Bacteriological and Physicochemical quality of Borehole water used for drinking at Olusegun Agagu University of Science and Technology, Okitipupa, Nigeria

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Abstract— *The concern over exposure to drinking water contaminants and the resultant adverse effects on human health has prompted several studies evaluating the quality of drinking water sources at Olusegun Agagu University of Science and Technology (OAUSTECH). Six (6) Borehole water samples were collected from three (3) functional boreholes in OAUSTECH. Two water samples from each borehole were collected using standard techniques. The physicochemical parameters analyzed include, odor, color, taste, temperature, pH, conductivity, alkalinity, total dissolved solid, total hardness and chloride. All physicochemical parameters of the Borehole water samples were shown to be within recommended permissible limit of WHO and NAFDAC standard for potable drinking water. The bacteriological analysis of the three borehole water samples were carried out using the Most Probable Number technique (MPN). From the analysis BH1, BH2 and BH3 tested negative for total coliforms and fell within the recommended limit of WHO and NAFDAC standard for drinking water. This study has shown that water from the boreholes at Olusegun Agagu University of Science and Technology is safe for drinking. However, good and proper environmental and personal hygiene must be maintained especially by the users of these boreholes to prevent their contamination with bacteria pathogen. Boreholes should also be properly constructed with good understanding of site locations.*

Keywords— *Boreholes, Bacteriological analysis, physicochemical analysis, potable water.*

I. INTRODUCTION

Water is essential for the existence of humans and all living things and hence a satisfactory (adequate, safe and accessible) supply must be available to all. Water used for domestic purposes must be clean and not contain any microorganism, parasites and other substances which can pose danger to human health [1], [2], [3]. Safe water supply and sufficient sanitation to secure health are among the essential human rights. However, many people do not have access to safe drinking water and risk to waterborne diseases is a critical public health problem in many developing countries [3]. So securing safe drinking water for all is one of the significant difficulties of the 21st century. In a recent report, close to a billion people mostly living in the developing world do not have access to adequate and safe drinking water [3].

Control of the microbial quality of drinking water should be a priority in all countries, given the immediate and potentially devastating consequences of waterborne infectious diseases [4]. Contaminated water serves as a mechanism to transmit communicable diseases such as cholera, typhoid and guinea worm infection [5] [3]. Around 88% of diarrhea cases worldwide are linked to unsafe water, inadequate sanitation or insufficient hygiene. Most cases of diarrheal illness and death occur in developing countries with an estimated annual incidence of 4,600 million episodes and cause 2.2 million deaths every year [1]. Almost 6.1 billion people (89% of the world population) have used an improved drinking water source. This is 1% more than the 88%

Millennium Development Goal target [6]. Improved sources of drinking water in developed countries has reached 99%. In contrast, in the developing world – especially in sub-Saharan countries – the coverage is still low (63%) with 51% and 84% coverage rates among rural and urban populations, respectively. Moreover, above 40% of all people globally who lack access to safe drinking water live in sub-Saharan Africa [6]

Water is a key component in determining the quality of our lives. Although water covers about 70 percent of the earth's total surface, only 0.3% of it can be used by humans [7]. Among the various sources of water, ground water is the largest reservoir of drinking water, it is that water reservoir found in the saturated part of the ground underneath the land surface. It normally accumulate there when the water seep into the ground and move downward due to gravity through the pore spaces found between soil particles and crack in rock. The water eventually reaches a depth where the soil and rock are saturated [8]. Ground water is an important source of water supply with a number of advantages;It is commonly free from pathogenic organism due to infiltration and requires little or no treatment; turbidity and colour are generally absent and Its chemical composition is almost stationary [9]. Despite this advantage, ground water is susceptible to pollution as a result of recent or past human activities [10]

Water from boreholes may be free from dangerous water - related human diseases such as cholera, typhoid fever, dysentery, guinea worm and many others. Borehole water is ground water available in an aquifer obtained by installing a pump to draw the water to the consumers. Any contaminated surface water with pathogen that infiltrates into the soil and becomes groundwater would be filtered by the soil profile before reaching the depth of aquifer. An aquifer is saturated water bearing stratum that is capable of holding, transmitting and yielding sufficient water in underground to well. The major problems of boreholes is chemical content of the ground water, which must be analyzed to ascertain if these dissolved products are within the permissible limits for consumption purpose by the authorities such as the World Health Organization [11]. Many diseases in developing countries are caused by drinking contaminated water [12]. Quality of drinking water is fast becoming an essential aspect of water quality studies [12]. Therefore, the provision of potable water to the rural and urban population is necessary to prevent health hazards [13]..Certain minerals are also toxic such as the heavy metals. Though some of the heavy metals such zinc, manganese, nickel and copper act as micro-

nutrients at lower concentrations, but become toxic at higher concentrations [14].. Health risk due to heavy metal contamination of water through soil has been reported. Therefore, auditing and monitoring of physicochemical, minerals and microbial until very recently ground water has been thought of as being a standard of water purity in itself and to a certain extent that is indeed true [15] .Groundwater pollution which is a product of human activities had profound impacts on the quality of water bodies due to the introduction of various pollutants such as organic compounds, heavy metals, agricultural waste, etc [16] Various studies confirmed the effect of heavy metals on the human health[17] Suitability of water for various uses depends on the type and concentration of dissolved minerals and ground water has more mineral composition than surface water.[18] The quality of ground water is constantly changing in response to daily, seasonal and climatic factors. Continual monitoring of water is highly crucial because changes in the quality of water have far reaching consequences in terms of its effects on man and biota[19].Contamination of ground water also depends on the geology of the area especially in limestone where extensive cavern systems are below the water table [14]. The changes in quality of groundwater response to variation in physical, chemical and biological environments through which it passes [20]. To safeguard the health of people and to reduce to the barest minimum experiences of drinking and/or using of low quality waters, it is necessary that the quality of water should be monitored with the view to finding lasting solutions to health problems associated with the use and drinking of low quality waters. Both liquid and solid waste materials dumped either on soil surface or buried are known to decompose to produce leaches that penetrate aquifers and contaminate the ground water thereby raising the potential toxicity of the water to consumers [21]

Burying and surfaces dumping of both industrial and domestic wastes are a common practice among rural and urban dwellers [22].[12] have described bore hole as a source of potable drinking and domestic use water for rural and urban population. [23] have explained that in order to understand the quality of borehole water, the physical, chemical and microbiological parameters must be analyzed. The quality of ground water however, principally depends on the elements present in it while seeping down. The World Health Organization (WHO) has set a quality guideline for drinking water and recommends that the properties of every drinking water should fall within the acceptable limit set by it [1]. The quality of water is assessed in terms of its

physical, chemical, biological characteristics, and it's intended uses. For example, although distilled water is physically, chemically and bacteriologically pure, its taste is rather bland and it is highly corrosive [24]. It has been demonstrated repeatedly that water containing some dissolved constituents is far more palatable than pure water. Water quality varies for different purpose in every daily activity [18]. Water quality standards are standards established to determine whether water of a certain quality is suitable for its intended use. All portable water must confirm to these standards [1].

At Olusegun Agagu University of Science and Technology Okitipupa, there is not enough data on the bacteriological quality of water from boreholes sources in the university. Thus, evaluation of the bacteriological quality of these water sources will provide benchmark data about the bacteriological status and might enable insight into the development of further protective and treatment measures. Furthermore, information obtained from the present study might help in maintaining borehole hygiene and determine the sources of contamination possible to prevent outbreak of water borne diseases among the students which might prove very fatal as the population of the University is getting higher with each admission year. Therefore, the evaluation of groundwater quality is essential for the development of civilization and to establish database for future water resources strategic planning and development. Studies on groundwater have been carried out in different parts of Nigeria; however, no comprehensive study has been conducted on the groundwater quality in Okitipupa, ondo state.

II. MATERIALS AND METHODS

2.1 Sample collection
Six (6) borehole water samples from OAUSTECH study area were collected. Two (2) samples were collected from each borehole. The samples were taken from borehole of average depth 25-85 meters. All samples were collected in clean one (1) liters plastics container stored and transported in a cool box at a very low temperature into the microbiology laboratory and analyzed within 2 hours of collection.

2.2 Physicochemical Analysis
The water samples collected were analyzed for pH, temperature, odour, colour, taste, turbidity, electrical conductivity, alkalinity, acidity, total suspended solid, total dissolved solid, total hardness and chloride

2.3 Temperature Determination

This is the degree of coolness and hotness of a system. It is an important physical parameter, determined because of its effect on living organism. Usually the temperature of polluted water is higher than the water supply due to eutrophication process and geographical location which heat up the water. This was conducted at the site of sample collection using mercury in glass thermometer

2.4 pH Determination
The pH of the water samples was determined using the Wagtech pH meter. 10ml of each of the samples was poured into a sterile beaker and the anode of the pH meter was dipped into it and readings were obtained when it was stable.

2.5 Determination of Colour, Odour and Taste
A 20ml volume of each water sample was poured into a clean beaker. The sample was then shaken vigorously to check for any frothing and allowed to settle. Colour was determined through visual examination and those odours were determined through the sensation of smell.

Taste test was determined by putting a small volume of the water sample in the tongue and then immediately raised with distilled water (taste free) after sample.

2.6 Determination of Turbidity
The digital turbidity meter (2100P) was switched on, allowed to warm up for 30 minutes. It was set at zero NTU (Neplometric turbidity unit). The cell (60ml) was rinsed with distilled water and filled with 60ml of the water sample. The side of the cell was wiped with a tissue paper to clean the digital meter and after shaking for 20 minutes. The samples were inserted in the compartment. The selection button was turned to the appropriate turbidity range 0-10. The turbidity was then read off directly on the digital meter. The value was obtained and recorded in Nepholometric turbidity units.

2.7 Determination of Total Hardness
Total hardness was analyzed by titration of 50ml water sample into conical flask and 0.1ml of buffer solution was added or with standard EDTA. The EDTA was added in drops at pH 10 using Erichrome black I indicator and was gently shaken until the colour change into purple, and the hardness was calculated by multiplying the average number of drops of EDTA used for the sample by the calibration factor of 20.

2.8 Mohr Method Determination of Chloride
The Mohr method uses chromate ions as an indication in the titration of chloride ion with a silver nitrate standard solution. After all the chloride has been precipitated as white sulphur chloride, the first excess of titrant results in the formation of a silver chromate precipitate which signal the end points.

The reactions are:

$Ag^+ + Cl^- \rightleftharpoons AgCl_{(s)}$ White precipitate

$2Ag^+ + CrO_4^{2-} \rightleftharpoons Ag_2CrO_{4(s)}$ Yellow precipitate

25ml of the Bore Hole water sample was measured and put into a conical flask and the pH of the sample was measured or adjusted, 1.0ml of the potassium chromate indicator solution was added and the solution were titrated with standard silver nitrate solution (0.02N until the pinkish yellow and point was observed. The normality of the silver nitrate end point was observed. The normality of the silver nitrate used here is 0.0141N (blank) [25].

2.9 Determination of Electrical Conductivity

A 20ml of volume of each sample was poured into a clean beaker at room temperature. The conductivity meter (Wagtech Electrode) was switched ON for 10 minutes to standardize. The Wagtech Electrode was then rinsed with distilled water and was placed in the beaker containing the Bore Hole sample, and following stirring, the electrical conductivity values was determined after the pointer and the selector knob were adjusted, the reading was taken and recorded.

2.10 Determination of Total Dissolved Solid (TDS)

This is the term used for material residue that dissolves in water. Water with suspended solid may be aesthetically unsatisfactory for domestic purpose such as laundry, bathing, also water with high concentration of dissolved solid is unsuitably not potable for drinking and as well as for agriculture and industrial application or purpose. The total dissolved solids were determined by submersing the Wagtech probe into 100ml of each sample which the reading is taken and recorded.

2.11 Bacteriological Analysis

The coliform count was obtained using the 5 tube assay of the Most Probable Number (MPN) technique as described by [25]. The MPN technique for faecal coliform testing is useful in determining the faecal coliform density in most water. The technique is based on the most probable number of bacteria present in a sample [25].

2.12 Presumptive Test

Presumptive coliform test was performed using Macconkey broth. The first set of 5 test tubes had sterile 10ml double strength broth and the second 5 tubes and third sets of 5 tubes had 10ml of single strength broth. The test tubes are arranged in a row in three test tube racks. Each of the tubes contained Durham tubes before sterilization process was carried out using the autoclave.

Before sterilization all the test tubes containing the broth and Durham tubes were closed with non-absorbent cotton wool

and then sealed with aluminum foil paper. After autoclaving for 15 minute at a temperature of 121^0C and pressure of approximately 1.1 kg/cm^3. The test tube were removed from the autoclave and allowed to cool to room temperature before the borehole water samples were aseptically transferred to the sterilized tubes. The first sets of test tubes for the double strength received 10ml each of the borehole water sample and for the second and third sets of test tubes for the single strength received 1ml and 0.1ml of the borehole water sample respectively using sterile pipettes. The tubes were incubated at 15^0C for 24-48h for estimation of total coliform and at 44.5^0C for faecal coliform for 24-48h and examined for acid and gas production. Acid production was determined by colour change of the broth from reddish purple to yellow and gas production was checked for by entrapment of gas in the Durham tubes. A combination of positive tubes at each inoculum was compiled and the MPN index/ 100ml of water samples were estimated using the MPN table.

2.13 Confirmed Test

Confirmed test was carried out by transferring a loopful of culture from the positive tube from the presumptive test into a tube of Brilliant Green Lactose Bile (BGLB) broth (Oxide) with Durham tubes. The tubes were incubated at 37^0C for 24-48h for total coliform and 44.5^0C for faecal coliforms and were observed for gas production.

2.14 Completed Test

To establish the presence of coliform bacteria and to provide quality control data, the positive tube from the confirmed test was carried out by streaking a loopful of broth from a positive tube onto prepared Eosine methylene Blue (EMB) agar and prepared nutrient agar plate for pure colonies. The plates were inoculated at 37^0C for 24-48h. Colonies developing on EMB agar, were further identified as coliform or faecal coliform, using cultural characteristics, morphology and biochemical tests. For faecal coliform, colonies with green metallic sheen were Gram stained and the IMVIC test was carried out on Nutrient agar stock cultures and used to identify the colony.

2.15 Identification of Bacterial Isolates

Stock cultures of the isolates with different cultural characteristics were made on nutrient agar slants. Gram staining was used to check for morphology and biochemical tests were performed to aid in identification. Various tests performed and used in probable identification of isolate.

III. RESULTS AND DISCUSSION

3.1 Results

The sanitary assessment of the boreholes used are as shown in Table 1 while the result obtained from the physicochemical and bacteriological analysis of borehole water in OAUSTECH are shown in Table 2.

Table 1: Sanitary Assessment of the Sampling Location

Sample Site	Physical Appearance	Proximity To Drainage	Proximity To Sewage Tank	Proximity To Refuse Dump Site
BH1	Clean	Far	Far	Close
BH2	Clean	Far	Far	Far
BH3	Clean	Close	Close	Far
BH4	Clean	Close	Far	Far

Keys:-

BH   - Borehole   close ≤ 15 meters from pollution source

BH1   - Borehole at Car park   far ≥ 20 meters from pollution source

BH 2 - Back of ICT block

BH 3 - Microbiology laboratory

Table 2: Bacteriological and Physicochemical Parameters of water from sampled Boreholes.

	Parameters							
	pH	Electrical Conductivity (μS/cm)	Temperature (^{0}c)	Total dissolved solid(ppm)	Alkalinity Mg/L	Total hardness (ppm)	Chloride Mg/L	Most probable number (MPN/100ml)
Borehole 1	6.50	50.7μs/ cm	35.8^{0}c	3.52mg/L	0.20mg/L	10.77mg/L	69.00	0
Borehole 2	7.20	179.6μs/ cm	32.1^{0}c	0.10mg/L	53.40mg/L	151.06mg/L	1.37	0
Borehole 3	6.80	11. 2μs/ cm	30.7^{0}c	22.77mg/L	28.50mg/L	151.00mg/L	5.10	0
WHO guideline	6.8–8.5	≤ 400 μS/cm	25 - 39	<1000	20 - 200	< 500	≤ 250	0

3.2 Discussion

Table 1 revealed the sanitary assessment of the sampling locations, all the locations of the borehole water samples were clean. However, serious efforts should be made to maintain and sustain this level of hygiene as dirty environment can pollute the underground water and also lead to high prevalence of diseases like cholera, typhoid fever etc. which lead to high mortality rate. The table also showed that the appearance of all the borehole water sample is clear, it was also odourless, tasteless and colourless and they fell within the World Health Organization and National Agency for Food and Drug Administration and Control (NAFDAC) standard for drinking water. These could be due to the absence of particles and non- accumulation of solid and slits. Colour in natural water usually result from leaching of organic materials and is primarily the result of dissolved and colloidal humic substance, primarily humic acid and fluvic acid. However the overall colour do not pose any health threat to those that use the water.

Table 2 showed the various biological and physico-chemical parameters measured to ascertain the potability of water from sampled boreholes. The pH value ranged from 6.5 to 7.9, which falls within the recommended standard for drinking water standard. Water is said to be safe of the concentration

of the substance do not exceed the level set by the regulatory bodies.this is consistent with results obtained by [27]. The World Health Organization [28] recommends a pH value of 6.5 or higher for drinking water to prevent corrosion. Although, a pH above 8.0 would be disadvantageous in the treatment and disinfection of drinking water with chlorine [29]. However, pH values between 6.5 and 8.5 usually indicate good water quality and this range is typical of most drainage basins of the world [30]

The Temperature of any water body affects the rate of proliferation of micro- organisms[16]. The Temperature values ranged from 30.7 to 35.8^0c, falling within the recommended permissible level of WHO and NAFDAC standard for drinking water standard of $25 – 39^oC$ as the temperature varies across different regions of the world. high temperature negatively impact water quality by enhancing the growth of micro-organisms which may increase taste, odour, colour and corrosion problems [28]. Therefore, it is important that groundwater temperature is not too high in order not to have microbial proliferation. Temperature affects biological, chemical and physical activities in the water [30]. Besides, increase in temperature of water decreases solubility of gases such as O_2, CO_2, N_2 and CH_4 [30]

The conductivity value ranged from 11.2 to $179.6 \mu s/cm$ falling within the recommended standard, of WHO and NAFDAC for drinking water standards, indicatives of the absence of dissolved minerals and presence of some ions in low levels, thus conductivity was well below the standards of the regulatory bodies and therefore fell within the permissible limit for potable drinking water. Conductivity of the groundwater for the entire study area stands at an average of 80.5 µS cm-1 and it is in accordance with the findings of [31] which submit that values within the permissible WHO standards give a picture of very little solute dissolution generally in the groundwater, rapid ion-exchange between the soil and water, or basically a poor and rather insoluble geologic rock and mineral types.

The values for Alkalinity ranged from 0.20 to 53.4 mg/L which fell within the WHO and NAFDAC recommended standard for drinking water. Total dissolved solid values ranged from 0.27 to 22.77mg/L which fell within the permissible level recommended standard of WHO and NAFDAC. The total suspended solid values ranged from 0.02 to 3.52mg/L, fell within the recommended standard by the regulatory bodies. The Total Hardness of water is not a specific constituents but is a variable and complex mixture of

cations and anions. Principally the water hardness are changed by ions such as calcium and magnesium. The total hardness from the bore hole water samples analyzed ranged from 3.30 to 151.06 mg/L fell within the permissible level of WHO and NAFDAC standard for potable drinking water from the result the total hardness analyzed is either soft or moderately hard .Soft water are associated with rickets in children and have been found to be statistically related to high mortality from cardio vascular diseases. Very hard water is not good for drinking and is associated with rheumatic pains and goiter [32]

The bacteriological analysis using Most Probable Number technique (MPN), showed that only all the Borehole water samples were free from the presence of coliforms which probably might have resulted from the clean environment. Potable water should be totally devoid of coliform. Borehole water samples from BH1a, BH1b, BH2a, BH2b, BH3a and BH3b all fell within the recommended standard of WHO and NAFDAC standard for drinking water standard have no presence of coliform. This results corroborates the finding of [17] that the MPN coliform index per 100ml of water sample collected from selected Bore Holes in Ilorin metropolis ranged from 0 to 16 MPN/ 100ml. The presence of total coliforms in groundwater indicates that the groundwater sources may be vulnerable to contamination by more harmful microorganisms hence the water samples are all fit for human consumptions as they have no such coliforms. This result coincides with the results of [33]; [34] [34]]8] who all posited that except groundwater is contaminated, it should be naturally free from faecal coliform and fall to the 0MPN/100ml standard recommendation by the WHO.

IV. CONCLUSION

Temperature, pH, conductivity, total dissolved solids, alkalinity and electrical conductivity, of groundwater in OAUSTECH were studied. Temperature values are consistent with tropical belt, it can be considered as being ambient relative to the geographical region and good enough in terms of supporting microbial growth. Average pH is slightly acidic and indicates susceptibility of metals and pipes to easy corrosion problems. The values of Electrical conductivity and total dissolved solids give a measure of the ionic load and contaminants in the water. Hence, from the EC and TDS values, the groundwater of this study area can be said to have low salt concentration and good for drinking

and crop production. Furthermore, the pH and EC values infer that the water is clearly not saline and suggest its possible likelihood for irrigation agriculture. Although, other factor like Sodium Absorption Ratio (SAR) and Residual Sodium Carbonate (RSC) of the groundwater will have to be studied. Meanwhile, findings suggest that the groundwater in this aquifer is fresh. All parameters clearly fell below WHO international best standards for water quality.

Therefore, from results of this study, the groundwater in the study area can be regarded as being of good quality for drinking and agriculture purposes with reference to the parameters under consideration, although with little pH treatment because of its slight acidity. However, further studies with reference to the chemical and microbial analyses will have to be done to have a broader picture of this water quality.

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