



## Physicochemical and Microbial Evaluation of Selected Residential Borehole Water Samples in Awka, Anambra State, Nigeria

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### Authors' contributions

This work was carried out in collaboration among all authors. Author VHAE designed and supervised the study. Author PEO managed the analyses of the study and literature searches while author UCO wrote the protocol and first draft of the manuscript. All authors read and approved the final manuscript.

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### ABSTRACT

Water is very important to the existence of humans though could also serve as vehicle for pathogenic organisms and dangerous organic and inorganic matters. The physicochemical and microbial analyses of selected borehole water samples in Awka residential areas were conducted with the aim of ascertaining suitability or otherwise for human consumption. The total hardness, pH, alkalinity, some common elements and presence of toxic metals were determined by standard methods of American Public Health Association. The presence of microorganisms in the water samples was also determined. Results of the physicochemical analysis of the borehole water samples showed a mean pH value of 5.52 below the WHO standard of 6.5 - 8.5 and mean total hardness of 150 ppm greater than the WHO standard of 70 ppm. The microelements such as manganese, zinc, lead, selenium, nickel and cadmium were found to be below detectable levels in the water samples. Five bacteria species were isolated and identified in the water samples as *Staphylococcus epidermidis*, *Pseudomonas aeruginosa*, *Enterobacter aerogenes*, *Escherichia coli*

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and *Klebsiella pneumoniae*. The physicochemical properties and the bacteria load of most of the water samples indicate that they were unfit for human consumption as the samples were outside WHO reference standard for potable water suggesting a need for increased awareness for improved sanitation and hygiene practices in the state.

**Keywords:** Water; physicochemical; microbial; human consumption; hygiene.

## 1. INTRODUCTION

Water as a basic requirement of life constitutes 80-85% of the body's composition and serves as a milieu for most of the biochemical processes necessary for metabolism and growth. It is fundamental to sustaining life on earth. Without it, almost all water-dependent forms of life would be stalled. Safety and purity as water quality indices require that water is free from contamination and void of impurities, which is essential for human consumption.

The World Health Organization in a situation analysis reported that 1.1 billion people have no access to potable water and that this population reside in the Middle Asia and sub-Saharan African regions of the world [1,2]. According to the UNICEF report in 2015, approximately 663 million lacked improved drinking water sources and some 946 million people still practice open defecation thus undermining efforts at sustainable health improvements [3]. In Nigeria alone, 53% of the populace in rural and 28% in urban areas have no access to improved water sources [4]. Consequently, an estimated more than two million deaths occur due to incidents of water borne diseases and more than four billion cases of diarrhea are recorded annually [1,5].

Besides, water borne diseases, there is also the burden of heavy metal poisoning in water bodies, which contributes to high mortality associated with impure water consumption in humans. Heavy metals are defined as metallic elements that have a relatively high density compared to water. In biological systems, heavy metals have been reported to affect cellular organelles and components such as cell membrane, mitochondrial, lysosome, endoplasmic reticulum, nuclei, and some enzymes involved in metabolism, detoxification, and damage repair [6]. Metal ions have been found to interact with cell components such as DNA and nuclear proteins, causing DNA damage and conformational changes that may lead to cell cycle modulation, carcinogenesis or apoptosis. With the assumption that heaviness and toxicity

are inter-related, heavy metals have been reported to induce toxicity at low levels of exposure [7].

The fast growing trend of industrialization, technological advancement, urban-rural migration, increased urban activities [8], poor sanitation and hygiene habits have further exacerbated this ugly scenario. The spate of water-borne diseases and heavy metal poisoning has raised a public health concern because of the indispensable role that water plays in human existence. The World Health Organization recommendation that quality of potable water remains at a standard of 99.9% behooves the need for the evaluation of groundwater/borehole water bodies in our immediate environment if sustainable millennium goals of water, sanitation and hygiene were to be attained.

Considering the fact that the study area, Awka is a densely populated city and capital of Anambra State, South-East Nigeria, home to a vast student and working elite population drawn from different walks of life and major source of drinking water is the underground borehole, incidence of poor sanitation habits, lack of enforcement of environmental sanitation laws and agricultural activity have contributed immensely to the pollution of water bodies in the city, and thus necessitated for a physicochemical and microbiological evaluation of selected water borehole samples in order to determine the portability of these water sources if outbreaks of water-borne diseases and metal-induced disorders were to be curbed.

## 2. MATERIALS AND METHODS

### 2.1 Sample Collection

A total of 10 water samples from different borehole locations in residential buildings were randomly selected from within and around Awka metropolis. These were collected into sterile containers under aseptic conditions and moved to Springboard Chemical Laboratories, Awka, for analysis.

## 2.2 Physicochemical Analysis

Water samples were analyzed in accordance to the standard methods of the American Public Health Association [9]. Physical parameters such as odour and colour were evaluated by sensory perceptions and spectrophotometric methods respectively. Water pH was determined by electrometric method using pH meter Hanna Model [9], electrical conductivity was carried according to APHA 2510B guideline model DDS-307 [9] while Total solids (total suspended and total dissolved) were determined by evaporation to dryness in a desiccator to constant weight. Total water and calcium hardness were estimated using  $\text{NH}_3$  as buffer and titrated with 0.01N EDTA solution with 3 drops of Solochrome black as indicator [9]. Sulphate was estimated by evaporation to dryness and weighing of sample in a crucible while Nitrate and Phosphate were determined spectrophotometrically according to the methods as described by APHA [9].

## 2.3 Heavy Metal Analysis

Heavy metal analysis was conducted using Varian AA240 Atomic Absorption Spectrophotometer (AAS) according to the method of APHA [10]. Exactly 100ml of sample was transferred into a glass beaker of 250 ml volume and 5ml of concentrated nitric acid was added. The mixture was heated to evaporation until the volume was reduced to about 20 ml. Nitric acid was added in increments of 5 ml till the residue was completely dissolved. The mixture was cooled and then made up to 10 ml using metal free distilled water. The sample was aspirated into the oxidizing air-acetylene flame of the AAS while the sensitivity for 1% absorption was observed.

## 2.4 Microbial Analysis

According to the methods of Bezuidenhout et al. [11], bacteriological characteristics were profiled. Total bacterial count was done on the samples by ten-fold serial dilutions, plating on nutrient agar plates, incubating at  $37^\circ\text{C}$  for 24 hours and developing colonies enumerated. Total coliform was determined using membrane-filter technique in a two-step enrichment procedure according to the method of APHA [9]. Morphological and biochemical identification tests such as gram reactions, catalase test, motility test, indole test, Methyl Red/Voges-Proskauer (MR/VP), fermentation tests (glucose, sucrose, fructose,

maltose, lactose, Simmon's citrate agar test) were also conducted as confirmatory tests of the various isolates in the water samples.

## 2.5 Data Analysis

Data was subjected to statistical analysis using Statistical Package for Social Sciences (SPSS) International Business Machines (IBM) version 23.0 (SPSS Inc., Illinois Chicago, USA) and presented as mean $\pm$ SD of triplicate determinations.

## 3. RESULTS AND DISCUSSION

The work studied physicochemical and microbial characteristics of borehole water sources in the study area. The physicochemical values of the various indices are presented in Table 1. It showed a mean pH value of 5.52 indicating a lower pH level than the WHO standard acceptable limit of 6.5 - 8.5. Lower pH value of water is not good for consumption as it can be corrosive and exacerbate existing skin conditions [5,12]. On the other hand, consuming water of elevated pH levels can cause skin, eye and mucous membrane irritation [5]. Thus our finding of a mean pH value of 5.52 is not in agreement with WHO recommendation for potable water and so is unfit for consumption due to the potential health effects over a long period of time. However, to avert this effect would require water treatment measures so as to increase the pH to an acceptable level.

From the result of the study as shown in Table 1, water hardness was found to be 150 ppm which indicates a far greater value than the WHO acceptable limit of 70 ppm. Water hardness is a property in water that indicates the concentration of calcium and magnesium found in water. Even though calcium is required for building strong bones and teeth, it can be obtained from other dietary sources and not necessarily from water [5]. This implies that water with detectable calcium levels is not pure and eliminates the requirement of purity for water. Also the presence of calcium in these water samples at high concentrations indicates that it cannot be used for domestic purposes because it will not lather well with soap.

The total dissolved solid of the water samples were within acceptable WHO limit of less than 250 mg/l. Total dissolved solid in drinking water has been associated with natural sources,

sewage urban runoff, industrial waste water and chemical used in water treatment processes [13,14]. The total dissolved solid is a secondary drinking water standard as it poses no health hazard [15].

Electrical conductivity is a measure of water capacity to convey electric current. It indicates the amount of total dissolved salts. In the present study, mean electrical conductivity in the water samples was found to be 204  $\mu\text{S}/\text{cm}$ , within the WHO acceptable limit of  $<500\mu\text{S}/\text{cm}$ . High conductivity values in water implies the presence of high amounts of dissolved inorganic substances in ionized form [15].

The Phosphate concentration was found to be 40.261 mg/l which was beyond the WHO acceptable limit of less than 2mg/l while the sulphate concentration was 344.84 mg/l which was much greater than the WHO range of less than 200mg/l. The presence of phosphate in water may be as a result of domestic sewage, detergents, agricultural effluents with fertilizers and industrial waste water while sulphate concentration may be due to leaching from gypsum and other common minerals [16]. This may predispose the residents to health hazards associated with consuming high concentrations of phosphate and Sulphur. In the present study, the water samples can be said to be unsafe for human consumption owing to these observations. This then calls for prompt measures for proper disposal of agricultural, industrial and domestic wastes.

Heavy metals are any metallic chemical elements that have relatively high density compared to water [5,7,17]. They tend to bioaccumulate in biological matter over time and can induce toxicity at low levels [5,18]. Health hazards due to heavy metal toxicity include mental and Central Nervous System (CNS) dysfunction, muscular dystrophy, Parkinson's disease, multiple sclerosis, organ-specific damage etc. [19,20]. In the present study as shown in Table 1, mercury, chromium, iron, copper, cobalt, silver, aluminum, molybdenum, sodium, potassium, arsenic and magnesium were all within the WHO acceptable limits while cadmium, lead, nickel, magnesium, and selenium exceeded WHO reference standards. Previous studies have shown contamination of water bodies with these heavy metals such as lead,

arsenic and cadmium [19,21,22]. Lead and cadmium can affect enzyme function in biochemical systems for example alkaline phosphatase, alcohol dehydrogenase, carbonic anhydrase in the case of cadmium exposure and marked porphobilinogen synthase activity in lead poisoning.

The findings of the microbial analysis as presented in Table 2 showed a total coliform count (cfu/ml) for the borehole water sample is 184 cfu/ml and the WHO standard for bacteria in potable water states this is unacceptable because WHO standard of potable water states that no coliform should be present in any drinking water. From these data, the borehole water is unsafe and unsuitable for drinking. Total coliform bacteria are known as "indicator organisms" meaning that their presence provides indication that other disease causing organisms may also be present in the water body. They are the commonest bacteria responsible for a range of water-related diseases such as typhoid, dysentery, diarrhea etc. with global mortality attributed to its consumption especially in Africa [1,5,23]. There is urgent need for further treatment of water from this study area before they can be used for drinking and other domestic uses.

The mean of the total Bacterial count (TBC) as shown in Table 3 for the borehole water sample is 17 cfu/ml. The total bacteria count should not be more than 100 cfu/ml [24]. The presence of bacteria counts exceeding the WHO limits indicated that the water samples contain bacteria that could make the water unsafe for drinking and domestic purposes. The high values obtained could be due to poor environmental conditions and the presence of stagnant water around the borehole which provide an excellent breeding ground for bacteria.

All five isolates from the culture agar were subjected to preliminary identification tests and results are shown in Table 4. The detection of *Staphylococcus epidermidis*, *Pseudomonas aeruginosa*, *Enterobacter aerogenes*, *Escherichia coli*, and *Klebsiella pneumoniae* in borehole water samples that are intended for human consumption is a cause for concern. These isolates may pose severe health complications to humans especially if they harbour virulence gene determinants.

**Table 1. Physicochemical analysis of borehole samples and WHO standards**

Measured parameters	Mean +/- Standard deviation	WHO Standard	Pass/Fail
pH	5.52 +/- 0.04	≤ 6.5- 8.5	Fail
Conductivity	204 +/- 2.00	≤ 500 $\mu$ S/cm	Pass
Temperature	28.5 +/- 0.50	-	-
Hardness	150 +/- 2.00	≤ 70ppm	Fail
Alkalinity	28.75+/- 1.25	-	-
Acidity	81.25 +/- 1.75	-	-
Chloride	141 +/- 1.00	≤ 200 mg/l	Pass
Sulphate	344.84 +/- 0.40	≤ 200 mg/l	Fail
Phosphate	40.26 +/- 0.00	≤ 2 mg/l	Fail
Total dissolved solid	0.17 +/- 0.01	≤ 250 mg/l	Pass
Total solid	1.20 +/- 1.00	≤ 250 mg/l	Pass
Nitrate	4.87 +/- 0.17	≤ 10 mg/l	Pass
Mercury	0.00 +/- 0.00	≤ 0.03 ppm	Pass
Cadmium	0.05 +/- 0.00	≤ 0.01 ppm	Fail
Chromium	0.00 +/- 0.00	≤ 0.005 ppm	Pass
Zinc	5.60 +/- 0.26	≤ 5 ppm	Fail
Iron	0.00 +/- 0.00	≤ 1.00 ppm	Pass
Copper	0.02 +/- 0.03	≤ 1.00 ppm	Pass
Cobalt	0.00 +/- 0.00	≤ 1.00 ppm	Pass
Lead	0.58 +/- 0.00	≤ 0.05 ppm	Fail
Nickel	0.48 +/- 0.08	≤ 0.03 ppm	Fail
Manganese	0.07 +/- 0.04	≤ 0.05 ppm	Fail
Silver	0.00 +/- 0.00	≤ 0.05 ppm	Pass
Magnesium	0.08 +/- 0.07	≤ 10.00 ppm	Pass

*Data are expressed as Mean +/-SD*

**Table 2. Total bacterial count of borehole samples**

Sample	Number of sites	Mean (plate count) $10^{-1}$
Borehole water	10	17 cfu/ml

**Table 3.Total coliform count**

Water sample	Number of colonies on plate	Number of colonies per 100 ml	Nature of colonies	Isolates
Borehole water	92	184	Purple with black center and green metallic sheen	D
			Pink, mucoid looking colonies	E
			Colouless looking colonies	C
			Pink, glistening colonies	B
			White, irregular circular colonies	A

**Table 4. Morphological and biochemical identification of the various isolates from the water samples**

Isolate	Form	Surface	Colour	Margin	Elevation	Opacity	Gram	Cat	Mot	Ind	MR	VP	Cit	Lat	Glu	Suc	Fru	Mal	Identity
A	Circular	Smooth	White	Irregular	Flat	Rough	+	+	-	-	-	-	-	+	+	+	+	+	<i>Staphylococcus epidermis</i>
B	Circular	Smooth	Whitish	Entire	Convex	Translucent	-	+	+	-	-	-	+	-	-	-	-	-	<i>Pseudomonas aeruginosa</i>
C	Circular	Shiny	White	Entire	Convex	Moist	-	+	+	-	-	+	+	+	+	+	+	+	<i>Enterobacter aerogenes</i>
D	Circular	Smooth	Whitish	Entire	Convex	Translucent	-	+	+	+	+	-	-	+	+	var	-	-	<i>Escherichia coli</i>
E	Irregular	Glistening	Cream	Entire	Raised	Opaque	-	+	-	+	+	-	+	+	+	+	-	+	<i>Klebsiella pneumoniae</i>

Key: Gram: Gram reaction; Cat: Catalase test; Mot: Motility test; Ind: Indole test; MR: Methyl-red test; VP: Voges-Proskauer test; Cit: Citrate Utilization test; Lac: Lactose Fermentation; Glu: Glucose Fermentation; Suc: Sucrose Fermentation; Fru: Fructose Fermentation; Mal: Maltose Fermentation; +: Positive; - :Negative; var: Variable

#### 4. CONCLUSION

The study revealed heavy contamination of borehole water sources in the study area due to presence of microorganisms and heavy metals. This has become a major constraint to attaining the United Nations Sustainable Development Goals of 2015 as any outbreak of water borne diseases would impact on the quality of lives and concomitant effect on the economy. It then becomes imperative that strategies and efforts aimed at curbing this public health challenge should aim at government enforcement of established Water Acts and regulations and community participation and protection for improved quality. It should also include education on water treatment, best management practices for agriculture and efficient pit latrine siting. This would ensure sustainable safe and quality potable water for both human and animal consumption.

#### CONSENT

As per international standard or university standard, respondents' written consent has been collected and preserved by the author(s).

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#### COMPETING INTERESTS

Authors have declared that no competing interests exist.

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