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Assessment of Bacteriological Contamination of Hand-Dug Wells in Rural and Urban Areas in Ondo State, Nigeria

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ABSTRACT

The study analysed the total bacteria, total coliform and *Escherichia coli (E. coli)* concentrations of ten randomly selected hand-dug groundwater wells: five each from Alagbaka (Urban area) and another five from Ijare communities (Rural area) in Ondo State. Collins and Lyne's pour plate method was used for the laboratory analysis. The laboratory results showed that 30%, 90% and 0% of the groundwater samples were above the WHO drinking water standards for total bacteria, total coliform and *E. coli*, respectively. Furthermore, the groundwater samples collected in the urban study area had total bacterial and total coliform mean levels of 24 and 15 cfu/100mL respectively compared to those of the rural study area with mean concentrations of 15 and 5 cfu/100mL, respectively. There was however no *E. coli* in the groundwater of both areas studies indicating the absence of faecal contamination in groundwater. It can therefore be concluded that there is a higher risk of microbial contamination of groundwater in urban land use than in rural land use and that groundwater in the study areas is unsafe for consumption unless it is first treated with appropriate treatment methods. For future research, the contamination level of other micro-organisms such as fungi, viruses, protozoa etc. should be assessed in study areas, as well the sources of microbial contamination in groundwater.

Keywords: Environmental pollution, water quality assessment, groundwater quality, microbial contamination, urbanization

INTRODUCTION

Groundwater, the naturally occurring freshwater transmitted and stored underground in geologic formations such as aquifers, is the most important water supply source in urban and rural areas of many developing countries (Agori et al., 2021). In Ondo state, Nigeria, groundwater is the primary source of water as most communities cannot access surface water (Ojo, 2016). Groundwater resources are usually of excellent quality because they have been naturally filtered on their way through the ground; therefore, they are relatively clear, colourless, and free of microbial contamination, and usually only need minimal treatment (Singha et al., 2015). However, the quality of groundwater resources can be affected by a variety of factors including rain and surface water infiltration, geological structures, topography, weathering, local hydrogeology, and anthropogenic processes, such as pollution caused by human activity (Adimalla and Venkatayogi, 2017, 2018; Amalraj and Pius, 2018).

As an important source of safe drinking water, groundwater contamination poses many health risks (Srivastav, 2020). Microbial contamination in particular has been a source of concern for many people in recent years (Sorlini et al., 2013; Geng et al., 2016). Typhoid fever, cholera, dysentery, hepatitis and polio are just a few of the diseases that have emerged as a result of contaminated drinking water and poor sanitation, which have led to health problems and even occasionally death (Ojo, 2022a; WHO, 2019). Apart from the severity of these water-borne diseases, the ability of water to spread these diseases among a large population makes the compliance of potable water with water quality standards of particular relevance (Ojo, 2016). However, there is a lack of adequate monitoring and evaluation systems for drinking water quality in developing countries (Gibson et al., 2011) such as Nigeria, which is also the case for Ondo State.

Anthropogenic activities such as agricultural activities, industrialisation, urbanization, and increased exploitation of water resources, as well as atmospheric input, all play a significant role in determining the quality of the water (Qin et al., 2013). Agricultural practices such as animal husbandry, the intensive use of fertilizers for crop farming etc. are anthropogenic activities relatively peculiar to rural areas, while industrialization, discharge of sewage and other domestic activities are common in urbanized zones.

Furthermore, as a result of the conversion of croplands, forests, grasslands, wetlands, and other forms of land cover to residential, transportation, commercial, and industrial uses, more impermeable surfaces are created in urban areas (Tsegaye et al., 2006). This, in turn, decreases the infiltration rate into the earth, reducing recharge rates into groundwater systems (Adhikari et al., 2020). Groundwater quality is significantly affected by low recharge rates since less amount of water is available to reduce the concentration of contaminants in groundwater and mitigate their effects. Also, the use of on-site sanitation systems such as pit latrines and septic tanks in contrast with sewerage which removes sewage from the site renders groundwater sources more susceptible to contamination by microbial pathogens (Lutterodt et al., 2018).

According to WHO (2022), the most significant microbial risks are linked to the consumption of water contaminated with human and animal faeces, which is a source of pathogenic bacteria, protozoa, helminths and viruses. Popular indicator parameters for microbial contamination of groundwater sources are total bacteria, total coliform bacteria and *E. coli*. Total coliform bacteria (excluding E. coli) occur in both sewage and natural waters (WHO, 2022). The majority of coliform bacteria seen in human faeces are obtained from sewage. Faecal indicators that are appropriate do not proliferate outside of their animal hosts (Khatri and Tyagi, 2014). *Escherichia coli*, a subset of total coliform, was discovered to be a good indicator of faecal contamination and has traditionally been used to monitor drinking water quality, and remains an important parameter in monitoring undertaken as part of verification or surveillance (Cheung et al., 1990; WHO, 2022).

This study thus aims to assess the bacterial pollution levels of groundwater in selected urban and rural areas in Ondo State, Nigeria to determine the suitability of groundwater for drinking by comparing levels of selected bacterial classes in groundwater samples with WHO drinking water standards.

MATERIALS AND METHODS

Description of study area

The study was carried out in Alagbaka and Ijare, both located in Ondo state, Nigeria. Alagbaka is located in Akure south Local Government Area (L.G.A.) of Akure, Ondo State. Akure is the capital city of Ondo State, located in the south-western region of Nigeria. The geographical location of the city is latitude 7^{o} 15’ 0” North and longitude 5^{o} 12’ 0” East (Ojo, 2022b). Ijare on the other hand is a town located in Ifedore L.G.A of Ondo State. The town is located at latitude 7^{o} 22’ 0” North and longitude 5^{o} 10’ 0” East and is situated about 10.3km North of Akure (Oladapo, 2013). Ijare is the study area representing the rural setting in Ondo state and a street view of the town is shown in Figure 1. Alagbaka on the other hand is the study area representing the urban setting and a street view of the community is shown in Figure 2.

Sample collection

Water samples were collected from a total of ten hand-dug wells at different locations within Alagbaka and Ijare. Five groundwater samples were collected from Alagbaka representing an urban setting, while the other five samples were collected from Ijare representing a rural setting. The sample collection points were chosen randomly. The coordinates of the groundwater wells are presented in Table 1. At sample collection points, the groundwater samples were collected in clean, well-labelled 1.5 L capacity sampling bottles which were properly rinsed with distilled water before sample collection. After collection, the bottles were well-corked, stored in a cooler and transported to the laboratory within 4 hours to preserve the integrity of the water samples (Ojo, 2022b).

Table 1. Geographical coordinates of sampled groundwater wells

Groundwater	Latitude	Longitude
U1	7.255014	5.219304
U2	7.255454	5.220446
U3	7.253524	5.218707
U4	7.251192	5.218291
U5	7.248972	5.218363
R1	7.359262	5.169494
R2	7.358603	5.167156
R3	7.358599	5.167161
R4	7.358065	5.169643
R5	7.357530	5.172125

U1 to U5 are the sampled groundwater wells in Alagbaka (Urban); R1 to R5 are the sampled groundwater wells in Ijare (Rural)

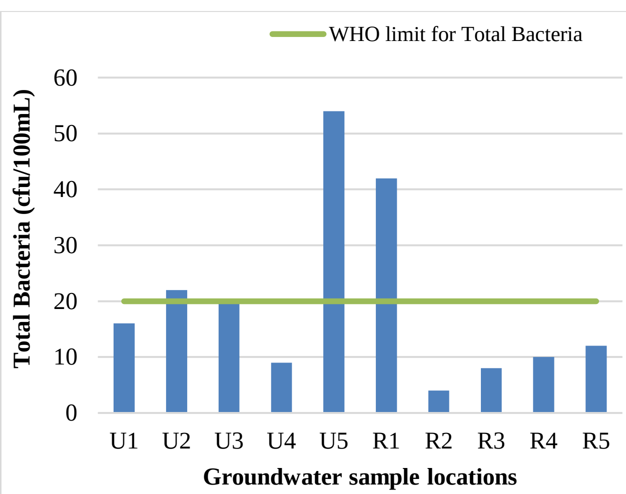
Laboratory analyses of samples

The pour plate method of Collins and Lyne (Clarke, 2004) was adopted for culture. About 1 ml of the samples was taken aseptically with a sterile pipette and transferred carefully into each of the test tubes containing 9.0 ml of cooled sterilized diluent. Each sample in different test tubes was mixed thoroughly to ensure dislodgement and even distribution of microorganisms into the suspended sterile water. A two-fold serial dilution of each 1ml homogenate was prepared. Exactly 1.0ml of dilution factor 10^{-1} and 10^{-2} were inoculated into the sterile Petri dishes for culturing. Incubation was carried out at 37^{o}C for 24 hours for bacteria growth. Colonies were then counted to obtain the total viable count.

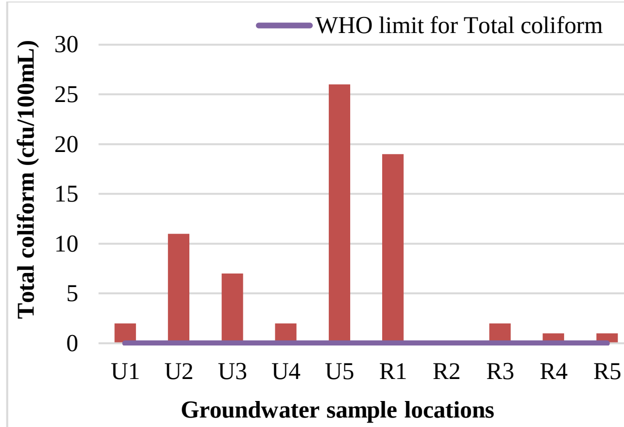
RESULTS AND DISCUSSION

Comparison with WHO drinking water standards

The levels of total bacteria in sampled wells ranged from 4 to 54 cfu/100mL, with seven out of the ten wells within the WHO drinking water standard limit of 20 cfu/100mL (Hamad et al., 2022), while the remaining three wells had total bacterial levels above the recommended limit as displayed in Graph 1. Total coliform bacteria on the other hand had levels ranging from 0 to 26 cfu/100mL with only one of the wells having no coliform as the WHO drinking water standard limit recommends while the remaining nine wells were above the recommended limit of 0 cfu/100mL (WHO, 2022) as shown in the Graph 2. There was no presence of *E. coli* in any of the samples conforming to the WHO recommended limit of 0 cfu/100mL (WHO, 2022), hinting that groundwater in urban and rural study areas is free from faecal contamination since the presence of *E. coli* in drinking water indicates contamination of water with faecal material (WHO, 2022). Therefore, based on the comparison of microbial levels of groundwater with WHO drinking water standards, groundwater from all sampled wells is unfit for drinking except for R2 which had microbial levels within recommended limits.



Graph 1. Variation of total bacteria in urban and rural study wells with WHO standard



Graph 2. Variation of total coliform in urban and rural study wells with WHO standard

The higher presence of total coliform in groundwater resources in this study is in line with the result of Lutterodt et al. (2018) who reported higher microbial contamination in groundwater samples from hand-dug wells than from boreholes. This could be as a result of aquifers nearer to the earth's surface which are more prone to microbial contamination.

Comparison of Urban and Rural Groundwater Quality

Levels of total bacteria in the urban groundwater samples with a mean of 24 cfu (colony-forming unit)/100mL were found to be generally higher than that of rural with a mean of 15 cfu/100mL. Similarly, the concentrations of total coliform in the urban groundwater samples were generally higher than that of the rural groundwater samples with means of 10 and 5 cfu/mL, respectively. This is in agreement with Taiwo et al. (2015) that groundwater in the rural areas was less contaminated than those in the urban areas. This could be a result of the artificial sealing of a large portion of the ground surface in urban areas with concrete and asphalt pavement, and the channelling of runoffs into large water bodies via drainages as shown in Figure 1 (Bhaskar et al., 2016; Liaqat al., 2021). This however hinders the infiltration of rain and surface water into the soil, thereby preventing adequate groundwater recharge which is necessary for reducing the concentration of groundwater contaminants (Liaqat et al., 2021; Obiora-Okeke et al., 2021). Khatri and Tyagi (2014) also reported that, since anthropogenic influences are generally less intense in rural environments, especially in developing countries, groundwater resources in urban areas are usually more polluted than in rural areas.

Other factors for the higher groundwater contamination in urban areas than in rural areas could be the use of deeper soak-away pits and septic tanks, seepage of untreated industrial effluents into groundwater resources etc. These cause pollution sources to be nearer to aquifers of hand-dug wells, thus increasing the risk of bacterial pollution. Studies have revealed that the higher contamination in natural water sources in urban areas than in rural areas in different study areas could be due to anthropogenic activities such as domestic and industrial effluent discharge, land use and land cover changes etc. (Peters and Meybeck, 2000; Buck et al., 2004; Alam et al., 2006; Zhang et al., 2007; Hussain et al., 2008).

Figure 1. Street view of an Ijare (rural) neighbourhood

Figure 2. Street view of an Alagbaka (urban) neighbourhood

CONCLUSION

The results of the bacterial analysis of groundwater in the urban and rural study areas showed that the levels of total bacteria in 30% of the groundwater samples collected were above the WHO standard limit for drinking water while the rest was within the limit. However, nine out of the ten groundwater samples collected had total coliform above the WHO recommended standard limit for drinking water while no *E. coli* was found in all groundwater samples. The study, therefore, concludes that there is no risk of faecal contamination of groundwater in study areas; however, based on WHO standards for drinking water, groundwater in the study area is not fit for drinking and must be treated appropriately before consumption.

DECLARATIONS

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Authors' contribution

Conceptualization and supervision were carried out by Ochuko Mary Ojo and Taiwo Oreoluwa Olabanji. Data collection and analysis were carried out by Joy Toluwani Ojo and Rebecca Taiwo Aluko. The first draft of the manuscript was written by Joy Toluwani Ojo. All authors commented on the previous versions of the manuscript and approved the final manuscript.

Data availability

The datasets used and/or analysed during the current study available from the corresponding author on reasonable request.

Competing interests

The authors declare no competing interests in this research and publication.

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