Comparative Assessment of Borehole Water Quality in Mgbom Community, Afikpo North Local Government Area of Ebonyi State

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ABSTRACT

This study was aimed at assessing the quality of selected public and private borehole water used in different locations at Mgbom community, Afikpo North, of Ebonyi state, Nigeria. The water samples collected were from four different boreholes; two from selected private boreholes (A and B) and two from functional public boreholes (C and D) in the area. The samples were analysed using standard analytical methods. One-way analysis of variance (ANOVA) and Tukey Post Hoc test for significant differences (at 0.05 significant levels) was also applied to the measured parameters. The results obtained were compared with the WHO standards for drinking water.The results revealed that Temperature(^{o}C) ranged from 29 – 33, pH (6.12 – 7.02), Electrical Conductivity (μS/cm) (8.40 – 18.20), Turbidity (NTU) (10.56 – 28.60), DO (mg/l) (161.20 – 194.00), BOD (mg/l) (40.40 – 74.40), Total Alkalinity (mg/l) (18.67 – 32.00), Total Hardness (ppm) (40.00 – 126.67), TSS (mg/l) (346.67 – 406.67), TDS (mg/l) (140.00 – 533.33), Cadmium (ppm) (0 – 0.006), Lead (ppm) (0 – 0.048), and Iron (not detectable) for all the water samples analysed. Regular monitoring of groundwater quality, abolishment of unhealthy waste disposal practices and introduction of modern techniques are recommended in order to ensure the availability of safe and potable water in the area.

KEYWORDS: Borehole water, physicochemical properties, heavy metals.

I. INTRODUCTION

Borehole water serves as the major source of drinking water in the local population of Nigeria, since purified and treated bottled water are not affordable by all (Akpoveta*et al.*, 2011). A borehole is a hydraulic structure which when properly designed and constructed, permits the economic withdrawal of water from an aquifer. It is a narrow well drilled with machine (Ukpong and Okon, 2013).

There is this common saying that "No life without water", because water is the essential requirement of all life supporting activities (Aktar and Moonajilin, 2017). Water is used numerous ways in a community, and the requirement in quantity and quality are varied. The uses of water include domestic use, public purposes, industrial purposes, agriculture purposes *etc*. (Aktar and Moonajilin, 2017).

In Nigeria alone, about 52% of the population lack access to safe drinking water and some industries lack access to pipe borne water, thus depend solely on groundwater (shallow, hand dug wells and boreholes) for their domestic and industrial use (Titilayo and Dahiru, 2018).

According to Ukpong *et al.* (2013) the provision of water in the past was solely a government affair; but the inability of the government to meet the daily demands of water for the people has forced some private individuals and communities to seek alternatives and self-help measures of providing water.

Drinking water standards are based on two main criteria, namely; the presence of objectionable tastes, odour and colour and; the presence of substances with adverse physiological effects (Titilayo and Dahiru, 2018).

Water is one of the most important natural resource for all kinds of life on the earth, but due to various activities, the quality and quantity of water adversely affected (Jigarkumar and Reddy 2016).The incidents of water borne diseases and epidemics nationwide resulting from drinking water of questionable quality have become a great concern; hence this study was conductedin order to assess the quality of selected public and private borehole water supplies in Mgbom community, Afikpo. The result of this study will help enlighten the general public, while environmental protection

agencies and related organizations will by this research become more proactive in the monitoring of some anthropogenic activities that might lead to pollution of water bodies.

II.   MATERIALS AND METHOD
Study Area
The study area wasMgbom community, Afikpo, Afikpo North Local Government Area of Ebonyi state, Nigeria. Its geographical location lies at the Longitude 7° 56' E and the Latitude 5° 53' N and its climate is Tropical monsoon climate (https://www.mindat.org/feature-2328926.html).

Water Sample Collection
The borehole water samples were collected from four different boreholes (two public and two private) within Mgbom community, Afikpo, using sterilized sampling bottles and were labeled accordingly as samples A, B, C and D. The samples were transported in ice bath to the laboratory for physicochemical analysis. The locations of the various selected borehole water samples are listed below:
Borehole sample A (private) – Sir Ogburubi's residence
Borehole sample B (private) – Chief Gary Enwo-Igariwey's residence

Borehole sample C (public) – AhiaOgoMgbom Community (at Gbamgbam)
Borehole sample D (public) – EcharaMgbom community

Sample Analyses
The physicochemical properties such as temperature, pH, Electrical Conductivity (EC), turbidity, total dissolved solid (TDS), total suspended solids (TSS), dissolved oxygen (DO), biological oxygen demand (BOD), total alkalinity, total hardness and Heavy metals (Cadmium, Lead and Iron) wereanalysed of the collected water samples using standard protocols and methods of American Public Health Organization (APHA) as described in Olubanjo *et al.* (2019); Okeke *et al.* (2018) and Rahmanian *et al.* (2015), and were compared with WHO drinking water standards.
Temperature**:** This was determined on-site using thermometer (mercury-in-glass thermometer).pH: pH was measured using pH meter OHAUS STARTER 3100C model.
Electrical Conductivity (EC):EC of the samples was measured using a conductivity meter; OHAUS STARTER 2100 model.
Turbidity: Turbidity of the water samples was measured using Lutron turbidity meter (Model Tu 2016)
Dissolved Oxygen (DO): DO was determined through titration.

$$D.O = \frac{Mole\ of\ titrant \times Normality\ of\ titrant \times 8000}{ml\ of\ sample}$$

Biological Oxygen demand (BOD): the procedure for dissolved oxygen determination was followed to get the dissolved oxygen for day 1 (DO_1) then the procedure was repeated after five days (DO_5) and the difference was calculated as the biological oxygen demand. The BOD_5 was calculated thus:
$$BOD_5(mg/l) = DO_1 - DO_5$$

Alkalinity: A 50 cm^3 burette was severally rinsed with 0.02 N HCl. The burette was filled with the HCl solution, making sure there were no air bubbles in the tip, and that the meniscus was readable at close to 0.00 cm^3 on the burette scale. Then50 cm^3 of the water sample to be analysed was measured into a 250 cm^3 Erlenmeyer flask. This was titrated to a bromocresol green (pH = 4.5) end point. The alkalinity was titrated using the formula below:

$$Alkalinity = \frac{Titre \times normality\ of\ HCl \times 50000}{Volume\ of\ sample\ used}$$

This is expressed in terms of milligrams of calcium carbonate per liter.
Total Hardness:The burette was filled with standard EDTA solution to the zero level, ensuring that there were no air bubbles. Then 20 cm^3 of the given water sample was pipette into a clean conical flask. 5 cm^3

ammonia buffer and 2 drops of EBT indicator were added and titrated against EDTA from the burette. The end point was indicated by the change of colour from wine red to steel blue.The titration was repeated to get concordant titre values.

Total hardness was calculated using the formula below, expressed in ppm
$$Total\ hardness = \frac{Volume\ of\ EDTA\ solution\ consumed\ X\ 1000}{Volume\ of\ water\ sample}$$

Total Suspended Solids (TSS):TSS was determined through filtration, oven-drying of the pre-weighed filter paper at103 ± 2 ^{o}Cand reweighing of the dried filter paperallowed to cool in a desiccator.

$$TSS = \frac{Weight\ loss\ (W_2 - W_1)\times 1000}{Volume\ of\ sample}$$

Where W_1 = Initial weight of filter paper, W_2 = Final weight of filter paper

Total Dissolved Solid (TDS):The water sample was stirred manually using stirring rod and a measured volume was taken onto a glass fiber. Then 50 cm^3 volume of the sample was measured into the weighed dried beaker (using previously dried filter). The beaker containing the suspended particles was put into the oven for 1 hour at 103 ± 2 ^{o}C to dry. This is allowed to cool in desiccators and weighed again to get W_2.

$$TDS = \frac{Weight\ loss\ (W_2 - W_1)\times 1000}{Volume\ of\ sample}$$

Where W_1 = Initial weight of beaker, W_2 = Final weight of beaker

Heavy metals: The analysis of Cadmium (Cd), Lead (Pb), and Iron (Fe) was conducted using Flame Atomic Absorption Spectrophotometer (Varian Spectra AA 55B model)according to the method of APHA (1995).

Statistical Analysis:
The determinations of the physicochemical parameters were done in triplicate. The data collected wereanalysed using One-way analysis of variance (ANOVA) employing the Statistical Package for Social Sciences (SPSS) version 23 at α = 0.05. Tukey post hoc test was also used to analyze the level of significance between various water quality parameters from the different boreholes under study.

III. RESULTS AND DISCUSSION
The results of the physiochemical and heavy metals assessment of the various borehole water samples are shown in the table 1 below. The results were also compared with the WHO standards for drinking water.

Table 1: Comparison of the mean ± standard deviation of the water quality parameters of various water samples with World Health Organization (WHO) standards

Parameter	Sample A	Sample B	Sample C	Sample D	WHO limit (2006)
Temperature (^{o}C)	31.00	33.00	31.00	29.00	25.00
pH	6.50	6.90	6.12	7.02	6.50 – 8.50
Turbidity (NTU)	23.40 ± 1.2	12.40 ± 0.3	10.56 ± 0.2	28.60 ± 1.1	5
EC (µS/cm)	12.10 ± 0.6	8.40 ± 1.4	18.20 ± 0.7	14.20 ± 0.1	400
DO (mg/l)	194 ± 2.3	161.20 ± 1.6	182.40±1.3	179.20±0.5	5 – 14
BOD$_5$ (mg/l)	44.40 ± 1.7	40.40 ± 2.2	64.40 ± 0.2	74.40 ± 2.6	NG
Alkalinity (mg/l)	25.33±2.31	32.00 ± 4.0	18.67±2.31	32.00 ± 4.0	100
Total hardness (ppm)	58.33±15.28	126.67±5.77	40.00±5.00	53.33±5.77	500
TSS (mg/l)	366.67±30.55	406.67±50.33	346.67±11.55	353.33±50.33	NG
TDS (mg/l)	280.00±52.92	533.33±185.8	140.00±34.64	235.33±30.55	500 – 1000
Cadmium (ppm)	0.006	0.002	ND	ND	0.003
Lead (ppm)	0.048	ND	0.029	0.022	0.01
Iron (ppm)	ND	ND	ND	ND	0.3

ND = Not detectable; NG = No guideline

The results shows that some of the water quality parameters either were exceeding the permissible values established by WHO or going below the average limits. The low level observed for some parameters may be as a result of low level of industrialization or lack of proximity to possible source of contaminants in the study areas.

Temperature: Water temperature is a physical and ecological factor that has important effect on both living and non-living components of environment of an ecosystem (Toure*et al.*, 2017). The temperature

of the various borehole water samples ranged between 29 °C to 31 °C with sample C having the least temperature, thiswas above the WHO permissible limit of 25 °C as shown in table 1. This was above the findings of Bernard and Ayeni (2012), and Ukpong and Okon (2013) whose range were 24.5 – 26.2 °C and 26.2 – 27.7 °C respectively, although the temperature was in agreement with the 30 – 30.33 °C obtained by Adekunle*et al.* (2007). This temperature range obtained this study may be as a result of the time of collection of the water sample or as a result of high biological activities thus placing high demand on the dissolved oxygen thus raising the temperature.

pH: Acidic water can lead to corrosion of metal pipes and plumping system. Alkaline water shows disinfection in water. The normal drinking water pH range mentioned in WHO 6.5 and 8.5 (table 1).The pH values of all the drinking water samples studied were within the range of 6.12 to 7.02°C with sample C being below the WHO permissible limit.In line with the findings of Aktar andMoonajilin (2017), the normal range for pH in surface water systems is 6.5 to 8.5 and for groundwater systems 6 to 8.5. Aktar andMoonajilin (2017) also opined that pH greatly affects biological activity. The pH was below the upper limit of 6.01 – 10.61 °C obtained by Tukura*et al*.(2013).

Turbidity: The standard recommended maximum turbidity limit set by WHO for drinking water is 5 nephelometric turbidity units (NTU). All the water samples where above the permissible standard as shown in table 1 and this may pose some health risks if the water is not properly treated before consumption. The range of turbidity (NTU) in the water samples was 10.56 – 28.60 NTU, which was above the 0.06 – 0.2 NTU and 1.2 – 2.4 NTU obtained by Olubanjo*et al*. (2019) and Bernard and Ayeni (2012) respectively.It was in agreement with the 3.33 – 42.12 NTU obtained by Adekunle*et al.* (2007) but not in conformity with the 0.2 – 544.0 NTU obtained by Sorlini*et al*. (2013).

There was a statistically significant difference ($p < 0.05$) in turbidity between groups as determined by one-way ANOVA ($F_{(3,8)} = 325.242$, $p < 0.001$). A Tukey post hoc test revealed that there was statistically significant difference between sample B (12.40 ± 0.3 NTU), sample C (10.56 ± 0.2 NTU) and sample D (28.60 ± 1.1 NTU) when compared with sample A (23.40 ± 1.2 NTU) ($p < .001$). But there no was statistically significantly difference between sample B and sample C ($p = .101$).

Electrical conductivity (EC): electrical conductivity is the ability of any medium; water in this case, to carry an electric current (Okeke*et al*., 2018). Table 1 showed that the EC of various water

samples were below the WHO permissible limit of 400 μS/cm. The sample's EC in all the samples was 8.40 – 18.20 μS/cm, this was lower than the range of values (126 – 143 μS/cm) gotten by Bernard and Ayeni (2012). It was also below the 290 - 694 μS/cm observed byMohsin*et al*. (2013) suggesting that the water samples have less amount of dissolved ions.

There was a statistically significant difference ($p < 0.05$) in EC between groups as determined by one-way ANOVA ($F_{(3,8)} = 71.273$, $p < 0.001$).

Dissolved Oxygen (DO): The result showed high levels of DO across the four water sample (table 1). These were all higher than the WHO standard of 5 to 14. High DO level in a community water supply is good because it makes drinking water taste better. However high dissolve oxygen levels speed up corrosion of water pipes. The DO of various borehole water studied ranged from 161.20 – 194.00 mg/l, this was above the 3.00 – 5.03 mg/l observed by Adekunle*et al*. (2007). Also Okeke*et al*., (2018) got lower range of values (43.04 – 76.80 mg/l). Titilayo*et al*. (2018) attributed the highest DO value (2.70 mg/l) obtained for the borehole water source from three Senatorial Areas (Kaduna, Kafanchan and Zaria) in Kaduna State, Nigeria to aeration process during water treatment.

The statistical analysis of DO showed a statistically significant difference ($p < 0.05$) between groups as determined by one-way ANOVA ($F_{(3,8)} = 226.059$, $p < .001$). A Tukey post hoc test however revealed that there wasno statistically significant difference between samples C and D ($p = .133$).

Biological oxygen demand (BOD$_5$): Research has revealed high BOD$_5$of borehole water sourcesare indices of organic pollution. Sample D (74.40 ± 2.6 mg/l) had the highest BOD$_5$; this is also evident with its marked increase in turbidity when compared with the other samples. According toAdekunle*et al*. (2007), drinking water sources should have BOD less than 3mg/l. BOD is set at less than 10 mg/l to prevent odour caused by the anaerobic decomposition of organic matter and water with BOD$_5$ less than 4 mg/l is of good quality and levels greater than 10 mg/l are polluted as reported by Environment Canada. BOD$_5$of various samples is shown in table 1. Titilayo and Dahiru (2018) opined that the DO and BOD results after five days (BOD$_5$) found within the range of 0.30 - 2.70 mg/l and 0.001 - 0.009 mg/l respectively, suggests that the water from the whole area is less polluted by organic matter and they could support aquatic life.

The statistical analysis of BOD showed a statistically significant difference ($p < 0.05$) between groups as determined by one-way ANOVA ($F_{(3,8)} = 230.936$, $p < .001$). A Tukey post hoc test revealed

that there was no significant difference between sample A (44.40 ± 1.7 mg/l) and sample B (40.40 ± 2.2 mg/l, p = .097).

Total Alkalinity: alkalinity in drinking water is defined as its capacity to neutralize acid. The alkalinity values of various borehole water samples were below the WHO standard of 100 mg/l as shown in table 1. Samples C and D showed higher alkalinity values of 32.00 mg/l each and conformed to the pH which is 6.90 and 7.02 respectively when compared with samples A and B that are slightly acidic. The Total Alkalinity of the water samples was in the range of 18.67 – 32.00 mg/l, which was within the range (5.0 – 48.00 mg/l) observed by Okeke*et al*. (2018), although Bernard and Ayeni (2012) got higher values (74.3 - 88.2 mg/l).When water has high alkalinity it is concluded that it is well buffered. It resists a decrease in pH when acidic rain snowmelt enters it. If water has an alkalinity below about 100mg/l as $CaCO_3$, it is poorly buffered and pH sensitive. This could be harmful to the plants and animals that live there,(Bernard and Ayeni, 2012).

There was a statistically significant difference (p < 0.05) in alkalinity between groups as determined by one-way ANOVA (F(3,27) = 11.458, p = 0.003). A Tukey post hoc test revealed that there was no statistically significant difference between sample B (32.00 ± 4.0 mg/l, p = 0.134), sample C (18.67 ± 2.31 mg/l, p = 0.134) and sample D (32.00 ± 4.0 mg/l, p = 0.134) when compared with sample A (25.33 ± 2.31 mg/l).

Total Hardness:total hardness is due to the presence of bicarbonates, chlorides and sulphates of calcium and magnesium ions. The total hardness (table 1) of various water samples were below the WHO permissible limit of 500 ppm. Sample B showed the highest value which is 126.67 ppm and the least was 40 ppm in sample C. Bernard and Ayeni (2012) reported the range of hardness analysed as 68.0 - 73.8 mg/l and fell below WHO standard of drinking water. Depending on the interaction of other factors, such as pH and alkalinity, water with hardness above approximately 200 mg/l may cause scale deposition in the treatment works, distribution system and pipe work and tanks within buildings. Soft water, with a hardness of less than 100 mg/l, may have a low buffering capacity and so be more corrosive for water pipes, (Bernard and Ayeni, 2012).

The statistical analysis showed a statistically significant difference (p < 0.05) between groups as determined by one-way ANOVA (F(3,8) = 55.684, p < .001). A Tukey post hoc test revealed that sample C was however not statistically significantly higher than sample A (p = .133). Also, there was no

statistically significant difference between sample C and sample D (p = .335).

Total Suspended Solid (TSS):there was no WHO guideline for TSS. However, the highest value 406.67 mg/l was found in water sample B whereas the least value 346.67 mg/l was found in sample C as shown in table 1. These values were higher than the 0 – 4.00 mg/l and 0.67 – 69.33 mg/l observed by Olubanjo*et al*. (2019) and Adekunle*et al*. (2007) respectively.

There was no statistically significant difference (p > 0.05) between groups as determined by one-way ANOVA (F(3,8) = 1.413, p = .308). A Tukey post hoc test however revealed that sample C was statistically significantly lower than sample B and sample D (p = 0.05).

Total Dissolved Solids (TDS):TDS are the inorganic matters and small amounts of organic matter, which are present as solution in water (Okeke*et al*., 2018). The allowable value of the TDS set by WHO is 500 – 1000 mg/l. All the water samples were below the WHO threshold limit, with sample B having the highest value 533.33 mg/l, and sample C (140 mg/l) being the least, this was within the range of 100 – 330 mg/l observed Olubanjo*et al*. (2019). The values obtained were also higher than the values reported by Tukura*et al*. (2013) for some selected borehole water in the vicinity of public health facilities in Nasarawa State, Nigeria.

There was no statistically significant difference (p > 0.05) between groups as determined by one-way ANOVA (F(3,8) = 8.373, p = .008). A Tukey post hoc test revealed that sample C was statistically significantly lower than sample B and sample D (p = 0.05).

Heavy Metals Analysis: The presence of heavy metals in drinking water higher than a certain concentration can be detrimental to human health.

Cadmium occurs naturally in rocks and soils and enters water when there is contact with soft groundwater or surface water. Moreover, it may be introduced by paints, pigments, plastic stabilizers, mining and smelting operations, and other industrial operations such as electroplating and fossil fuel, fertilizer, and sewage sludge disposal (Rahmanian*et al*., 2015).

The level of cadmium in sample A was 0.006 ppm which was above the 0.003 ppm WHO permissible level and may pose health risk. This high concentration may be attributed to the rocky nature of the study area. Sample B was 0.002 ppm which was below the WHO threshold limit. However, there was no detectable Cd in samples C and D as shown in table 1. Cadmium (Cd) in water samples as reported by Olubanjo*et al*. (2019) had a mean of 0.0025 ppm at dry season as against a mean of 0.003

ppm during the wet season; this was below the amount detected in private borehole sample A. Adekunle*et al*. (2007) detected the concentration of Cd in the groundwater near dumpsite of a typical rural settlement in Southwest Nigeria to be in the range of 0.30 – 0.78 mg/l and 0.24 – 0.34 mg/l for dry and wet season respectively. These elevated concentrations in their study were attributed to anthropogenic influence (Adekunle*et al.*, 2007)

The levels of lead (Pb) in sample A, sample C and sample D were 0.048 ppm, 0.029 ppm and 0.022 ppm respectively as shown in table 1, but there was no detectable amount of lead in sample B. These were above the 0.01 ppm threshold limit set by WHO and may pose serious health risks on bioaccumulation. The range of concentrations of Pb in the drinking water of Logone Valley (Chad-Cameroon)reported by Sorlini*et al*. (2013) was 0.01 – 1.52 mg/l in which the upper limit was above that detected in various water samples in this study. The concentration of Pb reported by Adekunle*et al*. (2007) was also higher when compared with the values determined in this study. However, Olubanjo (2019)reported a lower range(0 – 0.01 ppm) of concentration of Pb fromborehole and well water used in Akungba-Akoko, Ondo state, Nigeria.

There were no detectable traces of iron in various borehole water samples in this study. Although Akpoveta*et al*. (2011) reported a range of 0.045 – 0.065 mg/l iron in borehole water used in the vicinities of Benin, Edo State and Agbor, Delta State of Nigeria.

Variations in some physiochemical parameters suggest that there is the need for continuous monitoring of the borehole water quality, especially for heavy metal levels which may be affected by change in pH. There were no marked differences in the quality of water samples from the private boreholes (A and B) and public boreholes (C and D) although sample A had higher loads of heavy metals thus rendering it unsafe for drinking and other household uses.

IV.   CONCLUSION

Safe drinking water is vital to sustain life and a potable supply must be available to all. The results of water quality parameters such as pH, Electrical Conductivity, Total Alkalinity, Total Hardness, TDS, TSS and iron (heavy metal) from all samples collected from various private and public borehole water sources were within the WHO recommended limits for drinking water. Some parameters like Turbidity, temperature, Dissolved Oxygen and Heavy metals(Cadmium and Lead) exceeded the WHO recommended limits in some of the water samples making them unsafe for drinking

without proper treatment. Therefore, there is the need for continuous monitoring of the borehole water quality, especially for heavy metal levels which may be affected by change in pH.

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