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Physicochemical Studies of Water from Selected Boreholes in Umuahia North Local Government Area, in Abia State, Nigeria

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ABSTRACT

The physicochemical parameters of water from 12 boreholes from 12 different communities in Umuahia North Local Government Area, Abia State, Nigeria were determined within the period of six months (February to July) 2011 to investigate their quality. Analyses were done on water samples for Temperature, pH, Electrical conductivity (EC), Total dissolved solids (TDS), Total suspended solids (TSS), Dissolved Oxygen,(DO), Biochemical Oxygen Demand (BOD), Chemical Oxygen Demand (COD), Alkalinity, Acidity, Total hardness, Turbidity, Salinity, Nitrate, Phosphate, Calcium ion, and Magnesium ion using standard methods and evaluated with the World Health Organization standards. All physicochemical parameters analysed in borehole water samples were within recommended standards except the following: total suspended solids (TSS) ranged from 31.3 to 55.0mg/l with a mean value of 37.9±7.67 mg/l, salinity151-227 mg/l (171±37.6 mg/l mean), nitrate 12.4-35.4mg/l (19.6±14.5 mg/l mean), phosphate 6.22-7.97mg/l (6.99±1.74 mean), biochemical oxygen demand (BOD) values 5.35-15.9 mg/l (9.92±5.15mg/l mean) and Dissolved Oxygen (DO) 29.4-33.5 mg/l (31.6±3.33mg/l mean) all generally above WHO permissible limit respectively. These results indicated that the water sources were contaminated and unfit for human consumption. This therefore, calls for appropriate treatment measures before the consumption of these waters by the populace to avoid long term accumulative health problems of these pollutants. Recommendations on the strategies to reduce/eliminate some of these pollutants were made.

***Keywords**: Borehole, water, quality, physicochemical, properties, contaminants, Umuahia.*

INTRODUCTION

Quality drinking water is essential for life. Contaminants such as bacteria, viruses, heavy metals, nitrates and salt have polluted water supplies as a result of inadequate treatment and disposal of waste from humans and livestock, industrial discharges, and over-use of limited water resources.

Over one billion people lack access to clean safe water worldwide [1,2,3]. In sub-Saharan Africa alone, up to 300 million rural people have no access to safe water supplies. Without safe water near dwellings, the health and livelihood of families can be severely affected [4,5]. Groundwater exploitation is generally considered as the only realistic option for meeting dispersed rural water demand [5]. Due to inability of governments to meet the ever-increasing water demand, people resort to groundwater sources such as shallow wells and boreholes as alternative water resources[6]. The effect of uncontrolled disposal systems in Nigeria and Umuahia in particular can render groundwater and surface waters unsafe for human, agricultural and recreational use, pose a threat to human life and is therefore against the principle of sustainable development [7].

Studies on groundwater pollution have been carried out in different parts of Nigeria [8,9,10]. Consistent in their findings is that groundwater is polluted from physical processes and anthropogenic activities. In Nigeria and other developing countries, these hazardous materials are disposed off with municipal solid waste into open dumps and surface water bodies, often used for domestic purposes [11]. When disposed through these routes, toxic substances can leach and eventually contaminate surface and groundwater [12].

In Nigeria, open dumping of municipal solid wastes, is mainly the existing method of waste disposal used even in capital cities except perhaps among few and affluent institutions [13]. Water contamination by Leachate can transmit bacteria and disease, typhoid fever is a common problem for the people of developing nations, many of them cannot afford to dig wells deep enough to reach fresh aquifers [11]. The water quality of borehole is generally neglected based on the general belief that it is pure through the natural purification process. There is inadequate information or knowledge of the quantity, quality and pattern of distribution of Nigeria's water resources [14]. Due to the absence of municipal water supply, many of the inhabitants of Umuahia, in Abia State of Nigeria depend on boreholes for their need. However, the quality is under intense stress from increasing demand and withdrawal, significant changes in land use pattern, climate change and pollution arising from geology and geochemistry of the environment [3,15]. Water from some of the boreholes could not be used for drinking on account of colour, odour and taste. Consumers to a large extent have no means of judging the safety of water themselves, but their attitude toward drinking water and drinking water supplies will be affected to a considerable extent by the aspects of water quality they are able to perceive with their senses. It is natural for consumers to regard with suspicion water that appear dirty or coloured or has unpleasant taste or smell, even though these characteristics may not in themselves be of direct consequence to health [16]. Polluted water is not just dirty, it is deadly [2].

Pollution of groundwater stems from different sources. These include insanitary condition during borehole construction, splashing of runoff into wells, if left uncovered, flooding at borehole site, leachate from old buried waste pit or latrine into the hole through cracks in aquifer and annular of the hole, closeness of boreholes to septic tanks especially where space is a constraint and as such boreholes are drilled at times at old garbage landfill site formations through which the wastewater is retrieved from the holes [17]. Sanitation at the surface around the well also affects the quality of the water as seepage through the soil surrounding the casing may also impart pollutant on the water quality. Entrained pollution particles that run off the ground surface and polluted water which enters a stream through its channel sides and bottom may pollute surface streams and ponds and then, leach into the soil to pollute groundwater. Also, pollution might arise from a storm runoff, laden with particle pollutants, that infiltrates into the soil to a shallow depth [18]. The water from such a shallow source does not guarantee good water quality [17].

Physicochemical examination study of water in the area is unavoidably important. It is against this backdrop we are carrying out this study, to determine whether these parameters meet the (WHO) World Health Organization standard for drinkable water, as well as to ascertain the possible causes of any contaminations in order to make appropriate recommendations. The results of the study will also serve as baseline data for water quality study in the Local Government Area and Abia State in the future.

MATERIALS AND METHOD

Study Area

The study took in Umuahia North, the capital city of Abia State, Nigeria. Geographically, Umuahia North is located within Latitude 5º 29.5′-5º 42′ N and Longitude 7º 24.3′ - 7º 34.7′ E within the forest belt. The area is characterized by high temperatures of about 29º-31ºC and has double maximal rainfall peaks in July and September. It is bound in the North by Isuikwuato LGA, Umuahia South in the South, Bend LGA in the East and the Imo River demarcates it with Imo State in the Western part. It has an area of 245km^2 and a population of 220,660 at the 2006 census [11].

Geologically, Umuahia North is within the Benin formation which comprises of shale/sand sediments with intercalation of thin clay beds [19,20]. It is a part of the coastal plain sands of the Cenozoic Niger Delta region of Nigeria [21,22].

Sample Collection, Treatment and Preservation

The grab and composite sampling methods [23,24] were used in collecting water samples from the pumped boreholes water quantities at various locations. Water samples were collected from twelve different borehole sampling points at one month interval for six months. The average sampling time was 9am each day of sampling. Table 1 showed the description of the sampling areas. Before collection, the mouth and the outer parts of the borehole taps were sterilized with the flame of a cigarette lighter, and allowed to cool by running the water for about 1 minute. Each sample for analysis was collected using a clean two litre plastic container with a screw cap which was thoroughly washed with detergent, soaked with acid and rinsed with distilled water. At the point of collection, the container was rinse three times with the water sample. All the samples were stored in laboratory, freshly refrigerated at 4°C in a cooler packed with, ice blocks prior to analysis to avoid microbial action affecting their concentration. All the chemicals used were of the analytical grade.

Table 1: Sampling Area Descriptions

Sampling Number	Sampling Location/Description
Sample 1	Isieke Community
Sample 2	Amuzukwu Community
Sample 3	Uwalaka Street
Sample 4	Isingwu Community
Sample 5	Ngbuka Mechanic Workshop Area
Sample 6	Ubakala Street/Okigwe Road
Sample 7	Ossah Community
Sample 8	Government House Community
Sample 9	World Bank Housing Estate Community
Sample 10	Timber Shed Community
Sample 11	Afaraukwu Community
Sample 12	Low Cost Housing Estate Community

Physicochemical Analyses

The physicochemical properties of the water samples were determined according to standard methods. The physicochemical properties determined include Temperature, pH, Turbidity, Dissolved Oxygen (DO), Total alkalinity, Acidity, Conductivity, Total hardness, Total Dissolved Solids (TDS), Total Suspended Solids (TSS), Total Solids (TS), Chemical Oxygen Demand (COD), Biochemical Oxygen Demand (BOD), Salinity, Nitrate, and PO_4^{3-}. Presence of minerals (such as magnesium and calcium) was determined by methods EDTA Titration method.

Determination of pH: The pH was carried out in-situ at the site of sample collection using the Hanna microprocessor pH meter. It was standardized with a buffer solution of pH range between 4-9.

Measurement of temperature: This was carried out in-situ at the site of sample collection using a mobile thermometer. This was done by dipping the thermometer into the sample and recording the stable reading.

Determination of conductivity: This was done using a conductivity meter. The probe was dipped into the container of the samples until a stable reading was obtained and recorded.

Determination of acidity: The followed the procedure in the American society for testing and materials (1982), (acidity was determined by titration), 50mL of the sample was pipetted into a clean 250mL conical flask. Two drops of phenolphthalein indicator were then added and the solution titrated against a standard 0.01M NaOH solution to a pink end-point.

Calculation:

Acidity (mg/l) = [V x M x 100,000] / ml of sample used

Where V = volume of NaOH used

M = molarity of NaOH used.

Determination of Alkalinity: 50mL of the sample was pipetted into a clean 250ml conical flask. Two drops of methyl red indicator were then added and the solution titrated against a standard 0.01M HCl solution to a pink end-point. (American society for testing and Materials, 1982).

Total alkalinity (mg/l) = [V x M x 100,000] / ml of sample used

Where V = volume of acid used

M = Molarity of acid used.

Determination of Turbidity: This was determined using a standardized Hanna H198703 Turbidimeter. The samples were poured into the measuring bottle and the surface or the bottle was wiped with silicon oil. The bottle was then inserted into the turbidimeter and the reading was obtained.

Determination of total solids (TS) by Gravimetric Method: 10ml of the samples were measured into a pre-weighed evaporating dish which was then dried in an oven at a temperature of 103 to 105^{o}C for two and half hours. The dish was transferred into a desiccators and allowed to cool room temperature and was weighed. The total solid was represented by the increase in the weight of the evaporating dish.

Total solids (mg/l) = [(W2-W1) mg x 1000] / ml of sample used

Where W1 = initial weight of evaporating dish

W2 = Final weight of the dish (evaporating dish + residue)

Determination of total dissolved solids (TDS) by Gravimetric Method: A portion of water was filtered out and 10ml of the filtrate was measured into a pre-weighed evaporating dish. Following the procedure for the determination of total solids above, the total dissolved solids content of the water was calculated.

Total dissolved solids (mg/l) = [(W2-W1) mg x 1000] / ml of filtrate used.

Where W1 = initial weight of evaporating dish

W2 = Final weight of the dish (evaporating dish + residue).

Determination of total suspended solids (TSS)

The total suspended solids were easily obtained by simple calculation, i.e.

Total suspended solids = total solid — total dissolved solids.

Determination of dissolved oxygen: This was done using Winkler's method. In this procedure, an excess of Manganese (II) salt, iodide (I-) and hydroxide (OH-) ions were added to the samples causing a white precipitate of Mn $(OH)_2$ to form. This precipitate was then oxidized by the dissolved oxygen in the water sample into a brown Manganese precipitate. In the next step, a strong acid (either hydrochloric acid or sulphuric acid) was added to acidify the solution. The brown precipitate then converted the iodide ion (I-) to iodine. The amount of dissolved oxygen was directly proportional to the titration of iodine with a thiosulphate solution.

In this study, 300ml BOD bottles were filled with the samples respectively, 2ml of manganese sulphate and 2ml of alkali-iodide-azide solution added by inserting a pipette just below the surface of the liquid. The bottles were stoppered to avoid the introduction of air and were mixed by inverting several times. The bottles were left to stand for a few minutes. The presence of oxygen was indicated by the formation of a brownish –orange precipitate. Two millimeters (2ml) of H_2SO_4 was added to the samples. It was mixed again by inverting to dissolve the precipitate. Two hundred and one milliliter of the sample was then measured into a clean 250ml conical flask and titrated against sodium thiosulphate

Solution ($Na_2S_2O_3.5H_2O$) using the starch indicator until the solution turned colourless [39].

Calculation:

DO (mg/L) = [16000 x M xV] / [V_2/V_1 ($_{V1-2}$)]

Where = Molarity of thiosulpahte used.

V = volume of thiosulphate used for titration

V_1 =Volume of bottle with stopper

V_2 = Volume of aliquot taken for titration.

Determination of Biochemical Oxygen Demand (BOD): The method involves filling the samples to overflowing, in an airtight bottle of the specified size and incubating it at the specified temperature for 5days. Dissolved oxygen (DO) was measured initially and after incubation and the BOD was computed from the difference between initial and final (DO). Because the initial (DO) was determined shortly after the dilutions was added, all oxygen uptake occurring after this measurement was included in the BOD measurement. One Millimeter (1ml) of $MgSO_4$, $CaCl_2$, phosphate buffer, $FeCl_3$ were added to 1L of water. The solution was then shaken thoroughly to saturate the dissolved oxygen. This solution was used to dilute samples. One hundred millimeters (100ml) of the samples were measured into different one Liter flasks and were made up to (1L) mark with the dilution water previously prepared. The dilution sample solution was then poured into BOD bottles and subsequently incubated at 20^oC in the dark for 5 days.

Determination of initial dissolved oxygen: Three hundred millimeters (300ml) BOD bottles were filled with the diluted samples previously prepared and the initial dissolved oxygen (DO) was determined using the Winkler's method

Determination of Final Dissolved Oxygen: After incubation for 5days, the final dissolved oxygen (DO) was determined using the same procedure above

BOD (mg/L) = [DO_1-DO_0] / B

Where DO_0 = initial dissolved oxygen (immediately after preparation)

DO_1 = final dissolved oxygen (after 5days of incubation)

B = Fraction of sample used.

Determination of Chemical Oxygen Demand (COD): 250ml of borehole water was warmed to 27ºC and transferred to cleaned flask. 10ml of $KMnO_4$ 0.0125M was added and 10ml of 20% V/VH_2SO_4 was added. It was mixed gently and incubated at 27ºC for 4 hours. The mixture was examined at intervals, when the pink colour of permanganate tends to disappear, 10ml of $KMnO_4$ was added. After 4 hours, 1ml KI solution was added and titrated with 0.0125M $Na_2S_2O_3$ using starch as an indicator, until the blue colour just disappeared.

Calculation: COD (mg/l) = [(ml of Blank-ml required of sample) x 1000] / A x Volume of sample used.

Where A = Total Volume of $KMnO_4$ 0.0125M added to samples.

Determination of salinity (chloride ion test): To a 50ml of the sample was added 5 drops of a phenolphthalein indicator solution and neutralized with 0.1N sulphuric acid to the colourless side of phenolphthalein. 1ml of potassium chromate indicator solution was added before titration with standard silver nitrate solution to a pinkish-yellow endpoint. A reagent blank titration was carried out in parallel to the sample titration.

Chloride quality was calculated as follows:

Chloride, mg/l = [(A-B) (N)(35.45) / V] x 100

A = Silver nitrate solution, in ml for sample titration

B = Silver nitrate solution, used for blank titration (in ml)

N = Normality of the silver nitrate solution

V = Sample volume (in ml)

Determination of Total Hardness: 25ml of the samples was placed in different clean 250ml conical flasks. To this were added 3ml of ammonium chloride in concentrated ammonia buffer and 2 drops of Eriochrome Black T indicator. This was titrated against 0.01M EDTA solution until there was a colour change from violet to blue.

Calculation:

Hardness in mg/l $CaCO_3$= [V x M x 1000] / ml of sample used

Where M = Molarity of EDTA Used

V =Volume of EDTA used.

Phosphate determination: The mild acid hydrolysis was used to convert the phosphate content to the soluble orthophosophate before colorimetric determination was carried out. One drop of phenolphthalein indicator solution was added to 100ml of the sample and the colour adjusted to red by the addition of 7N sodium hydroxide solution. A strong sulphuric acid was added to the solution which was thereafter boiled gently for 90mins, while adding water to keep the volume between 25 and 50ml. The solution was then cooled, neutralized to a faint pink colour, and diluted to the original 100ml volume. The transmittance of the sample was measured against a reagent blank at 400-490 nm, and the result compared with a calibration curve of a standard phosphate solution.

Phosphate, phosphorus, mg/l = [Phosphorus content (mg) x 1000] / Sample volume (ml).

Determination of nitrate: A photometric method was used for the determination, NO_3^-. Analytical water test tablets prescribed for Palintest® Photometer 5000 (Wagtech, Thatcham. Berkshire, UK) series were used.

RESULTS AND DISCUSSION

A summary of the results of the Borehole waters physicochemical analysis were compared with the World Health Organization (WHO, 2006) standards (Table 2). Overall descriptive analysis of the results are shown in Table 3.

Table 2: The mean values of physicochemical analysis

Paramters	Sample 1	Sample 2	Sample 3	Sample 4	Sample 5	Sample 6	Sample 7	Sample 8	Sample 9	Sample 10	Sample 11	Sample 12	WHO Standard
Temp (^{o}C)	27.4	27.3	27.2	27.3	28.0	28.0	28.2	28.3	27.1	27.8	27.9	28.0	30-32°C
pH	7.04	7.04	7.15	6.79	7.06	6.97	7.24	6.90	6.91	6.92	6.89	7.00	6.5-8.5
Turbidity (NTU)	2.67	3.17	3.00	3.50	3.00	3.00	2.50	2.50	2.83	3.50	3.67	2.50	5 NTU
DO mg/l	30.5	30.6	32.8	33.0	33.5	30.3	33.3	31.8	29.9	29.4	32.7	31.4	7.5 mg/l
COD mg/l	5.30	5.26	5.35	3.75	3.73	4.62	5.45	4.09	4.58	5.64	4.93	3.61	7.5 mg/l
Alkalinity	15.7	15.3	15.0	20.1	12.7	13.3	20.0	15.4	16.7	11.4	14.8	15.2	100 mg/l
Acidity m/l	5.83	8.05	9.26	8.15	11.9	13.9	13.6	19.1	21.3	13.8	11.5	15.7	
TSS mg/l	35.4	31.3	36.8	55.0	35.3	34.7	36.3	35.0	37.5	40.4	42.8	34.3	30 mg/l
TDS mg/l	20.7	11.0	7.07	20.6	17.8	9.27	20.5	19.7	11.6	9.20	18.5	20.4	259-500 mg/l
TS mg/l	56.2	42.4	43.8	75.6	53.1	44.0	56.8	54.8	49.1	49.6	61.2	54.7	500 mg/l
EC µs/cm	124	66.1	42.5	123	107	55.6	123	118	69.7	55.2	111	123	500 µs/cm
Salinity mg/l	206	151	155	153	151	171	166	227	175	163	164	169	200-250 mg/l
Nitrate mg/l	14.4	14.9	15.9	15.5	17.8	31.8	35.4	35.2	12.4	14.6	15.3	12.6	10 mg/l
PO_4^{3-} mg/l	6.98	7.97	7.78	7.85	7.07	7.07	6.52	6.22	6.62	6.92	6.65	6.25	0-5 mg/l
BOD mg/l	13.6	12.0	9.06	11.5	15.9	11.1	8.57	8.26	10.7	6.34	5.35	6.72	6-9 mg/l
Total Hardness	70.4	58.1	54.0	70.4	104	100	97.4	106	56.0	60.0	68.4	59.5	200mg/l
Ca^{2+} mg/l	42.5	31.8	22.8	37.0	53.1	55.8	60.4	65.0	32.0	33.7	38.0	32.4	75 mg/l
Mg^{2+} mg/l	28.0	26.3	31.2	33.4	52.6	44.4	37.0	41.1	25.7	26.3	30.4	27.2	150 mg/l

The temperature of the sampled borehole waters ranged between 27.1 to 28.3°C with a mean value of 27.7±0.617°C as shown in Table 3. These values obtained are similar to those reported by Obi and Okocha, (2007) and Chukwu, (2008). Cool waters are generally more potable for drinking purposes, because high water temperature enhances the growth of micro-organisms and hence, taste, odour, colour, and corrosion problem may increase (Okoye and Okoye, 2008). Metal corrosion problem are also associated with high temperature especially when the pH of the water happens to be more acidic. The pH values obtained ranged from 6.79 to 7.24. All samples fell within the WHO range for potable water. The mild acidic increases in the water samples increased the capacity of the water to attack geological materials and leach toxic trace metals into the water. But these values obtained are similar to previously reported values in Umuahia Metropolis [7]. In the case of turbidity, the values ranged between 2.50 to 3.67NTU, which are below the limit 5NTU (Table 2). The electrical conductivity (EC) for all samples fell within the permissible limit of 500 µS/cm set by WHO. EC is an indicator of water quality and soil salinity, hence the relatively high values observed in some water samples showed high salinity; thus the waters might not be very suitable for domestic and agricultural use.

Total dissolve solid (TDS) values are generally below 250mg/l which was within the WHO permissible limit for potable water [25]; this showed that borehole water in the area was quite fresh in most locations. The presence of these total dissolved solids (TDS) in the water samples as observed in Table 2 indicated the presence of solid materials or solutes in water. Sample 1(Isieke Community) had the highest TDS while Sample 3 (Uwalaka Street) had the least (Figure 1). It was observed that the EC of samples increased with increasing TDS results (Table 2). The total suspended solids (TSS) values are generally above WHO permissible limit 30mg/l [26], ranged from 31.3 to 55.0mg/l with a mean value of 37.9±7.67 mg/l. The highest value was observed in Sample 4, (Isingwu Community) 55.0 mg/l likewise TS as shown in Figure 1.The alkalinity values of all the sampled waters are below the stipulated limit 100 mg/l by WHO (Table 2). They ranged from 11.4 to 20.1 mg/l (Figure 1). This again confirmed the slightly acidic nature of water of the study area. Hence, water from these commercial boreholes requires some level of treatment to attain the required WHO standard.

The World Health Organization (WHO) International Standard for Drinking Water (1998) classified water with a total hardness of $CaCO_3$ less than 50 mg/l as soft water, 50 to 150 mg/l as moderately hard water and water hardness above 150 mg/l as hard $CaCO_3$. Based on this classifications, all the water samples analysed are moderately hard water (Figure 2), thus the waters are suitable for domestic use in terms of hardness. This is because moderately hard water is preferred to soft water for drinking purposes as hard water is associated with low death rate from heart diseases (ISO, 1990; [27]. Ca^{2+} and Mg^{2+} values obtained for the water samples ranged from 22.8 to 65.0 mg/l with a mean value 42.0±17.6mg/l for Ca^{2+} and 25.7 to 52.6 mg/l with a mean value 33.6±14.6mg/l for Mg^{2+} (Table3, Figure 2). They fell far below WHO standard (Table 2). Ca and Mg are among the general elements essential for human health and metabolism and should be available in normal drinking water [28]. However, if one or more of these elements occur in the water above certain limits, the water may become objectional to consumers and even become hazardous to health.

Biochemical Oxygen Demand (BOD), and Dissolved Oxygen (DO) had the highest concentration at sample 5 (Ngbuka Mechanic Workshop Area) (Table 3). The biochemical oxygen demand (BOD) values ranged from 5.35 to 15.9 mg/l and Dissolved Oxygen (DO) from 29.4 to 33.5 mg/l all generally above WHO permissible limit respectively. The BOD was slightly above the WHO permissible range values of BOD for drinking water. This is an indicative of a slight pollution of the groundwater which might be attributed to perculation of hydrocarbon especially the Ngbuka Mechanic Workshop Area and other solid organic wastes as shown in Figure 3. COD values fell below WHO permissible limit.

Phosphate is a generic term for the oxy-anions of phosphorous. Enrichment of water with organic phosphates and nitrates results in an excessive growth of plants and other micro-organisms leading to eutrophication and increased biochemical oxygen demand. Results obtained in Table 2 indicated that phosphate values were generally above WHO permissible limit of 5mg/l. It ranged from 6.22 to 7.97mg/l with a mean value 6.99±1.74mg/l. Sample 2 (Amuzukwu Community) had the highest phosphate contents among the water samples analyzed while Sample 8(Government House Community) had the least as shown in Figure 4. Salinity (chloride ion) which is in form of chlorine is one of the major anions in water, it is known for maintenance of acid-base balance, and hence excess of it might cause edema [29]. The values obtained for chloride ranged from 151 to 227 mg/l with a mean value 171±37.6 mg/l. These values obtained are well below the recommended standard value of 250 mg/l by WHO (Table 2); they are also within the range of values reported by Obi and Okocha, (2007). Nitrate values in the samples ranged from 12.4 to 35.4 mg/l with a mean value of 19.6±14.5 mg/l as shown in Figure 4. The values are above the WHO recommended limit of 10.0 mg/l. Methemoglobinemia is a disease caused by nitrate, which is converted to nitrite in the intestines [30]. The safe nitrate limit for domestic water is set at 45mg/l [31]. Nitrate cannot be removed from water by boiling but must be treated by distillation [32].

Table 3: Descriptive Analysis of the Results

Parameter	Mean	STDEV(n=12)	Range	Variance	%CV
Temp (^{o}C)	27.7	0.617	27.1-28.3	0.380	2.23
pH	6.99	0.309	6.79-7.24	0.0957	4.42
Turbidity (NTU)	2.99	0.970	2.50-3.67	0.942	32.5
DO mg/l	31.6	3.33	29.4-33.5	11.1	10.5
COD mg/l	4.69	1.20	3.61-5.64	1.44	25.6
Alkalinity	15.5	4.72	11.4-20.1	22.3	30.5
Acidity m/l	12.7	6.68	5.83-21.3	44.6	52.6
TSS mg/l	37.9	7.67	31.3-55.0	58.8	20.2
TDS mg/l	15.5	8.62	7.07-20.7	74.3	55.5
TS mg/l	53.4	12.6	42.4-75.6	160	23.6
EC μs/cm	9.32	5.17	42.5-124	26.7	55.5
Salinity mg/l	171	37.6	151-227	1.41×10^3	22.0
Nitrate mg/l	19.6	14.5	12.4-35.4	211	73.9
PO_4^{3-} mg/l	6.99	1.74	6.22-7.97	3.03	24.9
BOD mg/l	9.92	5.15	5.35-15.9	26.6	51.9
Total Hardness	75.4	25.4	54.0-106	643	33.6
Ca^{2+} mg/l	42.0	17.6	22.8-65.0	309	41.8
Mg^{2+} mg/l	33.6	14.6	25.7-52.6	212	43.3

Temp: Temperature, EC: Electrical Conductivity, STDEV: Standard Deviation, %CV: Coefficient of Variation

Figure 1: Distribution of Solids

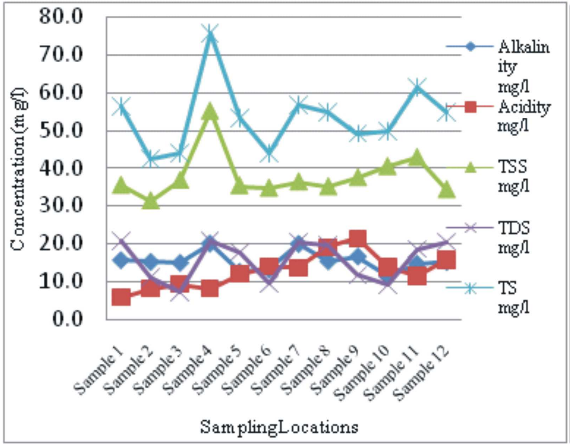


Figure 2: Distribution of Hardness

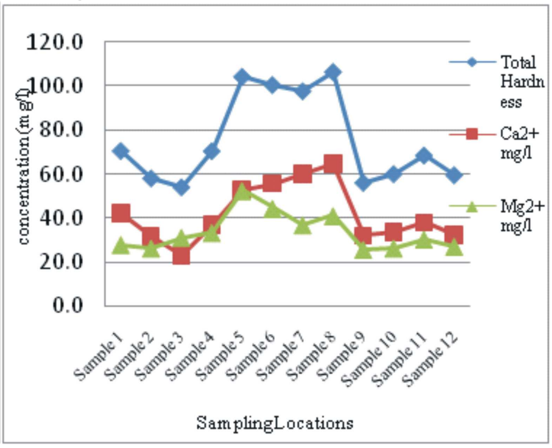


Figure 3: Distrbution of Oxygen Demands

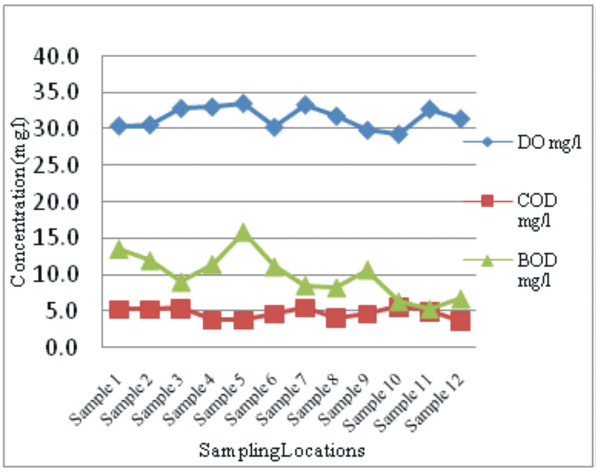
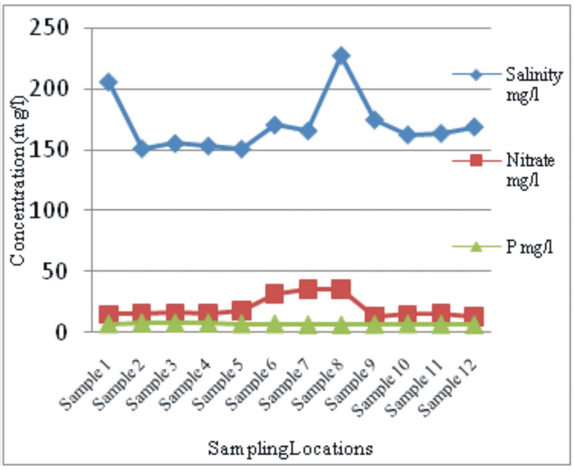


Figure 4: Distribution of Anions



CONCLUSION

The high level of non-metallic ion such as nitrate and phosphate of the borehole waters may be traced to dissociation of their metallic compounds, oxidation of other forms of the compounds, high degree organic pollution, and type of minerals in the bedrock, eutrophication, agricultural activities and use of detergents [33,25]. Nitrate concentration above 10mg/l is dangerous to pregnant women and poses a serious health threat to infants less than three to six months of age because of its ability to cause methaemoglobinaemia or blue baby syndrome in which blood loses its ability to carry sufficient oxygen [34]. This implies that the potable water in Umuahia North is polluted with organic and inorganic substances and therefore unfit for drinking at its present state.

High values of BOD and DO [35,25] shows that the water samples are polluted. Another evidence of pollution is the high level of Total Suspended Solids (TSS) and this indicate materials carried in suspended form [36]. Low level of total solids shows good quality borehole waters. The above result agrees with the reports of other researchers [37,38] in polluted water samples. Suspended solids in water can be removed by sedimentation or water filtration, followed by disinfection which renders pathogens ineffective.

All boreholes waters in this area should be treated according to the groundwater quality analysis of that particular borehole water to meet the various WHO parameter standards for portable water before releasing it to the public for consumption.

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