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Bacterial Contamination of Drinking Wells in Makurdi Metropolis

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Abstract

This study was carried out to assess the bacterial contamination of drinking wells in Makurdi metropolis. Fifteen (15) untreated water samples, five (5) each were collected from wells in High Level, Wurukum and Wadata areas for physicochemical and bacteriological analysis was done using pour plating and the bacteriological quality was assessed by measuring the total viable, total coliform and fecal coliform counts of bacteria in the samples using Mac Conkey agar and Nutrient agar. The results of the analysis showed that the pH ranged from 6.70 ± 0.16 to 7.40± 0.87, the temperature levels ranged from 28.72 ± 0.04 to 28.87 ±0.05; biological oxygen demand values ranged from 0.02 ±0.04 to 0.02 ± 0.41; the dissolved oxygen values ranged from 1.50 ±0.16 to 170 ± 0.14 while the Electrical conductivity values ranged from 599.20 ±88.98 to 1582.80±199. The results also showed the total viable count, total coliform count and fecal coliform counts ranging from 75.80±16.01cfu/ml to 117.40±34.45cfu/ml; 5.60±5.13cfu/ml to 6.60±6.88cfu/ml and 0.40±0.89cfu/ml to 4.20±3.77cfu/ml respectively. The total viable counts ranged from 75.80±16.01 to 117.40±34.4 (Wadata having the highest and Wurukum having the least), the total coliform counts ranged from 5.60±2.61 to 6.60±6.88 while the fecal coliform count ranged from 0.40±0.89 to 4.20±3.77. The variation in Total Viable Count (TVC) across locations could be as a result of localized factors influencing microbial populations and geographical differences such as land use, anthropogenic activities, and environmental conditions. The bacterial isolates were Bacillus, Escherichia coli, Klebsiella spp, Proteus spp, Enterobacter spp, and Staphylococcus spp. The frequency of occurrence and prevalence percentages of the bacteria isolated from the well water samples show that Klebsiella spp had the highest percentage (23.33%) while Enterobacter spp and Escherichia coli had the least prevalence percentage, representing 10.00% each. Overall, High Level had the highest contamination rate, accounting for 43.33% of the total contamination while Wurukum had the least contamination, representing 23.33% of the total contamination. The distribution patterns of bacterial isolates among the studied locations illuminate discernible trends. The prevalence of pathogenic bacteria in well water sources could be possibly linked to higher urbanization and population density, highlighting the dynamic and site-specific nature of microbial communities. The study highlights the importance of using specific plans to manage water quality. These plans should take into account the special features of each area.

Keywords: Bacteria; Well; Coliform; Water; Makurdi

Abbreviations: WASH: Water, Sanitation and Hygiene; IDP: Internally Displaced Persons; CFUs: Coliform Colony-Forming Units; SIM: Sulfide, Indole and Motility; TDS: Total Dissolved Solids; DO: Dissolved Oxygen; EC: Electrical Conductivity; BOD: Biochemical Oxygen Demand; TVC: Total Viable Count; TCC; Total Coliform Count; FCC: Fecal Coliform Count; DO: Dissolved Oxygen; BOD: Biological Oxygen Demand.

Introduction

Water is the very foundation of life, an indispensable resource that supports all living beings on Earth. Its significance is immeasurable, playing a critical role in the survival and well-being of every organism, be it human, animal, or plant. For humans, water is an absolute necessity, vital for hydration, sanitation, and maintaining good health. It occurs in nature as snow, glaciers, ice packs and icebergs, clouds, fog, dew, aquifers and atmospheric humidity. It is an excellent solvent for a wide variety of chemical substances; as such it is widely used in industrial processes, and in cooking and washing [1]. Water not only maintains our bodies on a daily basis but also plays a crucial role in disease prevention. Drinking eight glasses of water daily can reduce the risk of colon cancer 45%, bladder cancer by 50% and it potentially reduces risk of breast cancer [2].

Access to safe drinking water is vital for human survival and is considered one of the most basic human rights, thus it requires compliance with certain microbiological standards [3]. Water serves as a vehicle for the transmission of diseases such as typhoid fever, botulism, diarrhea, dysentery, ascariasis and schistosomiasis. Unfortunately, over 10% of the World's population, including Nigeria faces significant water scarcity issues, resulting in water shortages, inaccessibility to clean water, and increased vulnerability to waterborne diseases World Health Organization (WHO) [4]. Inadequate access to safe water leads to the spread of diseases; Children, the elderly, pregnant women, and the immuno-compromised individuals are particularly susceptible to waterborne illnesses, which are among the top five causes of death in children under the age of five [5].

It is reported that up to 80% of health challenges in developing countries are related to water and sanitation [6]. Diarrheal diseases primarily caused by poor water supply, sanitation, and hygiene, result in 1.73 million deaths annually and contribute significantly to the global burden of disease World Health Organization (WHO) [7]. Bacterial contamination of drinking water is a significant contributor to waterborne diseases, particularly in rural areas of developing countries where water sources are communally shared. These water sources are often exposed to multiple fecal-oral transmission pathways within the neighborhood boundaries [8,9]. The contamination of groundwater with fecal and total coliform bacteria can result from effluent leaching from septic tanks or sewage pits, the presence of domestic or wild animal excreta, and runoff from agricultural areas [10]. Open or poorly covered well heads pose the most common risk to well water quality. The most serious source of pollution of well water is contamination by human waste from latrines and septic tanks resulting in increased levels of microorganisms, including pathogens World Health Organization (WHO) [11]. The importance of water quality in public health cannot be overstated. Many infectious diseases are transmitted through water via the fecal-oral route; diseases contracted through drinking water cause about 5 million child deaths yearly, making one-sixth of the world's population ill World Health Organization (WHO) [12].

Despite significant investments by the Nigerian government in water supply programs, more than 52% of the population still lacks access to clean drinking water World Health Organization (WHO) [12]. Most communities in Nigeria that face the lack of access to reliable water sources often turn to unsafe alternatives like streams, hand-dug wells, and ponds as their primary sources of water. These alternatives have been found to be highly susceptible to bacterial contamination and the spread of waterborne diseases, posing significant health risks to the population.

Collaborative efforts have been made between the Nigerian government, NGOs, and international partners towards achieving improved water access and sanitation in the country. These initiatives aim to enhance water infrastructure and provide clean water access to vulnerable communities. One such initiative is the "Water, Sanitation and Hygiene (WASH) Nigeria" program, which focuses on improving water supply, sanitation, and hygiene practices in underserved regions of Nigeria, particularly in rural areas and internally displaced persons (IDP) camps United Nations Children's Fund (UNICEF) [13]. Also, NGOs like WaterAid Nigeria have been actively involved in water and sanitation initiatives, working to improve water access and hygiene practices in communities. WaterAid's efforts include the "Water for Nigeria" program, launched in 2018, which focuses on delivering clean water, sanitation, and hygiene education to vulnerable communities, schools, and healthcare facilities [14]. However, challenges persist, and sustained commitment is crucial to ensuring that clean water becomes accessible to all communities in Nigeria. This study aims to assess the bacterial contamination of drinking wells in the study area.

The bacterial contamination of drinking wells in Makurdi metropolis poses a grave threat to public health and water safety. Despite the city's reliance on groundwater from wells as a primary source of drinking water, there is growing evidence of bacterial pollutants infiltrating these water sources [15]. The presence of harmful bacteria in drinking wells not only jeopardizes the health of residents but also contributes to an increased incidence of waterborne diseases and related health complications. The extent and sources of bacterial contamination in the wells remain poorly understood, impeding the formulation of effective mitigation strategies [16]. Rapid urbanization, inadequate waste management, and agricultural practices could exacerbate the

problem, necessitating a comprehensive assessment of the contributing factors.

The scarcity of piped water has made communities, including those in Makurdi metropolis to find alternative sources of water: ground water sources being a ready source. Wells are a common ground water source readily explored to meet community water requirement or make up the short fall [17]. The challenge of lack of supply of pipe borne water, has forced households in Makurdi metropolis to use unreliable and unsafe sources of water like shallow wells, water vendors, small streams, and the Benue River itself with wells been the major source of water for household uses (drinking, cooking, washing etc.). Water supply that is provided and controlled by the Water Board is inefficient and, in spite of the increased demand, the services have not been extended to cover the people waiting to be connected. Therefore, thousands of people, especially the poor, lack adequate access to safe drinking water [18]. This study is aimed at assessing the bacterial contamination of drinking wells in Makurdi metropolis.

Materials and Methods

Study Area

This study will be carried out within Makurdi metropolis, Benue State. Makurdi the administrative headquarter of Benue state, lies approximately between latitude 7039' and 7045'N and longitudes 8033' and 8035'E. The town is located along the coast of the River Benue. The climatic condition in Makurdi is influenced by two air masses: the warm, moist south westerly air mass, and the warm, dry northeasterly air mass. The southwesterly airmass is a rain – bearing wind that brings about rainfall from the months of May to October. The dry northeasterly airmass blows over the region from November to April, thereby bringing about seasonal drought. The mean annual rainfall in Makurdi is about 1,290mm [15]. Temperature in Makurdi is however, generally high throughout the year, with February and March as the hottest months. Temperature in Makurdi varies from a daily of 40oC and a maximum of 22.5oC. Makurdi town, like most other cities in the lower Benue valley is drained by the Benue River and its tributaries. Other minor river that drains the Makurdi town, and in turn empties their waters in the River Benue includes: Rivers Idye, Genebe, Urudu, Kpege and Kereke. Due to the general low relief of Makurdi, sizeable portions of the area is waterlogged and flooded during heavy rainstorm [15].

Sample Collection

A total of fifteen (15) untreated drinking well water samples were collected into clean, sterile 50cl plastic bottles. Five (5) samples were collected from High level areas, Wurukum areas and Wadata areas. The samples were then immediately transported to the microbiology laboratory, Joseph Sarwuan Tarka University, Makurdi for bacteriological analysis.

Materials Used

The materials that were used for this research work include Glassware (Conical flasks, microscopic glass slides, measuring cylinder, Petri dishes), bijou bottles, sterile syringes, Microscope, Incubator, Pressure pot, Nutrient agar, MacConkey agar, Citrate agar, Urea agar base, Immersion oil, Wire loop, Bunsen burner, Distilled water, Weighing balance, Foil paper, and Biochemical test reagents.

Media Preparation

The media that were used for culturing include MacConkey agar, and nutrient agar. The media were prepared aseptically according to the manufacturer's specifications and sterilized by autoclaving at 1210C for 15minutes and allowed to cool to a temperature of 500C before inoculation.

Nutrient Agar: Nutrient agar was prepared by suspending 28.0g of the agar powder in 1000 ml of distilled water and heated to dissolve the agar completely. The media was then sterilized by autoclaving at 121°C for 15 minutes; allowed to cool and then poured into sterile Petri dishes for inoculation.
Macconkey Agar: MacConkey agar was prepared by weighing 48.5g of the agar powder into 1000ml of distilled water. It was then heated to dissolve the agar completely. The media was sterilized by autoclaving at 121°C for 15 minutes and allowed to cool to room temperature and then poured into sterile Petri dishes for proper inoculation.

Physico-Chemical Analysis

Determination of pH: This was carried out using the pH meter. The pH meter was standardized using buffer solution of a known pH. After standardization, the pH reading was taken on the meter scale by dipping the glass electrode in each of the water sample in the separate bottles.
Determination of Temperature: This was carried out using mercury-in-glass thermometer. The thermometer was immersed into labeled beakers containing the water samples and allowed to stay for about 3-5 minutes. The reading was taken when the thermometer became steady. Duplicate readings were taken and the average readings were recorded.

Bacteriological Analysis of Water Samples

Analysis of Samples: 1ml of the water sample from each bottle was dispensed aseptically into sterile petri dish using

the syringe. Sterile molten MacConkey medium of 10-15ml was then poured into each of the petri dish; the dish was gently swirled to mix the sample and medium. The plates were then placed on flat surface and allowed to gel/solidify for some minutes. After solidifying, the plates were incubated at 37°C for 24 hours to observe growth.

Colony Count: Colony count was carried out on MacConkey and Nutrient media. Discrete colonies appearing on plate after incubation were counted and recorded. The total bacterial (viable) count and total coliform count were obtained by counting discrete colonies on Nutrient and MacConkey agar respectively. The results were recorded as colony-forming unit per milliliter (CFU/ml).

Bacterial Isolation: After incubation at 37°C for 24 hours, distinct colonies that appered with different morphological features on MacConkey agar were isolated and sub-cultured on nutrient agar for further identification.

Coliform Test: 1ml of water sample was transferred aseptically into separate sterile petri dishes containing culture media. The inoculated plates were then incubated at 37°C for 48 hours, and examined for the presence of colonies or gas production, which is an indicative of the presence of coliform bacteria. Further biochemical tests (indole or citrate test) were carried out to confirm the presence of coliform bacteria. The number of coliform colonies on the agar plates were then counted to determine the coliform colony-forming units (CFUs) per ml of water sample.

Characterization and Identification of Bacterial Isolates: Characterization and identification of the bacterial isolates was carried out using Gram staining for cellular morphology and biochemical test.

Gram Staining

The Gram staining is a widely used technique in microbiology to differentiate bacterial species into Gram-positive and Gram-negative groups based on the differences in their cell wall composition. This technique can be useful in identifying potential pathogens in water sources and assessing the quality of water samples for potential contamination. Gram staining was carried out as follows:

A drop of water was added on to separate clean, grease-free slide. The slide was smeared with bacteria isolate and heat-fixed by passing it through flames several times. The heat fixed smear was flooded with the primary stain, crystal violet for 1 minute and then rinsed with distilled water to remove excess stain. The slide was then flooded with a mordant, Lugo's iodine, and left to stand for 60 seconds and then washed again with distilled water; it was further covered with 95% ethanol (decolorizer) for 20 seconds, and rinsed with distilled water to remove excess decolorizer, counter stained with safranin and allowed to stand for 1 minute. The smear was washed again, and the bottom of the slide was blotted gently to remove excess water; air-dried and examined under the microscope using oil immersion lens to observe the bacterial morphology and Gram staining characteristics. (Gram positive bacteria appear purple and gram negative bacteria which appear pink or red).

Biochemical Test

SIM (Sulfide, Indole and Motility) Test: Thirty grams (30g) of urea agar base was weighed into 1000ml of distilled water and mixed thoroughly; heated to dissolve completely; autoclaved at 121°C for 15 minutes and allowed to cool at room temperature in order to carry out Hydrogen sulfide, Indole and motility test. 2ml of the agar was then dispensed into bijou bottles for inoculation.

Indole Test: Distinct bacterial colonies were picked with a sterile wireloop and inoculated into the medium in separate tubes and incubated at 37°C for 24 hours. 5 drops of Kovac's reagent was added into the tube after 48hrs. The tubes were gently swirled and observed for a red ring on the surface layer within 5minutes. A red ring on the surface indicate a positive indole test and an absence of a ring will indicate a negative indole test.

Hydrogen Sulfide (H_2S) and Motility Test: Distinct colonies was taken from the 24hr old culture using a sterile inoculating loop. The loop was then stabbed into the medium, reaching the bottom of the tube without touching the sides. The medium was incubated at 37°C for 48hrs and observed for hydrogen sulfide (H_2S) production and motility of the test organisms. Blackening of the medium will indicate a positive H_2S test while absence of a blackening will indicate a negative test result, suggesting the absence of sulphide-producing bacteria in the water sample. Positive motility test is shown by a diffused zone of growth flaring from the line of inoculation, and a negative test is shown by a restricted growth along the stab line.

Citrate Test: This test helps to determine the presence of enterobacteria in a given medium. It also shows the ability of these organisms to utilize citrate present in Simmons citrate medium as a source of carbon for growth. Simmon citrate agar was prepared by weighing 2.40g of the agar in 100ml of distilled water, and heated to dissolve completely. The medium was autoclaved at 1210C for 15 minutes and allowed to cool at room temperature. 2ml of the agar was then dispensed into 5ml bijou bottle for inoculation.

Distinct bacterial colonies were picked and inoculated into tubes containing Simmon citrate medium. The tubes were then incubated at 37°C for 48 hours and observed for color change. Color change from green to blue along the slant indicates a positive citrate test and absence of color change indicates a negative test.

Catalase Test: A drop of hydrogen peroxide (H_2O_2) solution was placed on a grease-free slide, and a sterile loop was used to pick a colony from the plate and emulsified on the

slide, and observed for the formation of bubbles. The results were recorded for each slide and interpreted accordingly. The formation of bubbles indicates a positive catalase test, indicating the presence of catalase-producing bacteria in the water sample. The absence of bubbles indicates a negative test result, suggesting the absence of catalase-producing bacteria in the water sample.

In the absence of bubbles, the steps will be repeated 3 to 4 times to confirm the results.

Urease Test: This test is used to differentiate organisms based on their ability to hydrolyze urea with the enzyme urease. A loopful of isolated colony was inoculated into bijou bottle containing the prepared urea agar base medium, and incubated at 37°C for 48 hours and observed for the formation of a pink color afterwards. Formation of pink color indicates a positive urease test.

Data Analysis

The results obtained from the study were examined for completion and entered into the statistical package for social sciences (SPSS) version 20.0, and the analysis for variance (ANOVA) was used to compare the mean and standard deviation values for the entire data set. The results were expressed as the mean ± standard error of the mean. A ($P<0.05$) was considered as statistically significant.

Results

The study investigated a total of fifteen (15) untreated drinking well water samples collected from High Level areas, Wurukum areas and Wadata areas. Table 1 presents the physicochemical parameters of the water samples from the different locations studied. The results show that the pH values are within a neutral range (6.70 ± 0.16 to 7.40± 0.87), that is, the water is neither too acidic nor too alkaline. The total dissolved solid level varies among the location (295.40 ± 48.10 in High Level, 301.00 ± 112.29 in Wurukum and 797.80 ± 80.99 in Wadata) with Wadata having elevated values (797.80 ± 80.99) compared to the other locations. The DO in High Level (170 ± 0.14) indicates well-oxygenated water while the lower values in Wurukum (1.70 ± 0.18) and Wadata (1.50 ± 0.16) indicate potential issues with the availability of oxygen. The temperature levels (ranging from 28.72 ± 0.04 to 28.87 ± 0.05) are consistent across the three locations, indicating minimal variations in thermal conditions. The table also shows that Wadata exhibits a significantly higher electrical conductivity, indicating a higher concentration of ions, minerals, or pollutants in the water. The BOD values are consistently low across all locations, suggesting low organic pollution levels and good water quality.

Location	High Level	Wurukum	Wadata
pH	7.40± 0.87	6.70 ± 0.16	7.06±0.11
TDS	295.40±48.10	301.00±112.29	797.80±80.99
DO	170 ± 0.14	1.70±0.18	1.50 ±0.16
Temp	28.87 ±0.05	28.80± 0.10	28.72 ± 0.04
EC	599.20 ±88.98	602.60 ±226.10	1582.80±199
BOD	0.02 ± 0.04	0.02 ± 0.04	0.02 ± 0.41

Table 1: Physicochemical Parameters of the Samples.
Key: TDS: total dissolved solids; DO: Dissolved Oxygen; Temp: Temperature; EC: Electrical conductivity; BOD: Biochemical Oxygen Demand

Table 2 presents Total Viable Count (TVC), Total Coliform Count (TCC), and Fecal Coliform Count (FCC) for well water samples from different locations, along with corresponding p-values. The TVC values indicate the total number of viable microorganisms; TCC measures the presence of coliform bacteria, often used as an indicator of water quality. (All locations show relatively low TCC values, indicating acceptable levels) while FCC specifically assesses fecal contamination. The TVC ranged from 75.80 ± 16.01 to 117.40 ± 34.4 (Wadata having the highest and Wurukum having the least), the TCC ranged from 5.60 ± 2.61 to 6.60 ± 6.88 while the fecal coliform count ranged from 0.40 ±0.89 to 4.20 ± 3.77.

Location	TVC	TCC	FCC
High Level	102.80±11.82	6.60±6.88	3.00±2.35
Wurukum	75.80±16.01	5.60±2.61	0.40±0.89
Wadata	117.40±34.45	5.60±5.13	4.20±3.77
p-value	0.94	0.601	0.103

Table 2: Total Viable, Total Coliform and Fecal Coliform Count.
Keys: TVC: Total viable count; TCC: Total coliform count; FCC: Fecal coliform count

Table 3 shows the cultural, morphological and biochemical characteristics of the bacterial isolates. The results show that The table shows that six (6) genera of bacteria were isolated across the collection points based on their colony colour, morphology, Gram staining and biochemical characteristics. The bacterial isolates are *Bacillus* species, *Escherichia coli*, *Klebsiella* species, *Proteus* species, *Enterobacter* species, and *Staphylococcus* species.

Colony color	Colony shape	Morphology	Gram Rxn	Cat		Cit	Urs	Ind	H_2S	Mot	Bacteria specie
Yellow	Circular	Cocci	+	+	+	+	-	-	-	-	*Staphylococcus spp*
Mucoid pink	Circular	Rod	-	+	+	+	+	-	-	-	*Klebsiella* spp
Pale	Circular	Rod	-	+	+	+	-	-	-	+	*Enterobacter* spp
White	Irregular	Rod	+	+	+	+	-	-	-	-	*Bacillus* spp

Table 3: Cultural, Morphological and Biochemical Characteristics of Bacterial isolates.
Key: Gram rxn: Gram stain reaction; Cat: Catalase test; Cit: Citrate test; Urs: Urease test; H2S: Hydrogen sulphide test; spp: Species

Table 4 presents the frequency of occurrence and prevalence percentages of various bacteria isolates in well water samples. Staphylococcus species occurs 2 times in High Level (accounting for 6.67%), once in Wurukum (3.33%), and 3 times in Wadata (10.00%), contributing to 20.00% of the total isolates. Proteus species occurs 3 times in High Level (10.00%), 2 times in Wurukum (6.67%), and 1 time in Wadata (3.33%), also contributing to 20.00%. Escherichia coli is found once in High Level (3.33%) and twice in Wadata (6.67%), making up 10.00% while *Klebsiella* species occurs 3 times in High Level (10.00%), 2 times in Wurukum (6.67%), and 2 times in Wadata (6.67%), contributing to 23.33%; *Enterobacter* species is found once in High Level (3.33%) and twice in Wadata (6.67%), making up 10.00% and Bacillus species occurs 3 times in High Level (10.00%) and 2 times in Wurukum (6.67%), contributing to 16.67%. Overall, High Level has 13 occurrences (amounting to a total of 43.33%), Wurukum has 7 occurrences (representing 23.33%), and Wadata has 10 occurrences (representing 33.33%).

Bacteria species	High Level	Wurukum	Wadata	Total
Staphylococcus spp	2 (6.67%)	1 (3.33%)	3 (10.00%)	6 (20.00%)
Proteus spp	3 (10.00%)	2 (6.67%)	1 (3.33%)	6 (20.00%)
E. coli spp	1 (3.33%)	0 (0.00%)	2 (6.67%)	3 (10.00%)
Klebsiella spp	3 (10.00%)	2 (6.67%)	2 (6.67%)	7 (23.33%)
Enterobacter spp	1 (3.33%)	0 (0.00%)	2 (6.67%)	3 (10.00%)
Bacillus spp	3 (10.00%)	2 (6.67%)	0 (0.00%)	5 (16.67%)
Total	13 (43.33%)	7 (23.33%)	10 (33.33%)	30 (100%)

Table 4: Frequency of Occurrence and Prevalence Percentage of Bacteria Isolates.

Discussion

The physicochemical analysis as obtained from the study provides valuable insights into the overall quality of well water from High Level, Wurukum, and Wadata areas. Notably, the pH values fall within a neutral range, ensuring the water is neither too acidic nor too alkaline. This aligns with findings in a similar study by Omofonmwam DO, et al. [19] in Nigeria, indicating a common pH range for well water. However, the elevated total dissolved solid (TDS) levels in Wadata suggest potential contamination or mineral presence, deviating from Smith's study, which reported lower TDS levels in sampled regions. The variation in dissolved oxygen (DO) levels raises concerns, especially in Wurukum and Wadata, where lower values hint at potential oxygen availability issues, possibly linked to pollution sources. The significantly higher electrical conductivity in Wadata implies increased ion or pollutant concentrations, possibly due to industrial or anthropogenic activities, differing from the more pristine conditions reported in previous studies [20]. The consistently low biological oxygen demand (BOD) across all locations indicates good water quality and minimal organic pollution, consistent with findings by Hassan A, et al. [21].

The microbial assessment, particularly the Total Coliform Count (TCC) and Fecal Coliform Count (FCC), provides crucial insights into the overall water quality and potential health risks associated with untreated well water consumption. The generally low TCC values across all locations, in line with the findings of Adeyemo AO, et al. [22], suggest an overall acceptable microbial quality. This consistency may be indicative of shared environmental factors or commonalities in water sources across the studied regions. However, the variation in Total Viable Count (TVC) across locations indicates localized factors influencing microbial populations.

Geographical differences such as land use, anthropogenic activities, and environmental conditions can contribute to variations in microbial content. For instance, agricultural runoff, urbanization, or industrial activities in specific areas might influence the microbial load, emphasizing the importance of considering these localized factors in water quality assessments.

The elevated Fecal Coliform Count (FCC) in Wadata raises concerns and diverges from the findings of Ebah EE, et al, [23] which reported lower fecal coliform counts in well water. Several factors may contribute to these differences. Firstly, variations in sanitation practices, population density, and land use patterns can impact fecal contamination sources. Wadata's higher FCC may be attributed to increased human or animal activities in the vicinity of well water sources, posing potential health risks to consumers. Additionally, differences in hydrogeological conditions, such as aquifer characteristics and groundwater flow patterns, could influence microbial transport and persistence. Localized factors like inadequate well construction or maintenance practices might also contribute to increased fecal contamination. Understanding these factors is vital for targeted interventions to address specific contamination sources and improve water quality.

The identification of bacterial isolates in well water samples is instrumental in gauging potential health risks associated with waterborne pathogens. The presence of *Bacillus, Escherichia coli, Klebsiella, Proteus, Enterobacter,* and *Staphylococcus* species aligns with established studies in Nigeria, as documented by Igbinosa EO, et al. [24]. However, the key point is, different microorganisms are more common in certain areas, showing that microbial communities vary locally in the sampled regions. It's important because bacteria like E. coli and Staphylococcus in well water can have significant health risks due to their known harmful effects. Escherichia coli, a common indicator of fecal contamination, poses a particular concern as it is linked to gastrointestinal infections. Simultaneously, Staphylococcus species, known for their ability to cause skin infections, further amplifies the potential health risks associated with well water consumption.

The distribution patterns of bacterial isolates among the studied locations illuminate discernible trends. Notably, High Level displays a heightened prevalence of bacterial species, a trend that could be attributed to factors such as urbanization and higher population density. This observation is in agreement with the findings of Eze VC, et al. [25], indicating that areas with increased urban development tend to exhibit a more complex microbial ecology in water sources. The variations in the prevalence of these pathogenic bacteria underscore the dynamic and site-specific nature of microbial communities within the well water sources studied.

In areas with a lot of water problems, like High Level, it's crucial to take specific actions, such as improving sanitation and closely monitoring water quality, to reduce health risks from waterborne pathogens. However, even in places with fewer issues, occasional problems should be addressed to ensure public health. Anticipating the distribution of microorganisms in well water enables proactive measures to safeguard communities. This includes educational outreach programs to inform people about maintaining wells, advocating water treatment methods, and implementing precise interventions to reduce contamination risks. Recognizing the unique microbial profiles in different locations allows authorities to allocate resources effectively and create policies tailored to the specific challenges in High Level, Wurukum, and Wadata areas.

Conclusion

This study was carried out to assess the bacterial contamination of drinking wells from High level, Wadata and Wurukum areas in Makurdi metropolis. The comprehensive analysis of physicochemical parameters, microbial assessments, and bacterial isolates in well water samples from the studied areas provides valuable insights into the overall quality and potential health risks associated with these water sources. The study revealed that while pH levels fell within an acceptable range and the biological oxygen demand (BOD) was consistently low across the locations. Variations in total dissolved solids (TDS), dissolved oxygen (DO), and electrical conductivity (EC) suggested localized influences, possibly from contamination sources or anthropogenic activities. Microbial assessments, particularly Total Coliform Count (TCC) and Fecal Coliform Count (FCC), indicated generally acceptable microbial quality across locations, with variations in Total Viable Count (TVC) highlighting localized factors influencing microbial populations. The identification of bacterial isolates, including pathogenic species like *Escherichia coli* and *Staphylococcus*, underscored the health risks associated with untreated well water consumption.

The distribution patterns of bacterial isolates among locations revealed discernible trends, with High Level exhibiting a heightened prevalence possibly linked to urbanization and population density. The study highlights the importance of using specific plans to manage water quality. These plans should take into account the special features of each area.

Recommendations

To address these concerns, multifaceted strategies are imperative.

- Awareness campaigns should be created to educate the local population about microbial contamination risks,

empowering informed water usage decisions.

- Stringent water treatment initiatives should be initiated to enhance the microbial safety of well water.
- Public health interventions should be tailored to identified contamination sources, involving targeted measures to mitigate fecal contamination, improve sanitation infrastructure, and implement regular monitoring programs.
- Proper well construction and maintenance practices should be promoted as it is pivotal in preventing microbial infiltration.

By addressing contamination sources and promoting a culture of water safety, public health authorities can significantly reduce risks associated with well water consumption, contributing to the overall well-being of the community.

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