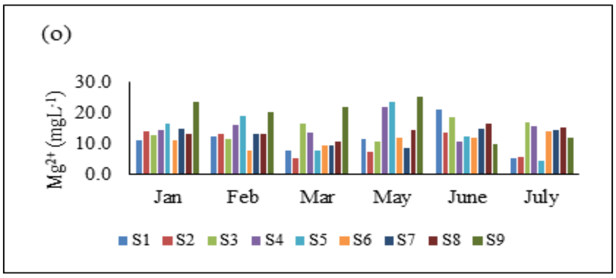


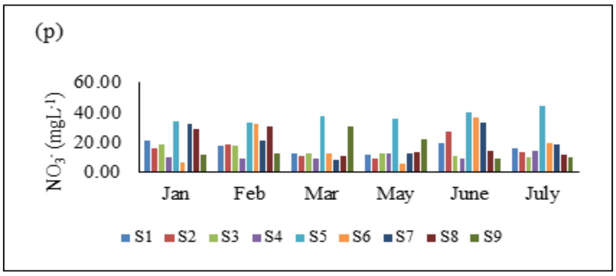


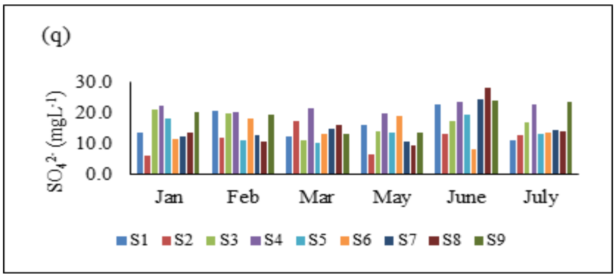


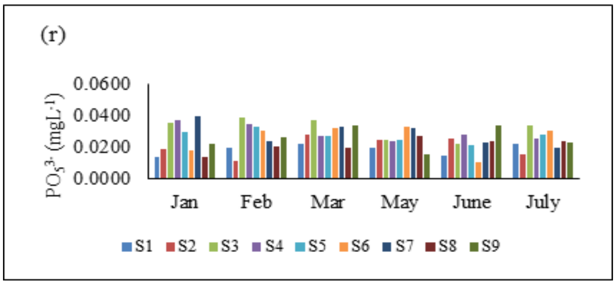












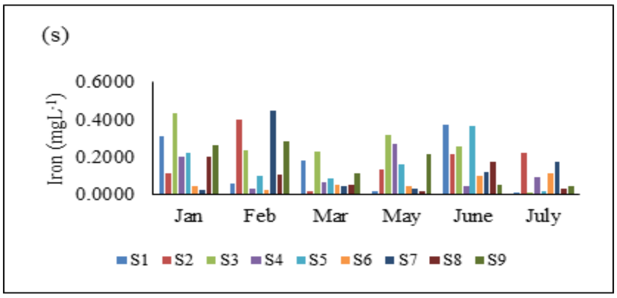


Fig 3.0(a-s): Average concentrations of the borehole water parameters such as; (a) The pH, (b) Temperature, (c) Turbidity, (d) Electrical conductivity (EC), (e) Total dissolved solids (TDS), (f) Total suspended solid (TSS), (g) Total Alkalinity (TA), (h) Total Hardness (TH), (i) Dissolved Oxygen (DO), (j) Biochemical oxygen demand (BOD), (k) Chloride (Cl-), (l) sodium (Na+), (m) Potassium (K+), (n) Calcium (Ca2+), (o) Magnesium (Mg2+), (p) Nitrate (NO3-), (q) Sulphate (SO42-), (r) Phosphate (PO53-) and (s) iron, of the various stations (S1, S2, S3, S4, S5, S6, S7, S8 and S9) from January to July.

c) Water quality assessment with WQI

The measured values of the physicochemical parameters of borehole water was used to compute the calculated WQI values as presented in Tables 3.0, 7.0, 10.0, 11.0, and Appendix (Tables 8.0, 9.0, 13.0, 14.0, 15.0, 16.0 and 17.0). In addition, Table 12.0 showed the summary values of WQI for each of the nine borehole water sources and their ranking based on the WQI grading technique presented in Table 2.0.

Generally, the result of the WQI analysis as tabulated in Table 12.0 reflected 2% of the samples as excellent quality, 52% as good quality, 43% as poor quality while 4% as very poor quality. Also, in same Table 12.0, the mean WQI showed that 44% of the samples fall in good water category while 56% of the samples falls into poor water quality category. This

ISSN No:-2456-2165

shows that the borehole waters from different stations fall mostly within the range of "Good water quality- B" and "Poor water quality- C" as displayed in Fig 4.0. Moreover, throughout the selected months, station S1 and S8 maintained a "Good water quality" with mean value of 41.78 and 42.18 respectively, as their line curves in Fig 4.0 lies within the region of "Good water quality". The same pattern was observed in station S2 with mean value of 47.59, except in June when the water quality was poor, maybe due to heavy rainfall during that period, which might have aggravated leachate from wastewater drainage through groundwater seepage.

In station S6, despite the variations in the water quality, an excellent water quality was observed in the month of June as displayed by sharp sloppy curve in Fig 4.0.

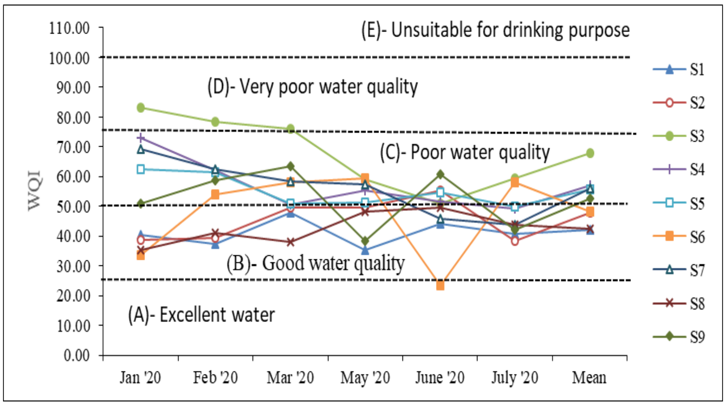


Fig. 4 : Illustration Curves of WQI status of the various borehole water stations

PARAMETERS	S3											
	Quality rating (q)						Sub-index (qW)					
	qJan	qFeb	qMar	qMay	qJun	qJul	qWJan	qWFeb	qWMar	qWMay	qWJun	qWJul
pH	83.53	84.12	88.47	86.47	83.65	94.24	0.40665	0.40951	0.43070	0.42097	0.40722	0.45877
Temperature (ºC)	81.29	80.89	81.26	77.29	76.00	80.63	0.09610	0.09563	0.09607	0.09138	0.08986	0.09533
Turbidity (NTU)	149.0	135.2	111.2	109.1	89.20	84.40	1.23314	1.11893	0.92031	0.90259	0.73823	0.69851
EC (µs/cm)	45.24	46.32	41.25	37.76	41.17	36.39	0.00187	0.00192	0.00171	0.00156	0.00170	0.00151
TDS (mgL^{-1})	50.69	46.91	46.60	40.71	50.85	50.31	0.00419	0.00388	0.00386	0.00337	0.00421	0.00416
TSS (mgL^{-1})	0.69	0.51	0.42	0.60	0.60	0.63	0.00006	0.00004	0.00004	0.00005	0.00005	0.00005
Total alk. (mgL^{-1})	46.68	46.75	46.86	45.55	35.26	46.95	0.01609	0.01612	0.01616	0.01571	0.01216	0.01619
Total Har. (mgL^{-1})	126.3	119.1	122.9	113.7	115.6	114.3	0.03484	0.03286	0.03389	0.03136	0.03188	0.03153
DO (mgL^{-1})	85.00	86.00	100.4	88.40	93.20	94.60	0.70347	0.71175	0.83092	0.73161	0.77134	0.78292
BOD (mgL^{-1})	60.80	60.60	66.20	67.00	48.60	51.00	0.50319	0.50153	0.54788	0.55450	0.40222	0.42208
Chloride (mgL^{-1})	20.55	19.22	20.44	18.93	17.30	16.36	0.00340	0.00318	0.00338	0.00313	0.00286	0.00271
Sodium (mgL^{-1})	10.84	10.96	6.14	5.15	6.79	5.27	0.00224	0.00227	0.00127	0.00107	0.00141	0.00109
Potassium (mgL^{-1})	63.75	64.00	73.17	77.75	73.50	72.92	0.21984	0.22069	0.25231	0.26811	0.25346	0.25145
Calcium (mgL^{-1})	72.31	70.19	62.17	66.95	50.95	53.85	0.03989	0.03873	0.03430	0.03694	0.02811	0.02971
Magnessium (mgL^{-1})	26.15	22.85	32.89	21.85	37.77	34.20	0.02165	0.01891	0.02722	0.01808	0.03126	0.02831
Nitrate (mgL^{-1})	36.14	34.40	24.22	24.68	21.76	18.86	0.02991	0.02847	0.02005	0.02043	0.01801	0.01561
Sulphate (mgL^{-1})	8.44	8.01	4.41	5.60	7.01	6.89	0.00139	0.00133	0.00073	0.00093	0.00116	0.00114
Phosphate (mgL^{-1})	72.00	78.00	75.20	50.00	44.00	68.00	59.5882	64.5538	62.2365	41.3807	36.4149	56.2777
Iron (mgL^{-1})	146.0	78.00	76.00	105.7	84.67	3.33	20.1386	10.7589	10.4831	14.5752	11.6785	0.45979
WATER QUALITY INDEX (WQI) = ∑qW =							**82.75**	**78.23**	**75.61**	**58.77**	**50.60**	**59.28**

Table 10 : The water quality index (WQI) computation for station S3

PARAMETERS	S4											
	Quality rating (q)						Sub-index (qW)					
	qJan	qFeb	qMar	qMay	qJun	qJul	qWJan	qWFeb	qWMar	qWMay	qWJun	qWJul
pH	83.24	78.41	82.35	82.00	84.88	88.59	0.40522	0.38173	0.40092	0.39920	0.41323	0.43128
Temperature (ºC)	76.63	79.87	76.49	75.71	79.87	77.76	0.09059	0.09443	0.09043	0.08952	0.09443	0.09193
Turbidity (NTU)	68.00	68.70	33.70	35.00	49.60	37.00	0.56279	0.56857	0.27891	0.28967	0.41049	0.30622
EC (µs/cm)	31.02	34.27	30.69	23.27	36.09	30.39	0.00128	0.00142	0.00127	0.00096	0.00149	0.00126
TDS (mgL^{-1})	44.38	34.46	24.95	28.79	32.25	28.25	0.00367	0.00285	0.00207	0.00238	0.00267	0.00234
TSS (mgL^{-1})	0.75	0.89	0.57	0.65	0.51	0.48	0.00006	0.00007	0.00005	0.00005	0.00004	0.00004
Total alka. (mgL^{-1})	34.35	63.51	46.20	37.27	47.07	19.66	0.01185	0.02190	0.01593	0.01285	0.01623	0.00678
Total Har. (mgL^{-1})	117.7	114.3	82.64	105.2	100.19	110.5	0.03246	0.03152	0.02279	0.02901	0.02764	0.03049
DO (mgL^{-1})	103.4	100.9	51.50	50.50	69.90	34.60	0.85575	0.83506	0.42622	0.41795	0.57850	0.28635
BOD (mgL^{-1})	49.20	48.80	60.20	86.20	56.20	78.30	0.40719	0.40388	0.49822	0.71340	0.46512	0.64802
Chloride (mgL^{-1})	14.24	24.31	8.42	16.34	12.00	7.41	0.00236	0.00403	0.00139	0.00270	0.00199	0.00123
Sodium (mgL^{-1})	6.09	4.59	5.37	10.04	6.88	4.68	0.00126	0.00095	0.00111	0.00208	0.00142	0.00097

ISSN No:-2456-2165

Potassium (mgL^{-1})	63.88	60.75	65.21	89.92	60.42	56.25	0.22027	0.20949	0.22486	0.31007	0.20834	0.19397
Calcium (mgL^{-1})	62.34	55.67	36.29	35.67	56.08	53.48	0.03439	0.03072	0.02003	0.01968	0.03094	0.02951
Magnessium (mgL^{-1})	28.92	32.53	27.14	44.09	21.91	31.79	0.02394	0.02692	0.02246	0.03649	0.01813	0.02631
Nitrate (mgL^{-1})	18.69	17.14	17.95	23.76	18.44	24.45	0.01547	0.01419	0.01486	0.01966	0.01526	0.02024
Sulphate (mgL^{-1})	9.00	8.10	8.68	8.00	9.51	9.13	0.00149	0.00134	0.00144	0.00133	0.00157	0.00151
Phosphate (mgL^{-1})	74.00	70.30	55.00	48.70	57.00	52.00	61.2434	58.1812	45.5187	40.3048	47.1739	43.0359
Iron (mgL^{-1})	66.83	9.33	21.67	91.00	15.67	30.83	9.21869	1.28755	2.98860	12.5521	2.16099	4.25301
WATER QUALITY INDEX (WQI) = ∑qW =							**72.61**	**61.59**	**50.26**	**54.93**	**51.27**	**49.17**

Table 11 : The water quality index (WQI) computation for station S4

Furthermore, the mean WQI rating of the following stations; S3, S4, S5, S7 and S9 falls within grade "C" category of the poor water quality, with significant temporal differences in some months, especially within the months of January and February as seen in Table 12.0, where high level of deterioration was recorded, which may be due to the effect of debris from roads and vehicle garage, as well as domestic wastewater from drainage network, which could have affected the groundwater quality in some aspect. The high value of WQI at these stations could be associated with mainly higher chemical parameter values of TDS (S5, S3), K^+ (S7, S9), NO_3^- (S5), PO_5^{3-} (S7, S4, S3) and Fe^{2+} (S3, S7), that if not controlled will continue contribute to the poor water quality of the boreholes overtime. Hence, to minimizing these pollution sources, priority should be given improve, maintain and protect the water quality in the affected areas.

Borehole codes	WQI														Ranking
	JAN "20		FEB "20		MAR "20		MAY "20		JUNE "20		JULY "20		Mean		
S1	40.06	B	36.94	B	47.52	B	35.05	B	43.97	B	40.20	B	41.78	B	1
S8	34.98	B	40.89	B	37.35	B	47.61	B	49.15	B	43.13	B	42.18	B	2
S2	38.34	B	39.00	B	49.12	B	49.50	B	54.89	C	38.25	B	47.59	B	3
S6	33.78	B	54.14	C	57.99	C	59.48	C	23.66	A	58.27	C	47.76	B	4
S9	51.07	C	58.98	C	63.67	C	38.66	B	60.80	C	41.98	B	52.43	C	5
S5	62.30	C	61.23	C	50.30	B	51.07	C	54.47	C	49.42	B	55.35	C	6
S7	68.87	C	62.03	C	58.29	C	57.07	C	45.68	B	43.27	B	55.87	C	7
S4	72.61	C	61.59	C	50.26	B	54.93	C	51.27	C	49.17	B	56.69	C	8
S3	82.75	D	78.23	D	75.61	B	58.77	C	50.60	B	59.28	C	67.37	C	9

Table 12 : Summary of WQI grading and ranking of the nine borehole water sources

IV. CONCLUSION

Drinking water sources are susceptible to pollutants depending on geological conditions and human activities [58]. Therefore, to ensure the safety of drinking water sources in some areas, we assess the physicochemical parameters as well as the water quality index (WQI) of those areas with the aim of improving public health system.

In the present study, water quality index (WQI) was computed to assess the suitability, portability and quality of some borehole water sources in Ishiagu for the purpose of drinking and other domestic uses. Out of the nineteen physico-chemical parameters selected, dissolved oxygen, potassium, turbidity and iron were found in some stations (S1, S2, S3, S7) exceed the WHO and SON standard permissible limit for drinking water in several months, while nitrate and phosphate as well needs some attention to avoid rising beyond limit in some other stations like station S5 (where the values were nearly closed to the standard limit) and station S3 & S4 where the values obtained in dry season were very close to the standard permissible limit. The results also showed that most the borehole water sources in the selected stations were mainly alkaline with average pH values within acceptable limit with dominant groundwater type that ranges from moderately hard to hard water. It further revealed that station S9 recorded the most calcium concentration throughout the inclusive months, and also recorded lower calcium and higher magnesium levels throughout the months of dry season. In the other hand, WQI system result revealed that borehole waters from different stations fall mostly within the range of "Good water quality- B" and "Poor water quality- C" as 52% of the water samples falls in good water category, 43% falls in poor water category, while in the month of June 2% of the samples fall in excellent water category in station S6, and 4% at station S3 fall within "very poor water" category (as it exceeded the WQI upper limit for drinking water) in the month of January and February as shown in Figure 3. Likewise, the mean WQI results revealed that 44% of the water samples are in "good water category", while 56% are in "poor water category". However, the water quality ranking of the sampling stations clearly showed that the status of the borehole water at stations S1, S8, S2 and S6 are good and suitable for drinking and for domestic use as of the time of this study, while the status of the borehole water at stations S9, S5, S7, S4 and S3 are poor and requires pre-treatment before consuming.

There is need for regular monitoring of the water quality in these study areas to observe when there are changes in the concentration of their physiochemical parameters, and then convey the information to general public via water quality index (WQI) technique. Hence, I recommend that some stringent measures should be taken with the guild of the present results, to discourage the inhabitants (dwellers) of

ISSN No:-2456-2165

these locations from dumping untreated waste close to these stations as in station S5, to avoid polluting the groundwater.

V. APPENDIX

Tables showing the results of the average concentrations of each of the nineteen physico-chemical parameters, and the water quality index (WQI) of the borehole water samples of the remaining stations not included in the main work are listed here, (from Table 11 to Table 20) with respect to sampling month.

PARAMETERS	S1											
	Quality rating (q)						Sub-index (qW)					
	qJan	qFeb	qMar	qMay	qJun	qJul	qWJan	qWFeb	qWMar	qWMay	qWJun	qWJul
pH	80.82	83.82	87.47	75.41	76.35	83.29	0.39347	0.40808	0.42583	0.36713	0.37171	0.40550
Temperature (ºC)	84.91	81.09	79.27	79.47	82.40	81.29	0.10039	0.09587	0.09372	0.09396	0.09742	0.09610
Turbidity (NTU)	41.80	39.80	32.90	50.20	54.10	75.10	0.34594	0.32939	0.27229	0.41546	0.44774	0.62154
EC (µs/cm)	33.12	35.77	35.04	36.31	40.73	32.04	0.00137	0.00148	0.00145	0.00150	0.00169	0.00133
TDS (mgL^{-1})	28.45	37.69	33.79	30.10	35.99	31.74	0.00235	0.00312	0.00279	0.00249	0.00298	0.00263
TSS (mgL^{-1})	0.42	0.49	0.38	0.49	0.98	0.72	0.00003	0.00004	0.00003	0.00004	0.00008	0.00006
Total Alk. (mgL^{-1})	37.37	46.72	46.20	34.23	39.06	61.23	0.01289	0.01611	0.01593	0.01180	0.01347	0.02111
Total Har. (mgL^{-1})	88.31	96.37	84.63	105.5	120.9	79.24	0.02436	0.02659	0.02335	0.02909	0.03334	0.02186
DO (mgL^{-1})	73.40	85.50	94.40	84.60	52.20	118.9	0.60747	0.70761	0.78127	0.70016	0.43201	0.98403
BOD (mgL^{-1})	44.20	60.70	66.60	56.00	80.10	54.80	0.36581	0.50236	0.55119	0.46346	0.66292	0.45353
Chloride (mgL^{-1})	12.77	19.88	19.69	20.24	29.84	18.47	0.00211	0.00329	0.00326	0.00335	0.00494	0.00306
Sodium (mgL^{-1})	6.09	10.90	5.64	6.84	4.11	5.17	0.00126	0.00226	0.00117	0.00141	0.00085	0.00107
Potassium (mgL^{-1})	67.79	63.88	75.46	62.25	66.71	73.08	0.23377	0.22027	0.26021	0.21466	0.23004	0.25202
Calcium (mgL^{-1})	45.67	50.05	50.05	59.04	49.79	51.55	0.02520	0.02761	0.02761	0.03258	0.02747	0.02844
Magnesium (mgL^{-1})	22.73	24.62	16.07	23.05	42.67	10.78	0.01882	0.02037	0.01330	0.01908	0.03532	0.00892
Nitrate (mgL^{-1})	41.47	35.27	24.45	23.47	38.08	95.14	0.03432	0.02919	0.02024	0.01942	0.03152	0.07874
Sulphate (mgL^{-1})	5.50	8.23	5.00	6.41	9.09	4.47	0.00091	0.00136	0.00083	0.00106	0.00150	0.00074
Phosphate (mgL^{-1})	29.00	39.00	45.00	39.00	30.00	45.00	24.0008	32.2769	37.2426	32.2769	24.8284	37.2426
Iron (mgL^{-1})	103.3	19.50	59.83	5.83	123.3	4.00	14.2533	2.68974	8.25315	0.80462	17.0121	0.55174
WATER QUALITY INDEX (WQI) = ∑qW =							**40.06**	**36.94**	**47.52**	**35.05**	**43.97**	**40.20**

Table 8 : Water quality index (WQI) computation for station S1

PARAMETERS	S2											
	Quality rating (q)						Sub-index (qW)					
	qJan	qFeb	qMar	qMay	qJun	qJul	qWJan	qWFeb	qWMar	qWMay	qWJun	qWJul
pH	82.12	83.24	88.94	78.00	90.94	78.59	0.39977	0.40522	0.43299	0.37973	0.44273	0.38259
Temperature (ºC)	78.81	81.93	78.31	78.81	80.07	79.57	0.09318	0.09687	0.09259	0.09318	0.09467	0.09408
Turbidity (NTU)	33.90	62.20	30.20	28.10	50.40	84.30	0.28056	0.51478	0.24994	0.23256	0.41712	0.69768
EC (µs/cm)	31.16	36.34	32.58	33.12	39.78	37.07	0.00129	0.00150	0.00135	0.00137	0.00165	0.00153
TDS (mgL^{-1})	31.94	35.04	27.91	30.21	36.50	31.58	0.00264	0.00290	0.00231	0.00250	0.00302	0.00261
TSS (mgL^{-1})	0.33	0.29	0.45	0.52	0.81	0.55	0.00003	0.00002	0.00004	0.00004	0.00007	0.00005
Total alk. (mgL^{-1})	42.24	31.71	41.10	40.24	52.62	45.47	0.01457	0.01094	0.01417	0.01388	0.01814	0.01568
Total Har. (mgL^{-1})	95.54	99.62	79.72	85.48	123.4	82.92	0.02636	0.02748	0.02199	0.02358	0.03405	0.02288
DO (mgL^{-1})	94.00	61.30	93.90	48.10	107.0	64.10	0.77796	0.50733	0.77713	0.39808	0.88555	0.53050
BOD (mgL^{-1})	35.30	56.40	49.80	90.20	62.10	87.70	0.29215	0.46677	0.41215	0.74651	0.51395	0.72582
Chloride (mgL^{-1})	15.11	16.26	16.83	13.21	28.84	27.85	0.00250	0.00269	0.00279	0.00219	0.00477	0.00461
Sodium (mgL^{-1})	5.26	6.23	6.03	5.20	0.35	7.73	0.00109	0.00129	0.00125	0.00108	0.00007	0.00160
Potassium (mgL^{-1})	67.63	69.29	73.21	88.33	69.00	74.83	0.23319	0.23896	0.25245	0.30461	0.23794	0.25805
Calcium (mgL^{-1})	45.85	50.35	52.40	51.79	68.79	53.19	0.02529	0.02778	0.02891	0.02857	0.03795	0.02935
Magnessium (mgL^{-1})	27.84	26.72	10.35	15.11	27.25	11.96	0.02304	0.02211	0.00857	0.01251	0.02255	0.00990
Nitrate (mgL^{-1})	31.67	36.30	20.31	17.08	54.22	26.56	0.02621	0.03004	0.01681	0.01414	0.04487	0.02198
Sulphate (mgL^{-1})	2.55	4.88	6.95	2.67	5.31	5.08	0.00042	0.00081	0.00115	0.00044	0.00088	0.00084
Phosphate (mgL^{-1})	38.00	22.40	56.00	50.00	51.60	31.00	31.4493	18.5385	46.3464	41.3807	42.7049	25.6560
Iron (mgL^{-1})	37.33	133.5	6.67	44.33	72.17	73.33	5.14959	18.4144	0.91957	6.11514	9.95435	10.1153
WATER QUALITY INDEX (WQI) = ∑qW =							**38.34**	**39.00**	**49.12**	**49.50**	**54.89**	**38.25**

Table 9 : Water quality index (WQI) computation for station S2

ISSN No:-2456-2165

PARAMETERS	S5											
	Quality rating (q)						Sub-index (qW)					
	qJan	qFeb	qMar	qMay	qJun	qJul	qWJan	qWFeb	qWMar	qWMay	qWJun	qWJul
pH	88.24	74.88	87.53	88.82	83.71	91.29	0.42956	0.36455	0.42612	0.43242	0.40751	0.44445
Temperature (ºC)	79.94	77.84	79.23	80.37	82.13	79.47	0.09452	0.09203	0.09367	0.09502	0.09710	0.09396
Turbidity (NTU)	78.50	57.70	28.20	48.80	56.70	49.20	0.64968	0.47753	0.23339	0.40388	0.46926	0.40719
EC (µs/cm)	33.13	31.87	32.23	23.13	38.02	31.47	0.00137	0.00132	0.00133	0.00096	0.00157	0.00130
TDS (mgL^{-1})	53.38	32.08	26.56	30.94	35.53	30.82	0.00442	0.00266	0.00220	0.00256	0.00294	0.00255
TSS (mgL^{-1})	0.47	0.65	0.55	0.58	0.69	3.23	0.00004	0.00005	0.00005	0.00005	0.00006	0.00027
Total alkalinity (mgL^{-1})	46.99	42.83	30.33	54.49	61.69	27.70	0.01620	0.01477	0.01046	0.01879	0.02127	0.00955
Total hardness (mgL^{-1})	107.7	114.3	78.67	101.6	120.2	82.74	0.02970	0.03154	0.02170	0.02803	0.03316	0.02283
DO (mgL^{-1})	63.40	79.30	103.8	50.00	75.40	118.0	0.52471	0.65630	0.85906	0.41381	0.62402	0.97658
BOD (mgL^{-1})	84.30	44.20	42.20	72.80	65.40	90.70	0.69768	0.36581	0.34925	0.60250	0.54126	0.75065
Chloride, Cl^- (mgL^{-1})	16.19	20.14	12.71	20.11	23.49	11.87	0.00268	0.00333	0.00210	0.00333	0.00389	0.00196
Sodium, Na^+ (mgL^{-1})	5.64	2.69	4.03	5.89	5.76	0.63	0.00117	0.00056	0.00083	0.00122	0.00119	0.00013
Potassium, K^+ (mgL^{-1})	58.88	62.83	60.88	93.08	50.17	50.83	0.20302	0.21667	0.20992	0.32099	0.17299	0.17529
Calcium, Ca^{2+} (mgL^{-1})	50.01	49.11	45.69	29.43	69.09	55.76	0.02759	0.02709	0.02521	0.01624	0.03812	0.03077
Magnessium, Mg^{2+} (mgL^{-1})	32.88	38.56	15.70	47.19	24.65	9.50	0.02721	0.03191	0.01299	0.03905	0.02040	0.00786
Nitrate, NO_3^- (mgL^{-1})	13.55	20.47	15.54	41.98	37.65	16.32	0.01121	0.01694	0.01286	0.03474	0.03116	0.01351
Sulphate, SO_4^{2-} (mgL^{-1})	7.26	4.46	4.18	5.43	7.75	5.24	0.00120	0.00074	0.00069	0.00090	0.00128	0.00087
Phosphate, PO_5^{3-} (mgL^{-1})	60.00	66.00	54.00	50.00	43.00	56.00	49.6568	54.6225	44.6911	41.3807	35.5874	46.3463
Iron	74.33	34.17	28.00	54.67	121.8	5.17	10.2532	4.71280	3.86220	7.54048	16.8052	0.71267
WATER QUALITY INDEX (WQI) = ∑qW =							**62.30**	**61.23**	**50.30**	**51.07**	**54.47**	**49.42**

Table 13 : Water quality index (WQI) computation for station S5

PARAMETERS	S6											
	Quality rating (q)						Sub-index (qW)					
	qJan	qFeb	qMar	qMay	qJun	qJul	qWJan	qWFeb	qWMar	qWMay	qWJun	qWJu
pH	95.65	84.82	85.41	98.59	85.06	84.12	0.46564	0.41295	0.41581	0.47996	0.41409	0.409
Temperature (ºC)	77.46	76.11	84.49	81.91	78.14	77.80	0.09158	0.08999	0.09989	0.09685	0.09239	0.091
Turbidity (NTU)	33.00	28.60	64.60	77.40	37.80	40.80	0.27311	0.23670	0.53464	0.64057	0.31284	0.337
EC (µs/cm)	32.13	31.32	34.52	33.11	31.16	34.36	0.00133	0.00130	0.00143	0.00137	0.00129	0.001
TDS (mgL^{-1})	32.08	33.95	34.53	36.08	34.68	35.65	0.00266	0.00281	0.00286	0.00299	0.00287	0.002
TSS (mgL^{-1})	0.42	0.24	0.49	0.44	0.40	0.62	0.00003	0.00002	0.00004	0.00004	0.00003	0.000
Total alkalinity (mgL^{-1})	54.51	46.84	42.10	62.85	22.11	28.60	0.01880	0.01615	0.01452	0.02167	0.00762	0.009
Total hardness (mgL^{-1})	97.69	99.03	105.5	106.9	98.43	116.2	0.02695	0.02732	0.02910	0.02951	0.02715	0.032
DO (mgL^{-1})	67.00	42.60	106.6	124.6	35.60	50.80	0.55450	0.35256	0.88224	1.03121	0.29463	0.420
BOD (mgL^{-1})	49.40	55.20	69.20	59.60	44.60	49.20	0.40884	0.45684	0.57271	0.49326	0.36912	0.407
Chloride, Cl^- (mgL^{-1})	17.26	22.92	21.66	26.08	27.21	28.80	0.00286	0.00379	0.00359	0.00432	0.00450	0.004
Sodium, Na^+ (mgL^{-1})	3.61	5.06	2.16	2.77	5.21	5.67	0.00075	0.00105	0.00045	0.00057	0.00108	0.001
Potassium, K^+ (mgL^{-1})	62.92	62.58	85.00	87.00	80.58	78.75	0.01041	0.01036	0.01407	0.01440	0.01334	0.013
Calcium, Ca^{2+} (mgL^{-1})	53.40	61.60	63.28	58.80	52.31	61.55	0.02946	0.03399	0.03491	0.03244	0.02886	0.033
Magnesium, Mg^{2+} (mgL^{-1})	22.53	16.04	19.20	24.36	24.06	28.59	0.01865	0.01327	0.01589	0.02016	0.01991	0.023
Nitrate, NO_3^- (mgL^{-1})	13.08	18.42	24.80	16.64	20.24	38.90	0.01083	0.01524	0.02052	0.01377	0.01675	0.032
Sulphate, SO_4^{2-} (mgL^{-1})	4.69	7.26	5.25	7.72	3.29	5.48	0.00078	0.00120	0.00087	0.00128	0.00054	0.000
Phosphate, PO_5^{3-} (mgL^{-1})	36.00	62.00	64.00	66.00	20.80	62.00	29.7941	51.3120	52.9673	54.6225	17.2144	51.31
Iron	15.00	8.00	17.67	15.00	34.00	36.67	2.06903	1.10348	2.43686	2.06903	4.68981	5.057
WATER QUALITY INDEX (WQI) = ∑qW =							**33.78**	**54.14**	**57.99**	**59.48**	**23.66**	**58.2**

Table 14 : Water quality index (WQI) computation for station S6

ISSN No:-2456-2165

PARAMETERS	S7											
	Quality rating (q)						Sub-index (qW)					
	qJan	qFeb	qMar	qMay	qJun	qJul	qWJan	qWFeb	qWMar	qWMay	qWJun	qWJul
pH	93.18	82.82	90.24	84.00	82.29	94.59	0.45361	0.40321	0.43929	0.40894	0.40063	0.46049
Temperature (oC)	84.50	80.50	76.79	79.66	81.94	82.20	0.09990	0.09518	0.09078	0.09418	0.09688	0.09719
Turbidity (NTU)	47.00	38.70	30.80	47.60	53.90	43.50	0.38898	0.32029	0.25490	0.39394	0.44608	0.36001
EC (µs/cm)	37.20	36.19	31.73	35.26	34.41	35.10	0.00154	0.00150	0.00131	0.00146	0.00142	0.00145
TDS (mgL^{-1})	32.44	33.08	33.02	34.37	32.21	34.04	0.00268	0.00274	0.00273	0.00284	0.00267	0.00282
TSS (mgL^{-1})	0.47	0.38	0.33	0.34	0.54	0.35	0.00004	0.00003	0.00003	0.00003	0.00004	0.00003
Total alkalinity (mgL^{-1})	30.84	35.73	50.68	26.07	38.00	36.18	0.01063	0.01232	0.01747	0.00899	0.01311	0.01248
Total hardness (mgL^{-1})	116.4	100.9	98.36	99.10	107.1	112.2	0.03210	0.02785	0.02713	0.02734	0.02956	0.03094
DO (mgL^{-1})	42.10	67.50	54.80	86.20	40.70	84.30	0.34843	0.55864	0.45353	0.71340	0.33684	0.69768
BOD (mgL^{-1})	95.80	38.70	52.30	53.20	67.40	59.70	0.79285	0.32029	0.43284	0.44029	0.55781	0.49409
Chloride, Cl^- (mgL^{-1})	17.78	19.73	20.09	14.14	11.93	26.29	0.00294	0.00327	0.00333	0.00234	0.00198	0.00435
Sodium, Na^+ (mgL^{-1})	3.03	5.31	4.33	3.25	7.07	7.66	0.00063	0.00110	0.00090	0.00067	0.00146	0.00158
Potassium, K^+ (mgL^{-1})	86.00	72.54	62.75	69.71	75.88	71.25	0.29656	0.25015	0.21639	0.24038	0.26165	0.24570
Calcium, Ca^{2+} (mgL^{-1})	60.37	51.69	57.50	60.09	52.78	57.39	0.03331	0.02852	0.03173	0.03316	0.02912	0.03166
Magnessium, Mg^{2+} (mgL^{-1})	29.78	26.46	19.28	17.47	29.97	29.43	0.02464	0.02190	0.01596	0.01446	0.02481	0.02436
Nitrate, NO_3^- (mgL^{-1})	20.37	41.21	15.75	24.48	27.88	84.84	0.01686	0.03411	0.01303	0.02026	0.02307	0.07021
Sulphate, SO_4^{2-} (mgL^{-1})	4.98	5.22	5.98	4.34	9.83	5.73	0.00082	0.00086	0.00099	0.00072	0.00163	0.00095
Phosphate, PO_5^{3-} (mgL^{-1})	79.00	48.00	66.00	65.00	46.10	40.00	65.3815	39.7254	54.6225	53.7949	38.1529	33.10454
Iron	9.00	149.2	14.17	9.50	40.00	58.33	1.24142	20.5754	1.95409	1.31039	5.51742	8.04624
WATER QUALITY INDEX (WQI) = ∑qW =							**68.87**	**62.03**	**58.29**	**57.07**	**45.68**	**43.27**

Table 15 : Water quality index (WQI) computation for station S7

PARAMETERS	S8											
	Quality rating (q)						Sub-index (qW)					
	qJan	qFeb	qMar	qMay	qJun	qJul	qWJan	qWFeb	qWMar	qWMay	qWJun	qWJul
pH	90.24	84.59	92.00	93.76	87.00	85.94	0.43929	0.41180	0.44788	0.45648	0.42354	0.41839
Temperature (^oC)	81.11	77.97	83.20	86.77	84.19	79.21	0.09590	0.09219	0.09837	0.10259	0.09953	0.09366
Turbidity (NTU)	29.80	39.30	71.00	57.10	51.30	41.90	0.24663	0.32525	0.58761	0.47257	0.42457	0.34677
EC (µs/cm)	31.16	32.76	33.82	40.83	35.06	35.77	0.00129	0.00136	0.00140	0.00169	0.00145	0.00148
TDS (mgL^{-1})	31.56	35.17	35.31	41.56	34.95	31.19	0.00261	0.00291	0.00292	0.00344	0.00289	0.00258
TSS (mgL^{-1})	0.51	0.51	0.47	0.46	0.65	0.47	0.00004	0.00004	0.00004	0.00004	0.00005	0.00004
Total alkalinity (mgL^{-1})	53.83	25.35	52.48	51.05	43.28	49.26	0.01856	0.00874	0.01810	0.01760	0.01492	0.01699
Total hardness (mgL^{-1})	94.96	107.3	106.2	99.96	118.6	118.9	0.02620	0.02960	0.02930	0.02758	0.03272	0.03279
DO (mgL^{-1})	47.80	43.20	115.6	96.00	82.70	112.0	0.39560	0.35753	0.95672	0.79451	0.68444	0.92693
BOD (mgL^{-1})	37.70	46.90	64.40	54.80	33.30	42.80	0.31201	0.38815	0.53298	0.45353	0.27560	0.35422
Chloride, Cl^- (mgL^{-1})	13.73	28.01	23.87	10.52	24.37	23.38	0.00227	0.00464	0.00395	0.00174	0.00403	0.00387
Sodium, Na^+ (mgL^{-1})	5.21	5.44	2.47	4.79	5.92	6.59	0.00108	0.00112	0.00051	0.00099	0.00122	0.00136
Potassium, K^+ (mgL^{-1})	76.88	79.67	86.00	72.88	77.67	76.88	0.26509	0.27472	0.29656	0.25130	0.26782	0.26509
Calcium, Ca^{2+} (mgL^{-1})	46.35	56.93	61.04	47.84	58.70	61.49	0.02557	0.03141	0.03368	0.02640	0.03239	0.03392
Magnesium, Mg^{2+} (mgL^{-1})	26.96	26.33	21.78	29.25	32.94	30.59	0.02231	0.02179	0.01802	0.02420	0.02726	0.02531
Nitrate, NO_3^- (mgL^{-1})	17.30	29.57	20.72	25.54	27.56	138.3	0.01432	0.02447	0.01715	0.02114	0.02281	0.11443
Sulphate, SO_4^{2-} (mgL^{-1})	5.49	4.38	6.49	3.80	11.30	5.61	0.00091	0.00073	0.00107	0.00063	0.00187	0.00093
Phosphate, PO_5^{3-} (mgL^{-1})	29.00	41.40	39.40	54.00	47.42	48.00	24.0008	34.2632	32.6080	44.6911	39.2454	39.7254
Iron	67.83	35.33	16.33	5.33	58.00	9.50	9.35663	4.87372	2.25295	0.73566	8.00026	1.31039
WATER QUALITY INDEX (WQI) = ∑qW =							**34.98**	**40.89**	**37.35**	**47.61**	**49.15**	**43.13**

Table 16 : Water quality index (WQI) computation for station S8

PARAMETERS	S9											
	Quality rating (q)						Sub-index (qW)					
	qJan	qFeb	qMar	qMay	qJun	qJul	qWJan	qWFeb	qWMar	qWMay	qWJun	qWJul
pH	86.47	77.53	89.76	87.88	85.65	84.12	0.42097	0.37744	0.43700	0.42784	0.41696	0.40951
Temperature (°C)	73.71	77.71	77.49	83.26	80.86	78.89	0.08715	0.09188	0.09161	0.09844	0.09560	0.09327
Turbidity (NTU)	40.80	29.20	42.20	55.40	51.00	48.20	0.33767	0.24166	0.34925	0.45850	0.42208	0.39891
EC (µs/cm)	23.27	23.27	24.43	21.83	38.04	34.14	0.00096	0.00096	0.00101	0.00090	0.00157	0.00141
TDS (mgL^{-1})	29.93	27.64	31.65	30.24	33.67	30.84	0.00248	0.00229	0.00262	0.00250	0.00279	0.00255
TSS (mgL^{-1})	0.78	0.52	0.60	0.55	0.49	0.53	0.00006	0.00004	0.00005	0.00005	0.00004	0.00004
Total alkalinity (mgL^{-1})	38.43	36.10	53.55	55.43	47.60	46.53	0.01325	0.01245	0.01847	0.01912	0.01641	0.01605
Total hardness (mgL^{-1})	106.9	103.4	100.3	102.9	94.74	105.6	0.02948	0.02853	0.02766	0.02839	0.02614	0.02914
DO (mgL^{-1})	55.20	45.80	46.40	53.60	67.80	72.00	0.45684	0.37905	0.38401	0.44360	0.56112	0.59588
BOD (mgL^{-1})	82.40	90.00	75.40	70.20	68.00	44.40	0.68195	0.74485	0.62402	0.58098	0.56278	0.36746
Chloride, Cl^- (mgL^{-1})	16.84	15.83	20.96	19.26	11.90	12.10	0.00279	0.00262	0.00347	0.00319	0.00197	0.00200
Sodium, Na^+ (mgL^{-1})	10.08	10.01	5.67	6.11	6.67	7.09	0.00208	0.00207	0.00117	0.00126	0.00138	0.00147
Potassium, K^+ (mgL^{-1})	76.25	103.6	84.58	101.6	69.42	51.42	0.01262	0.01715	0.01400	0.01681	0.01149	0.00851
Calcium, Ca^{2+} (mgL^{-1})	33.52	37.83	31.96	26.89	53.72	58.44	0.01849	0.02087	0.01763	0.01484	0.02964	0.03224
Magnesium, Mg^{2+} (mgL^{-1})	47.31	40.88	43.92	50.45	20.09	23.73	0.03915	0.03383	0.03635	0.04176	0.01663	0.01964
Nitrate, NO_3^- (mgL^{-1})	22.96	24.56	40.22	43.74	16.82	20.06	0.01900	0.02033	0.03329	0.03620	0.01392	0.01660
Sulphate, SO_4^{2-} (mgL^{-1})	8.14	7.86	5.33	5.52	9.60	9.42	0.00135	0.00130	0.00088	0.00091	0.00159	0.00156
Phosphate, PO_5^{3-} (mgL^{-1})	44.40	53.00	68.00	32.00	68.00	46.00	36.7460	43.8635	56.2777	26.4836	56.2777	38.0702
Iron	88.00	94.00	38.00	71.33	17.00	14.33	12.1383	12.9659	5.24155	9.83940	2.34490	1.97708
WATER QUALITY INDEX (WQI) = ∑qW =							**51.07**	**58.98**	**63.67**	**38.66**	**60.80**	**41.98**

Table 17 : Water quality index (WQI) computation for station S9

REFERENCES

[1.] Okpara, O.G., Ogbeide, O.M., Ike, O.C., Menechukwu, K.C., and Ejike, E.C., 2020. Optimum isotherm by Linear and nonlinear regression methods for lead (II) ions adsorption from aqueous solutions using synthesized coconut shell-activated carbon (SCSAC). Toxin Reviews, Pp.1-15

[2.] Ibiam J.A., Afiukwa J.N., Ugbo, U.l., Ezem, S.N. and Ehiri, R.C., 2015. Quality Evaluation of Acid Radicals of Some Selected Boreholes in Edda, Ebonyi State. International Journal of Scientific & Engineering Research. 6(12):223-231, ISSN 2229-5518

[3.] Obiekezie S.O., Okereke J.N., Anyalogbu E., Okorondu S.I. and Ezejiofor T.I.N., 2006. Underground Water Quality Of Rock Mining In Ishiagu, Ebonyi State, Nigeria. Estud. Biol., 28(63):61-71

[4.] Akubugwo E.I., Ude V.C., Uhuegbu F.O. and Ugbogu. O., 2012. Physicochemical properties and heavy metal content of selected water sources in Ishiagu, Ebonyi State- Nigeria. Journal of Biodiversity and Environmental Sciences (JBES). 2 (2), 21-27, ISSN: 2220-6663.

[5.] Ukiwe L.N., Onyedika G.O., Uche V.I And Iwu C.I., 2012. Physicochemical Water Quality Indicators Of Groundwater In Ishiagu, Ebonyi State, Nigeria. Terrestrial Aquatic Environmental Toxicology, Global Science Book. 6(1):55-60.

[6.] Ogbeide Osareme .M, Ezeh Emmanuel .C, Okpara Onyedikachi .O., 2019. Isotherms, kinetics and equilibrium Studies of adsorption of Lead (II) ions from aqueous solutions Using Polymer-Modified Coconut Shell Activated Carbon (MCSAC)" IOSR Journal of Environmental Science, Toxicology and Food Technology (IOSR-JESTFT) 13(8):28-43.

[7.] Tlili-Zrelli, B., Gueddari, M. And Bouhlila, R., 2018. Spatial And Temporal Variations Of Water Quality Of Mateur Aquifer (Northeastern Tunisia): Suitability For Irrigation And Drinking Purposes. Hindawi Journal Of Chemistry. Volume 2018, Article Id 2408632, 15 Pages, Https://Doi.Org/10.1155/2018/2408632

[8.] Onuorah, S., Igwemadu, N., Odibo, F., 2019. Effect of Seasonal Variation on the Physicochemical Characteristics of Borehole Water in Ogbaru Communities, Anambra State, Nigeria. Natural Resources and Conservation. 7(1): 1-8

[9.] Aladejana, J.A., Kalin, R.M., Sentenac, P., And Hassan, I., 2020. Assessing The Impact Of Climate Change On Groundwater Quality Of The Shallow Coastal Aquifer Of Eastern Dahomey Basin, Southwestern Nigeria. Water - (MDPI). 12 (224), 1-19, Doi:10 3390/W12010224

[10.] Ofomata, G. E. K., 2002. “Relief, Drainage and Landforms” in “A survey of Igbo Nation” by Africana Publishers Ltd, Onitsha, pp. 83 – 98.

[11.] Chima, G.N., Nwaugo, V.O. and Ezekwe, I.C., 2010. Impacts of rock quarrying on Akwukwuo tributary of the Ivo River in Ishiagu Ebonyi State, Nigeria. Journal of Applied and Environmental Sciences. 6 (2), 68-73

[12.] American Public Health Association, American Water Works Association and Water Pollution Control Federation (APHA, AWWA and WPCF)., (1998). Standard methods for the examination of water and wastewater. 18th edition, American Public Health Association, Washington D.C. and Food Chemistry.10 (6), 2296-2304.

[13.] APHA, 1985. Standard methods for the analysis of water and wastewater, American Public Health Association, New York, 1287p.

[14.] APHA, AWWA and WPCF (American Public Health Association, American Water Works Association and Water Pollution Control Federation), 1998). Standard methods for the examination of water and wastewater. 18th edition, American Public Health Association, Washington D.C.
[15.] USEPA (United States Environmental Protection Agency), 2009. (Electronic: http://www.epa.gov/waterscience/methods/method/files/352_1.pdf.www.sarasota.wateratlas.usf.edu/shared/learnmore.asp?toolsection=Im_dissolvedox
[16.] Khan, T.I., Dular, A.K., and Solomon, D.M. 2003. Biodiversity Conservation in the Thar Desert; with Emphasis on Endemic and Medical Plants. The Environmentalist, 23:137-144, https://doi.org/10.1023/A:1024835721316
[17.] Horton, R.K., 1965. An index number system for rating water quality, J. Water Pollu. Cont. Fed., 37 (3), 300-305. 1965.
[18.] Brown, R.M., McClelland, N.I., Deininger, R.A. and Tozer, R.G., 1970. Water quality index-do we dare?, Water Sewage Works, 117 (10), 339-343.
[19.] Tyagi S., Sharma B., Singh P., and Dobhal R., 2013. Water Quality Assessment in Terms of Water Quality Index. American Journal of Water Resources. 1(3):34-38. doi: 10.12691/ajwr-1-3-3.
[20.] Garcia, C.A.B., Silva, I.S., Mendonça, M.C.S., and Garcia, H.L., 2018. Evaluation of Water Quality Indices: Use, Evolution and Future Perspectives. Advances in Environmental Monitoring and Assessment, Chap 2; pp 21-37. http://dx.doi.org/10.5772/intechopen.79408
[21.] Ekhator, O., Izegaegde, J.I., And Osadebamwen, O.S., 2015. Assessment Of Water Quality Index (Wqi) For Osse River In Edo State, Southern Nigeria. Nigerian Annals of Natural Sciences. 15 (1), 031 – 041
[22.] Rao, C.S., Rao, B.S., Hariharan, A.V.L.N.S.H. and Bharathi, N.M., 2010. Determination of water quality index of some areas in Guntur district Andhra Pradesh", Int. J. Appl. Bio. Pharm. Tech., I (1), 79-86.
[23.] Chowdhury, R.M., Muntasir, S.Y. and Hossain, M.M., 2012. Water quality index of water bodies along Faridpur-Barisal road in Bangladesh", Glob. Eng. Tech. Rev., 2 (3), 1-8.
[24.] Chauhan, A. and Singh, S., 2010. Evaluation of Ganga water for drinking purpose by water quality index at Rishikesh, Uttarakhand, India, Report Opinion, 2 (9), 53-61.
[25.] Balan, I.N., Shivakumar, M. and Kumar, P.D.M., 2012. An assessment of ground water quality using water quality index in Chennai, Tamil Nadu, India", Chronicles Young Scient., 3 (2), 146-150.
[26.] Imneisi I.B. and Aydin M., 2016. Water Quality Index (WQI) for Main Source of Drinking Water (Karaçomak Dam) in Kastamonu City, Turkey. Journal of Environmental & Analytical Toxicology, 6 (5), 407. doi: 10.4172/2161-0525.1000407
[27.] Chukwuma, C.E., Chukwuma, C.G., Uba, I.J., Orakwe, C.L. and Ogbu, N.K., 2016. Irrigation Water Quality Index Assessment of Ele River in Parts of Anambra State of Nigeria. Archives of Current Research International. 4 (3), 1-6
[28.] Krishan G., Singh S., Kumar C.P., Gurjar S, Ghosh N.C., 2016. Assessment of Water Quality Index (WQI) of Groundwater in Rajkot District, Gujarat, India. Journal of Earth Science & Climatic Change. 7 (3), 1-4, 341. doi:10.4172/2157-7617.1000341
[29.] Olasoji, S.O., Oyewole, N.O., Abiola, B. and Edokpayi, J.N., 2019. Water Quality Assessment of Surface and Groundwater Sources Using aWater Quality Index Method: A Case Study of a Peri-Urban Town in Southwest, Nigeria. Environments-MDPI Environments. 6 (23), 1-11, doi:10.3390/environments6020023
[30.] Brown, R.M., McClelland, N.I., Deininger, R.A., and O'Connor, M.F., 1972. Water Quality Index-Crashing, the Psychological Barrier, Proc. 6th Annual Conference, Advances in Water Pollution Research, pp 787-794. http://dx.doi.org/10.1016/b978-0-08-017005-3.5
[31.] APERA Instruments, 2017. Why pH is Important?, https://aperainst.com.com/blog/why-ph-is-important/
[32.] Boyd, Claude E. (September, 4th, 2017). The impact of atmospheric carbondioxide, alkalinity in freshwater. Global Aquaculture Alliance. https://www.aquaculturealliance.org/advocate/atmospheric-carbon-dioxide-freshwater-aquaculture/
[33.] USDA FSIS (U.S Department of Agriculture's Food Safety and Inspection Service), (2013). Why is Chilling important. (Fighting BAC@by Chilling Out. https//www.fsis.usda.gov/wps/portal/fsis/topics/food-safety-education/get-answers/food-safety-fact-sheets/safe-food-handling/fighting-bac-by-chilling-out/ct_index
[34.] Lenntech. (1998-2020). Turbidity. Water treatment solutions. https://www.lenntech.com/turbidity.htm
[35.] Omer, N.H., 2019. Water Quality Parameters. Water Quality - Science, Assessments and Policy. (Chapter). IntechOpen. Pp 1-18, DOI: http://dx.doi.org/10.5772/intechopen.89657
[36.] WHO (World Health Organization), Guidelines for drinking water, 1996. 2nd Ed. Vol.2. Health Criteria and other supporting Information, WHO, Geneva, Switzerland.
[37.] Obasi P.N., Esom N.E., Okolo C.M. and Edene E. N., 2018. Assessment of Water Pollution Status in the Mining Area of Ameka, South Eastern Nigeria Using Metal Pollution Index. International Journal of Scientific Engineering and Science. 2 (1), pp. 66-73
[38.] Silas, I.I., Wuana R.A., and Augustine A. U., 2018. Seasonal Variation In Water Quality Parameters Of River Mkomon Kwande Local Government Area, Nigeria. International Journal of Recent Research In Physics and Chemical Sciences (Ijrrpcs). 5 (1), 42-62
[39.] Abida, B. and Harikrishna, 2008. "Study on the Quality of Water in Some Streams of Cauvery River", Journal of Chemistry, 5 (2), 377-384.
[40.] EPA (Environmental Protection Agency), 2001. Parameters of Water Quality: Interpretation and Standards. (Principal parameters for water quality-Chap 26). Published by Environmental Protection Agency, Ireland. P. 26
[41.] Agbaire P.O. Akporido S.O. and Akporhonor E.E., 2014. Water Quality Index Assessment of Borehole Water in the Hostels in one of the Higher Institutions in Delta

State, Nigeria. Research Journal of Chemical Sciences. 4 (7), 77-81.
[42.] Sawyer C.N. and Mc Carty P.L., 1967. Chemistry for Sanitary Engineers, 2nd Ed. McGraw-Hill: New York, 518
[43.] Alex, A.A., Chinedu, N.V., Olatunde, A.M., Longinus, N.K., Omosileola, J.A. 2015. Groundwater Quality Assessment In Eliozu Community, Port Harcourt, Niger Delta, Nigeria. International Journal of Scientific & Technology Research. 4 (12), 149-156
[44.] Nduka, J.K., Orisakwe, O.E., and Ezenweke, L.O., 2008. Some physicochemical parameters of potable water supply in Warri, Niger Delta area of Nigeria. Scientific Research and Essay. 3(11):pp. 547-551.
[45.] Nagami, T. Glenn, 2016. Hyperchloremia-Why and how. Nefrologia. 36 (4), 347-353. http://dx.doi.org/10.1016/j.nefroe.2016.06.006
[46.] Kieneker, L., Gansevoort, R.T., Mukamal, K.J, de Boer, R.A., Navis, G., Bakker, S.J.L., and Joosten, M.M., 2014. Urinary Potassium Excretion and Risk of Developing Hypertension. Hypertension. 64 (4), 769-776.
[47.] Newberry, S.J., Chung, M., Anderson, C.A.M., Chen, C., Fu, Z., Tang, A., Zhao, N., Booth, M., Marks, J., Hollands, S., Motala, A., Larkin, J., Shanman, R., and Hempel, S., 2018. Effects of Dietary Sodium and Potassium intake on Chronic Disease Outcomes and Related Risk Factors. Systematic Review No. 206. AHRQ Publication No. 18-EHC009-EF. Rockville, MD: Agency for Healthcare Research and Quality.
[48.] El Ghandour, M.F.M., Khail, J.B., and Atta, S.A., 1983. Distribution of sodium and potassium in the groundwater of the Nile Delta region (Egypt). Sciencedirect: Catena. 10 (1-2), 175-187.
[49.] Webster, A., 2019. Your Nutrition and Food Safety Resource. What is Calcium?. International Food Information Council Foundation. https://foodinsight.org/what-is-calcium/
[50.] Meride, Y., and Ayenew, B., 2016. rinking water quality assessment and its effects on residents health in Wondo genet campus, Ethiopia. Environmental System Research. 5 (1), 1-7. DOI 10.1186/s40068-016-0053-6
[51.] APEC water, (1997-2020). Nitrate (nitrate nitrogen) in drinking water system. www.freedrinkingwater.com/water-education2/79-nitrate-nitrogen.htm
[52.] Daniels, B. and Mesner, N., 2010. Drinking water facts...; Nitrate. Utah State University Water Quality Extension. p.4, http://extension.usu.edu/waterquality
[53.] Ward, M.H., Jones, R.R., Brender, J.D., de Kok, T.M., Weyer, P.J., Nolan, B.T., Villanueva, C.M., and van Breda, S.G., 2018. Drinking Water Nitrate and Human Health: An Updated Review. International Journal of Environmental Research and Public Health-mdpi. 15, 1557, doi:10.3390/ijerph15071557
[54.] MPCA (1999) Minnesota Pollution Control Agency, Environmental Outcomes Division
[55.] WHO (World Health Organization), Guidelines for drinking water, 2004. 2nd Ed. Health Criteria and other supporting Information, WHO, Geneva, Switzerland.
[56.] Freeze, R. A. And Cherry, J. A., 1979. Groundwater. Englewood Cliffs: Prentice-Hall.
[57.] Singh, A.L., Tripathi, A.K., Kumar, A. and Singh, V.K., 2012. Nitrate and phosphate contamination in ground water of Varanasi, Uttar Pradesh, India. Journal of Industrial Research & Technology. 2 (1), 26-32
[58.] Akter, S., Wamba, S.F., Gunasekaran, A., Dubey, R., and Childe, S.J. (2016). How to improve firm performance using big data analytics capability and business strategy alignment? International Journal of Production Economics, 182, 113-131.