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Physico-Chemical, Microbiological and Mineral Quality of Selected Boreholes and Stream Waters in Elele Community, Rivers State, Nigeria West Africa

NA Okonkwo [a*], SN Awolo [b], OA Ikeh [a*], CE Anarado [a], VO Mgboh [b] and G Otobo [a]

[a] *Department of Industrial Chemistry, Nnamdi Azikiwe University, Awka, Anambra State, Nigeria.*
[b] *Department of Industrial Chemistry, Madonna University, Elele, Rivers State, Nigeria.*

Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

The analysis of the quality of drinking water from selected boreholes in Elele Community of Rivers State was conducted. The results obtained were compared with WHO standards. The physicochemical parameters values obtained were as follows: colour (all clear), pH (4.09 – 7.04 with mean value of 5.11. which is slightly acidic), temperature (24.5 -32.0 with mean value of 29.2), total dissolved solids (5-180 mg/l with mean value of 46.6 mg/l), conductivity (8-242 µs/cm with mean value of 63µs/cm), chloride (<1.0-24.7 mg/l), total hardness (<0.2 mg/l), calcium (<0.08), magnesium (<0.05mg/l), total alkalinity (4.0 – 8.0mg/l with mean value of 5.0), sulphate (<1.0mg/l), phosphate (<0.05 mg/l), and nitrate (<0.2 – 5.92mg/l), all of which did not exceed WHO standards, except for turbidity values in STN 7and 8 (5.51 and 7.40 NTU) which were slightly above the standard. For mineral analyses, Fe was in compliance with the standards, so also was Mn, except

**Corresponding author: Email: na.okonkwo@unizik.edu.ng, oa.ikeh@unizik.edu.ng;*

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for STN 1 and 2 (2.576 and 0.471ppm) which were slightly above the limits. For microbiological analyses, FCB and TCB were less than detection limit, while THB values (2.4 x 10^2 – 8.0 x 10^2 efu/ml) all exceeded the WHO limits for portable water, which is the major source of contamination of the water samples. However, these variations in the results were not too pronounced to cause serious health hazards, since most of the parameters analyzed met the WHO limit and others which did not meet were slightly above the limit. But, this does not rule out completely the need for appropriate treatment of these water sources for portability and safe drinking. Recommendations on the strategies to reduce/eliminate some of the pollutants in the water were made.

Keywords: Borehole; physicochemical parameters; standards; pollutants.

1. INTRODUCTION

"Water, after air, is the most essential commodity to the survival of life. Human life depends, to a large extent, on water" [1-5]. "Obviously, water is gotten from either of the two natural sources; surface water (fresh water, lakes, rivers, streams e.t.c) and ground water (borehole and well)" [6]. "Agricultural activities, soil erosion, drought, weathering of rocks, precipitation, dissolution of minerals, industrial activities, population growth are all natural and human activities that contribute to surface and groundwater contamination. Ground water is less polluted with emerging micro-pollutants than surface water" [7]. Environmental pollution by heavy metals and microbes is a threat to the environment and of public concern [8]. Contamination of water by petroleum and petrochemicals is on high increase due to their dependence as major source of energy worldwide [9]. When surfactants such as soap and detergents get in contact with drinking water and water bodies, they adversely affect the water [10]. "Water is used for an array of activities, chief among these being for drinking, food preparation, as well as for sanitary purposes. Water has been globally used for domestic, industrial and agricultural purposes" [11]. "A community lacking a good quality water will be saddled with a lot of health problems which could otherwise be avoided" [12-16]. "Water is a fundamental resource, integral to all environmental and social processes. Access to adequate safe drinking water is of prime importance to many governmental and international organizations, since, undebatable, it is the core component of primary health care and a basic component of human development, as well as a pre-condition for man's success to deal with hunger, poverty and death" [17]. There is a growing concern everywhere that in the coming century, cities will suffer imbalances in quality water supply, consumption and population. Many regions of the world are already limited by the amount and quality of available water. According to World Health Organization [18], "in the next thirty years alone, accessible water is unlikely to increase by more than ten percent, but the earth's population is projected to rise by approximately one-third. Unless the efficiency of water use rises, this imbalance will reduce quality water services, reduce the conditions of health of people and deteriorate the environment and the world. Although many international conferences as well as researches have held on in the past, little by way of success has been chalked so far". Report from World Health Organization [18,19] indicated that "over 2.6 billion people were still suffering from the effect of poor water around the world". "The growing demands for adequate quality water resources create an urgent need to link research with improved water management, better monitoring, assessment, forecasting of water resources and sanitation issues with much emphasis on the roles of stakeholders" [20]. "It must, however, be emphasized that adequate water quality needs seem to have improved greatly in some regions and countries, especially in the developed world; but for poor nations, this is still a major issue (Stockholm International Water Institute, SIWI, 2006). In order to meet the 2015 target of the United Nations Millennium Development Goals (MDG) on access to safe drinking water, therefore, it will require that countries create the political will and resources to manage water, especially in growing urban cities in Africa" [21].

2. MATERIALS AND METHODS

2.1 Sample Collection, Treatment and Preservation

Six different containers were used to collect water samples from six different boreholes in Elele community after rinsing them with water from their respective boreholes. All the samples were stored in the laboratory, freshly refrigerated at 4^0C in a cooler packed with ice blocks prior to analysis so as to avoid microbial action affecting their concentration.

2.2 Physicochemical Analysis

2.2.1 pH, temperature, TDS

These were carried out in situ at the site of sample collection using Hanna microprocessor meter.

2.2.2 Conductivity, turbidity

These were done using a conductivity meter and a turbidimeter, respectively.

2.2.3 Total Hardness (TH)

This was done using two drops of ammonia buffer and solochrome black indicator on 25ml of the sample, the sample solution was then titrated against a standard 0.01M EDTA solution to a blue end point.

2.2.4 Determination of calcium, Ca^{2+}

This was done using two drops of IN NaOH and murexide indicator on 25ml of the sample, the solution was titrated against a standard 0.01M EDTA solution to pink end-point.

2.2.5 Determination of magnesium, Mg^{2+}

Since total hardness is made up of calcium and magnesium, Mg2+ is obtained by the difference between total hardness and $Ca^{2+.}$

2.2.6 Alkalinity

This was done by adding two drops of methyl orange to 50ml of the sample, which was then titrated against a standard 0.02N H_2SO_4 to a red end-point.

2.2.7 Chloride, Cl^-

100ml of the sample was measured into a clean conical flask. 100ml of deionized water was also measured as a blank into another flask. 0.5ml of K_2Cr0_4 was added to both flasks, and the solutions titrated against a standard 0.0141N $AgNO_3$ to a red end-point.

> **Note:** The end-point is marked by a change in colour from yellow to red. All fluorescent lights are to be put off before titration for early recognition of end-point.

2.2.8 Phosphate, $P04^{3-}$

25ml of sample was measured into a flask, 25ml of distilled water was measured as a blank into another flask. 1ml of ammonia molybdate was added, and the initial value of the phosphate in the sample was measured using a spectrophotometer. Two drops of stannous chloride were added to the mixture and allowed to stand for about 5 minutes before the final absorbance was taken at 690nm.

2.2.9 Sulphate, $SO4^{2}$-

10ml of sample was measured into a flask, 10ml of distilled water was measured as black into another flask. 0.5ml of conditioning reagent was added to both, and the initial absorbance was measured using UV spectrophotometer at 420nm wavelength. A little barium chloride was added to the mixture and allowed to stand for 3 minutes, after which the final absorbance was measured.

> **Note:** At about 3 minutes of adding barium chloride, there will be a cloudy colour development in the sample, depending on the sulphate level.

2.2.10 Nitrate, $N0_3$

2ml of sample was measured into a test tube, 2ml of deionized water was measured into another test tube as blank. 2ml of 4+1 H_2S0_4 was added and allowed to cool. 0.2ml of brucine was added and the mixture heated in a water bath for 25 minutes. After cooling, absorbance was measured at 410nm wavelength using UV spectrophotometer.

> **Note:** When the 4+1 H_2S0_4 was added, sample became hot and was allowed to cool before brucine was added. After heating, a yellowish colour development confirmed the presence of nitrate in the sample.

2.3 Procedure for Bacteriological Analysis

2.3.1 Preparation of serial dilution

For 10^{-1} or $^1/10$ dilution, 1ml sterile pipette tip was used; 1ml aliquot from an inch below the surface was added and drawn to 9ml of sterile ringers i a test tube. This is the 10^{-1} dilution. For a 10^{-2} or $^1/100$ dilution, a fresh sterile pipette was used to mix the 10^{-1} dilution by drawing the suspension up and down ten times. 1ml of the 10^{-1} dilution was drawn and placed into another tube containing 9ml of the sterile ringer's solution. This is the 10^{-2} dilution.

2.3.2 Total viable count (for checking the total heterotrophic bacterial in water samples)

Using a fresh sterile pipette tip for each dilution aseptically, 1ml of dilution of water was added to each sample. The diluted water samples were placed into universal bottles containing molten plate count agar. The sample and agar were mixed by rotating the bottle between the palms, taking care not to form bubbles. The mixture was then poured into a sterile petri dish and incubated at 37^0C for 48 hours, after which the colony counter was used to count the number of micro-organisms on countable plates.

2.3.3 Total coliforms

Using a fresh sterile pipette tip for each aseptically, 1ml of each of the dilution of water samples was added to 5ml of MacConkey broth provided in the following ratios: 1ml of water samples to 3 tubes of MacConkey broth and 1ml of 10-1 dilution to 3 tubes of MacConkey. broth.1ml of the 10^{-2} dilution was also added to 3 tubes of MacConkey, and so on, up to the last sample. The bottle and tubes containing the Durham tubes for the collection of gas ensured that there was no gas in the inverted tubes before they were incubated. The samples were labelled and incubated at 37^0C for 48 hours. Tubes with gas in the inverted Durham tubes and change in colour from pink to yellow were observed to be positive, while those with no change in colour indicated negative.The colonies were counted using the colony counter and the result obtained.

3. RESULTS AND DISCUSSION

The physiochemical analysis results in Table 1 shows that the temperature range is 24.5 – 32.0ºC. These values meet the WHO standard and the water samples are potable for drinking purposes. This range has to be checked so that it does not go beyond this and enhance the growth of micro-organisms, and hence, taste, odour, colour and corrosion problem may increase. Metal corrosion problem is also associated with high temperature especially when the pH of the water is more acidic. The pH values obtained were between 4.09 – 7.04. All the samples except Alumini 2 were acidic and deviated from WHO standard. All the samples (apart from Alumini 1 which is surface water are groundwater; this shows that the groundwater of the area is slightly acidic (which could be as a result of poor digging of boreholes by using pipes that are highly corrosive) and acidic water results in corrosion of iron and steel materials (pipe and plumbing fixture), thus, the corrosion level of pipes and water storage materials will be high. The turbidity values ranged between 0.13 NTU and 7.40 NTU. This shows that all the samples apart from the surface water Alumini 1 and 2) met the WHO standard for portability, while others did not, but could be used from domestic and agricultural uses. The electrical conductivity for all the samples fell within the permissible limit of 1,000μs set by WHO) TDS values were generally below 250mg/l which is within WHO permissible limit. This represents the amount of inorganic substances (salts and minerals) present in water. High TDS gives unobjectionable odour or offensive taste. The result of TDS conforms to the regulatory standard; this explains the reason why the water were odourless. The alkalinity values of all the samples also conform to the standard. WHO International Standard for Drinking Water (1998) classified water with a total hardness of $CaCO_3$ less than 50mg/l as soft water, 50 – 150mg/l as moderately hard water, and above 250mg/l as hard $CaCO_3$. Based on these classifications, all the water samples analyzed are soft water, and are suitable for domestic use such as washing and drinking in terms of hardness. In the case of drinking water, the water has to be slightly hard, that is, it should contain Ca^{2+} and Mg^{2+} which make up hardness of water but in little amount. Ca and Mg are among the general elements essential for human health and metabolism and should be available in normal drinking water. However, if one or more of these elements occur in water above certain limits, the water may become objectionable to consumers and even hazardous to health. Phosphate and sulphate values were generally less than detection limit which implies that they were not found in all the samples. All samples showed values less than detection limit for chlorine, except for Wokoma and Roundabout. Nitrate values in the samples were also less than detection limit, except for Wokoma and Roundabout which had 5.02 and 5.36 respectively. The safe nitrate limit for domestic water is set at 50mg/l above which results in Methemoglobinemia, a disease caused by increased nitrate in the body.

Table 2 indicates; the absence of Faecal Coliform Bacteria (FCB) and Total Coliform Bacteria (TCB) which means that the samples met WHO standard, which means the water is portable. The Total Heterotrophic Bacteria (THB values ranged between 2.4 x 10^2 cfu/ml and 8.0 x 10^2 cfu/ml,

Table 1. Physico-chemical analysis results

S/n	Parameters	Wokoma	Roundabout	Madonna	Setraco	Healthcare	Vintage	Alimini 1	Alimini 2	WHO
1	Colour	Clear	Clear	Clear	Clear	Clear	Clear	5.82	7.04	Clear
2	pH	4.34	4.09	4.84	4.10	5.36	5.36	28.6	28.0	6.5-8.5
3	Temperature (ºC)	32.0	24.5	31.1	30.5	30.0	28.8	5.51	7.40	30-32
4	TDS	135	180	6	6	12	20	12	12	600
5	Conductivity (µS /cm)	179	242	8	8	16	27	9	5	1,000
6	Turbidity (NTU)	0.13	0.16	0.21	0.16	0.17	0.26	Clear	Clear	5
7	Total hardness (mg/l)	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	8.0	4.0	100-300
8	Calcium (mg/l)	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<1.0	<1.0	NS
9	Magnesium (mg/l)	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<1.0	<1.0	20
10	Alkanity (mg/l)	4.0	4.0	4.0	4.0	4.0	8.0	<0.2	<0.2	250
11	Chloride (mg/l)	14.8	24.7	<1.0	<1.0	<1/0	<1.0	<0.05	<0.05	250
12	Phosphate (mg/l)	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.08	<0.08	NS
13	Sulphate (mg/l)	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<0.2	<0.2	250
14	Nitrate (mg/l)	5.92	5.36	<0.2	<0.2	<0.2	0.1	<0.05	<0.05	50

NS =Not specified, >=less than detection limit

Table 2. Mineral analysis results

S/n	Parameters	Wokoma	Roundabout	Madonna	Setraco	Healthcare	Vintage	Alimini 1	Alimini 2	WHO
15	Mn(ppm)	2.576	0.471	<0.001	0.012	0.014	<0.001	<0.001	0.008	0.05
16	Fe (ppm)	<0.001	<0.001	<0.001	<0.01	<0.001	<0.001	0.163	0.308	0.3

Table 3. Microbial analysis results

S/n	Parameters	Wokoma	Roundabout	Madonna	Setraco	Healthcare	Vintage	Alimini 1	Alimini 2	WHO
1.	FCB (MPN/100ml)	Nile	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil
2	TCB (MPN/100ml)	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	0.2
3	THB (cfu/ml)	$3.2x10^2$	$8.0x10^2$	$3.6x10^3$	$3.5x10^2$	$8.2x10^2$	$2.4x10^2$	$4.7x10^3$	$3.5x10^2$	<100

which were above the recommended safe limit of 1.0 x 10^2 cfu/ml for drinking by WHO. Hence, the water samples were contaminated. The presence of coliform could be from surface runoff, seepage or discharge from septic tank. Contamination could also be from close proximity to toilets and dump sites (especially private boreholes). These pathogens which cause contamination can cause diarrhea, cramps, nausea, headaches and other special risks especially for infants. Hence, water from these sites requires some treatments to attain required WHO standard.

Table 3 shows Mn range to be 0.008 – 2.57 ppm and Fe 0.163-0.308 ppm. Mn concentrations in all samples were within WHO standard, except for Wokoma and Roundabout which had 2.576 and 0.471 ppm, respectively. Since these samples were from individual boreholes, possible pollution could be from proximity to toilets, dumpsites and construction sites like road construction. The concentrations of iron recorded were within WHO standard for all samples. Above this limit would result a high turbidity and brownish coloration of the water when allowed to settle.

4. CONCLUSION

The results in Table 1, 2 and 3 show that most of the results fell within the limits set by WHO and other water quality regulating bodies like FEPA. However, some of the parameters like turbidity, Mn and THB slightly deviated from the recommended standard, while Mn values (for Wokoma and Roundabout) were slightly high. The THB values also exceeded the WHO limits for drinking water which is the major source of contamination of the water samples. However, these variations were not too pronounced to cause serious health hazard, since most of the parameters analyzed met the WHO limit and others which did not meet were slightly above the limit. But, this does not rule out completely the need for appropriate treatment of these water sources for portability and safe drinking.

5. RECOMMENDATIONS

From the results obtained from the research, the following recommendations are made:

1. Proper borehole location is as well as good sanitation of environment and control.
2. Minimizing faecal pollution of wells within communities must be an integrated approach.
3. More surveys of water quality analysis should be carried out in the community.
4. Household treatment such as boiling should be encouraged before water from these sites (especially the stream water) is used for drinking purposes.
5. All water in this area should be treated according to various WHO parameter standards for portable water before releasing to livestock and the public for consumption.
6. The location and construction play a large part in reducing the contaminations in these wells, but do not guarantee that the water obtained from shallow well will be safe to drink.

There is the need for greater community participation in water management in these areas of the community where the study was conducted.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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