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Original Research Article

Quality Assessment of Groundwater in Mowe, Ogun State, Nigeria

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ABSTRACT

Drinking water contamination by heavy metals and microbes is increasingly implicated in a variety of diseases around the world, prompting quality assessment of all drinking water sources. This study evaluated the safety of borehole and well water in Mowe metropolis, Ogun State, Nigeria. The levels of heavy metals, namely copper (Cu), nickel (Ni), lead (Pb), cadmium (Cd), iron (Fe), and chromium (Cr), as well as microorganisms were determined in the samples of the water using conventional procedures. The mean of the values obtained for each parameter was then compared with the World Health Organization (WHO) permissible limits. In addition, the average daily ingestion (*ADI*) and hazard quotients (*HQ*) of the heavy metals were estimated. The heavy metal analysis revealed that both the borehole and well water samples had non-tolerable concentrations of Pb and Fe, while Ni, Cd, Cr, and Cu were within the tolerable limits. The *ADI* and *HQ* of the heavy metals were within the recommended limits. However, the cumulative *HQ* (health risk index) of the heavy metals in the well water was higher than the threshold of 1. The microbiological examinations indicated that the borehole and well water samples contained non-permissible levels of bacterial and yeast colonies, while only the well water had non-permissible concentrations of coliforms. Heavy metals and microbiological contaminants in well water samples were higher in comparison. These findings indicate that the water may pose some health hazards if consumed in its current form. As such, consumers are advised to treat groundwater before consuming it.

Keywords: Bacteria, Boreholes, Heavy metal, Lead, Microorganisms.

Introduction

Water is one of the necessities for a healthy life. It is needed for the formation and functional activities of the cells and the coordination of the entire body.[1] However, contaminated water can act as a vehicle for disease transmission.[2, 3] Common waterborne diseases include typhoid fever, cholera, and diarrhea, among others.[4] Population expansion, increased anthropogenic activities, as well as rapid urbanization and climate change, are the major factors in the increasing contamination of water worldwide. [5] About 2.2 million people die from diarrheal diseases annually, many of which are linked to contaminated water.[6] The burden of contaminated water is particularly high in third-world countries due to poor healthcare facilities. [7] In developing countries such as Southeast Asia and Africa, diarrhea alone accounts for up to 8.5 and 7.7% of annual mortality, respectively.[6]

Drinking water is derived primarily from two sources, which are surface waters such as rivers and reservoirs, as well as groundwater such as boreholes and wells. [3] Water sources naturally contain contaminants, particularly inorganic substances that emanate from the geological strata through which the water flows.[3] Artificial contamination of water may occur through anthropogenic activities.[3]

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Among the toxic chemicals in water, heavy metals are the most suspected owing to their persistence, toxicity, and wide distribution in the environment. Long-term human exposure to heavy metals such as copper (Cu), cadmium (Cd), lead (Pb), zinc (Zn), and nickel (Ni) causes health hazards.[8] Some heavy metals can combine together to produce additive effects.[9] More than 25% of the total burden of disease is linked to environmental factors to which toxic chemicals contribute significantly.[10] Heavy metals enter the environment through both natural and anthropogenic sources, including mining, oil exploration, household and industrial waste, and urban runoff. [11] Besides heavy metals, microorganisms are another group of water contaminants that are of public health concern. There are over 500 waterborne pathogens capable of contaminating drinking water and are grouped mainly into viruses, bacteria, parasitic protozoa, and fungi. [12] Waterborne diseases kill more than 5 million people per year, [13, 14] of which over 50% are microbial intestinal infections.[13]

In Mowe metropolis, Ogun State, Nigeria, groundwater, mainly boreholes and wells, is the major source of drinking water. About 81% of the residents of Ogun State depend on groundwater for drinking. [15] This is due to the cost-effectiveness of groundwater and the inadequacy of pipe-borne water in the state, which is characteristic of developing nations. Though groundwater is less vulnerable to pollution than surface waters,[3] it may be contaminated by anthropogenic activities and urban runoffs in metropolitan areas such as Mowe. Thus, periodic monitoring of groundwater in Mowe is necessary to prevent disease outbreaks. Monitoring of water quality for its improvement can reduce the global disease burden by approximately 4%.[16] There is a dearth of documented studies on heavy metal and microbial pollution of groundwater in the Mowe metropolis. Therefore, this study assessed the quality of borehole and well water in Mowe metropolis, Ogun State, Nigeria.

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Materials and Methods

Description of the study site

This study was carried out in Mowe, Ogun State, Southwestern Nigeria (Figure 1). Ogun State borders Lagos State and the Atlantic Ocean on the south, Oyo State on the north, the Benin Republic on the west, and Ondo State on the east. The climate of the state is tropical with mainly a wet season. The rainfall averages between 40 and 60 mm, with its peaks occurring between May and August.[17] The daily average temperature is between 25 and 27°C.[17]

Mowe, the study site, is in the Obafemi-Owode Local Government Area of the state at latitude 6°51'N and longitude of 3°27'E. [17] Mowe is a linear settlement along the Lagos-Ibadan expressway that is increasingly being populated by the outflux of the ever-increasing Lagos population. Thus, Mowe is characterized by heavy anthropogenic activity that can potentially contaminate groundwater, necessitating periodic monitoring. These activities include food crop and livestock farming, fishing, quarrying, artisanal work, and handicrafts, such as dye-making and pottery.

Collection of water samples

Between March and June 2021, 42 water samples (21 boreholes and 21 wells) were collected at random from seven popular streets in Mowe metropolis. The samples were collected in pre-washed and sterilized plastic bottles, covered tightly, and transported immediately in a sealed polyethylene bag into the laboratory. The samples were stored in a refrigerator at about 4°C prior to analysis.

Heavy metal analysis

The concentrations of copper (Cu), iron (Fe), cadmium (Cd), chromium (Cr), lead (Pb), and nickel (Ni) in the water samples were determined by atomic absorption spectroscopy (AAS) as described by Yahaya *et al*. [18]

Microbiological analysis

The total bacteria, coliform, and fungi counts in each water sample were estimated using the membrane filtration technique as described by Yahaya *et al.* [19]

Quality assurance and control

The reagents used for the heavy metal analysis and other tests were prepared from chemicals of high analytical grade (AnalaR). The container for each reagent was washed with a detergent solution, after which it was rinsed properly. Background contamination of the samples was checked by analyzing blank samples after every five sample analyses. Each sample was analyzed thrice, and the reproducibility of the values obtained was ensured.

Health risk assessment of the heavy metals

The health risks of daily consumption of borehole and well water in the area under study were calculated from the average daily ingestion (*ADI*) and the hazard quotient (*HQ*) of the heavy metals in the water, as shown in equations 1 and 2. [20]

$$ADI = \frac{Cx \times Ir \times Ef \times Ed}{Bwt \times At} \quad (1)$$

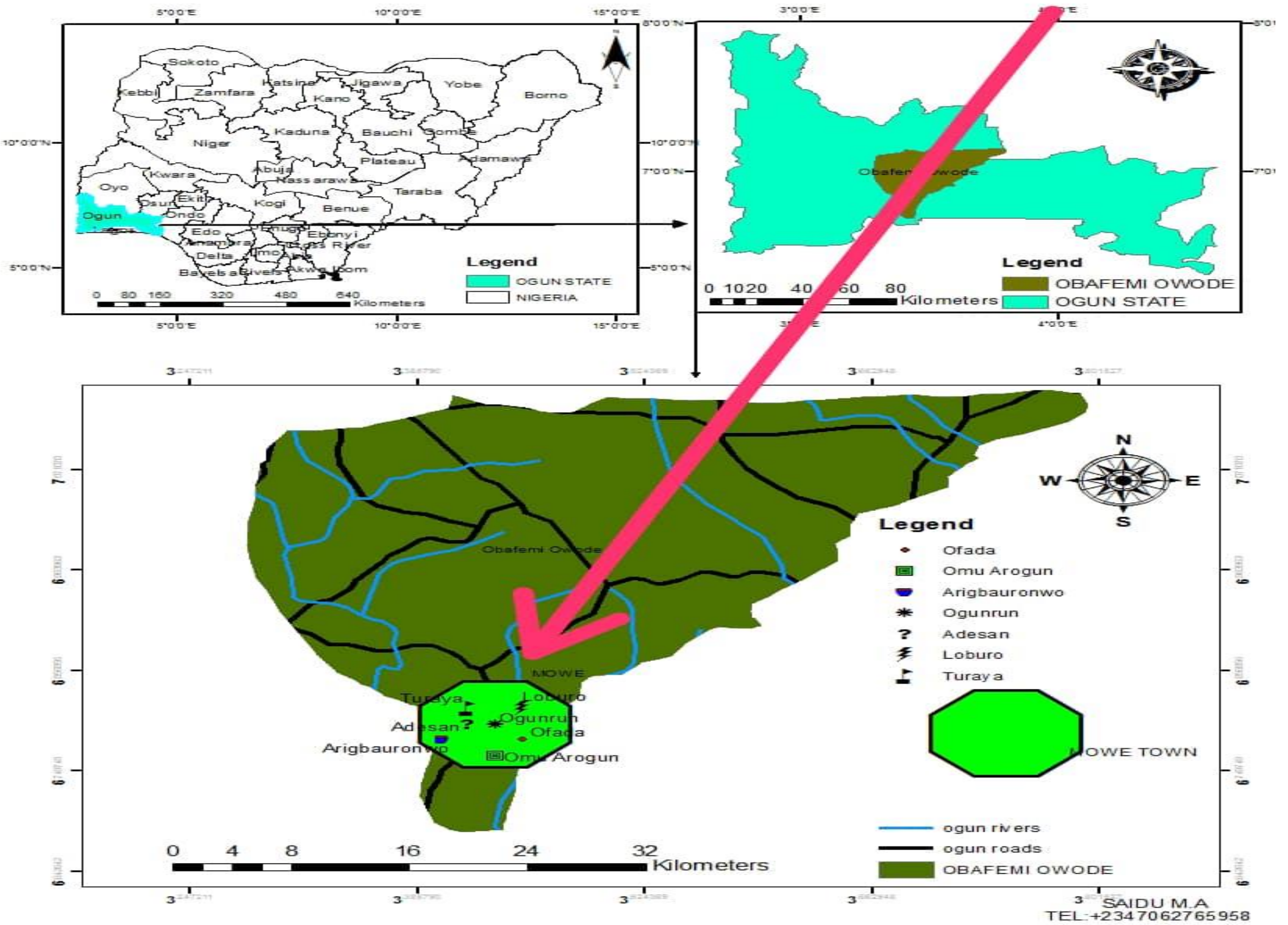

Figure 1: Locations of the study site (drawn using ArcGIS 10.3 software).

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In equation 1, *ADI* stands for the average daily ingestion of a heavy metal per kilogram of body weight, *Cx* is the concentration of heavy metals in water, *Ir* represents the ingestion rate per unit time, *Ef* denotes the exposure frequency, *Ed* means exposure duration (equals the average life expectancy of a resident Nigerian), *Bwt* represents the body weight, and *At* is the average time (*Ed* x *Ef*). The standard values and units for these parameters are given in Table 1.

$$HQ = \frac{\mathrm{ADI}}{\mathrm{RFD}} \qquad (2)$$

In equation 2, *HQ* represents the hazard quotient and *RFD* is the oral reference dose (mg/L/day) for the selected heavy metals (Table 2). A *HQ* of less than one was deemed non-toxic. [21]

Data analysis
Values were presented as mean ± standard deviation (SD) using the Microsoft Excel software version 21. The same software was used to calculate the *ADI* and *HQ* of the heavy metals.

Table 1: Standard values for calculating average daily ingestion of heavy metals [46]

Exposure Factor	Unit	Value
Exposure frequency (*Ef*)	Days/year	365
Ingestion rate (*Ir*)	L/day	2
Exposure duration (*Ed*)	Years	55
Average body weight (*Bwt*)	Kg	65

Table 2: Oral reference doses (*RFD*) for Pb, Ni, Cd, Cr, Zn, and Cu in water [47]

Heavy metal	Value (mg/L/day)
Pb	0.0035
Ni	0.0200
Cd	0.0005
Cr	0.0003
Fe	0.0070
Cu	0.0400

Results and Discussion

Levels of heavy metals in the water samples
Tables 3 and 4 revealed the levels of Pb, Cu, Cd, Cr, Ni, and Fe in the samples of the borehole and well water obtained from Mowe, Ogun State, Nigeria. Pb and Fe were detected at the World Health Organization's (WHO) non-permissible limits in the borehole water samples from all the streets, of which Ofada Street had the highest concentrations of the two heavy metals (Table 3). However, Cu, Cd, Cr, and Ni were detected in the borehole water within the permissible limits in all the streets (Table 3). Similar trends were observed in the well water samples, in which Pb and Fe were detected in all the streets at non-tolerable levels, while other evaluated heavy metals were within the permissible range (Table 4). Overall, Fe was the most abundant heavy metal in both the borehole and well water samples, while Cd and Ni were the least abundant (Tables 3 and 4). There is a dearth of literature on the heavy metal concentrations in groundwater in Mowe metropolis. However, the results of some studies conducted in the settlements and local governments close to Mowe showed some consistencies with the present study. Notably, Ayedun *et al*.[22] find non-tolerable concentrations of Pb, Fe, and Cd in groundwater in Ifo, a neighboring local government to the study site. In a related study conducted in Ibafo and Magboro metropolis (neighboring towns) by Adeniyi *et al*. [23] Cd and Fe were detected at non-permissible levels. However, unlike the present study, Adewoyin *et al*.[24] reported non-tolerable concentrations of Cu and Cr in groundwater in Ota, still in the Ifo local government area of the state. This showed that there is an uneven distribution of heavy metals across the state, which could be related to the diverse anthropogenic activities, population densities, and levels of environmental awareness across the state. On average, the heavy metals were more abundant in the well water than the boreholes (Table 5).
The detection of Pb and Fe beyond the permissible limits in both the well and borehole water samples suggests that the two water sources may pose some health risks to the consumers in Mowe metropolis unless the water is treated. Prolonged exposure to Pb can affect the hematological, nervous, renal, and reproductive systems as well as disrupt neurotransmitter release and bone mineral density.[25, 26] Iron is essential for biological systems, but at certain levels, it can induce cell death by generating free radicals.[27] Although Cu, Cd, Cr, and Ni were detected within the permissible limits in the borehole and well water, strictly speaking, there are no safe levels for most heavy metals. This is because heavy metals are non-biodegradable and so can accumulate to toxic levels in human tissues, resulting in health problems. Cu has been reported to cause neurotoxicity, commonly known as “Wilson’s disease,” as well as kidney failure.[28] Ni exposure can cause skin irritation as well as lung, nervous system, and mucous membrane damage.[28] Long-term exposure to Cd causes cancer and multi-organ damage such as skeletal, urinary, reproductive, cardiovascular, nervous, and respiratory systems.[29] Cr is cytotoxic, genotoxic, and carcinogenic. [30] The observed sources of these metals in the water are wastes from homes and industries, artisan workshops, dumpsites, urban gardens, and vehicular release, among others.

Health hazards of the water samples
The average daily ingestion (*ADI*) and hazard quotient (*HQ*) of Pb, Cu, Cd, Cr, Ni, and Fe by the residents of Mowe via the borehole and well water are revealed in Table 6.

Table 3: Levels of heavy metals detected in borehole water in Mowe

Water Samples Location	Mean concentrations of the heavy metals (mg/mL)					
	Lead (Pb)	Copper (Cu)	Cadmium (Cd)	Chromium (Cr)	Nickel (Ni)	Iron (Fe)
Adesan	0.01 ± 0.000	0.21 ± 0.012	BDL	0.02 ± 0.003	0.01 ± 0.002	0.33 ± 0.104
Loburo	0.01 ± 0.000	0.26 ± 0.052	BDL	0.02 ± 0.002	0.01 ± 0.002	0.38 ± 0.083
Arigbawonwo	0.01 ± 0.000	0.23 ± 0.011	0.001 ± 0.000	0.02 ± 0.004	0.01± 0.002	0.41 ± 0.157
Ogunnun	0.01 ± 0.000	0.25 ± 0.053	0.002 ± 0.000	0.02 ± 0.002	0.01 ± 0.003	0.33 ± 0.077
Omu-Aro	0.01 ± 0.000	0.24 ± 0.006	BDL	0.02 ± 0.004	BDL	0.41 ± 0.155
Turaya	0.01 ± 0.000	0.25 ± 0.052	0.002 ± 0.000	0.02 ± 0.002	BDL	0.34 ± 0.155
Ofada	0.02 ± 0.000	0.23 ± 0.009	BDL	0.02 ± 0.001	BDL	0.47 ± 0.084
WHO [47]	0.01	1.0	0.003	0.05	0.02	0.3

Note: WHO stands for World Health Organization and BDL means Below Detectable Levels

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Table 4: Levels of heavy metals detected in well water in Mowe

Water Samples Location	Mean concentration of the heavy metals (mg/L)					
	Lead (Pb)	**Copper (Cu)**	**Cadmium (Cd)**	**Chromium (Cr)**	**Nickel (Ni)**	**Iron (Fe)**
Adesan	0.02 ± 0.002	0.33 ±0.104	BDL	0.01 ± 0.003	BDL	0.33 ± 0.163
Loburo	0.03 ± 0.002	0.34 ± 0.067	0.001 ± 0.000	0.02 ± 0.001	BDL	0.33 ± 0.088
Arigbawonwo	0.03 ± 0.007	0.29 ± 0.125	BDL	0.02 ± 0.002	BDL	0.36 ± 0.150
Ogunnun	0.03 ± 0.002	0.35± 0.010	0.002 ± 0.000	0.02 ± 0.004	BDL	0.31 ± 0.102
Omun Aro	0.03 ± 0.004	0.24 ± 0.049	BDL	0.02 ± 0.003	0.005 ± 0.003	0.39 ± 0.115
Turaya	0.03 ± 0.001	0.39± 0.057	0.01 ± 0.000	0.02 ± 0.003	0.005 ± 0.003	0.24 ± 0.016
Ofada	0.03 ± 0.001	0.27 ± 0.057	BDL	0.02 ± 0.005	0.005 ± 0.003	0.36 ± 0.061
WHO [47]	0.01	1.0	0.003	0.05	0.02	0.3

Note: WHO stands for World Health Organization and BDL means Below Detectable Levels

Table 5: Comparison between the levels of heavy metals (mg/L) in borehole and well water in Mowe

Water Source	Lead (Pb)	Copper (Cu)	Cadmium (Cd)	Chromium (Cr)	Nickel (Ni)	Iron (Fe)
Borehole	0.013 ± 0.033	0.24 ± 0.031	0.012 ± 0.006	0.204* ± 0.003	0.078* ± 0.002	0.379* ± 0.104
Well	0.027* ± 0.039	0.32 ± 0.082	0.15* ± 0.004	0.018 ± 0.003	0.005 ± 0.003	0.332 ± 0.102

Note: Values with an asterisk are significantly different at $p \leq 0.05$ (Student's *t*-test)

Table 6: Average daily ingestion (*ADI*) and hazard quotient (*HQ*) of heavy metals in borehole and well water in Mowe, Ogun State

Heavy metal	Average Daily Ingestion (*ADI*)			Hazard Quotient (*HQ*)	
	Borehole	**Well**	**WHO [47]**	**Borehole**	**Well**
Pb	0.0004	0.0008	≤ 0.01	0.111	0.222
Cu	0.007	0.0097	≤ 5.00	0.175	0.243
Cd	0.0001	0.0004	≤ 0.02	0.133	0.889
Cr	0.0006	0.0005	≤ 0.05	0.200	0.167
Ni	0.0002	0.0002	≤ 0.02	0.010	0.010
Fe	0.012	0.0100	≤ 8.00	0.017	0.014
CADI/CHQ	0.0203	0.0216		0.646	1.545

CADI = cumulative average daily ingestion; *CHQ* = cumulative hazard quotients

The *ADI* of the heavy metals were within the respective recommended limits (Pb ≤0.01, Cu ≤ 5.00, Cd ≤ 0.02, Cr ≤ 0.05, Ni ≤ 0.02, and Fe ≤ 8.00), while the *HQ* was less than 1, the upper limit within which a substance could be considered non-toxic. However, the cumulative *HQ* (*CHQ*), otherwise known as the health risk index, of all the heavy metals in the well water was above 1, indicating that the heavy metals in the water may combine to pose some health effects. It has been established that heavy metals can interact synergistically and pose health hazards. In a study by Andjelkovic*et al*., [31] the combined effects of Pb and Cd produced more hematological and biochemical effects than the individual metals. Ubani-Rexet *et al*.[32] also shows that Cu and Cd can induce synergistic effects in animals. The higher *CHQ* of the well water compared to the borehole indicates that the well water was more polluted with heavy metals. This observation is consistent with that of Amori *et al*.,[33] who reported higher concentrations of Zn, Pb, and Ni in well water than in the boreholes in Odeda, Ogun State. Yusuf *et al*.[34] and Imam *et al*.[35] also reported higher concentrations of heavy metals in well water than in boreholes in Gombe and Kaduna State, Nigeria, respectively. However, Eminike *et al*.[36] detected higher concentrations of heavy metals in boreholes than in well water in Atan District, Ogun State. It is possible that the well water received more heavy metals from the surface than the borehole water.

Levels of microorganisms in the water samples

The total bacterial, coliform, and yeast counts in the borehole and well water samples from Mowe metropolis are shown in Tables 7 and 8. Bacteria and yeast colonies were detected above the permissible limits in the borehole water obtained from all the selected streets, but coliforms were not detected (Table 7). The borehole water samples from Ofada Street had the highest bacterial colonies, while Laburo Street had the highest yeast colonies (Table 7). Except for Laburo, Ogunu, and Thuraya (coliform only), well water samples from all the streets had bacterial, coliform, and yeast colonies beyond the permissible limits (Table 8). Laburo had the highest bacteria counts, Arigbawonwo had the highest coliform counts, and Ogunun had the highest yeast counts (Table 8). An earlier study by Aladejana and Talabi [37] also reported abnormal counts of total bacteria and coliforms in groundwater in Abeokuta, Ogun State. In a study that examined the bacterial contents of borehole water in some towns bordering Mowe, including Ilishan, Sagamu, Ogere, Ilara, and Oderemo, non-tolerable bacterial and coliform counts were reported.[38] Similarly, in an assessment of the bacterial quality of well water in Abeokuta, non-permissible levels of total bacteria and coliforms were detected.[39] There is a dearth of literature on the occurrence of yeast colonies in groundwater, not only in Mowe but the entire state. Compared with the previous studies mentioned, the levels of microbiological contaminants in the water evaluated in this study were far higher. This could be due to the variations in sanitary conditions and population densities across the state. Mowe is close to Lagos (a megacity), so Mowe is highly populated and crowded, which could be responsible for the high microbiological populations in the groundwater in the area.

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Table 7: Levels of microorganisms detected in borehole water in Mowe

Water samples	Bacterial Count (CFU mL^{-1})	Coliform Count (CFU mL^{-1})	Yeast Count (CFU mL^{-1})
Adesan	2.10×10^8	0.00	1.0×10^1
Loburo	3.40×10^8	0.00	3.0×10^1
Arigbawonwo	1.90×10^8	0.00	2.0×10^1
Ogunnun	2.80×10^8	0.00	0.0×10^1
Omun Arogun	3.10×10^8	0.00	1.0×10^1
Turaya	4.20×10^8	0.00	0.0×10^1
Ofada	5.60×10^8	0.00	2.0×10^1
WHO [48]	≤ 100 CFU mL^{-1}	0 CFU100 mL^{-1}	≤50CFUmL^{-1}

Table 8: Levels of microorganisms detected in well water in Mowe

Water samples	Bacterial Count (CFU mL^{-1})	Coliform Count (CFU mL^{-1})	Yeast Count (CFU mL^{-1})
Adesan	4.0×10^8	1.100×10^3	4.0×10^3
Loburo	10.0×10^8	0.00	8.0×10^3
Arigbawonwo	3.0×10^8	1.400×10^3	11.0×10^3
Ogunun	2.0×10^8	0.00	16.0×10^3
Omun Arogun	8.0×10^8	1.300×10^3	10.0×10^3
Turaya	4.0×10^8	0.00	6.0×10^3
Ofada	4.0×10^8	1.700×10^3	18.0×10^3
WHO [48]	≤ 100 CFU ml^{-1}	0 CFU100 ml^{-1}	≤50CFUml^{-1}

Table 9: Comparison between the levels of microorganisms in borehole and well water

Water Source	Bacterial Count (CFU mL^{-1})	Coliform Count (CFU mL^{-1})	Yeast Count (CFU mL^{-1})
Borehole	3.37×10^8	0.000×10^3	1.29×10^3
Well	5.00×10^8	$0.77^{*} \times 10^3$	10.43×10^3

Note: Values with an asterisk are significantly different at $p \leq 0.05$ (Student's *t*-test)

Generally, the well water contained more bacteria, coliform, and yeast colonies than the borehole water in all the streets (Table 9). This indicates that the well water in Mowe metropolis contained more microbiological contaminants than the borehole water. Bello *et al.*[40] reported a similar observation in which fecal coliforms were found in abundance in well water in Ijebu Ode but no trace was found in the borehole water in the same environment. This could be because boreholes are deeper than wells and thus receive fewer microbiological contaminants from the surface compared to well water. In a study of microbiological populations in well water, shallow wells were more contaminated. [41] The detection of total bacteria, yeast, and coliform (well only) colonies above the permissible limits in both the borehole and well water in this study again proved the unsuitability of the water in its current form for drinking. Some bacteria species can cause cholera, typhoid fever, gastrointestinal diseases, diarrhea, dysentery, and respiratory diseases. [42] Some species of bacteria can also disrupt the normal gut microbiome and immune function, resulting in diseases such as cancer, diabetes mellitus, cardiovascular disease, and obesity. [43] The majority of coliform bacteria do not cause illness. However, some *E. coli* strains, particularly the 0157:H7 strain, can cause serious disease. [44] Certain yeast can cause allergic reactions, and some can secrete mycotoxins. [45] The microorganisms in the water are thought to come from dump sites, sewage, waste from small-scale industries, septic tanks, and garden soil, among other things.

Conclusion

The results established that both the borehole and well water in Mowe metropolis contained non-tolerable concentrations of Pb and Fe, as well as permissible concentrations of Ni, Cd, Cr, and Cu. The *ADI* and *HQ* of the heavy metals in both the well and borehole water were within the recommended limits. However, the *CHQ* of the heavy metals in the well water was higher than the threshold of 1. The well and borehole water also contained non-permissible levels of bacterial and yeast colonies, while coliforms were detected beyond the permissible levels in the well water only. Comparatively, the well water contained more microbial and heavy metal contaminants. The results indicate that both the borehole and well water may not be suitable for consumption.

Conflict of Interest

The authors declare no conflict of interest.

Authors' Declaration

The authors hereby declare that the work presented in this article is original and that any liability for claims relating to the content of this article will be borne by them.

References

1. Sharma S and Bhattacharya A. Drinking water contamination and treatment techniques. Appl Water Sci. 2017; **7**:1043–1067.
2. Balogun SA, Akingbade OA, Oyekunle MA, Okerentugba PO. Physicochemical and Microbiological Profile of Drinking Water Sold in Abeokuta, Ogun State, Nigeria. Nat Sci. 2014; 12(3):103-105.
3. Fawell J and Nieuwenhuijsen MJ. Contaminants in drinking water: Environmental pollution and health. Br Med Bull. 2003; 68(1):199-208.
4. Fazal-Ur-Rehman M. Polluted Water Borne Diseases: Symptoms, Causes, Treatment and Prevention. J Med Chem Sci. 2019; 2(3):85-91.
5. Fronczyk J, Radziemska M, Dynowski P, Mazur Z, Bazyd OM. Quality of water in the road drainage systems in the Warsaw agglomeration, Poland. Water. 2016; 8(10):1–12.
6. World Health Organization. Water-related diseases-Diarrhoea. [2020]. Available at https://www.who.int/water_sanitation_health/diseases-risks/diseases/diarrhoea/en/(Accessed February 15, 2022).
7. World Health Organization. Fact Sheet: Drinking-Water. [2018]. Available at http://www.who.int/countryfocus/cooperation_strategy/ccs_npl_en.pdf. (Accessed February 15, 2022).
8. Singh R, Gautam N, Mishra A, Gupta R. Heavy metals and living systems: An overview. Indian J Pharmacol. 2011; 43(3):246-53.
9. Yoo J-W, Cho H, Lee K-W, Won E-J, Lee Y-M. Combined effects of heavy metals (Cd, As, and Pb): Comparative study using conceptual models and the antioxidant responses in the brackish water flea. Comparative Biochemistry and Physiology Part C: Toxicol Pharmacol. 2021; 239:108863.
10. World Health Organization. Health Risk Assessment Toolkit. Chemical hazards. International Program on Chemical Safety Harmonization Project Document. No. 8, WHO, 2010.

http://www.who.int/ipcs/publications/methods/harmonization/toolkit.pdf.

11. Anyanwu BO, Ezejiofor AN, Igweze ZN, Orisakwe OE. Heavy Metal Mixture Exposure and Effects in Developing Nations: An Update. Toxics. 2018; 6(4):65.
12. Soller JA, Bartrand T, Ashbolt NJ, Ravenscroft J, Wade, TJ. Estimating the primary etiologic agents in recreational freshwaters impacted by human sources of faecal contamination. Water Res. 2010; 44 (16):4736–4747.
13. Cabral JP. Water microbiology. Bacterial pathogens and water. Int J Environ Res Pub Health. 2010; 7(10):3657-3703.
14. Malik A, Yasar A, Tabinda A, Abubakar M. Water-borne diseases, cost of illness and willingness to pay for diseases interventions in rural communities of developing countries. Iran J Pub Health. 2012; 41(6):39-49.
15. Omole DO and Okunowo. OS. People Perception of Domestic Water Supply Situation in Ogun State, Nigeria. Res J Appl Sci Eng Technol. 2016; 12(1):94-99.
16. World Health Organization. Water Sanitation and Health [2015]. Available online at http://www.who.int/water_sanitation_health/diseases (Accessed February 9, 2022).
17. Adeoti L, Alile OM, Uchegbulam O, Adegbola RB. Geoelectrical Investigation of the Groundwater Potential in Mowe, Ogun State, Nigeria. Br J Appl Sci Technol. 2012; 2(1):58-71.
18. Yahaya T, Oladele E, Sifau M, Audu G, Bala J, Shamsudeen A. Characterization and Cytogenotoxicity of Birnin Kebbi Central Abattoir Wastewater. UNIPORT J Eng Sci Res. 2020; 5 (special issue):63-70.
19. Yahaya T, Esther O, Mutiu S, Aminu M, Esther O. Characterization and Cytogenotoxicity of Water Samples from River Challawa in Kano, Northwest Nigeria. Songklanakarin J Sci Technol. 2021; 43(4):1-8.
20. United States Environmental Protection Agency. Exposure factors handbook: 2011 edition. Washington, D.C, 2011; 1436 p.
21. Yahaya TO, Ogundipe OA, Abdulazeez A, Usman B, Danjuma J. Bioaccumulation and Health Risk Assessment of Heavy Metals in Three Vegetables Consumed in Lagos, South-West Nigeria. Trop J Nat Prod Res. 2019; 3(11):332-338.
22. Ayedun H, Taiwo AM, Umar BF, Oseni OA, Oderinde AA. Assessment of groundwater contamination by toxic metals in Ifo, Southwestern Nigeria. Indian J Sci Technol. 2011; 4(7):820-823.
23. Adeniyi A, Yusuf K, Okedeyi O, Sowemimo M. Classification and Health Risk Assessment for Borehole Water Contaminated by Metals in Selected Households in Southwest Nigeria. J Water Resour Prot. 2016; 8:459-471.
24. Adewoyin OO, Kayode OT, Omeje O, Odetunmibi OA. Risk assessment of heavy metal and trace elements contamination in groundwater in some parts of Ogun state. Cogent Eng. 2019; 6(1):1632555.
25. Beier EE, Maher JR, Sheu T-J, Cory-Slechta DA, Berger AJ, Zuscik MJ, Puzas JE. Heavy metal lead exposure, osteoporotic-like phenotype in an animal model, and depression of Wnt signaling. Environ Health Perspect. 2013; 121 (1):97-104.
26. Towle KM, Garnick LC, Monnot AD. A human health risk assessment of lead (Pb) ingestion among adult wine consumers. Int J Food Contam. 2017; 4:7.
27. Eid R, Arab NTT, Greenwood MT. Iron mediated toxicity and programmed cell death: A review and a re-examination of existing paradigms. Biochim Biophy Acta (BBA) - Mol Cell Res. 2017; 1864 (2):399-430.
28. Parmar M and Thakur LS. Heavy Metal Cu, Ni and Zn: Toxicity, Health Hazards and their Removal Techniques by Low Cost Adsorbents: A Short Overview. Int J Plant Anim Environ Sci. 2013; 3 (3):143-157.
29. Rahimzadeh MR, Rahimzadeh MR, Kazemi S, Moghadamnia A. Cadmium toxicity and treatment: An update. Caspian J Intern Med. 2017; 8(3): 135–145.
30. Shrivastava R, Upreti RK, Seth PK, Chaturvedi UC. Effects of chromium on the immune system. FEMS Immunol Med Microbiol. 2002; 34 (1): 1–7.
31. Andjelkovic M, Djordjevic AB, Antonijevic E, Antonijevic B, Stanic M, Kotur-Stevuljevic J, Spasojevic-Kalimanovska V, Jovanovic M, Boricic N, Wallace D, Bulat Z. Toxic Effect of Acute Cadmium and Lead Exposure in Rat Blood, Liver, and Kidney. Int J Environ Res Pub Health. 2019; 16 (2):274.
32. Ubani-Rex OA, Saliu JK, Bello TH. Biochemical Effects of the Toxic Interaction of Copper, Lead and Cadmium on Clarias gariepinus. J Health Pollut. 2017; 7(16):38-48.
33. Amori AA, Oduntan OO, Okeyode IC, Ojo SO. Heavy metal concentration of groundwater deposits in Odeda region, Ogun state, Nigeria. E3 J Environ Res Manag. 2013; 4(5): 0253-0259.
34. Yusuf A, Olasehinde A, Mboringong MM, Tabale RP, Daniel EP. Evaluation of Heavy Metals Concentration in Groundwater around Kashere and its Environs, Upper Benue Trough, Northeastern Nigeria. Glob J Geol Sci. 2018; 16: 25-36.
35. Imam MM, Kankara IL, Abba Y. Determination of some heavy metals in borehole and well water from selected industrial areas of Kaduna metropolis. Discov Sci. 2018; 14:93-99.
36. Emenike PC, Tenebe I, Ogarekpe N, Omole D, Nnaji C. Probabilistic risk assessment and spatial distribution of potentially toxic elements in groundwater sources in Southwestern Nigeria. Sci Rep. 2019; 9: 15920.
37. Aladejana JA and Talabi AO. Assessment of Groundwater Quality in Abeokuta Southwestern, Nigeria. Assessment of Groundwater Quality in Abeokuta Southwestern, Nigeria. Research Inventory: Int J Eng Sci. 2013; 2 (6): 21-31.
38. Aina DA, Olawuyi OJ, Coker OA, Ojelabi DO, Alatise FA. Bacteriological analysis of borehole water from different towns in Ogun State, Nigeria. Afr J Microbiol Res. 2012; 6 (10): 2462-2468.
39. Olabisi OE, Awonusi AJ, Adebayo OJ. Assessment of bacterial pollution of shallow well waterin Abeokuta, Southwestern Nigeria. Life Sci. 2008; 5 (1): 59-65.
40. Bello OO, Osho A, Bankole SA, Bello TK. Bacteriological and Physicochemical Analyses of Borehole and Well Water Sources in Ijebu-Ode, Southwestern Nigeria. IOSR J Pharm Biol Sci. 2013; 8(2): 18-25.
41. Egwari L and Aboaba OO. Environmental impact on the bacteriological quality of domestic water supplies in Lagos, Nigeria. Rev Saúde Púb. 2002; 36(4): 513-520.
42. Igarashi H, Nago N, Kiyokawa H, Fukushi M. Abdominal pain and nausea in the diagnosis of streptococcal pharyngitis in boys. Int J Gen Med. 2017; 10:311-318.
43. Tlaskalova-Hogenova H, Stěpánková R, Kozáková H, Hudcovic T, Vannucci L, Tučková L. The role of gut microbiota (commensal bacteria) and the mucosal barrier in the pathogenesis of inflammatory and autoimmune diseases and cancer: contribution of germ-free and gnotobiotic animal models of human diseases. Cell Mol Immunol. 2011; 8 (2):110-120.
44. New York State Department of Health. Coliform bacteria in drinking water supplies. [2017] Available online at https://www.health.ny.gov/environmental/water/drinking/coliform_bacteria.htm.
45. Patterson R and Lima N. Fungal contamination of drinking water. In book: Water encyclopedia. 1st ed. John Wiley & Sons; New York, USA: 2005. 1–7 p.
46. Adesiyan IM, Bisi-Johnson M, Aladesanmi OT, Okoh AI, Ogunfowokan AO. Concentrations and Human Health Risk

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of Heavy Metals in Rivers in Southwest Nigeria. Environ Pollut. 2018; 8(19):1-14.
47. World Health Organization. International year of freshwater. General assembly resolution A/RES/55/196. [2003]. Available online at http://www.wateryear2003.org/(Accessed on March 18, 2022).
48. WHO (World Health Organization) (2017). Guidelines for Drinking-Water Quality: Fourth EditionIncorporating the First Addendum. World Health Organization, Geneva, Switzerland. Available at https://www.who.int/publications/i/item/9789 24154995 (Accessed April 12, 2022).