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Assessment of Physicochemical and Bacteriological Quality of Government Intervention Borehole Water in Ipetu-Ijesa, Osun State

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Abstract

Access to clean and safe drinking water remains a significant public health concern in Nigeria, where millions lack improved water sources. This study assessed the physicochemical and bacteriological quality of water from selected government intervention boreholes in Ipetu-Ijesa, Osun State. Water samples were collected from five boreholes and analyzed for parameters including pH, electrical conductivity, turbidity, total dissolved solids (TDS), dissolved oxygen (DO), nitrate levels, salinity, and microbial contamination (total coliform and Escherichia coli counts). The results indicated that most physicochemical parameters fell within the permissible limits set by the World Health Organization (WHO) and Nigerian Standards for Drinking Water Quality (NSDWQ). However, turbidity and total coliform counts exceeded safe limits in some locations. Total coliform counts ranged from 2.0 to 14.0 cfu/100mL, with a mean value of 7.0 cfu/100mL. Borehole D (Oko Owo) exhibited the lowest contamination levels, while Borehole C (Bamikemo) recorded the highest total coliform count. No fecal coliforms were detected in the examined samples. Boreholes A, B, and C exhibited elevated conductivity, TDS, and temperature, suggesting potential contamination from environmental and anthropogenic sources. Borehole D had slightly acidic water, indicating possible metal leaching. Principal Component Analysis (PCA) revealed strong correlations between conductivity, TDS, and temperature, highlighting potential underground contamination sources. Although the physicochemical characteristics and total coliform counts were mostly within permissible limits, deviations in some boreholes suggest the need for continuous monitoring and quality assessment to ensure safe drinking water.

Keywords: Coliform, physicochemical, boreholes, water quality, bacteria

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Introduction

Water, a fundamental resource holds unparalleled significance in sustaining life. Its importance transcends mere sustenance, encompassing crucial functions vital for the well-being of all living organisms [1]. Over 60 million Nigerians lack access to safe and quality water, and more than 110 million lack improved sanitation facilities [2]. According to Bhardwaj *et al*. [3], water quality encompasses the physical, chemical, biological, and radiological properties of water. Several factors can affect the drinking water quality, including natural processes, human activities, and environmental pollution [4]. Natural factors such as geological formations, climate, and rainfall patterns can influence the composition and characteristics of water sources. Human directed activities including industrial processes, agriculture, urbanization, and waste disposal can introduce pollutants into water bodies, leading to contamination [4]. Contaminated drinking water can harbor various pathogens, chemicals, and pollutants that pose significant health risks, including gastrointestinal illnesses, reproductive problems, and even cancer [5].

The insufficient supply of clean portable drinking water and the persistent pollution of available water sources leads to occurrence of diverse and severe health issues among people in developing nations like Nigeria [6]. Contaminated water serves as a medium through which diseases like cholera, typhoid fever, diarrhea, Schistosomiasis and dysentery spread within communities. This disease burden has significantly slowed down the economic growth of some developing countries [7]. Water from sources such as surface waters and boreholes are usually not necessarily chemical free, even rainwater have been found to contain dissolved airborne pollutants and suspended dust laden with microorganisms [8]. Contaminated water from boreholes can present a significant health risk to consumers, including the spread of waterborne diseases and exposure to toxic substances leading to long-term health effects from exposure to harmful substances [7]. Microbial parameters such as total coliforms, fecal coliforms, and E. coli are directly related to the risk of waterborne diseases [9]. High levels of these indicators suggest fecal contamination and increase the risk of gastrointestinal illnesses. Additionally, physicochemical parameters such as heavy metals and nitrates can have adverse health effects if present in high concentrations [9]. It is important to assess the potential health risks associated with specific contaminants found in borehole water as it is critical for protecting public health [10]. Hence, this study assessed the quality of water from selected Government intervention boreholes in Ipetu-ijesa, Osun State.

Materials and Method

Study area

This study was conducted in Ipetu-Ijesa, a town located in the western part of Nigeria, holds both historical and geographical significance within the region. IpetuIjesa lies on latitude 7.467^0, longitude 4.883^0, it is situated approximately 40 km from Ile-Ife and 37 km from Akure, the capital of Ondo State.

Sample collection

Boreholes provided as intervention projects within Ipetu-Ijesa community, specifically White House, Ifeda (A), Ifopin (B), Bamikemo (C), and, Oko Owo (D), were selected sources of water used for the physicochemical and bacteriological quality assessment. The water samples from each selected sources were collected in triplicates.

Physiochemical analysis

The quality and portability of the drinking water samples were evaluated using standard metrics such as pH, electrical conductivity, and total dissolved solids. All analysis was carried out using the methods of APHA 2012. The pH of the sample was measured with a pH meter (Model: Mettler Toledo Mp 220). After inserting the pH meter probe into the beaker-containing water sample, the READ key was depressed to obtain the pH reading. pH was standardized using a standard buffer of pH 4.0 and sterilized water [11].

Turbidity was determined using a standardized Turbidimeter (Model: Hanna H198703). The samples were poured into the turbidity bottle; the surface of the bottle was wiped with silicon oil to remove possible fingerprints that might influence the readings obtained. The bottle was then inserted into the turbidimeter and the reading was obtained. Temperature readings were taken using the mercury in bulb thermometer. The thermometer bulb was inserted into the water sample in the beaker and left there for a few minutes before the reading was obtained. Total dissolved solid was obtained using a TDS meter (Analytic TDS meter) with the electrode rinsed in distilled water before measurements. This was done to avoid any error or contaminant that could skim the result [11]. Also, **c**onductivity was taken using Suntex Sc - 120 Conductivity meter which measures in milli Siemens/centimeter (ms/cm). A conductivity reading was displayed after the conductivity meter probe had been cleaned with distilled water and put into the sample in a beaker. Dissolved oxygen (DO) was determined using titration method described by APHA [12]. The end point reading states the DO of the water samples. The concentration of nitrate was evaluated using the turbidity method described by APHA [12]. Likewise, salinity was assessed through the measurement of electrical conductivity, which is directly proportional to the salt concentration in a water sample [12].

Microbial analysis

Bacteriological assessments of water samples were carried out using Plate Count method. All the media were prepared according to the Manufacturer's specification. Total coliform counts were carried out by the standard plate count technique using MacConkey agar, inoculated plates were inverted and incubated at 37^{o}C for 24 h using an incubator. Pink colonies growth discovered on plates were counted and reported as colony-forming units of the samples analyzed. Faecal coliform was determined using Eosin methylene blue medium via spread plate technique, inoculated plates were inverted and incubated at 37^{o}C for 24 - 48 h. E. coli colonies which appear as purple colonies with a green metallic sheen were counted and reported as E. coli/faecal coliform count.

Statistical analysis

Data obtained for physicochemical analysis and Enumeration of Coliforms 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 mean values of water quality results were compared with that of the World Health Organization (WHO) and Nigeria Standard for Drinking Water Quality (NSDWQ) [13] for reference.

Results and Discussion

The results of electric conductivity from bore hole (Table 1) showed that the sampled water ranged between 104.2 and 192.4 µS/cm with the mean value 136.5 µS/cm, where the least and highest value were found in Ifopin (B) and Oko Owo (D) respectively, temperature ranged between 26.9 to 27.3^{o}C with a mean value of 27.1^{o}C, the least value was recorded in Oko Owo (D) and the highest value was recorded in Ifopin (B), pH ranged between 7.4 and 7.7, with the mean value of 7.6, the least value was recorded in White house, Ifeda (A) and the highest value in Ifopin (B). Turbidity ranged between 5.4 to 7.0 NTU, with a mean value of 6.1 NTU, the least value was recorded in White house, Ifeda (A) and the highest value in Oko Owo (D), Total dissolved solid ranged between 52.0 to 96.2 mg/L, with a mean value of 68.4 mg/L, the lowest value was found in Ifopin (B) and the highest one in Oko Owo (D), dissolved oxygen (DO) ranged between 6.2 to 14.1 mg/L, with the mean value of 9.4 mg/L, the lowest value was found in Ifopin (B) and the highest value in Oko Owo (D), nitrate level ranged between 0.010 and 0.0376 mg/L, with the mean value of 0.124 mg/L, the lowest value was found in Bamikemo (C) and the highest value in Oko Owo (D), the salinity level ranged between 0.0326 and 0.380 ppt, with the mean value of 0.24 ppt, the lowest value was found in White house, Ifeda and the highest one in Oko Owo, the quantity of lead (Pb) found in the analyzed water samples were low, the mean value is 0.003 mg/mL. Total coliform count (TCC) ranged between 2.0 to 14.0 cfu/100 mL, with the mean value of 7.0 cfu/100 mL the lowest value was found in Oko Owo (D) and the highest one in Bamikemo (C).

The results of temperature values obtained from analyzed water samples all fall within the range for WHO and NDSWQ standard, the outcome corroborates the report of Oka and Upula [14], who recorded a range of 23.5 to 25.5°C from the research carried out. Appropriate water temperature is not only essential for human consumption but also for maintaining the ecological balance of aquatic environments [15]. The mean pH levels across four distinct locations used for the study ranged from 7.4 to 7.7, it showed that the samples were neutral aligning with the permitted range for drinking water. This suggests that the samples meet the acceptable pH limits by WHO and NSDWQ (6.5 - 8.5) and the observed pH values being within the acceptable range implied that the water quality in the studied locations is suitable, minimizing potential adverse effects on the environment and human health. This is in conformity with earlier reports of Aleru *et al*. [16]; Adeyemi [17] and Oka and Upula [14] whose works found the pH of borehole water to be within the WHO permissible limits. Zhang *et al*. [18] reported that the pH value of portable water determines the degree of corrosion of the metals that came in contact with the water, and the effectiveness of the water treatment disinfection process for the treated water source. Also, water with a low pH value can reduce the potency of chlorine or other disinfectants, resulting to incomplete disinfection and allowing persistent presence of pathogens in treated water posing a public health risk if the water is not treated properly [19]. Drinking acidic water irritates the digestive system and causes health conditions such as acid reflux in sensitive individuals, although the direct effects of slightly acidic water are generally minimal, it is still recommended to neutralize the pH for long-term consumption [20].

The electrical conductivity (EC) for the analyzed water samples are within the permissible limit of 500 µS/cm set by WHO, this is in contrast with the findings of Gbarakoro *et al.* [21] , he reported that water samples from industrialized regions showed electrical conductivity values exceeding 500 µS/cm. 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. Total Dissolved Solids (TDS) concentrations play a crucial role as they reflect the quantity of dissolved inorganic and organic substances in water. The TDS concentrations in the water samples are considerably lower in comparison with WHO and NSDWQ standard. The result of this study confirms with that of Morka *et al.* [22] who recorded a low TDS range of 56.44 to 138.42 mg/L from water. The WHO standard of 5 NTU for turbidity is set to ensure water clarity and safety for various purposes [23]. Turbidity values of three out of the four samples slightly exceed WHO and NSDWQ standard, but the overall turbidity value is still below the Not Permissible Limit (NPL). It is crucial to note that turbidity levels above the WHO Most Desirable Limit (MDL) may affect water aesthetics but might not necessarily pose health risks. Oladikpo *et al*. [24] conducted a study on urban water sources, reporting turbidity levels ranging from 3 to 8 NTU. The current study's results align with this range, indicating similar turbidity levels in urban water sources.

In contrast, Loi *et al*. [25], Müller and Cornel [26] investigated water quality in agricultural areas, reporting turbidity levels exceeding 10 NTU. The difference in turbidity levels between their findings and the current study suggests varying impacts of different land uses on water clarity. The moderately elevated turbidity levels in the current study may be attributed to local environmental factors. The observed DO levels in this study significantly exceed this water quality standard used for comparison, indicating a surplus of dissolved oxygen in the water samples. Adequate DO levels are essential for sustaining aquatic ecosystems and supporting various forms of aquatic life. Jackson *et al*. [27] conducted a study on urban water bodies, reporting DO levels ranging from 4 to 7 mg/L. The current study's results align with this range but generally indicate higher DO levels, suggesting potentially healthier water in the studied locations. Healthy water consists of dissolved oxygen levels that range from 6.5 -8.0 mg/L. While high DO levels will make drinking water taste better. The observed nitrate concentrations in the current study are well below this international standard, indicating a low risk of nitrate-related health concerns in the studied locations. Loi *et al*. [25] investigated water quality in agricultural areas, reporting nitrate concentrations exceeding 20 mg/L. The contrast between their findings and the current study underscores potential differences in land use impact on water quality, with lower nitrate levels in the current study indicating a lesser influence of agricultural runoff. In contrast, Gbarakoro *et al.* [21] conducted a study on urban water sources, reporting nitrate concentrations ranging from 5 to 15 mg/L. The current study's results align with this range, suggesting a potentially lower impact of urban activities on nitrate levels in the studied locations. This observed salinity results of this study corroborates with Ibietela *et al.* [28], who conducted a study on borehole water sources in Abonnema Rivers State and reporting a similar salinity level outcome. Minimal amount of Lead (Pb) was recorded one of the water samples analyzed in this study, with it being absent in some samples. The concentration of lead discovered in this sample surpassed the WHO and NSDWQ standard limits of 0.01 mg/L conforming with the result of the study conducted by Fakeye *et al.* [29] on borehole water assayed in some rural areas in Edo State.

Table 1: Physicochemical analysis of selected water Borehole sources in Ipetu-Ijesa

Parameters/Unit	Location				Range	Mean±SD	WHO [23]		NSDWQ [13]
	A	B	C	D			MDL	NDL	
Temperature (°C)	27.2	27.3	27.1	26.90	26.9 - 27.3	27.1 ± 0.15	22 - 30	40	22 - 30
pH	7.4	7.7	7.5	7.6	7.4 - 7.7	7.6 ± 0.13	6.5 - 8.5	7.0 - 8.5	6.5 - 8.5
Conductivity (us/cm)	136.1	104.2	114.3	192.4	104.2 - 192.4	136.5 ± 39.42	500	1500	1500
TDS (mg/L)	68.10	52.0	57.2	96.2	52.0 - 96.2	68.4 ± 19.73	500	1500	1400
Turbidity (NTU)	5.4	6.2	5.8	7.00	5.4 - 7.0	6.1 ± 0.68	5	25	5
DO (mg/mL)	8.5	6.2	8.9	14.1	6.2 - 14.1	9.4 ± 3.33	14	-	-
NO3 (mg/L)	0.040	0.070	0.010	0.376	0.010 - 0.070	0.124 ± 0.17	5	50	10
Salinity (ppt)	0.0326	0.275	0.296	0.380	0.275 - 0.326	0.24 ± 0.15	-	-	-
Pb (mg/L)	0.001	0.000	0.011	0.000	0.000 - 0.011	0.003 ± 0.005	0.01	-	0.02

TDS = Total Dissolved Solid, DO = Dissolved Oxygen NO_3 = Nitrates, MDL = Most Desirable Limit, NPL= Not Permissible Limit, Ifeda (A), Ifopin (B), Bamikemo (C), and Oko Owo (D); WHO = World Health Organizations, NSDWQ = Nigeria Standard for Drinking Water Quality

Table 2: Total coliform counts of selected Borehole water sources in Ipetu-Ijesa

Parameters/Units	Location				Range	Mean ± SD	WHO [23]	NSDWQ
	A	B	C	D				
TCC(cfu/100mL)	8.0	4.0	14.0	2.0	2.0-14.0	7.0 ±5.29	0.0	0.0
TFC(cfu/100mL)	ND	ND	ND	ND				

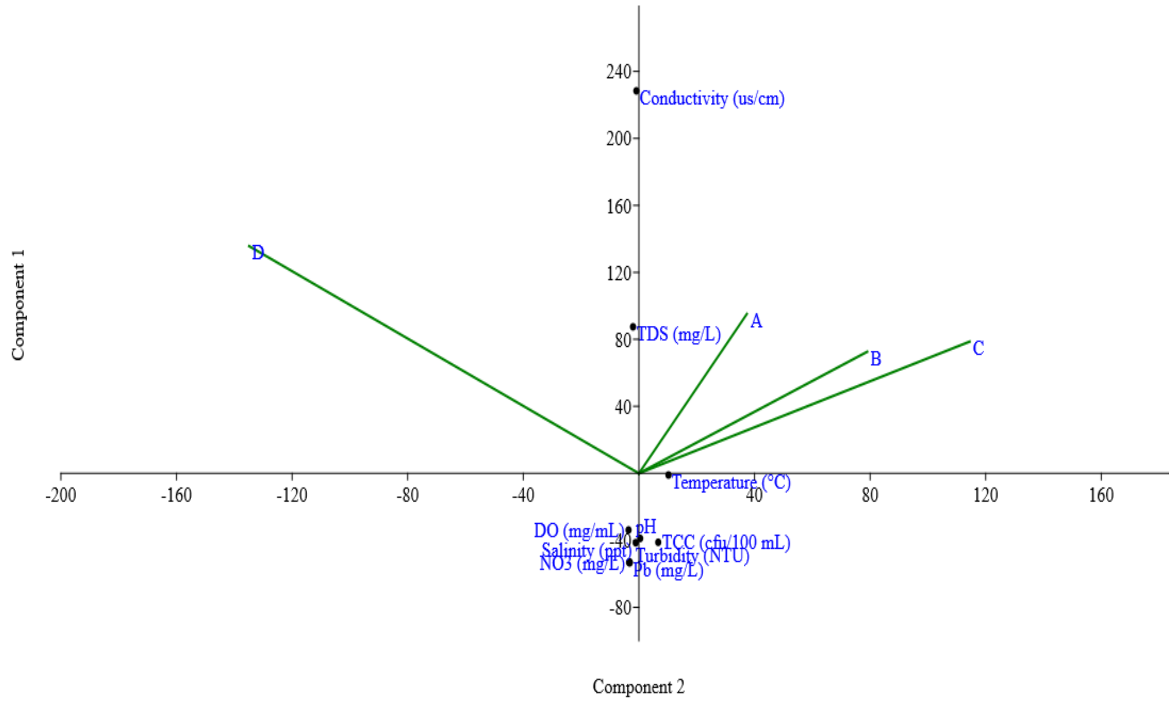

Figure 1: Principal Component Analysis (PCA) showing the interrelationship between sampling locations and physicochemical parameters of water and Coliform counts

Enumeration of coliforms

All the water samples analyzed recorded high total coliform counts in comparison with permissible limits approved by WHO and NSDWQ. The presence of coliforms, especially in a consistent pattern across samples, suggests potential contamination with fecal matter. The results of total coliforms may not always pose immediate health risks, their presence necessitates further investigation to identify and address potential sources of contamination. The low levels of total coliforms observed in some samples may be attributed to natural sources or minor breaches in the borehole casing, rather than widespread contamination from surface pollutants [30].

Fecal coliforms and *Escherichia coli,* being more specific indicators of recent fecal contamination, carry higher health risks upon exposure. Moreover, fecal contamination in water bodies can have detrimental effects on aquatic ecosystems. The absence of fecal coliforms and *E. coli* in this study suggests a low risk of waterborne pathogens [9]. Principal component Analysis (PCA) revealed a strong positive correlation between conductivity, TDS, temperature and sampling station A, B and C while showed a negative association between DO, salinity, nitrate, Pb and sampling station A, B and C (Fig. 1). Only sampling station D showed negative correlation with pH, TCC and turbidity as presented in Fig. 1. Given that the water samples are from government-provided boreholes as part of a water intervention program, the PCA results raise critical public health and water quality concerns. At Stations A, B, and C, high conductivity, TDS, and temperature dominates suggesting the presence of dissolved salts, minerals, or pollutant. This could be due to many reasons including poor construction and maintenance of borehole, leaching from agricultural/surrounding soil or underground contaminants.

The Ipetu-Ijesha is in close proximate town to a mining community and the activities of artisanal mining could impact on the quality of the underground water in this region. The low dissolved oxygen (DO) and negative correlation with salinity, nitrate, and Pb shown by the PCA may indicate that contaminants are slipping into the boreholes reducing oxygen levels. High TDS and conductivity can affect the taste, odor, and long-term safety of drinking water, potentially leading to health risks such as kidney stress and gastrointestinal issues if contaminants exceed permissible limits.

However, Lower pH, TCC, and Turbidity were the factors of concern for borehole D. Although the listed indicators potentially shows that the water is safe, however the low pH shows acidity which suggests acidification, which could indicate leaching of metals (e.g., iron, manganese, or lead) from underground sources. Acidic water can lead to corrosive effects on plumbing, causing heavy metal leaching (e.g., lead and copper), which can pose serious neurological and developmental health risks, especially in children. Therefore, the government's intervention boreholes may not be providing fully safe drinking water, especially in Stations A, B, and C, due to potential contamination risks.

There is need to conduct regular water quality testing and implement water treatment strategies to ensure safe drinking water. Public health monitoring should be conducted to assess any potential health effects related to water quality in the area.

Conclusion

The study revealed that while government intervention boreholes in Ipetu-Ijesa serve as a critical water source, concerns persist regarding their safety. Although most physicochemical parameters complied with WHO and NSDWQ guidelines, elevated turbidity and total coliform counts in some boreholes suggest potential health risks. The presence of high conductivity and TDS in Boreholes A, B, and C raises concerns about dissolved contaminants, while the slightly acidic nature of Borehole D highlights potential metal leaching. The findings emphasize the need for regular water quality assessments, improved borehole maintenance, and implementation of appropriate water treatment solutions to mitigate contamination risks. Continuous monitoring of these residential water sources, particularly concerning their purification processes, is necessary to maximize safety and promote a disease-free and healthy population. Public health authorities should establish sustainable monitoring systems to safeguard community health and ensure long-term access to potable water. Addressing these water quality concerns will significantly contribute to reducing waterborne disease risks and improving overall public health outcomes in the region.

Conflict of interest: Authors declare no conflict of interest.

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