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Bacteriological Quality of Borehole Water in Gusau Metropolis

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Abstract

Microbes are ubiquitous and are known to contaminate materials, including food and water. We examined the bacteriological quality of borehole water in Gusau metropolis to determine its potability. Triplicate samples were collected from fifteen (15) different boreholes and analyzed. The total bacterial load, total coliform, fecal coliform, and Salmonella-Shigella count were determined using the membrane filtration technique. The average counts were as follows: total bacteria ranged from 6×10^1 cfu/ml to 39×10^1 cfu/ml, total coliform count from 3×10^1 cfu/ml to 65×10^1 cfu/ml, fecal coliform count from 1×10^0 cfu/ml to 4×10^0 cfu/ml, and Salmonella-Shigella count from 0 cfu/ml to 4×10^0 cfu/ml. The isolated organisms were identified as Escherichia coli, Salmonella typhi, and Shigella spp. The predominant bacterial isolate was Escherichia coli. Our study indicated that the bacteriological quality exceeded the World Health Organization (WHO) allowable limits of 0 cfu/100ml for total bacterial load, total coliform count, fecal coliform count, and Salmonella-Shigella count due to the underground aquifers. Therefore, we recommend that borehole water sources be adequately treated before consumption to reduce the risk of waterborne diseases.

Keywords: Bacteriological, Quality, Borehole, Water and Coliform.

INTRODUCTION

Water is a ubiquitous substance essential for life on Earth, composed of the chemical elements hydrogen and oxygen. Its molecular formula is H_2O, indicating that each water molecule consists of two hydrogen atoms bonded to one oxygen atom (Theodore *et al.*, 2017). It is one of the most essential compounds that is colorless, tasteless, and odorless liquid. Under room temperature, it possesses the ability to dissolve many other substances (Zumdahl, 2023). Water from both surface and groundwater sources plays vital roles in meeting diverse human needs, including domestic, industrial, agricultural, and environmental purposes (United Nations, 2019). Surface water includes water that flows across the land in the form of streamlets, springs, streams, and rivers or it collects to form ponds, lakes, and seas (Niyogi, 2011). In contrast, groundwater is located in aquifers underground and links with surface water through penetration and springs (Gleeson *et al.*, 2012). The underground water supplies are usually considered safe provided they are located, constructed, and operated according to the guidelines for drinking water (WHO 2018).

Owing to the government's failure to meet the ever-increasing water demand, many individuals turn to groundwater sources like boreholes as an alternative water source (Harvey, 2014). Therefore, people can obtain groundwater through boreholes drilled into aquifers for industrial, agricultural, and domestic purposes. Despite access to water, it does not guarantee access to safe water; as per the United Nations International Children Emergency Fund (UNICEF) and World Health Organization (WHO), Nigeria is classified among countries lacking access to improved water sources (UNICEF and WHO, 2019).

Lack of basic sanitation and poor hygienic practices in the supply of water for drinking and other domestic uses have been associated with a high morbidity and mortality rate globally, with diarrhea and cholera being reported as killer diseases (WHO 2018). These issues have been persistent in Gusau metropolis (NCDC, 2021). Therefore, this study aimed to assess the bacteriological quality of borehole water in Gusau metropolis.

MATERIALS AND METHODS

Study Area

This study was conducted in Gusau local government area, Zamfara state. The area is situated between latitude 12.09°N-12.5°N and longitude 6.67°E, covering an area of 3,364 km^2 with an estimated population of 582,100 as of March 21, 2019 (NPCN, 2019). The samples were gathered from 15 distinct boreholes in Gusau metropolis and conveyed to the microbiology laboratory at Federal University Gusau for bacteriological analysis.

Boreholes location

Fifteen boreholes situated in the following locations within the study settings were sampled in triplicate:
Danbedi, Maryam hall, Ugwuan Dallatu, Gidan Musa, Gidan Mohammed, Gidan Kabiru, Bayan NTA, Tankin Ruwa, Bayan NEPA, Makaranta, Dan Buba, Living Faith, Gidan Duchi, Gidan Ahmed, Gidan Kema

Sample collection

Samples for bacteriological analysis were aseptically collected in sterilized 250ml screw-capped plastic containers. All plastic containers used for sample collection were sterilized, rinsed with 70% ethanol, distilled water, and the water samples. Borehole water samples were collected into sterile plastic containers by allowing the water to flow for 5 minutes, then the containers were uncapped, filled with the water samples, and recapped. Care was taken to prevent air bubbles from entering the container. The samples were transported to the laboratory in an ice box and analyzed within 24 hours of collection following the method outlined by Onuorah *et al*., 2022.

Determination Of Bacteriological Quality

The total bacterial, total coliform, fecal coliform, salmonella, and shigella counts were determined as described by APHA, (2017).

Total Bacterial Count

Nutrient agar was weighed and prepared according to the manufacturer's instructions. It was sterilized in an autoclave at 121°C for 15 minutes, allowed to cool, and then aseptically dispensed into Petri dishes. The membrane filter paper containing the bacteria was carefully placed with the grid side facing up on the nutrient agar. Duplicate plates were prepared and labeled for the fifteen water samples. Incubation was carried out in an inverted position at 28°C for 24 hours, after which the bacterial colonies that developed were counted, and the results were recorded. The colonies were subcultured and stored on a sterile nutrient agar slant for characterization and identification (APHA, 2017).

Total Coliform Count

MacConkey agar was weighed and prepared according to the manufacturer's instructions. It was sterilized in an autoclave at 121°C for 15 minutes, allowed to cool, and then aseptically dispensed into Petri dishes. The membrane filter paper containing the bacteria was carefully placed with the grid side facing up on the MacConkey agar. Triplicate plates were prepared and labeled for the fifteen water samples. Incubation was carried out in an inverted position at 28°C for 48 hours, after which the bacterial colonies that developed were counted, and the results were recorded. The colonies were subcultured and stored on a sterile nutrient agar slant for characterization and identification (APHA, 2017).

Faecal Coliform Count

Endo agar was prepared according to the manufacturer's instructions, sterilized in an autoclave at 121°C for 15 minutes, cooled, and then dispensed aseptically into Petri dishes. The membrane filter paper with bacteria was placed on the endo agar with the grid side up. Duplicate plates were prepared and then placed in an incubator at 28°C for 48 hours. The developed faecal coliform bacteria were counted, and a few colonies were subcultured and stored on a sterile nutrient agar slant for additional studies (APHA, 2017).

Salmonella-Shigella count

The **Salmonella-Shigella** agar (SSA) was prepared following the manufacturer’s instructions, and a 1ml aliquot of each water sample was transferred onto the dried and sterilized SSA plates. The plates were inoculated, evenly **spread**, and then incubated at 37°C for 48 hours. Subsequently, pure cultures were obtained by sub-culturing onto freshly prepared SSA **plates**, and pure colonies were identified based on their biochemical and morphological characteristics (Onuorah *et al*., 2022**).**

Sample Preparation

The membrane filtration apparatus was utilized to filter the water samples. The samples were adequately mixed by inverting the container multiple times. A sterile forceps was used to place the filter paper in the apparatus. Subsequently, 100ml of borehole water sample was slowly filtered through the membrane filter in the funnel. The membrane filter paper was then delicately removed with a sterile smooth-tipped forceps and placed grid side up on the culture medium in the Petri dish, ensuring no air bubbles were trapped underneath the membrane (APHA, 2017).

Characterization and Identification of the Isolates

The bacterial isolates were characterized based on their morphological and biochemical characteristics. Gram staining, catalase, **urease,** indole, coagulase, citrate utilization, Carbohydrate utilization test, motility test, Methyl Red, Voges-Proskauer **test**, and Hydrogen Sulphide production tests were all conducted following the procedures outlined by Willey *et al*. (2020). **The** isolates were identified according to the scheme **proposed by** Patel (2020).

RESULTS

The total bacteria, total coliforms, faecal coliforms and Salmonella Shigella count per 100ml of the borehole water in Gusau metropolis are shown in Table 1. The Total bacterial count ranges from 6 to 39 cfu/100ml,Total coliform count 3 to 65 cfu/100ml while the faecal coliform count range is 1 to 4 cfu/100ml, also the total *Salmonella Shigella* count range is from 0 to 4 cfu/100ml, (Table 1).

The morphological and biochemical characteristics of the bacterial isolates from borehole water samples are depicted in Table 2. The isolated bacteria include *Salmonella* typhi, *Shigella* spp, and *Escherichia* coli.

The frequency of occurrence of the bacterial isolates in the borehole water in Gusau metropolis is depicted in Table 3. *Escherichia coli* exhibited the highest frequency of occurrence, with 15 instances (65.21%), while *Salmonella typhi* and *Shigella* spp had the lowest frequency of occurrence, with 4 instances each (17.39%), in the borehole water samples analyzed.

Table 1: Total bacterial count, Total coliform count, feacal coliform count, and Salmonella-Shigella count.

Sample	Borehole Location	Total Bacterial Count (CFU/ml)	Salmonella-Shigella Count (CFU/ml)	Total Coliform Count (CFU/ml)	Feacal Coliform Count (CFU/ml)
1	Danbedi	33×10^1	0×10^0	10×10^1	1×10^0
2	Maryam Hall	26×10^1	0×10^0	20×10^1	1×10^0
3	UgwanDallatu	29×10^1	0×10^0	31×10^1	1×10^0
4	Gidan Musa	39×10^1	0×10^0	13×10^1	2×10^0
5	GidanMuhammadu	35×10^1	0×10^0	19×10^1	1×10^0
6	GidanKabiru	13×10^1	3×10^0	6×10^1	1×10^0
7	Bayan NTA	29×10^1	2×10^0	8×10^1	2×10^0
8	TankinRuwa	15×10^1	0×10^0	5×10^1	3×10^0
9	Bayan NEPA	22×10^1	0×10^0	4×10^1	2×10^0
10	Makaranta	33×10^1	1×10^0	3×10^1	1×10^0
11	Dan Buba	9×10^1	0×10^0	65×10^1	4×10^0
12	Living Faith	15×10^1	4×10^0	17×10^1	1×10^0
13	GidanDuchi	6×10^1	0×10^0	22×10^1	2×10^0
14	Gidan Ahmed	12×10^1	3×10^0	30×10^1	1×10^0
15	GidanKema	7×10^1	1×10^0	22×10^1	3×10^0
WHO Standard		0	0	0	0

Table 2: Morphological and Biochemical characteristics of the Bacteria Isolates from Borehole water samples in Gusau Metropolis.

Isolates	1	2	3
Gram Staining	-	-	-
Form	Rod	Rod	Rod
Indole	+	-	-
Methyl Red	+	+	+
Voges Proskaer	-	-	-
Citrate	-	-	-
Urease	+	-	-
Glucose	+	+	+
Lactose	+	-	-
Sucrose	-	-	-
H_2S	+	-	-
Catalase	+	+	+
Motility	+	+	-
Suspected Organisms	*Escherichia coli*	*Salmonella typhi*	*Shigella* spp

Key; + = Positive - = Negative

Table 3: Occurrence of the Bacterial Isolates in the Borehole water investigated in Gusau Metropolis

Sample	Borehole Location	*Salmonella typhil*	*Escherichia coli*	*Shigella* spp
1	Dambedi, Hayan Buba	-	+	-
2	Maryam Hall, Hayan Buba	-	+	-
3	Ugwan Dallatu Hayan Buba	-	+	-
4	Gidan Musa Low-cost	-	+	-
5	Gidan Muhammadu Low-cost	-	+	-
6	Gidan Kabiru Low-Cost	-	+	-
7	Bayan NTA Samaru	-	+	+
8	Takin Ruwa Samaru	+	+	-
9	Bayan NEPA Samaru	+	+	-
10	Makaranta Premier	-	+	+
11	Dan Buba Premier	-	+	-
12	Living Faith Premier	+	+	-
13	Gidan Duchi Gadabiyu	-	+	+
14	Gidan Ahmed Gadabiyu	-	+	+
15	Gidan Kema Gadabyu	+	+	-

Key; + = Present - = Absent

DISCUSSION

The quality of the borehole water from the various sample points varies as follows: The total bacterial count ranges from 6×10^1 to 39×10^1 cfu/ml (Table 1). The sample from Gidan Musa, Low cost had the highest count of 39×10^1 cfu/ml, while the sample from Gidan Duchi Gadabiyu had the least count of 6×10^1 cfu/ml, indicating a high level of pollution of borehole water due to human and animal activities. The values obtained from all the water samples were higher than the WHO standard (Table 1). This is in agreement with the previous work by Fardami *et al.* (2020), who had earlier reported high microbial counts in drinking water in Zamfara North Senatorial District, Nigeria. The result of the total coliform counts ranges from 3×10^1 to 65×10^1 cfu/ml (Table 1). The results showed the total coliform counts for all the various water sources, where the least coliform counts were 3×10^1 cfu/ml at Gidan Kabiru Low-cost, and the highest total coliform counts were 65×10^1 cfu/ml at Dan Buba, Premier borehole water. This corresponds with the work of Onwughara *et al*., (2013), who recorded a high coliform count above the WHO standard in Umuahia North Local Government Area, Abia State, Nigeria. The fecal coliform counts ranged from 1×10^0 cfu/ml to 4×10^0 cfu/ml (Table 1) and this exceeded the WHO standard for coliform bacteria in water, which is zero total coliform per 100 ml of water (Table 1). Eight locations had 1×10^0 cfu/ml, while Dan Buba had the highest fecal coliform count of 4×10^0 cfu/ml. The presence of coliforms in the samples is an indication of fecal contamination. This is in agreement with the findings of Kumarasamy *et al.* (2009), who reported fecal coliform counts ranging from 1 to 6 CFU/100ml. The Salmonella-Shigella count ranges from 0 to 5×10^0 CFU/ml, with all the samples analyzed within the WHO standard except for Gidan Kabiru, Bayan Nepa, Makaranta, Living Faith, Gidan Ahmed, and Gidan kema, which exceeded the WHO standard of 0 CFU/ml (Table 1). This is in correspondence with the findings of Fardami *et al.* (2019), who reported Salmonella-Shigella counts ranging from 0 to 4 CFU/ml in borehole water samples analyzed in Zamfara, North Senatorial District, Nigeria. Water samples from all the analyzed sample locations are only fit for domestic purposes due to the fact that the water samples analyzed contained total coliform, fecal coliform, total bacterial count, and some Salmonella-Shigella count above the WHO standard limits of 0 CFU/ml, making them unfit for human consumption. Further analysis of the bacteriological quality of water samples collected in this study revealed the presence of three dominant bacterial genera, namely; *Escherichia coli, Salmonella* typhi, and *Shigella* spp (Table 2).

The most frequently isolated bacterium in this study was *Escherichia coli* (Table 3), commonly found in the lower intestine of warm-blooded organisms. Its presence indicates fecal contamination of the water due to human and animal waste, which can lead to gastrointestinal disorders (Kuta, 2008; Onwughara *et al*., 2013). Escherichia coli is known to cause various illnesses, including watery and bloody diarrhea, dysentery, urinary tract infections (WHO, 2018), and bacteremia if it enters the bloodstream. Moreover, certain strains of *E. coli* have the ability to produce enterotoxins in the human small intestine, leading to diarrhea (Obioma *et al*., 2017).

Salmonella typhi, which was also predominant in the samples analyzed, can be acquired by ingestion of food and water contaminated by feces of infected humans or through person-to-person contact. The symptoms include fever, headache, abdominal pains, anorexia, and malaise. The bacteria can reinfect the gastrointestinal tract, producing abdominal pain and diarrhea (Willey *et al*., 2008).

Shigella, which was also predominant in the samples, causes shigellosis or bacillary dysentery, a diarrheal illness resulting from an acute inflammatory reaction of the intestinal tract caused by the four species of the genus *Shigella*. The organism is transmitted by the fecal-oral route, primarily through food, feces, fingers, and flies (the four fs) (Willey *et al*., 2008). This is in agreement with the findings of Fardami *et al*., (2019), who isolated similar microorganisms in their analysis of drinking water.

CONCLUSION

The bacteriological parameters affecting groundwater originate from various sources, including human waste, agricultural waste, and industrial waste. The borehole water in Gusau metropolis that was studied exhibited poor quality concerning the microbiological parameters assessed. Most of the microbiological parameters exceeded WHO standards, except for some of the *Salmonella-Shigella* counts that fell within the WHO specified limit. The presence of indicator bacteria such as *Escherichia coli*, *Salmonella* typhi, and *Shigella* spp (Table 2) in high concentrations indicates the potential presence of pathogenic bacteria in the borehole water analyzed. Therefore, it is imperative to treat borehole water before human consumption.

REFERENCES

American Public Health Association (APHA), American Water Works Association (AWWA), & Water Environment Federation (WEF). Standard methods for the examination of water and wastewater, 23rd Edition. Washington, DC: APHA, 2017.

Fardami, A. Y., Ibrahim, K. Ismail, H. Y. and Ibrahim, U. B. Bacteriological Analysis of Drinking Water in Zamfara North Senatorial District, Nigeria: Brief Overview. *Theory and Application of Microbiology and Biotechnology*, **3**, 65-75, 2020.

Gleeson, T., Wada, Y., Bierkens, M. F. P. and Van Beek, L. P. H. Water balance of global aquifers revealed by groundwater footprint. *Nature*, 488(7410), 197–200, 2012. **[Crossref]**

Harvey, P. A. Borehole sustainability in rural Africa: Analysis of routine field data; Proceedings of 30th WEDC Conference; Lao PDR, Vientiane, 2014.

Jabu, G.C. and Grimason, A. M. Faecal contamination of primary school children hands, in Chikwawa, Malawi (submitted). *Journal of Dental and Medical Sciences*, **13**: 86-89, 2005.

Kumarasamy, P.S.,Vignesh, R., Arthur-James, K., Muthkuman, R. and Rajendra, A. Enumeration and Identification of Pathogenic pollution indicators in Cauvery Rivers, South India. *Research Journal of Microbiology*, **4**: 540-549, 2009. **[Crossref]**

Kuta, F.A. Antifungal effect of Calotropisprocera stem bark on Epidermophytonflocosum and Trichophytongypseum. *African Journal of Biotechnology*, 7(13): 2116-2118, 2008.

National Population Commission of Nigeria (NPCN). *Nigeria Data Dissemination Service (NDDS)*, 2019.

Nigeria center for disease control (NCDC), National Monthly Update for Cholera in Nigeria: Cholera outbreak: 4 die, 130 affected in Zamfara, NCDC Situation Report, 2021.

Niyogi, S.K. Shigellosis. *Journal of Microbiology* (Seoul, Korea) 43 (2): 133-143, 2011.

Obioma, A., Chikanka, A.T. and Loveth, N.W. Evaluation of Bacteriological Quality of Surface, Well, Borehole and River Water in Khana Local Government Area of Rivers State, Niger Delta. Annals of Clinical and Laboratory Research, **5**(3):183, 2017. **[Crossref]**

Onuorah, S., Chimaobi, O. and Patrice, O. Physicochemical Quality of Borehole Water Stored in Household Plastic Containers. *Malaysian Journal of Science and Advanced Technology*, **2** (2), 42-49, (2022). **[Crossref]**.

Onwughara, N.I.; Ajiwe, V.E.; Nnabuenyi, H.O. and Chima, C.H. Bacteriological Assessment of Selected Borehole Water Samples in Umuahia North Local Government Area, Abia State, Nigeria. *Journal of Environmental Treatment Techniques*, **1**(2): 117-121, 2013.

Patel, J. B. Manual of clinical microbiology, 12th Edition. Washington, DC: American Society for Microbiology, 2020.

Theodore, L., Brown, H., Eugene, L.M., Bruce, E. B., Catherine, M., Patrick, W., Matthew, E. S. Chemistry: The Central Science, Pearson Edition: 14th Edition (2017).

UNICEF and WHO. *Progress on household drinking water, sanitation and hygiene 2000-2017: Special focus on inequalities*. New York: UNICEF and Geneva: WHO, 2019.

United Nations. *World Water Development Report 2019: Leaving No One Behind.* UNESCO, 2019.

Willey, J. M., Sherwood, L. M. and Woolverton, C. J. *Prescott's microbiology* (11th ed.). New York, NY: McGraw-Hill Education, 2020.

Willey, J.M., Sherwood,L.M. and Wolverton, C.J. Human Diseases Caused by Bacteria. Prescott, Harley and Klein's Microbiology. 7th edition. pp. 947, 2008.

World. Health Organization (WHO) (2018) Guidelines for drinking water quality. pp. 68.

Zumdahl, S. S (2023) "water". *Encyclopedia Britannica*, www.britannica.com