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Physicochemical and microbiological analysis of borehole water in Ihiagwa Local Government Area of Imo State, Nigeria

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ABSTRACT

The bacteriological and physicochemical properties of 3 samples of borehole water collected from the Federal University of Technology hostels at Ihiagwa in Imo state were determined and contrasted with the WHO permissible limit. The study results indicated the presence of TCC and TTCC at 37 °C and 45 °C respectively. The values of TCC and TTCC in all the samples exceeded the WHO limit (0.00E+00± 0.00E+00). However, the value of TFCC in all the samples met the WHO standard. The means separation achieved using Turkey HSD showed that the means of TCC and TTCC of sample C were significantly different from those of samples A and B statistically at 5%. The physicochemical parameters showed that the samples were slightly acidic. They fell outside the acceptable pH limits by WHO and NIS (6.5 – 8.5). The study also showed that turbidity and total suspended solids (TSS) were not detected in any of the samples analyzed. Total dissolved solids were generally low across all the samples and fell within the WHO-approved standard limits of 500 mg/l. This shows that the borehole water in the area was quite fresh in the locations. The electrical conductivity (EC) for all samples fell within the permissible limit of 500 µS/cm set by WHO. From the analysis, it was observed that the electrical conductivity of the samples increased with increasing total dissolved solids. The study concluded that borehole water sources in the study area were polluted and unsafe for human consumption. The study recommended that water quality analysis should be carried out on all the boreholes in the hostels regularly. This will ensure that incidences of contamination are noticed earlier for remedial action to be taken, to minimize acute problems of water-related diseases, which are endemic to human health.

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1. INTRODUCTION

Water is a vital resource for the continued existence of all living species, including humans. Therefore, a sufficient, safe, and easily accessible water supply must be accessible to everyone (Adeyemi, 2020). Ensuring access to clean water and adequate sanitation to protect health are fundamental human rights. Yet, many individuals lack access to potable water, making waterborne infections a crucial public health issue in many developing nations (Khalid *et al*., 2018). Universal access to safe drinking water is a major challenge in the 21st century. An analysis by Khalid *et al*. (2018) reveals that almost one billion individuals, primarily residing in poor countries, lack sufficient and safe access to potable water. The provision of accessible and uncontaminated fresh water is of utmost importance in attaining sustainable development and making substantial contributions to health, food production, and poverty alleviation.

Water can be obtained from several supply sources, including oceans, rivers, lakes, springs, ponds, precipitation, and subsurface (boreholes). In the context of water sources, borehole water is widely acknowledged as being more suitable and often meets the criteria of high-quality water due to its lack of exposure to the water contaminants commonly found in surface water (Mgbemena *et al*., 2014). In modern times, borehole water has emerged as the primary source of water in African countries, including Nigeria. Groundwater accounts for almost 20% of the total freshwater. The significance of groundwater rests not only in its broadly distributed occurrence and availability but also in its persistent good quality, which makes it an ideal supply for drinking water (UNESCO, 2006 in Alexander *et al*., 2019). However, groundwater supplies are under a major threat due to growing interest in mechanized agriculture practices, increasing population density, rapid urbanization, and home and industrial uses. Groundwater provisions are often unsustainable because of poor water productivity of wells, drying of wells after extended drought, and sometimes due to poor water quality (Xu and Usher, 2006 in Alexander *et al*., 2019).

Waterborne infections remain a major source of mortality and sickness in impoverished countries (Manetu & Karanja, 2021). Underground water can be contaminated from sources such as damaged septic tanks, pit toilets, sewage disposal, leachates from inorganic fertilizer applications, and erosion debris, thus containing pathogens or non-pathogenic microorganisms (Altalhi & Alrooqi, 2024). Pathogenic bacteria present in water result in the transmission of infectious diseases such as dysentery, cholera, diarrhea, typhoid, and various other bacterial infections (Mgbemena and Okwunedolu, 2015). Water-related health problems are a big human tragedy and according to WHO kill more than 5 million people a year with children being in most danger. The World Health Organization suggests that diarrheal diseases account for roughly 4.1% and deaths of 1.8 million persons of the total daily global burden of disease yearly. Further estimates imply that 88% of the burden is due to inadequate water supply, sanitation, and hygiene and is largely concentrated on children in developing nations (Ordia & Saidu, 2023). Nevertheless, adults are not exempted from the disease's wrath.

To safeguard the health of the student population, it is necessary to monitor the physiochemical and bacteriological quality of water supplies in the study area to highlight the quality of water supply. Conformity with bacteriological requirements is of great concern because of the propensity of water to spread diseases within the population. Thus, this study aimed at the bacteriological and physicochemical analysis of borehole water, to ascertain its safety for consumption when compared to standards set by the World Health Organization (WHO) for drinking water. Specifically, it sought to; assess the level of faecal and total coliform in samples, determine the coliform counts (most probable number) of the water samples, and determine the levels of physicochemical parameters in the borehole water: pH, turbidity, total suspended solids, total dissolved solids (TDS), and electrical Conductivity.

2. MATERIALS AND METHODS

This study was carried out at the Federal University of Technology located at Ihiagwa, Imo State, Nigeria. Two on-campus hostels (A and E) and an off-campus hostel were randomly selected systematically for this study. Hostel A is located between longitude 5º23´14” N and latitude 7º0’3” E, hostel E is located between longitude 5º23’15” N and latitude 7º0’8” E, while the off-campus hostel lies between longitude 5º23’32” N and latitude 7º0’13” E.

Figure 1. Satellite imaging of the study area (Google satellite).

2. 1. Sample Collection

Water samples were collected from boreholes used by students in hostels A, E, and off-campus as a source of water for domestic purposes such as cooking, bathing, drinking, washing, and performing ablution. Water was pumped out of the boreholes at a very fast rate to cool the metal pipe to eliminate the influence of the water temperature with that of the metal pipe. The pumping was sustained for at least five minutes.

The sample container was rinsed with some of the water and then filled leaving no air space and immediately covered. The cover of the container was then sealed with masking tape. Following this procedure, a total of 9 water samples were randomly collected from 3 boreholes selected in the study area using a systematic random sampling technique. Samples from the boreholes were collected using l50cl plastic bottles in triplicate and the water samples were well labeled and transported in black polyethylene bags to Silverpresh Microbial Laboratory, Owerri, Nigeria. The environmental sanitation condition around the borehole was taken into consideration. The human activity around the borehole as well as the underlying topography was noted. Thorough chemical and biological analyses were carried out on all the samples. The parameters analyzed from the samples are pH, turbidity, TSS, TDS, conductivity, total coliform count, and *E. coli* counts.

2. 2. Physicochemical analysis

2. 2. 1. pH determination

The pH meter was calibrated with 4.0, 7.0, and 10.0 pH buffers. A 100 ml aliquot of each sample was measured into a beaker and the pH was determined using a pH meter (Yilkal et al., 2019). This was done in situ.

2. 2. 2. Conductivity determination

The conductivity meter was standardized with 0.01N KCl solution. 100 ml sample of water was measured into a beaker and its conductivity was determined with the WTW conductivity meter within two hours of sampling. The determinations were made at room temperature.

2. 2. 3. Total dissolved solids (TDS) determination

A 50 ml well-mixed sample was measured into a beaker. The WTW TDS/Conductivity meter probe was immersed in the sample and its conductivity was recorded.

2. 2. 4. Turbidity determination

This was done using the microprocessor turbidity machine whereby the machine was calibrated with the standard (Kitchener, 2019). A 10 ml bottle of the water sample was collected and inserted into the machine's sample compartment and the values were read.

2. 2. 5. Total suspended solids (TSS) determination

TSS was determined using a gravimetric method by weighing the filter paper, the filtration apparatus was placed with the weighed filter paper in a beaker, and a mixed water sample was poured into a graduated cylinder to the selected volume (50 ml). 100 of the samples were filtered with filter paper and then transferred into an evaporating dish and oven to dry at 105 °C for 1 hour. The dried filter paper and evaporating dish were transferred into a desiccator and allowed to cool. Then weigh the filter paper and residue.

2. 3. Microbiological Analysis

2. 3. 1. Enumeration of total coliform count

Analysis of the coliforms was achieved using the pour plate technique. The water samples in the sterile bottles were inverted repeatedly twenty times using a 1000 ml micropipette, and 100 ml was inoculated into a sterile petri dish. The inoculum was overlaid with sterile molten McConkey agar 15 mls and rotated using to and fro/circular movement. The inoculated plates were inverted and inoculated at 37 °C for 24 hours using an incubator. Pink colonies that developed were counted and reported as colony-forming units of the samples analyzed.

2. 3. 2. Enumeration of *E. coli* (faecal coliform)/thermotolerant coliform

In achieving this, the pour plate technique was adopted. The water samples in the sterile bottles were inverted repeatedly twenty times. 100 mls of the samples were inoculated into a sterile petri dish. The inoculated plates were overlaid with sterile molten Eosin Methylene blue agar (15 mls) and rotated using to and fro/circular movement. The inoculated plates were inverted and incubated at 45 °C for 48 hours using an incubator. Typical *E. coli* colonies which appear as purple colonies with a green metallic sheen were counted and reported as *E. coli*/faecal coliform count. In contrast, other colonies that developed together with *E. coli* were counted and reported as total thermo-tolerant coliform because they could grow at 45 °C within 48 hours.

2. 4. Data Analysis

Data obtained for physicochemical and microbial analyses were recorded and analyzed using the Statistical Package for Social Science (SPSS) version 21. Mean and standard deviations were calculated for the three samples per sampling site. The average water quality results were compared with that of the World Health Organization drinking water standard for reference.

3. RESULTS AND DISCUSSION

3. 1. Bacteria counts cfu/ml of the water samples analyzed

From the analysis total coliforms counts, thermotolerant coliforms counts, and *Escherichia coli* counts were used as a measure of the level of microbial contamination of the water samples, while coliforms were used as an indicator of faecal contamination of the samples, total coliform counts are non-specific for faecal contamination while *Escherichia coli* (faecal coliform) counts are specific. All the water samples analyzed recorded high bacteria counts above the permissible limits approved by WHO.

Bacteria counts cfu/ml of the samples analyzed as shown in Table 1 below reveals that total coliform counts ranged from 2.05E+00 ± 3.54E-01 to 8.50E-01 ± 2.12E-01, total thermotolerant coliform counts ranged from 1.95E+00 ± 7.78E-02 to 3.50E-01 ± 2.12E-01, total *Escherichia coli* counts ranged from 0.00E+00 ± 0.00E+00 to 0.00E+00 ± 0.00E+00. However, the highest coliform counts were observed in samples from A (Hostel 1) (8.50E-01 ± 2.12E-01), highest thermotolerant coliform counts were from samples obtained from C (off camp) (3.50E-01 ± 2.12E-01) while the *Escherichia coli* counts were the same in all the samples across the sampling locations (0.00E+00 ± 0.00E+00). The mean separation to determine if the mean bacteria counts were significantly different across the samples was achieved with the aid of Turkish HSD. The results showed that the mean TTC of sample C was significantly different from that obtained in A and B statistically at 5%. Similarly, the mean TTCC of sample C was significantly different from that obtained in A and B statistically at 5%, while there was no significant difference in the mean of TFCC across all the samples.

Among the coliform counts analyzed, the results showed that the lowest coliform counts were as follows: total coliforms 2.05E+00 ± 3.54E-01 from samples obtained from C (off-campus), thermotolerant coliforms 1.95E+00 ± 7.78E-02 from samples obtained from A (Hostel 1) and *Escherichia coli* (faecal coliforms) recorded no counts in all the samples from the sampling stations. From the table, only the *Escherichia coli* counts test from the three samples met the WHO standard, however, the results of other parameters (total coliform, thermotolerant coliform counts test) did not meet the WHO standard. The results of this present study are in agreement with the findings of Mgbakor *et al.* (2011); Abiodun *et al.* (2013); Aleru *et al.* (2019); Onuorah (2019) who reported high total coliforms above the permissible limits approved by WHO. According to the WHO standard for portable water, total coliform counts should be 0/100 mls, and *E. coli* counts, be 0/100 mls, though the water samples passed the faecal coliform test (*E. coli*). Since the water samples failed the total coliform test and the total coliforms are still pathogenic, it poses a public health threat.

The coliform counts are indicators of faecal or sewage contamination of the water samples (Li *et al.*, 2021). The detection of coliforms in the samples implies that such water samples may have been contaminated by faecal matter, possibly from sewage, agricultural runoff, or improperly maintained water systems and as such were not safe for consumption (WHO). This contamination indicates poor sanitation practices and inadequate water treatment infrastructure. Banseka & Tume, (2024) suggest that bacteria in the coliform group cause varying degrees of ill health resulting from waterborne diseases such as gastroenteritis, diarrhea, dysentery, cholera, hepatitis, typhoid, etc and this counts for the high level of typhoid fever in developing countries such as Nigeria as a result of drinking contaminated water. The research stresses the fact that there is an impending action required to make water treatment and monitoring systems efficient. To reduce the risk of contamination and protect the public, some measures can be undertaken such as improving the sanitary facilities, provision for safe waste disposal coverage, increasing the frequency of water source treatment, and quality control of the water (Omarova *et al.*, *2018*, Pal *et al*., 2018).

Table 1. Bacteria Count of Borehole Water Samples (CFU/ml)

Parameters	**Water Samples**			
	A	**B**	**C**	**WHO Standard**
TCC (@37 °C)	8.50E-01± 2.12E-01[a]	6.00E-01± 1.41E-01[a]	2.05E+00± 3.54E-01[b]	0.00E+00± 0.00E+00[a]
TTCC (@45 °C)	1.95E+00± 7.78E-02[a]	2.36E+00± 6.22E-01[a]	3.50E-01± 2.12E-01[b]	0.00E+00± 0.00E+00[a]
TFCC (@45 °C)	0.00E+0± 0.00E+00[a]	0.00E+00± 0.00E+00[a]	0.00E+00± 0.00E+00[a]	0.00E+00± 0.00E+00[a]

Values are Mean ± Standard deviation of triplicate determinations per sample. Values with different superscripts across rows are statistically significantly different ($p<0.05$).
WHO standard TCC = 0/100*u*l of Water, TTCC/TFCC = 0/100*u*l of Water.
TCC = Total Coliform Count
TTCC = Total Thermotolerant coliform count
TFCC = Total Fecal Coliform count (*E. coli*)
A = Hostel 1, B = Hostel 2, C = Off Camp

3. 2. Physicochemical analysis of borehole water samples

The physicochemical parameters of the borehole water samples as shown in Table 2, revealed that the pH of the samples ranged from 5.40 ± 0.00 to 5.90 ± 0.00, turbidity 0.00 ± 0.00 to 0.00± 0.00, total dissolved solids (TDS) ranged from 2.00 ± 0.00 to 3.00 ±0.00, electrical conductivity (EC) ranged from 4.00 ±0.00 to 6.00 ± 0.00. Sample A had the highest pH, and samples B and C had the highest total dissolved solids and electrical conductivity. All the samples recorded no value for turbidity. Samples from B and C had the highest value for total dissolved solids and electrical conductivity. The Turkish HSD results showed that the means of all the parameters were not significantly different statistically at 5% across all the samples.

The physicochemical parameters showed that the samples were slightly acidic. They fell outside the acceptable pH limits by WHO and NIS (6.5 – 8.5). This is in contrast with earlier reports of Aleru *et al.* (2019); Adeyemi (2020) and Oka & Upula (2021) whose works found the pH of borehole water to be within the WHO permissible limits. The pH of drinking water determines the degree of corrosion of the metals that came in contact with the water, and the efficacy of the water treatment disinfection process for the treated water source (Zhang *et al.*, 2021). Leslie *et al.*, (2021) further suggest that water with a low pH can reduce the effectiveness of chlorine or other disinfectants, potentially leading to incomplete disinfection and allowing pathogens to persist in treated water. This poses a public health risk if the water is not treated properly. Consuming acidic water over long periods may irritate the digestive system or exacerbate conditions such as acid reflux in sensitive individuals (Zalvan *et al.*, 2020). Although the direct health effects of slightly acidic water are generally minimal, it is still recommended to neutralize the pH for long-term consumption. Also, Fisher *et al.*, (2021) opine that when water corrodes pipes, it can leach metals (such as lead or copper) into the drinking water, posing a risk of metal toxicity. Over time, this can degrade infrastructure, requiring costly repairs or replacements.

The recommended turbidity limit by WHO is <5NTU, however, the results of the study showed that turbidity was not found in any of the samples analyzed. Similarly, the results also showed that total suspended solids (TSS) were not detected in all the samples analyzed in the study. Total dissolved solids which indicate the presence of solid materials or solutes in water were generally found to be low across all the samples and fell within the WHO-approved standard limits of 500mg/l. This shows that the borehole water in the area was quite fresh in the locations. The electrical conductivity (EC) for all samples fell within the permissible limit of 500 μS/cm set by WHO. Electrical Conductivity is an indicator of water quality and soil salinity, hence the relatively high values observed in some water samples showed high salinity; thus, the water is suitable for domestic and agricultural use. From the analysis, it was observed that the electrical conductivity of the samples increased with increasing total dissolved solids.

Table 2. Physiochemical analysis of borehole water samples.

Parameters	Water samples			
	A	B	C	WHO Standard
Ph	5.40 ± 0.00^a	5.40 ± 0.00^a	5.90 ± 0.00^a	6.5-8.5
Turbidity (NTU)	0.00 ± 0.00^a	0.00 ± 0.00^a	0.00 ± 0.00^a	< 5.0
TSS (mol)	ND	ND	ND	05.00 mg/L
TDS (mol)	2.00 ± 0.00^a	3.00 ± 0.00^a	3.00 ± 0.00^a	< 500 mg/L
EC (µs/cm)	4.00 ± 0.00^a	6.00 ± 0.00^a	6.00 ± 0.00^a	500

Values are Mean ± Standard deviation of duplicate determinations per sample. ND= not detected, A=Hostel 1, B= Hostel 2, C= Off Camp

4. CONCLUSIONS

The need for controls over the quality of water meant for drinking purposes has been recognized by public health and environmental officials for many years. The results of this study demonstrate the presence of microorganisms in borehole water. Borehole water sources from the survey showed that the water samples were polluted and unsafe for human consumption. Hence the populace that consumes this water source is endangered as a result of varying degrees of ill health caused by consuming this water source, thus there is a need for the government and regulatory agencies to provide potable water to the populace and ensure that this water is fit for human consumption to alleviate ill health caused by the drinking of a polluted water source. Based on the outcome of this study, the following is recommended; it is recommended that water quality analysis should be carried out on all the boreholes in the hostels regularly. This will ensure that incidences of contamination are noticed earlier for remedial action to be taken, to minimize acute problems of water-related diseases, which are endemic to human health. The populace should be educated on the need to keep their surroundings clean, most especially around the boreholes. The Federal Government of Nigeria should educate people on the health hazards posed by indiscriminate faecal waste disposal and they should be educated on proper waste management disposal.

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