International Journal of Chemistry Studies
www.chemistryjournal.in
ISSN: 2581-348X
Received: 02-11-2021, Accepted: 19-11-2021, Published: 03-12-2021
Volume 5, Issue 2, 2021, Page No. 49-57

Assessment of physicochemical properties and water quality index of borehole water in mkpat enin local government area, Akwa Ibom State

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Abstract
The study assessed aspect of physicochemical properties of groundwater from different boreholes in Mkpat Enin Local Government Area, Akwa Ibom State. Water samples were collected from some boreholes in the sampling sites using standard methods. Triplicate samples were collected from five sampling sites within two weeks per months of October and November. The Water Quality Index (WQI) of the borehole water was calculated in order to ascertain the quality of water for public consumption. Water Quality Index was determined using some physicochemical parameters like pH, electrical conductivity, total dissolved solids, total alkalinity, calcium, chloride, nitrate and sulphate. Results showed that S1 and S3 had values of pH, that were within the WHO and NSDWQ recommended values of 6.5-8.5. However, observed values for S2, S4 and S5 were acidic in nature and therefore were below the permissible limit. Levels of the concentration of electrical conductivity at S1 ranged from 30.0-33.0 µS/cm (mean =31.33±1.51 µS/cm). The mean value of electrical conductivity from all the sampling sites was below the permissible level of 1000.0 µs/cm. The concentrations of alkalinity at S3 ranges from 12.33-12.36 mg/l (mean = 12.33±0.03 mg/l). The values of Ca for the sampling sites had the following trend; S1>S5>S2>S4>S3. The values were within the permissible limit of 75.0 mg/l set by WHO and NSDWQ. The observed highest levels of nitrate at S1 range from 7.15-7.20 mg/l while S5 levels was 4.02-4.04 mg/l and had the following sequence S3>S2>S4>S1>S5. The Water Quality Index for S2, S3, S4 and S5 were -18.75, 16.04, -19.31 and -19.51 respectively, these values fall within grade A; implying excellent water quality. S1 with the value of 37.42 was rated as grade B; implying a good water quality. This result indicates that the groundwater quality of the study area is suitable for drinking and poses no adverse health implication for the exposed populace.

Keywords: water quality index, ground water, physicochemical parameters

Introduction

Water is one of the most abundant and essential resources of nature, it has been regarded as a universal solvent that can dissolve many chemicals which may be beneficial to man and its environment. Water is essential to all living things and its environment. It has been stated than groundwater has greater importance to civilization than surface water, because groundwater is the largest reserve of drinkable water in regions where humans can live [1].

Ground water is found beneath the ground surface and fills the voids in the rocks and soil; it is a source of water for wells, boreholes and springs [2]. Groundwater quality in a region is largely determined by both natural processes (dissolution and precipitation of minerals, groundwater velocity, quality of recharge waters and interaction with other types of water aquifers) and anthropogenic activities [2]. As human population increases, the intensity of anthropogenic threat exerted on the environment increases through industrialization and agricultural activities [3]. Polluted groundwater has a great potential for transmitting a wide variety of diseases. Potable water for human consumption does not always occur in nature because of the presence of impurities in most natural water bodies, and this has been attributed to its high solvating capacity [4]. Sources of groundwater pollution range from anthropogenic to natural activities. According to [5], the increased use of metal-based fertilizer in agricultural revolution of government could result in continued rise in concentration of metal pollution in fresh water reservoir through water run-offs. In the rainy season, fecal matter from pit latrines and open sources are washed into water bodies, thereby contaminating the water [6] Some of these toxic compounds can seep into groundwater, thereby contaminating it. Similarly, the garbage in a landfill can create groundwater pollution when rainwater percolates through the toxic garbage and sinks into the soil, contaminating the underlying groundwater to a depth of about 33m in tropical environments (low level of metal accumulation within the soil) [7]. Furthermore, it has stated that groundwater contamination may arise from leaking underground storage tanks, poorly designed industrial waste stabilization ponds, and seepage from the deep-well injection of hazardous wastes into the underground geologic formations [8]. These anthropogenic activities pose serious threat to the groundwater users. Unfortunately, once the groundwater is contaminated, its quality cannot be restored by eliminating the pollutants from the sources. It therefore becomes imperative to regularly monitor the quality of groundwater and to devise ways and means to protect it from contamination [9]. The status of the study location (Mkpat Enin LGA) as the host of a university has led to an increase in construction of houses on buffers and buried pits, abandoned toilets and filled grounds, with an attendant groundwater pollution problem. Hence, this study aims to determine the water quality index of borehole water in

Mkpat Enin LGA, Akwa Ibom State, using some physicochemical parameters.

Materials and Methods

Determination of Electrical Conductivity

This parameter was equally measured at site electronically with the help of Extech instrument (DO 700) Dissolved Oxygen Meter. The probe was rinsed with distilled water before being immersed in the sample and the reading was taken.

Determination of Total Dissolved Solids (TDS)

This parameter was also measured at site electronically using Extech instrument (DO 700) Dissolved Oxygen Meter. The probe was rinsed with distilled water before being immersed in the sample and reading was taken directly from the meter by pressing the selection key for the parameter.

Determination of pH

The reading for this parameter was taken at site electronically using Extech instrument (DO 700) meter with another probe. The instrument was calibrated by inserting the probe into buffer 4, 7, and 10 before being placed in the water sample to take the readings directly [10].

Determination of Turbidity

Turbidity was determined as well at site electronically with the use of a turbidimeter (Extech Instrument, TB 400). After the meter was powered, 10ml of the water sample to be analyzed was filled into the cuvette and placed in the hole and closed. Then the enter button was pressed to take the reading directly [11].

Determination of Sulphate Concentrations

The reagent used in the determination of sulphate in the water sample was sulfaVer 4 powder contained in a pillow. The equipment model used was Hach DR 3800. 10ml of the water sample was measured into a cuvette and the content of the pillow was also poured into the sample cuvette, shaken and measured in the Hach DR 3800 using the same sample of 10ml in a cuvette without the reagent as blank sample. The reading for the concentration was displayed on the screen and taken [10].

Determination of Nitrate Concentration

This parameter was determined using the same Hach DR 3800 by the addition of NitraVer 5 powder to 10ml of water sample in a cell, shaken and an amber colour appeared indicating the presence of nitrate then measured in the Hach. Then another cell was filled to the mark with 10ml of the same sample without adding the reagent and used as the blank sample and the result was shown on the screen [10].

Determination of Calcium and Magnesium by Titrimetric Method

Using EDTA, 100mls of the water sample, 20mls of 20% KOH and 50ml of distilled water were placed into a 250mls conical flask. About 0.05g of calcon indicator powder was added into the flask. The mixture was titrated against 1.2857mg concentration of EDTA [10].
Calculation:

$$Ca^{2+} \text{ (mg/100ml sample)} = \frac{N \times V_1 \times 100}{100} \quad (1)$$

V1 = volume of EDTA used
N = normality of EDTA used

Procedure for Calcium and Magnesium Content Analysis

50mls of distilled water, 25mls concentration of ammonium hydroxide and 20mls of the water sample were placed in a 250mls conical flask. 5 drops of Eriochrome Black T was added. The mixture was titrated against 1.2857mg of EDTA. This titration was a measure of total calcium and magnesium content in the sample [10]. Calculation:

$$Ca^{2+} + Mg^{2+} \text{ (mg/20ml sample)} = \frac{N \times V_2 \times 100}{20} \quad (2)$$

V2 = volume of EDTA used
N = normality of EDTA used.
The amount obtained is subtracted from the amount of calcium to get magnesium.

Determination of Alkalinity as CO 2-

The reagents used for the determination of this parameter were: - methyl orange as indicator, 0.01N H2SO4. The burette was filled with the 0.01M H2SO4. 50ml of the water sample was measured into a 250ml conical flask, 3 drops of the indicator was added with the aid of a micro pipette and titrated with sulphuric acid till the colour changed from yellow to pink marking the end point [10].
Alkalinity as CO_3 was calculated using the formula: -

$$\frac{A \times N \times M \times 1000}{vol.\ of\ sample\ used} \quad (3)$$

A = volume of acid used,
N = normality of acid used,
M = molar mass of $CO3^{2-}$

Total Hardness as CaCO3

This parameter was measured using EDTA titration method. 50mls of the water sample was measured into a 250ml conical flask, 2mls of ammonia buffer solution was added and a tablet of total hardness indicator and titrated between 5 minutes with a 0.01 N EDTA. A deep purple solution changed to blue solution to mark the end point [10]. I t is calculated thus,

$$mg/l\ CaCO_3 = \frac{V_2 \times E \times N \times 1000}{Volume\ of\ sample\ used} \quad (4)$$

V2 = volume of EDTA
E = Equivalent weight of CaCO3
N = Normality of EDTA

Determination of Chloride

Chloride was determined using argentometric titration. 100mls of the water sample was titrated with 0.01N of AgNO3 using potassium chromate indicator. The chloride ions reacted preferentially with silver ions. Excess silver ions reacted with chromate ions to form silver chromate which indicated the end point of the titration [10]. Using the formula:

$$mg/l\ Cl^- = \frac{V_2 \text{ x } E \text{ x N x 1000}}{Volume\ of\ sample\ used} \quad (5)$$

$V2$ = volume of $AgNO_3$
E = Equivalent weight of Cl-
N = Normality of $AgNO_3$

Study Location

The study locations are presented on Table 2.1, while the map of the study sites is shown on Figure 1.0

Table 1: Global Positioning System (GPS) Coordinates for sampling sites

Sample ID	Longitudes	Latitudes	Description of area And Anthropogenic activities
S 1	N 04○ 73' 35.2"	E007○ 75'00.3'	Residential
S 2	N 04○ 65' 99.2"	E007○ 78'05.5'	Residential
S 3	N 04○ 62'21.6"	E007○ 74'89.7'	Residential/mechanic
S 4	N 04○ 62' 83.5"	E007○ 80' 23.4'	Agricultural farming
S 5	N 04○ 62' 28.9"	E007○ 77'03.6'	Residential

Table 2: Mean Results of the Physicochemical Parameters

	Parameters	S1	S2	S3	S4	S5	WHO, 2011	NSDWQ2015
1	pH	7.73	6.19	7.09	6.18	6.12	6.5-8.5	6.5-8.5
2	TDS (ppm)	16	9.97	14.33	22.33	25.33	500	500
3	EC (µs/cm)	31.33	20	29	45.33	46.33	1000	1000
4	Calcium (mg/L)	28.3	21.3	18.79	20.1	21.45	75	75
5	Chloride (mg/L)	0.02	0.28	0.28	0.22	0.24	250	250
6	Sulphate (mg/L)	7	6.92	3.05	1.82	1	100	100
7	Nitrate (mg/L)	4.42	7.05	7.15	4.51	4.02	50	50
8	Alkalinity (mg/L)	11.28	9.18	12.33	10.09	18.05	200	-
9	Mg	11.48	16	15.99	16	19	30	-
10	Total Hardness (mg/L)	50	190	170	10	80	300	-

Table 3: Calculated Unit Weight (Wn)

	Parameters	WHO, 2011	NSDWQ 2015	Wn	Sn
1	pH	6.5 – 8.5	6.5-8.5	0.21817	7.5
3	TDS (mg/l)	500	500	0.00371	500
4	EC (µS/cm)	1000	1000	0.00185	1000
5	Calcium (mg/L)	75	75	0.02473	75
6	Chloride (mg/L)	250	250	0.00742	250
7	Sulphate (mg/L)	100	100	0.01854	100
8	Nitrate (mg/L)	50	50	0.03709	50
9	Alkalinity (mg/L)	200	-	0.00927	200
10	Mg (mg/L)	30	-	0.06182	30
11	Hardness (mg/L)	300	-	0.00618	300
	$\sum W_n$			0.38878	

Table 4: Calculated Water Quality Rating (qn)

	Parameters	S1	S2	S3	S4	S5
1	pH	48.6667	-54.0000	6.0000	-54.6667	-58.6667
2	TDS (ppm)	3.2000	1.9940	2.8660	4.4660	5.0660
3	EC (µs/cm)	3.133	2.0000	2.9000	4.5330	4.6330
4	Calcium (mg/L)	37.7333	28.4000	25.0533	26.8000	28.6000
5	Chloride (mg/L)	0.0080	0.1120	0.1120	0.0880	0.0960
6	Sulphate (mg/L)	7.0000	6.9200	3.0500	1.8200	1.0000
7	Nitrate (mg/L)	8.8400	14.1000	14.3000	9.0200	8.0400
8	Alkalinity (mg/L)	5.6400	4.5900	6.1650	5.0450	9.0250
9	Mg (mg/L)	38.26667	53.33333	53.3	53.33333	63.33333
10	Hardness	16.66667	63.33333	56.66667	3.333333	26.66667

Table 5: Calculated Water Quality Rating and Unit Weight (Wnqn)

	Parameters	S1	S2	S3	S4	S5
1	pH	10.6176	-11.7812	1.3090	-11.9266	-12.7993
2	TDS (ppm)	0.011872	0.1113	0.0106	0.0166	0.0188
3	EC (µs/cm)	0.0058	0.0555	0.0054	0.0084	0.0086

4	Calcium (mg/L)	0.933145	0.7023	0.6196	0.6628	0.7073
5	Chloride (mg/L)	5.94E-05	0.2226	0.0008	0.0007	0.0007
6	Sulphate (mg/L)	0.12978	0.5562	0.0565	0.0337	0.0185
7	Nitrate (mg/L)	0.3279	0.5230	0.5304	0.3346	0.2982
8	Alkalinity (mg/L)	0.0523	0.2781	0.05715	0.0468	0.0837
9	Mg	2.3656	1.8546	3.2950	3.2971	3.9153
10	Hardness	0.103	0.1854	0.3502	0.0206	0.1648
	$\sum Q_n W_n$	14.5471	-7.2922	6.2347	-7.5055	-7.5835
	$\sum W_n$	0.38878				
	WQI	37.4172	-18.7566	16.0366	-19.3053	-19.5058

Table 6: Water quality index and quality of water

WQI Value	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

Source [31]

Table 7: Summary of Anova-Single Factor for different sampling sites

Groups	Count	Sum	Average	Variance
S1	10	167.56	16.756	235.3491
S2	10	286.89	28.689	3255.418
S3	10	278.01	27.801	2565.437
S4	10	136.58	13.658	179.0822
S5	10	221.54	22.154	609.0731

Table 8: Anova- Single Factor for different sampling sites

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	1753.291	4	438.3227	0.320207	0.862963	2.578739
Within Groups	61599.24	45	1368.872			
Total	63352.53	49				

Table 9: Summary of Anova- Single Factor for different parameters under study

Groups	Count	Sum	Average	Variance
pH	5	33.31	6.662	0.51817
TDS (ppm)	5	87.96	17.592	38.39882
EC (µs/cm)	5	171.99	34.398	126.9337
Calcium (mg/L)	5	109.94	21.988	13.59897
Chloride (mg/L)	5	1.04	0.208	0.01172
Sulphate (mg/L)	5	19.79	3.958	8.04312
Nitrate (mg/L)	5	27.15	5.43	2.35935
Alkalinity (mg/L)	5	60.93	12.186	12.16433
Mg	5	78.47	15.694	7.24058
Hardness	5	500	100	6000

Table 10: Anova-Single Factor for different parameters under study

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	38515.45	9	4279.495	6.892107	6.4E-06	2.124029
Within Groups	24837.07	40	620.9269			
Total	63352.53	49				

Table 11: Statistical concentration of the physicochemical parameters of water obtained from study sites

pH	S1	S2	S3	S4	S5
Range	6.34-8.51	4.65-7.01	5.08-8.18	5.29-6.87	4.31-7.04
Mean±Std	7.73±1.20	6.19±1.33	7.09±1.74	6.18±0.81	6.12±1.67
TDS (mg/l)					
Range	15.0-18.0	9.0 -10.0	12.0-18.0	21.0-23.0	22.0-32.0

Mean±Std	16.0±1.73	9.67±0.58	14.33±3.21	22.33±1.15	25.33±5.78
EC (µs/cm)					
Range	30.0-33.0	20.0-21.0	25.0-36.0	42.0-47.0	35.0-60.0
Mean±Std	31.33±1.51	20.00±1.00	29.00±6.08	45.33±2.90	46.33±12.66
Ca (mg/l)					
Range	28.30-28.40	21.20-21.30	18.78-18.79	20.10 – 20.11	21.44-21.45
Mean±Std	28.3±0.1	21.3±0.1	18.79±0.01	20.10±6x10-3	21.45±7x10-3
Cl- (mg/l)					
Range	0.01-0.02	0.28-0.30	0.27-0.28	0.22-0.24	0.24-0.25
Mean±Std	0.02±0.01	0.28±0.03	0.28±0.01	0.22±0.02	0.24±0.01
SO 2- (mg/l)					
Range	7.0-8.0	6.92-6.94	3.05-3.09	1.82-1.85	0.5-1.0
Mean±Std	7.0±1.00	6.92±0.02	3.05±0.04	1.82±0.04	1.00±0.5
NO - (mg/l)					
Range	4.42-4.44	7.05-7.10	7.15-7.20	4.51-4.53	4.02-4.04
Mean±Std	4.42±0.02	7.05±0.05	7.15±0.05	4.51±0.03	4.02±0.02
Turbidity NTU					
Range	1.25-1.29	0.21-0.25	1.03-1.04	0.05-0.07	0.5-1.0
Mean±Std	1.25±0.04	0.21±0.04	1.03±0.01	0.05±0.03	1.0±0.5
Alkalinity (mg/l)					
Range	11.28-11.29	9.18-9.21	12.33-12.36	10.09-10.12	18.05-18.10
Mean±Std	11.28±0.01	9.18±0.03	12.33±0.03	10.09±0.03	18.05±0.05
Magnesium (mg/l)					
Range	11.46 -11.50	15.97 -16.03	15.98- 16.00	15.98 – 16.02	18.98 – 19.02
Mean±Std	11.48±0.02	16.00±0.03	15.99±0.01	16.00± 0.02	19.00±0.02
Total Hardness (mg/l)					
Range	49.98 -50.02	189.5 – 190.5	169.5 -170.5	9.6 -10.4	79.6 -80.4
Mean±Std	50±0.02	190±0.05	170±0.05	10±0.04	80±0.04

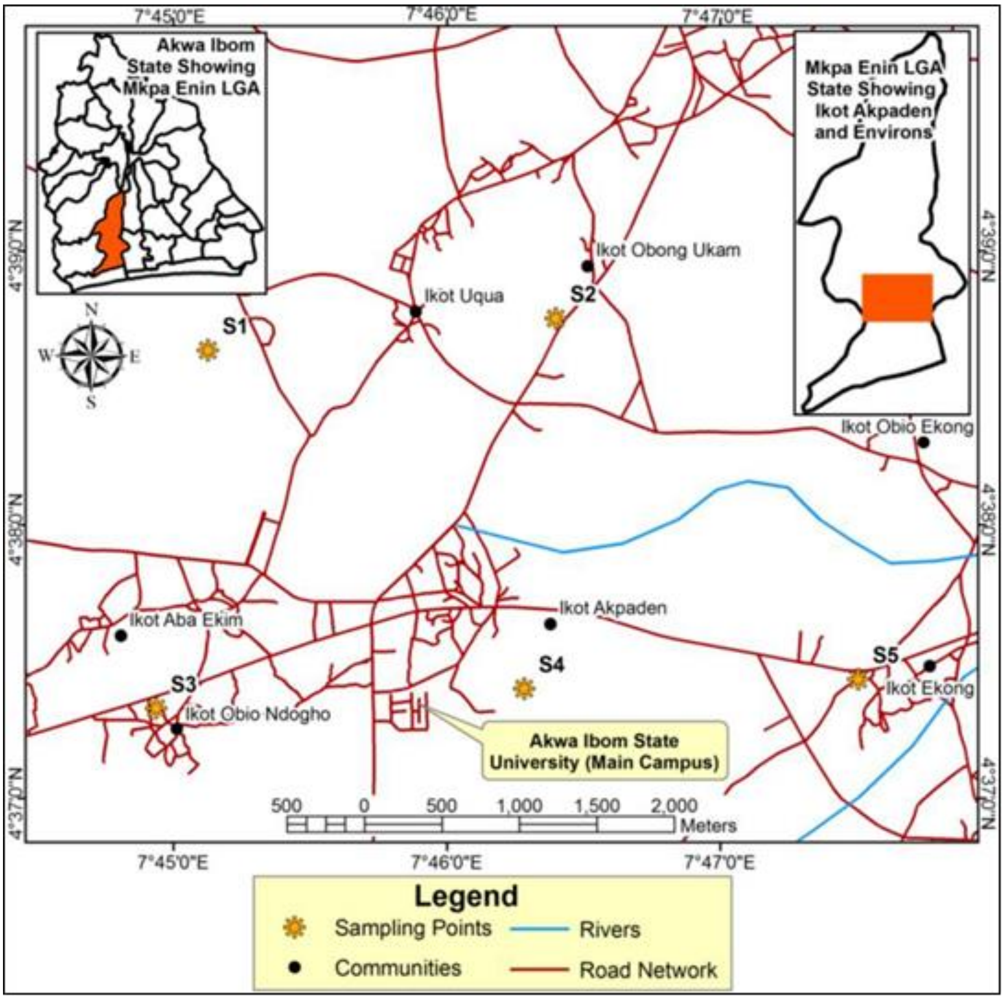

Fig 1: Map of Mkpat Enin L.G.A showing sample stations

Sample Collection and Analyses

Triplicate borehole water samples were collected from five sampling sites in the study area, within two weeks per months of October 2021 and November 2021. This led to a sample size of 60 samples. The physicochemical analyses were carried out using the methods shown on Table 2.2

Water Quality Index Estimation

The WQI was calculated using standards of drinking water quality recommended by the World Health Organization [12] and the Nigeria Standard of drinking Water Quality [13]. The weighted Arithmetic index method [14], was used for the calculation of WQI. Furthermore, quality rating or sub index was calculated using the following expression.

$$q_n = 100[V_n - V_i]/[S_n - V_i] \tag{6}$$

qn = Quality rating for the *nth* Water quality parameter
Vn = Estimated value of the *nth* parameter at a given water sampling station
Sn = Standard permissible value of the *nth* parameter
Vio = Ideal value of *nth* parameter in pure water (i.e., 0 for all other parameters except the parameters pH and Dissolved oxygen [7.0 and 14.6 mg/l respectively])

The unit weight was calculated by a value inversely proportional to the recommended standard value *Sn* of the corresponding parameter.

$$W_n = k/S_n \tag{7}$$

Where *Wn* = unit weight for nth parameter
Sn = standard permissible value for nth parameter
k = proportionality constant (K =1.85445).

The overall WQI is calculated by the following equation [15].

$$WQI = \sum q_n W_n / \sum W_n \tag{8}$$

Statistical analysis

Descriptive statistical analysis of the data was carried out in which the mean, standard deviation and ANOVA were determined using excel 2016 software.

Results

Table 3.1 shows the mean result of the physicochemical parameters drinking water quality recommended standard by the World Health Organization [12] and the Nigeria Standard of drinking Water Quality NSDWQ [13] and [15]. The unit weight (Wn) used for evaluation of the samples and calculated water quality rating (qn) of the samples are given in Table 3.2 and 3.3, respectively. Results also show the calculated water quality rating and unit weight (Wnqn) in table 3.4 and values for water quality index/ quality of water (Table 3.5).

Discussion of Findings pH

pH (potential hydrogen) of a solution refers to its hydrogen ion activity and is expressed as the logarithm of the reciprocal of the hydrogen ion activity at a given temperature, these are presented in Table 3.1.S1 had value that ranged from 6.3 - 8.5 as shown in Table 3.8. The mean pH of the samples at S1 and S3 had values that were within the recommended values of 6.5-8.5 set by WHO [12] and NSDWQ [13]. However, the observed range values for S5 was 4.31-7.04 while the mean values for S2, S4 and S5 were acidic in nature and therefore were below the permissible limit [12]. The pH values at the study sites followed the trend; S1 > S3 > S2 > S4 > S5. The variation in pH may be attributed to type of soil formation and other geological factors. The lower values of pH in water may cause acidosis, which leads to human health effects like osteoporosis, muscle loss and improper growth in children [16].

Electrical Conductivity

Electrical conductivity is the measure of water capacity to convey electric current. Electrical conductivity of water is directly proportional to its dissolved mineral matter content [15, 17]. The source of conductivity in groundwater may be traced to the geological formation of the area and the presence of inorganic salt. Salts enter groundwater through dissolution of soil, rock, and organic material [18]. The concentration at S1 ranged from 30.0-33.0 μS/cm while those of S4 varied from 42.0-47.0 μS/cm (Table 3.8) The The mean conductivity values were 31.33 ± 1.51 μS/cm (S1), 20.0 ± 1.0 μS/cm (S2), 29.0 ± 08 μS/cm (S3), 45.33 ±2.9 μS/cm (S4) and 46.33± 12.66 μS/cm (S5) Table 3.8. The mean values from all the sampling sites were below the permissible level of
1000.0 µScm by WHO [12] NSDWQ [13].

Total Dissolved Solids

The concentration of TDS at S1 varied from 15.0-18.0 mg/l and S5 was between 22.0-32.0 mg/l (Table 3.8).
Mean values were recorded as 16.00 ± 1.73 mg/l for S1, 9.67± 0.58 mg/l for S2, 14.33 ±3.21 mg/l for S3, 22.33±1.15 mg/l for S4, and 25.33± 5.78 mg/l for S5 (Table 3.1). These values obtained for TDS in all the sampling points were below 500.0 mg/l by WHO [12] and NSDQW [13]. Total Dissolved Solid (TDS) is a measure of the level of dissolved solid in water and also influences the taste of drinking water, [5]. The presence of TDS in ground water may result in the blockage and scale formation in pipes, filters and valves, causing blockage.

Turbidity

Turbidity is the degree of cloudiness of water and the measure to which water loses its transparency. According to [19], turbidity does not pose any health problem, but it affects the aesthetics of the water and could discourage consumption. The observed levels at S1 varied from 1.25-1.29 NTU and S4 ranged from 0.05-0.07 NTU (Table 3.8) the values of 0.21 - 0.54 NTU recorded were well below the acceptable NSDWQ value of 5.0 NTU (Table 3.1). Turbidity in groundwater is mostly inorganic and caused by natural geological factors [20].

Total Alkalinity

The concentrations of alkalinity at S1 varied from 11.28-11.29 mg/l and those of S4 was between 18.05-18.10 mg/l (Table 3.8). Mean values in this study were below the recommended value of 200.0 mg/l by WHO [12] Table 3.1. Similarly, low values of alkalinity were recorded by [5], with the range of 3.0 - 21.0 mg/l for borehole samples at Eket LGA, a location close to the present study area. Alkalinity of water may be due to the presence of one or more ions including hydroxides, carbonates and bicarbonates. Moderate concentration of alkalinity is desirable in most water supplies to balance the corrosive effect of acidity [21].

Sulphate

The mean concentrations of sulphate in all the sampling points varied between 1.00 mg/l and 7.00 mg/l (Table 3.1). High concentration of sulphate was recorded at *S*1 which ranged from 7.0-8.0 mg/l, while the lowest concentration was recorded at S5 that varied between 0.5-1.0mg/l (Table 3.8). High amounts of sulphate impart bitter taste to water, which is not desirable for drinking water. Furthermore sulphate, such as magnesium sulphate, causes laxative effects in children, particularly in hot weather or climates [22]. The recorded values in this study were below the permissible value of 100.0 mg/l by [15, 13] and [12]. According to [23] and [5], catharsis, dehydration and gastrointestinal irritation have been linked to high sulphate concentrations in drinking water.

Calcium

The levels at S1 were between 28.30-28.40 mg/l while those at S3 varied from 18.78-18.79 mg/l (Table 3.8). The mean values of Ca for the sampling sites had the following trend; S1 > S5 > S2 > S4 > S3. The observed value was within the permissible limit of 75.0 mg/l WHO [12] and NSDWQ [13] Table 3.1. Calcium is found in ground water that has come in contact with certain rocks and minerals, especially limestone and gypsum. When these materials are dissolved, they release calcium. Calcium is an essential mineral for human development, since it is used to build the bones and teeth. Therefore, a measurement amount of calcium is desirable in drinking water. However, at very high concentrations, they can also have some adverse effects. According to [24], Calcium can block the absorption of heavy metals in the body and cause an increase in bone mass, as well as prevent certain types of cancer.

Magnesium

The observed values for S1 ranged from 11.46 -11.50 mg/l and S1 varied from 18.98 – 19.02 mg/l (Table 3.8). Mean concentrations of magnesium in all borehole water samples varied from 11.48±0.02 mg/l (S1) to 19±0.02 mg/l (S5). They were all found to be lower than the WHO [12] limit of 30 mg/l), as indicated in Table 3.1. Presence of Mg in water samples is an indication of eroded rocks and minerals such as limestone, dolomite, calcite and magnetite into the water bed, which renders the water hard and unfit for human consumption [24].

Hardness

Water hardness is the total calcium and magnesium ion concentration in a water sample and is expressed as the concentration of calcium carbonate [25]. The levels observed at S2 varied from 189.5 – 190.5 mg/l and S4 was between 9.6 -10.4 mg/l (Table 3.8) the highest water hardness was recorded in S2 (190.0± 0.05 mg/l) while the least was in S4 (10.0±0.4 mg/l). As stated, earlier hardness is measured based on the concentration of calcium carbonate, where concentration of below 75 mg/L is generally considered soft, 76 - 150 mg/L (moderately hard), 151-300 mg/L (hard) and > 300 mg/ (very hard). The result of this study indicates that S1 and S4 can be classified as soft water, S5 is moderately soft, while S2 and S3 are hard water.

Chloride

High concentration of chlorides in water may reduce pH and lead to destruction of metal pipes and structures. The concentration at S2 ranges from 0.28-0.30 mg/l while S1 was between 0.01-0.02 mg/l (Table 3.8). The mean values for the sampling sites had the following sequence S2 = S3>S5>S4>S1. These values were below the permissible limit of 250.0 mg/l WHO [12] and NSDQW [13] Table 3.1. Similar observation was made by [5] in a related studies in a Eket LGA, a location of proximity with the present study area.

Nitrate

In nature, inorganic nitrogen exists in the form of nitrates, nitrites and ammonia nitrogen. Among them, nitrite and ammonia nitrogen are unstable, their concentration is low and easily converted to nitrate [26, 27]. Nitrate is a major ingredient of farm fertilizers and is necessary for plant uptake and is essential for plant growth. The levels of nitrate in all the study sites were below the permissible limits of 50.0 mg/l NSDWQ [13, 15] and WHO [12] Table 3.1. The observed highest levels at S1 range from 7.15-7.20 mg/l while S5 levels was 4.02-4.04 mg/l (Table 3.8). [27] Stated that the high concentration of nitrate in groundwater may be the result of the interaction of fertilizers and geological factors. It has been stated that high nitrate levels in drinking water during the first trimester of pregnancy are associated with birth defects in newborns [28], methemoglobinemia is directly related to high nitrate levels in drinking water [29].

Water Quality Index

According to [30], Water Quality Index is an algorithm that expresses a measure of the qualitative state of the water. The water quality index (WQI) of the sampling sites is given in Table 3.4. The WQI was calculated by using standards of drinking water quality recommended by the World Health Organization [12] and the Nigeria Standard of drinking Water Quality [13]. The rating was as follows: WQI values; 0 – 24 (Excellent water – A), 26 – 50 (Good water quality – B), 51 – 75 (Poor water quality – C), 76 – 100 (Very poor water quality – D) and > 100 (unsuitable for drinking purpose – E) Table 3.5 [31]. The Water Quality Index for S2, S3, S4 and S5 were -18.75, 16.04, -19.31 and -19.51 respectively, these values fall within grade A; implying excellent water quality. S1 with the value of 37.42 was rated as grade B; implying a good water quality. This result indicates that the groundwater quality of the study area is suitable for drinking and poses no adverse health implication for the exposed populace.

Statistical Analysis

Analysis of Variance (ANOVA)

The summary of the analysis of variance using single factor for the different sampling sites are presented on Table 3.6a. The observed mean values for the five (5) different sampling sites were subjected to Analysis of Variance (ANOVA) to verify if there is a statistically significant difference in the mean. From the result of ANOVA in Table 3.6a above, it is observed that the Fcrit > Fcal (2.58 > 0.32), therefore there is no statistically significant evidence at $\alpha = 0.05$ to show that there is a significant difference in the mean of the five different sampling sites. The observed P0.05 was 0.86 which concludes that there is no significant difference between the sampling sites. Table 3.7a gives the summary of the analysis of variance using single factor for the different physicochemical parameters under investigation. From the result of ANOVA in Table 3.7b, it is observed that the Fcrit < Fcal (2.12 < 6.89), therefore there is a statistically significant evidence at $\alpha = 0.05$ to show that there is a significant difference in the mean of the different parameters under study. The observed P0.05 was 6.4E-06 which concludes that there is a significant difference between the sampling sites.

Conclusions

This study assessed the water quality index of borehole water in Mkpat Enin LGA, Akwa Ibom State, using some physicochemical parameters. The results obtained have shown that Water Quality Index for four sample sites (S2, S3, S4 and S5) had excellent water quality while the remaining site (S1) recorded a good water quality, and therefore were suitable for human consumption. There is need for adequate sensitization and proper periodic monitoring of the water quality of the study area to safeguard well-being of the exposed populace.

Acknowledgements

The authors are grateful to the Research and Development Coordinator of Akwa Ibom State University, Nigeria for providing technical support.

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