Evaluation of Water Quality index of Some Borehole Water Sources in Ishiagu South-eastern Region of Ebonyi State, Nigeria

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Abstract— Water Quality Index (WQI), an effective tool to assess water quality and ensure sustainable safe use of the water for drinking. The present work is aimed to assess the suitability of borehole water of Ishiagu quarry town for the purpose of drinking and other domestic purposes using the weighted arithmetic water quality index (WAWQI) technique. In carrying out the experiment, Sampling was done twice every month in each of the selected three stations which lasted for three months. In-situ experiment was conducted for some parameters like pH, Temperature, Electrical conductivity (EC), Total dissolved solids (TDS), and Dissolved Oxygen (DO), while the rest of the parameters were determined in the laboratory. The analysis results showed that most of the borehole water sources in the selected stations were mainly alkaline with average pH values within the acceptable limit of 6.5-8.5. The mean WQI system results revealed that 67% of the stations had good water quality for drinking while 33% of the stations uses poor water quality which may not be suitable for direct consumption and may require pre-treatment before taken. Likewise, the poor water quality status of Amaedim (BH5) station (the least ranked station) depicts a significant level of deterioration in the area which could have resulted from increment in some parameter values such as TDS, NO_3^-, PO_5^{3-} and Fe^{2+}. However, the water quality rating based on the goodness and suitability status of the borehole water in the selected stations in respect to human consumption is clearly ranked in the following order; Ihuogwu (BH8) > Ogorji (BH2) > Amaedim (BH5).

Index Terms— Physicochemical Parameters, Borehole water, Drinking, Water Quality Index (WQI) Analysis, Ishiagu.

1. INTRODUCTION

Water is a dynamic renewable natural resource. Its availability with good quality and adequate quantity is very important for human life and other purposes [1]. Water is an essential universal solvent for the health of humans and survival of every living organisms in an ecosystem. Good management and conservation of the water supply services and resource gives access to safe drinking water, as well as maintaining the sanitation services which guarantees tremendous sustainable growth and socio-economic development of a nation, especially, in various sectors of economy like in agriculture, livestock production, forestry, industrial activities, hydropower generation, fisheries and other creative activities [2]. Water can be obtained from ground water and surface sources. The groundwater sources include boreholes and hand dug wells while surface water sources include rivers, lakes, reservoirs, and streams. However, water sources are often contaminated through leaching of rocks, industrial and agrochemical discharges by surface runoff during the rainy season, and by air discharged particles of dust especially during the dry season. These contaminations can affect the clarity and the chemical constituents of the water source, it can also introduce odor to the water thereby reducing the water quality and economic activities. Therefore, diverse

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conventional methods had been employed for water treatment which includes; chemical precipitation, filtration, ion exchange, reverse osmosis, sedimentation, solvent extraction, ultra-filtration, electrochemical deposition, coagulation and adsorption [3], [4]. However, these conventional methods are not economically viable and affordable due to huge capital required, coupled with government inadequacy in supporting water projects efficiently, which have contributed to the ineffective service and partial lockdown of our water supply infrastructure. In line with [5], the demand for portable water in most developing nations of the world particularly, in Nigeria surpasses the supply as one can still see long queues of people with their containers at the public water supplies. And Ebonyi State as a whole is not exception in the queue. The quest for potable water supply remains a major challenge to all the local government in Ebonyi State, even to Abakaliki metropolis. This problem is exacerbated in rural areas of most of her local governments due to lack of water supply infrastructures.

Ishiagu is known for her rich mineral resources and tropical weather, the town still faces challenges on getting clean water supply around the community, and mostly depend on alternative water supplies like underground reservoirs, wells, rivers and boreholes. These alternative water supply systems are not efficient and viable enough for water supply, some of the sources dries up during dry season, got polluted due to anthropogenic and farming activities all over the communities. Moreover, increasing cases of water pollution associated with surface waters has shifted more attention to groundwater sources, leading to an increase in well and borehole digging by the rural folks in the whole communities for drinking and domestic purposes without treatment. Water travels through the ground, causing dissolution of minerals in the form of ionic salts of some metals as it move down aquifer given room for total dissolved solids (TDS), which in turn leads to water hardness [6]. This hardness could be also associated with lead, zinc and other metals contamination from quarrying activities, and is a threat to human health. Further, owing to demand for clean water supply free from contaminations, borehole water are presumed to be the major source of good water supply in Ishiagu. It has been increasingly commercialized in some areas of the communities where they have functional boreholes. The quality of these borehole waters are yet to be ascertained generally, and could have caused health problems to consumers coupled with the anthropogenic activities going-on in some parts. Thus, several reports on the assessment of groundwater quality based on physicochemical and trace metals distributions in Ishiagu communities have been published by several researchers [7], [8], [9]. And it's also necessary to regularly monitor the quality of water at least to know the quality of borehole water being consumed by the people living in these areas whether exceeded permissible limit or not, and to device means to secure it for proper hygiene. In this case, the physicochemical properties of some water samples collected from the three different communities of Ishiagu (where they have functional boreholes) were analyzed for three months (May, June and July). Going by the previous work done on the water quality indices of several water resources by various researchers within and outside Nigeria [1], [10], [11], [12], the water quality index (WQI) of these boreholes were evaluated, and the information gotten via this WQI technique will be communicated to the concerned citizens, rural dwellers and policymakers for proper checks and balances. The results could also serve as baseline data for water quality study in the future for Ishiagu region, other Local Government Areas of Ebonyi State and for appropriate recommendation in Nigeria. Hence, the aim of this study is to evaluate the water quality index of some Borehole water sources in Ishiagu, for the purpose of drinking and other domestic purposes.

2. Material and Methods

2.1. Materials

2.1.1. Sampling Stations/Location

Sample station were mapped out in each of the three community locations (Amaeze, Ngwogwo and Amaokwo) where they have functional boreholes as shown in Table 1, with their locations, descriptions and their Global Positioning System (GPS) co-ordinates.

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

Sample station Codes	Location	Coordinate		Description
		Latitude	Longitude	
BH1	Ogorji Amaeze	5º57'20" N	7º33'25" E	The station is situated along the major tarred road with side gutters, drainage and surrounded by houses, shops, business centers, car wash spot, building materials shops and automobile repairing workshops.
BH2	Amaedim Ngwogwo	5º57'25" N	7º34'23" E	This area is public arena very close to people's houses, and opposite commercialized cassava grinding machine. It is very close to refuge dump and bushes. It also situated very close to drainage curvet where wastewaters from the surrounding homes and cassava grinding machine are channeled. And very close to predominant rock known as "Elu mkpume".
BH3	Ihuogwu Amaokwo	5º57'17" N	7º33'51" E	The station is situated at the residential building along the busy street road, surrounded by houses, nearby shops, bars, business center and close to the old General Hospital.

2.1.2. Sample collection/Preservation

Borehole water samples were collected twice in a month (usually in the beginning and towards end of the month), for three months in year 2020 at the designated stations; BH1, BH2 and BH3. Meanwhile, before sampling, the plastic containers and glass wares were soaked in nitric acid for 24 hours, thereafter thoroughly washed with detergent and rinsed with distilled water to remove any form of impurities in the containers to avoid contamination, and then air-dried. The average sampling time was 9:30 am each day. At each collection point, the water was allowed to run for about 1 minute, followed by rinsing the 1.5-liter containers properly with the representative sample three times and then filled with the sample and corked tightly. For DO and BOD analysis, the water samples were collected using BOD bottle and 1-liter container respectively, taking precaution of not allowing air bubbles into the bottle and container. Finally, the containers were labeled (coded) and properly packed into coolers containing ice blocks at 4 ºC, and later transported to the laboratory where it was freshly preserved in the refrigerator prior to the analysis.

2.2. Methods

2.2.1. Physicochemical analysis of the borehole sample

The physical and chemical parameters were analyzed using standard methods recommended by America Public Health Association [13]. Nineteen parameters were analyzed in the samples collected. All measurements were carried out in triplicate, and the results were expressed in average of the two samples in each month.

In-situ analysis: Some measurement were carried out at the sampling stations for the following parameters like; pH, Temperature, Electrical conductivity (EC), Total dissolved solids (TDS), and Dissolved Oxygen (DO). In this case, the pH, Temperature (ºC), Electrical conductivity (µS/cm) and Total dissolved solids (mg/L) were determined after calibration with the aid of a portable digital HANNA multi-purpose meter (Model: HI9813-6), while dissolved oxygen (DO) was determined by Winkler titration method.

Laboratory analysis: The following parameters were analyzed in the Laboratory using standard methods. In this case, the turbidity values were determined by Nephelometric method taking reading in Nephelometric turbidity units (NTU) with the aid of Hach's turbidmeter (Model2100A). Biochemical oxygen demand (BOD) was carried out by subjecting the samples to 5 days incubation at 20ºC and titration of initial and final DO. Total Suspended Solids (TSS) was determined by Gravimetric method. Total Alkalinity (TA) by titrimetric method. Total Hardness (TH) was determined using EDTA-Titrimetric method. Calcium, (Ca^{2+}) concentration by EDTA-Titrimetric method. The magnesium, (Mg^{2+}) concentration by EDTA-Titrimetric method. Chloride ion (Cl^{-}) was determined using Argentometric method. Sodium (Na^{+}) and potassium (K^{+}) by flame photometric method [14]. Phosphate ion (PO_4^{3-}) by

Spectrophotometric method [13]. Nitrate nitrogen (NO_3^-N) concentration by UV-spectrophotometric method [15], Sulphate ion (SO_4^{2-}) by UV spectrophotometric method [16], [17] and Iron concentration (F^{2+}) also by spectrophotometric method using Apel 3000UV-VIS spectrophotometer.

2.2.2. Water quality index (WQI)

WQI is an index number that expresses overall water quality at a certain location or region based on composite water quality parameters obtained in comparison with their respective regulatory standard values [18]. The technique is employed to simplify, understand or to rate the overall water quality status of water resources, be it surface water or groundwater, and properly disseminate the information as a guide to the general public, management teams and policymakers. WQI was initially proposed by [19] in United States, which was further developed by [20] as widely used National Sanitation Foundation's Water Quality Index (WQI-NSF). However, various WQI determination methods have been described by [2] and [21], but in the present study, the weighted arithmetic water quality index (WAWQI) method was applied to assess the measured water quality parameters. This arithmetic method has been widely used by various scientists [22], [23], [24], [11] to calculate the WQI, and the concept can be generalized in five steps procedures as follows:

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

$$w_i = \frac{k}{S_i} \quad (1)$$

Where, S_i is the recommended standard value of ith parameter, and k = proportionality constant which can be calculated using the equation: $= \frac{1}{\sum_{i=1}^{n}\left(\frac{1}{S_i}\right)}$, while n = the number of parameters.

Compute the Relative weight (W_i) of the parameters: This can be computed using a weighted arithmetic index method [19], [25] given as dividing the unit weight (w_i) with it summation as follows:

$$W_i = \frac{w_i}{\sum_{i=1}^{n} w_i} \quad (2)$$

Calculate the quality rating scale (q_i) for each ith parameter: This can be calculated by dividing each parameter concentration of the water sample by its respective standard concentration and then multiplied by 100 as follows:

$$q_i = \frac{(V_o - V_i)}{(V_{s_i} - V_i)} \times 100\% \quad (3)$$

Where, V_o = the observed concentration of ith parameter in the analysed water sample, V_{Si} = the recommended standard value concentration of ith parameter, while the 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

Determine the Sub-index (SI_i) of the ith parameter by finding the product of q_i and W_i from equation (2) and (3) above as follows:

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

Finally, the overall Water Quality Index (WQI) was calculated by summing up each sub-index values gotten for the water sample as follows:

$$WQI = \sum_{i=1}^{n} SI_i = \sum_{i=1}^{n} q_i W_i \quad (5)$$

The computed WQI values are usually rated or classified into five categories: Excellent, good, poor, very poor and unsuitable water for drinking purposes as shown in Table 2, while the various calculated WQI parameter constants; Standard values (Si), unit weight (wi) and Relative weight (Wi) are summarized in Table 3.

Table 2. Water Quality Rating as per Weighted Arithmetic WQI Method (Tyagi et al. 2013)

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. Drinking Water standards for each parameters, recommending Agencies [26], [27], [28], Unit weights (wi) and Relative weight (Wi).

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

2.2.3. Statistical Analysis

The descriptive statistical analysis of Mean, standard deviation (SD), Maximum (Max) and Minimum (Min) values of the obtained data were carried out using Microsoft Excel 2019, as well as the water quality index (WQI) calculations which was done by weighted arithmetic index method.

3. Results and Discussion

3.1. Physicochemical Results of Borehole Water

The physicochemical analysis results of the various borehole water samples from May to July are expressed in average concentrations of each of the nineteen physico-chemical parameters, and are included with their standard values in Table 4, while their statistical descriptions of the mean, minimum, maximum and standard deviation of each of the water samples (BHI, BH2 and BH3) are presented in Table 5.

Table 4. Physico-chemical parameters of borehole water samples in Ogorji (BH1), Amaedim (BH2), and Ihuogwu (BH3) stations with respect to sampling months

PARAMETERS	Standard	BH1			BH2			BH3		
	Values	May	June	July	May	Jun	Jul	May	Jun	Jul
pH	8.5	6.63	7.73	6.68	7.55	7.12	7.76	7.97	7.40	7.31
Temperature (ºC)	35	27.59	28.03	27.85	28.13	28.75	27.82	30.37	29.47	27.73
Turbidity (NTU)	5	1.41	2.52	4.22	2.44	2.84	2.46	2.86	2.57	2.10
EC (µs/cm)	1000	331.2	397.8	370.7	231.3	380.2	314.7	408.3	350.6	357.7
TDS (mgL^{-1})	500	151.0	182.5	157.9	254.7	277.7	254.1	207.8	174.8	156.0
TSS (mgL^{-1})	500	2.61	3.51	2.77	2.90	3.45	2.82	2.31	3.26	2.35
Total alkalinity (mgL^{-1})	120	48.29	63.14	54.57	65.39	74.03	33.24	61.26	51.94	59.12
Total hardness (mgL^{-1})	150	128.2	185.1	124.4	152.4	180.3	124.1	149.9	177.9	178.3
DO (mgL^{-1})	7.5	2.41	5.35	3.21	2.32	1.46	1.54	4.80	4.14	5.60
BOD (mgL^{-1})	5	4.51	3.11	4.39	3.64	3.27	4.54	2.74	1.67	2.14
Chloride, Cl^- (mgL^{-1})	250	33.03	72.10	69.64	50.27	58.74	29.67	26.29	60.93	58.45
Sodium, Na^+ (mgL^{-1})	200	10.39	0.71	15.47	11.78	11.52	1.26	9.58	11.84	13.18
Potassium, K^+ (mgL^{-1})	12	10.60	8.28	8.98	11.17	6.02	6.10	8.75	9.32	9.23
Calcium, Ca^{2+} (mgL^{-1})	75	38.84	51.59	39.90	22.07	51.82	41.82	35.88	44.03	46.12
Magnessium, Mg^{2+} (mgL^{-1})	50	7.55	13.63	5.98	23.59	12.32	4.75	14.62	16.47	15.29
Nitrate, NO_3^- (mgL^{-1})	50	8.54	27.11	13.28	35.43	40.34	44.04	12.77	13.78	11.65
Sulphate, SO_4^{2-} (mgL^{-1})	250	6.68	13.28	12.70	13.57	19.39	13.11	9.49	28.26	14.03
Phosphate, PO_5^{3-} (mgL^{-1})	0.05	0.025	0.026	0.016	0.03	0.02	0.03	0.03	0.02	0.02
Iron	0.30	0.133	0.217	0.220	0.16	0.37	0.02	0.02	0.17	0.03

Table 5. Descriptive statistics of the borehole water Samples (BH1, BH2, BH3) from May to Jul 2020.

PARAMETERS	BH1				BH2				BH3			
	Min	Max	Mean	Std. Dev	Min	Max	Mean	Std. Dev	Min	Max	Mean	Std. Dev
pH	6.68	7.93	7.23	0.45	7.44	7.76	7.53	0.12	7.19	7.97	7.56	0.31
Temperature (ºC)	27.41	28.68	27.86	0.46	27.25	28.75	27.94	0.50	27.29	30.37	28.73	1.15
Turbidity (NTU)	1.41	4.22	2.41	1.10	1.41	3.93	2.66	0.82	1.49	3.55	2.42	0.73
EC (µs/cm)	311.6	397.8	350.1	32.6	231.3	380.2	316.4	48.1	311.6	408.3	349.0	33.4
TDS (mgL^{-1})	139.5	182.5	160.9	15.73	182.8	266.9	174.4	47.5	156.0	207.8	174.8	18.6
TSS (mgL^{-1})	1.45	4.04	2.46	0.93	2.37	16.14	5.13	5.40	2.31	3.26	2.56	0.36
Total alkalinity (mgL^{-1})	38.06	63.14	50.68	8.21	33.24	74.03	52.80	15.98	30.43	64.59	55.05	12.84
Total hardness (mgL^{-1})	119.6	185.1	141.7	24.16	118.0	180.3	151.3	25.31	142.4	178.3	161.5	14.52
DO (mgL^{-1})	2.41	5.35	3.90	1.17	2.50	5.90	4.08	1.26	2.16	5.78	4.14	1.56
BOD (mgL^{-1})	1.77	4.51	3.18	1.08	2.11	4.54	3.33	1.01	1.67	3.22	2.33	0.57
Chloride, Cl^- (mgL^{-1})	33.03	72.10	49.21	17.07	29.67	58.74	43.54	11.52	26.29	70.02	51.62	17.19
Sodium, Na^+ (mgL^{-1})	0.71	15.47	10.26	5.03	1.26	11.78	8.21	4.23	4.93	13.18	10.14	2.84
Potassium, K^+ (mgL^{-1})	8.12	10.60	8.85	0.92	1.26	11.52	7.64	3.71	8.75	10.32	9.40	0.52
Calcium, Ca^{2+} (mgL^{-1})	34.39	51.59	40.30	5.87	22.07	51.82	37.39	9.72	34.76	46.12	41.54	4.99
Magnesium, Mg^{2+} (mgL^{-1})	5.18	13.92	9.94	4.13	4.75	23.59	14.04	7.10	10.89	16.47	13.99	1.94
Nitrate, NO_3^- (mgL^{-1})	8.54	27.11	15.51	6.69	1.58	47.99	25.13	8.17	8.65	69.13	21.58	23.40
Sulphate, SO_4^{2-} (mgL^{-1})	6.37	17.38	11.43	4.22	10.46	19.39	14.30	3.67	9.49	28.26	15.45	6.71
Phosphate, PO_5^{3-} (mgL-1)	0.01	0.03	0.02	0.01	0.022	0.033	0.027	0.004	0.01	0.03	0.02	0.00
Iron (mgL^{-1})	0.02	0.40	0.22	0.14	0.025	0.425	0.171	0.142	0.02	0.20	0.10	0.08

3.2. Assessment of water quality with the WQI technique

The calculated WQI values was computed using the measured values of some important physicochemical parameters of the borehole water as presented in Tables 6, 7 and 8. In addition, Table 9 showed the summary of WQI value of each of the three borehole water sources for each selected month from May 2020 to July 2020, and their ranking based on the WQI rating/grading technique presented in Table 2.

Table 6. The computation of water quality index for Ogorji (BH1) station

PARAMETERS	BH1					
	Quality rating (q)			Sub-index (qW)		
	qMay	qJun	qJul	qWMay	qWJun	qWJul
pH	78.00	90.94	78.59	0.37973	0.44273	0.38259
Temperature (ºC)	78.81	80.07	79.57	0.09318	0.09467	0.09408
Turbidity (NTU)	28.10	50.40	84.30	0.23256	0.41712	0.69768
EC (µs/cm)	33.12	39.78	37.07	0.00137	0.00165	0.00153
TDS (mgL^{-1})	30.21	36.50	31.58	0.00250	0.00302	0.00261
TSS (mgL^{-1})	0.52	0.81	0.55	0.00004	0.00007	0.00005
Total alkalinity (mgL^{-1})	40.24	52.62	45.47	0.01388	0.01814	0.01568
Total Hardness (mgL^{-1})	85.48	123.4	82.92	0.02358	0.03405	0.02288
DO (mgL^{-1})	48.10	107.0	64.10	0.39808	0.88555	0.53050
BOD (mgL^{-1})	90.20	62.10	87.70	0.74651	0.51395	0.72582
Chloride (mgL^{-1})	13.21	28.84	27.85	0.00219	0.00477	0.00461
Sodium (mgL^{-1})	5.20	0.35	7.73	0.00108	0.00007	0.00160
Potassium (mgL^{-1})	88.33	69.00	74.83	0.30461	0.23794	0.25805
Calcium (mgL^{-1})	51.79	68.79	53.19	0.02857	0.03795	0.02935
Magnessium (mgL^{-1})	15.11	27.25	11.96	0.01251	0.02255	0.00990
Nitrate (mgL^{-1})	17.08	54.22	26.56	0.01414	0.04487	0.02198
Sulphate (mgL^{-1})	2.67	5.31	5.08	0.00044	0.00088	0.00084
Phosphate (mgL^{-1})	50.00	51.60	31.00	41.3807	42.7049	25.6560
Iron (mgL^{-1})	44.33	72.17	73.33	6.11514	9.95435	10.1153
WATER QUALITY INDEX (WQI) =ΣqW=				**49.50**	**54.89**	**38.25**

Table 7. The computation of water quality index for Amaedim (BH2) station

PARAMETERS	BH2					
	Quality rating (q)			Sub-index (qW)		
	qMay	qJun	qJul	qWMay	qWJun	qWJul
pH	88.82	83.71	91.29	0.43242	0.40751	0.44445
Temperature (ºC)	80.37	82.13	79.47	0.09502	0.09710	0.09396
Turbidity (NTU)	48.80	56.70	49.20	0.40388	0.46926	0.40719
EC (µs/cm)	23.13	38.02	31.47	0.00096	0.00157	0.00130
TDS (mgL^{-1})	30.94	35.53	30.82	0.00256	0.00294	0.00255
TSS (mgL^{-1})	0.58	0.69	3.23	0.00005	0.00006	0.00027
Total alkalinity (mgL^{-1})	54.49	61.69	27.70	0.01879	0.02127	0.00955
Total hardness (mgL^{-1})	101.6	120.2	82.74	0.02803	0.03316	0.02283
DO (mgL^{-1})	50.00	75.40	118.0	0.41381	0.62402	0.97658
BOD (mgL^{-1})	72.80	65.40	90.70	0.60250	0.54126	0.75065
Chloride, (mgL^{-1})	20.11	23.49	11.87	0.00333	0.00389	0.00196
Sodium, (mgL^{-1})	5.89	5.76	0.63	0.00122	0.00119	0.00013
Potassium, (mgL^{-1})	93.08	50.17	50.83	0.32099	0.17299	0.17529
Calcium, (mgL^{-1})	29.43	69.09	55.76	0.01624	0.03812	0.03077
Magnessium, (mgL^{-1})	47.19	24.65	9.50	0.03905	0.02040	0.00786
Nitrate, (mgL^{-1})	41.98	37.65	16.32	0.03474	0.03116	0.01351
Sulphate, (mgL^{-1})	5.43	7.75	5.24	0.00090	0.00128	0.00087
Phosphate, (mgL^{-1})	50.00	43.00	56.00	41.3807	35.5874	46.3463
Iron	54.67	121.8	5.17	7.54048	16.8052	0.71267
WATER QUALITY INDEX, (WQI) = ∑qW =				**51.07**	**54.47**	**49.42**

Table 8. The computation of water quality index for Ihuogwu (BH3) station

PARAMETERS	BH3					
	Quality rating (q)			Sub-index (qW)		
	qMay	qJun	qJul	qWMay	qWJun	qWJul
pH	93.76	87.00	85.94	0.45648	0.42354	0.41839
Temperature (ºC)	86.77	84.19	79.21	0.10259	0.09953	0.09366
Turbidity (NTU)	57.10	51.30	41.90	0.47257	0.42457	0.34677
EC (µs/cm)	40.83	35.06	35.77	0.00169	0.00145	0.00148
TDS (mgL^{-1})	41.56	34.95	31.19	0.00344	0.00289	0.00258
TSS (mgL^{-1})	0.46	0.65	0.47	0.00004	0.00005	0.00004
Total alkalinity (mgL^{-1})	51.05	43.28	49.26	0.01760	0.01492	0.01699
Total hardness (mgL^{-1})	99.96	118.6	118.9	0.02758	0.03272	0.03279
DO (mgL^{-1})	96.00	82.70	112.0	0.79451	0.68444	0.92693
BOD (mgL^{-1})	54.80	33.30	42.80	0.45353	0.27560	0.35422
Chloride, (mgL^{-1})	10.52	24.37	23.38	0.00174	0.00403	0.00387
Sodium, (mgL^{-1})	4.79	5.92	6.59	0.00099	0.00122	0.00136
Potassium, (mgL^{-1})	72.88	77.67	76.88	0.25130	0.26782	0.26509
Calcium, (mgL^{-1})	47.84	58.70	61.49	0.02640	0.03239	0.03392
Magnesium, (mgL^{-1})	29.25	32.94	30.59	0.02420	0.02726	0.02531
Nitrate, (mgL^{-1})	25.54	27.56	138.3	0.02114	0.02281	0.11443
Sulphate, (mgL^{-1})	3.80	11.30	5.61	0.00063	0.00187	0.00093
Phosphate, (mgL^{-1})	54.00	47.42	48.00	44.6911	39.2454	39.7254
Iron	5.33	58.00	9.50	0.73566	8.00026	1.31039
WATER QUALITY INDEX (WQI) = ∑qW =				**47.61**	**49.15**	**43.13**

From the result of the WQI analysis in Table 9, it shows that 67% were of good water quality, while 33% were of poor water quality. This shows that the borehole waters from different stations fall mostly within the range of “Good water quality- B” as displayed in Table 9. Moreover, throughout the stipulated months, station (BH3) maintained a “Good water quality” with mean value of 46.48. Ogorji (BH1) station also maintained same pattern with mean value of 47.52 except in the month of June when the water quality was poor, perhaps due to heavy rainfall during the period causing the aggravated leachate from wastewater drainage through the groundwater seepage, or as a result of the geologic changes or fluctuation beneath the water table within the confined environment. In the same vein, the mean WQI rating of the Amaedim (BH2) stations falls within grade “C” category of poor water quality, which may be due to the effect of domestic wastewaters from grinding machine and drainage network, leachates from refuse dump around on the landfills, which could have affected the groundwater quality in some aspect.

From the analysis and assessment of the physicochemical parameters of the samples, the high values of WQI at some stations could be mainly be contributed by increment in some parameter values such as we have TDS and NO_3^- values higher in Amaedim (BH2) station than obtained in other stations, likewise the PO_5^{3-} and Fe^{2+} values btained in other stations, thus causing the borehole water quality to be poor. Hence, priority should be given to minimize these deterioration in order to maintain, improve and protect water quality in these areas.

Table 9. Summary and ranking of WQI values of the six borehole water sources and inclusive months.

Borehole codes	WQI								Ranking
	MAY “20		JUNE “20		JULY “20		Mean		
BH3	47.61	B	49.15	B	43.13	B	46.48	B	1
BH1	49.50	B	54.89	C	38.25	B	47.52	B	2
BH2	51.07	C	54.47	C	49.42	B	51.55	C	3

4. Conclusion

In the present study, water quality index (WQI) was computed to assess the suitability, portability and quality of some borehole water sources in Ishiagu town for the purpose of drinking and other domestic uses. The result revealed that the borehole waters from different stations fall mostly within the range of "Good water quality- B" and "Poor water quality- C" as 67% of the water samples falls in good water category while 43% falls in poor water category. Moreover, the water quality ranking of the sampling stations in Table 10.0 clearly showed that the status of the borehole water (during the period of this study) at Ogorji (BH1) and Ihuogwu (BH3) stations are good and suitable for drinking and for domestic uses although might require UV-pre-treatment before consuming in order to eliminate micro-organisms. Likewise, the poor water quality status of Amaedim (BH2) station (the least ranked station) depicts a significant level of deterioration in the area which could have resulted from increment in some parameter values such as TDS, NO_3^-, PO_5^{3-} and Fe^{2+} perhaps, due to geological condition of the rock and human activities such as wastewater release, agricultural activities and leachates from refuse dump. Hence, there is need for regular monitoring of water quality in these study areas in order to observe changes in physiochemical parameter concentration and thus convey the information to the general public through water quality index (WQI).

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