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Borehole Water Quality Characteristics and Its Potability in Iwo, Osun State, Nigeria

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Authors' contributions

This work was carried out in collaboration between all authors. Author OTA designed the study, did the microbiological aspect of the work and wrote the first draft of the manuscript. Author TOO performed the statistical analysis of the work and managed the literature searches. Author EOA did the analysis of physico-chemical parameters of the work. All authors read and approved the final manuscript.

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ABSTRACT

Human access to quality water is a prerequisite to a healthy living. Thus, a study aimed at assessing the spatial quality of borehole water in 16 different locations in Iwo, Osun State, Nigeria. The borehole water samples were subjected to physico-chemical and bacteriological analyses. The parameters analysed include pH, temperature, Electrical conductivity, Phosphate, Nitrate, Sulphate, Total Hardness, coliform and faecal coliforms. The results showed that the physico-chemical parameters were within the WHO limit, except for temperature and pH values which were above the WHO limits. Also, the bacteriological analyses showed that coliforms were present in 11 boreholes up to levels of 3 to 93 MPN/100 ml while only 5 boreholes showed zero coliform count while correlation analysis generally showed that most of the parameters are independent of one another. Bacteriological analysis results indicated that water from these sources may pose threat to human health by WHO standard if consumed. Hence, simple water treatment method such as boiling, regular disinfection and regular cleaning of borehole water storage tank as well as general

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education on proper disposal of sewage and location of boreholes are recommended. Further investigation on the quality analysis of borehole water in Iwo is required to ensure adequate monitoring of the quality parameters in the boreholes.

Keywords: Microbial; chemical analysis; coliforms; most probable number; spatial quality; correlation analysis.

1. INTRODUCTION

Water is one of the most important and abundant compounds of the ecosystem. All living organisms on the earth need water for their survival and growth, and human accessibility partly determines the quality of living. Its role as a medium of water borne disease which constitutes a significant percentage of the diseases that affect human and animals cannot be underestimated. Water that is fecally polluted spreads diseases in consumers to a great number of people. This makes quality of water to be of great concerns and guideline for bacteriological water differs from country to country but they all conform to WHO recommendation. It is well established that infectious diseases are transmitted primarily through supply of water contaminated with human and animal excreta particularly faeces [1]. Out breaks of water borne diseases continue to occur throughout the world but are especially serious in developing countries [2].

Water can be seen as a naturally occurring universal solvent on earth whose main sources include rivers, lakes, rivers, ponds [3]. Water source can be surface or underground. Surface water such as lakes, streams, rivers and ponds, to a greater or lesser degree are exposed to contamination by microorganisms from the atmospheric water during precipitation [4]. Ground water, which is found in aquifers (water -containing layers of rock, sand and gravel), such as spring, bore hole and wells are not directly exposed to rain, animals and atmosphere. They are protected from contamination. However, naturally occurring contaminant are present in rock and sediment. As groundwater flows through the sediments, metals such as iron and manganese are dissolved and may later be found in high concentrations in the water [5]. In addition, human activities can alter the natural composition of groundwater through the disposal or dissemination of chemicals and microbial matter on the land surface and into soils, or through injection of wastes directly into groundwater. Industrial discharges as revealed by [6], urban activities and agriculture, as observed by Moyo [5], groundwater plumage and disposal of waste as also noted by [7] can affect groundwater quality and poorly located or maintained septic tank or fertilizer can also lead to ground water contamination [8]. Proximity of some boreholes to solid waste dumpsites and animal droppings being littered around them [7] could also distort the quality of groundwater. The high prevalence of diseases such as diarrhea, typhoid fever, cholera, and bacillary dysentery among the populace has been traced to the consumption of unsafe and unhygienic drinking water [9].

Water can be classified based on certain qualities as portable water (clean, safe water, and tasteless), polluted water (water with added substances which impair colour, odour or taste), contaminated water (water which is rendered unsafe, through the addition of discharges from human or animals intestine or rendered dangerous by addition of chemicals) [8].

Microorganisms are widely distributed in nature, their diversity and density maybe used as an indicator for the suitability of water [10]. Indicator bacteria are types of bacteria used to detect and estimate the level of faecal contamination of water [11].

However, groundwater forms one of the major sources of water in the study area apart from surface. The groundwater source is reached through hand-dug activities and/or deep boreholes. Supply of water through pipe-borne water network in Iwo is almost non-existent due to rust pipes, management bottlenecks, poor financial support and so on [12]. There are publications on the physico-chemical characteristics of borehole water in the study area. For instance, [12] reported that borehole water in the Iwo is within the recommendation of the World Health Organisation. However, works on the bacteriological characteristics of groundwater is yet to be investigated. This work has its aim to investigate the bacteriological constituents of groundwater in Iwo Township.

The objectives of the work are (i) to assess the physic-chemical constituents of borehole water, (ii) to analysis the bacteriological status of the boreholes in the study area, and (iii) to determine the potability of borehole water based on (i) and (ii) cum WHO standard.

2. MATERIALS AND METHODS

2.1 Study Area

The study was carried out in Iwo, the headquarters of Iwo local Government in Osun State. The community is located in the western part of Nigeria and between the coordinates of 7°38′N and 4°11′E. Its agriculturally rich advantage makes it a major trading centre for cocoa, kola nuts, foodstuffs, meat and timber. The popular Odo-Ori market attracts traders from within and outside the State. Iwo is also strategic because the railway tracks from Ibadan passes through the town which helps the commercial and economic development of Iwo and its suburbs. The major source of potable water in Iwo is from Aiba Water Reservoir located within Government Forest Reservation Area in the town. This Water Works has not been able to discharge its responsibilities as expected, the problem linked to poor management, poor maintenance, corruption, poor power supply and also increase in the population of the area. The town has witnessed a relatively increase in the population as a result of the commencements of institutions such as Bowen University, Sharia College of Nigeria and the Oloba Cattle Hub. The persistent erratic supply of water from the Water Works and the quest for another alternative has led to the exploitation of underground and surface sources.

2.2 Sample Collection

Water samples were collected from 16 randomly selected boreholes in the southern part of the town during the month of March when the dry season was at its peak and the infiltration which may lead to dilution was at minimal. This is to

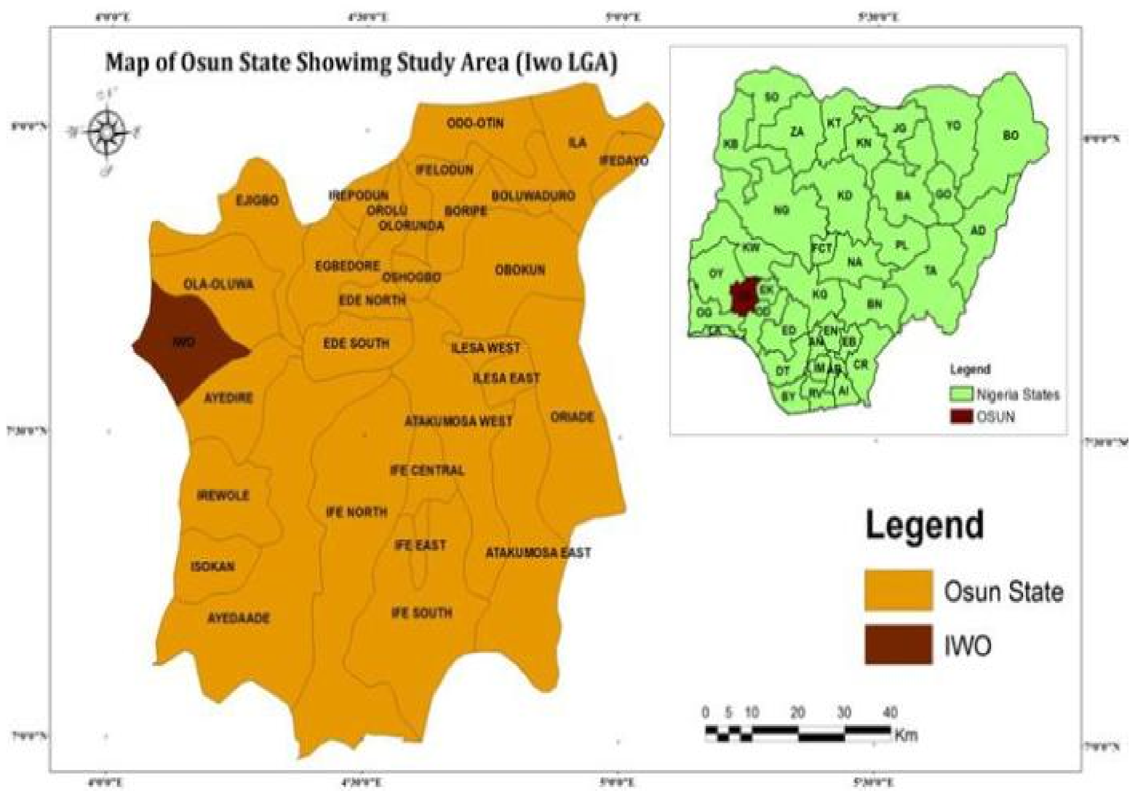

Fig. 1. Map of Nigeria showing the location of Osun state
After Ogunbode et al. (2016)

ensure that that water samples are taken from the concentrated source. Water samples from each of these locations were collected into appropriately labelled sterile glass bottles (250 ml). Cotton wool soaked in 70% alcohol was used to sterilize the nozzle of the borehole tap before water samples were collected. The tap was allowed to run freely for two minutes, and afterwards, the 250 ml capped glass bottles were carefully uncapped and filled with water and transported to the laboratory for microbiological and physico-chemical analysis.

2.3 Physico-Chemical Parameters

All the reagents used were of analytical grade and the instruments were pre-calibrated appropriately prior to measurement. Seven parameters were analysed. The pH, Water temperature and electrical conductivity were measured *in-situ* using Testr II dual range meter (Eutech instruments,Malaysia) after calibrating with standard buffer solution of 4 and 10; other parameters such as Sulphate, Phosphate, Nitrate and Total hardness (TH) were determined by procedure described by [13].

2.4 Determination of Bacteriological Quality

2.4.1 Total coliform count

This was determined by standard multiple tube fermentation also known as Most Probable Number (MPN) index technique using the three tube assay (3-3-3 regimen). MacConkey broth (LAB M) was prepared according to manufacturer's specification. Three test tubes, each containing 10 mls of double strength broth was prepared, while six test tubes, each containing 10 mls of single strength was also prepared for each water sample. A Durham tube was inverted in each of the tubes containing broth, all the tubes were plugged with cotton wool and sterilized at 121°C in an autoclave. The three set of tubes received 10 ml, 1 ml and 0.1 ml of each water samples. They were carefully labeled and incubated at 37°C for 72 hrs for estimation of total coliform. Acid production was determined by color change in tubes from purple to yellow and gas production was checked for by entrapment of gas in the durham tubes. Gas production after 48 hrs of inoculation indicated positive presumptive test. From the number with a positive reaction, the most probable number (MPN) of bacteria present in the original water sample was determined statistically using a standard table.

2.4.2 Faecal coliform count

Faecal coliform count was determined using Eosin Methylene Blue medium (LAB M) employing the streaking culture technique. A loopful of broth from positive tubes was streaked onto EMB agar plate for pure cultures. The plates were incubated at 37°C for 24 hrs. Colonies on EMB agar plate were further identified as fecal *Escherichia coli*. On Eosin Methylene Blue (EMB) agar, *E. coli* strains appeared as greenish metallic sheen colonies [14].

2.5 Identification of Isolates

The cultural, morphological and biochemical characteristics of the respective isolates were compared with the criteria in District Laboratory Practice for Tropical Countries, Part 2 [14]. The biochemical tests used in the identification and characterization of the isolates included: Gram-staining, Motility, Indole production, Methyl red-Voges Proskauer, Citrate utilization Catalase, and Sugar fermentation tests. Biochemical reactions were confirmed using Bergy's manual [15].

3. RESULTS AND DISCUSSION

Table 1 shows the Most Probable Number of coliform per 100 ml of water sample (MPN/100 ml). Out of 16 Bore hole water sample, sample D and N had the highest of 93MPN/100 ml, sample O, had the lowest of 3MPN/100 ml while sample A, B, C, K and P had zero coliform count. The MPN test provided presumptive evidence of the presence of coliforms. The MPN results of this study showed the number of coliform estimated to be high for majority of the sample which clearly exceeded the standard limit set by WHO; this is unacceptable because WHO standard of potable water states that no coliform should be present in any drinking water. Only five bore holes passed the WHO standard out of the sixteen bore holes sampled; the presence of coliforms in drinking water makes the water unsafe for domestic use.

In this study, the bacteriological analysis of the different borehole water sampled was found to be highly contaminated with faecal pathogenic microorganisms. The result of this study corroborates with the work of [16] which reported that water from bore hole and wells sampled in the cities of Lagos and Ibadan, both located in Nigeria, were found to be highly contaminated with pathogenic organisms. The high bacteria pollution observed in the study may be attributed to poor environmental condition such as improper disposal of sewage materials as well as domestic refuse.

Table 1. MPN table

Sample	MPN/100 mls	Faecal coliform count (CFU/100 ml)
A	0	No growth
B	0	No growth
C	0	No growth
D	93	1.5×10^5
E	9	2.0×10^4
F	15	4.0×10^4
G	4	2.0×10^4
H	9	3.0×10^4
I	23	1.0×10^3
J	9	3.0×10^4
K	0	No growth
L	7	4.0×10^4
M	9	4.0×10^4
N	93	1.3×10^5
O	3	1.0×10^4
P	0	No growth

Much of the ill health which affects humanity, especially in developing countries can be traced to lack of safe and whole water supply. There can be no state of positive health and well-being without safe water. Since water is vital for our life it should be clean and safe.

Out of the eleven positive tubes that were streaked on EMB plate, water samples H, L and M appeared as metallic sheen on it. Based on their Cultural and biochemical characteristic, three (3) genera of bacteria were identified as *Klebisella sp* and *Enterobacter sp* and *Esherichia coli* (Table 2). The coliforms are the most common group of indicator organism used in water quality monitoring and feacal contaimination of water can serve as a source of primary pollution. The presence of bacteria *E. coli* which is common coliform among intestinal floral of animal and *Klebsiella* sp suggest feacal contamination of water which is of public health importance [17]. Fasunwon et al. [18] reported that coliforms could emanate from two distinct sources, namely the gastrointestinal tract of humans and warm blooded animals (feacal origin) and from within the natural environment (non-feacal origin).

Though it was observed that most of the physcio-chemical analysis of the water sample falls within the permissible limit and safe for human consumption but they are bacteriologically poor as they did not meet the permissible standard set by WHO and they could harbour potential human and animal pathogens. The consumption of drinking water contaminated with pathogenic microbes of faecal origin is a significant risk to human health as diseases such as bacteria dysentery, cholera and food poisoning may possibly results from the consumption of such untreated water.

The results of physic-chemical parameters studied as shown in Table 3 revealed that pH value of most of the water sampled ranged from pH7-8 which is within the WHO limit, while the pH of sample D, H and N ranged between 9.02-9.12 which is above the WHO permissible limit. [19] reported that the dissolution of relative quantities of calcium, carbonates and biocarbonates can influence the pH value and make water to be more alkaline.

Temperature values of all the samples as indicated in Table 3 shows higher value above the WHO limit of 25°C. This may be attributed to the ambient temperature of the underground water as well as the sampling time. Determination of water temperature in boreholes according to [20] is a good measure of contamination as it marked effects of bacteria and chemical reaction rates in water. The results of total hardness, sulphate, phosphate, Nitrate, and Conductivity levels of the water samples from all the boreholes investigated are all within the WHO permissible limit.

The correlation analysis of the physico-chemical parameters in Table 4 showed that the parameters had poor relationship among each other. However, there are slight correlations between electrical conductivity and total hardness at 44.7% significant level implying they might have same source of contamination or interact effectively in the borehole, total hardness and coliform (41.5%) and also, between pH and electrical conductivity (40%). The analysis showed that the correlations between pH and phosphate, temperature and Sulphate, electrical conductivity, phosphate and sulphate, Nitrate, total hardness and coliform are negatively correlated implying that as the content of one increases, the value of the other decreases. Apart from this, the analysis showed that most of the parameters were generally independent of each other in the boreholes.

Table 2. The results of biochemical test

Isolate	Gram Reaction	Indole	MR	VP	Citrate	Motility	Lac	Suc	Man	Glu	Probable organism
D	-	-	-	+	+	-	+	+	+	+	*Klebisella sp*
E	-	-	-	+	+	+	+	+	+	+	*Enterobacter sp*
F	-	-	-	+	+	-	+	+	+	+	*Klebisella sp*
G	-	-	-	+	+	-	+	+	+	+	*Klebisella sp*
H	-	+	+	-	-	+	+	+	+	+	*E.coli*
I	-	-	-	+	+	-	+	+	+	+	*Klebisella*
J	-	-	-	+	+	+	+	+	+	+	*Enterobacter sp*
L	-	+	+	-	-	+	+	+	+	+	*E.coli*
M	-	+	+	-	-	+	+	+	+	+	*E.coli*
N	-	-	-	+	+	+	+	+	+	+	*Enterobacter sp*
O	-	-	-	+	+	+	+	+	+	+	*Enterobacter sp*

Key; - = negative, + = positive, Lac = lactose, Man = mannitol, Glu = glucose, Suc = sucrose

Table 3. Physico-chemical quality of bore hole water sample

Sample	pH	Temp°C	EC ($uSem^{-1}$)	PO_4^{3-} mg/L	SO_4^{2}- mg/L	NO_3- mg/L	TH mg/L
A	8.18	29.30	240	0.07	0.05	0.02	420.0
B	8.00	27.50	270	0.03	0.03	0.03	248.0
C	8.05	29.00	110	0.07	0.04	0.02	375.0
D	9.02	30.01	150	0.02	0.05	0.02	406.0
E	7.82	28.70	100	0.03	0.06	0.02	385.0
F	8.00	27.40	120	0.04	0.05	0.01	246.0
G	8.14	29.50	114	0.03	0.03	0.03	408.0
H	9.10	30.10	390	0.03	0.05	0.02	274.0
I	7.04	29.30	210	0.04	0.03	0.01	200.0
J	8.18	28.80	150	0.03	0.01	0.02	248.0
K	8.01	29.70	150	0.02	0.05	0.03	246.0
L	7.94	28.40	130	0.04	0.06	0.03	218.0
M	7.80	28.60	240	0.02	0.06	0.03	450.0
N	9.12	27.40	260	0.01	0.05	0.02	408.0
O	7.09	29.00	150	0.04	0.06	0.02	200.0
Mean	**8.10**	**28.55**	**185.60**	**0.04**	**0.05**	**0.02**	**315.5**
SD	**0.61**	**0.88**	**80.88**	**0.02**	**0.02**	**0.01**	**92.34**
WHO (Maximum limit)	**6.5-8.5**	**25°C**	**300**	**2.2 mg/L**	**250 mg/L**	**50 mg/L**	**500 ml/L**

Table 4. Correlation analysis of the physico-chemical parameters

PhCh	pH	Temp	EC	PO_4	SO_4	NO_3	TH	Coliform
pH	1	0.086	0.40	-0.330	0.026	0.088	0.447	0.147
Temp		1	0.056	0.109	-0.034	0.014	0.090	0.218
EC			1	-0.183	0.153	0.048	0.015	0.045
PO4				1	-0.360	-0.274	-0.038	-0.374
SO4					1	0.103	0.060	0.307
NO3						1	0.178	0.058
TH							1	0.415
Coliform								1

4. CONCLUSION

The results of this study showed that high coliform density occurred in most of the entire borehole sampled. There is need to control faecal pollution of water supply to avert the occurrence of waterborne diseases outbreak in the area of investigation. Based on the above investigation results, borehole should be situated far away from sewage material because of feacal contaminations. Proper sanitary survey and water treatment should be employed with proper regular monitoring programme to determine the primary source of contaminations. In addition, appropriate measures such as water purification method such as boiling, filtration, proper pre-settlement should be recommended to avoid any sudden public health risk from consuming water such bore holes. The results of correlation analysis generally show that most of the parameters are independent of one another. However further investigation is required to ensure adequate monitoring of the quality parameters in the boreholes.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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