

Comparative Assessment of Well Water Quality of three different locations in Gindin Dorowa, Wukari Local Government Area, Taraba State, Nigeria

*¹Mary Obioha, ¹Mohammed Muslim Tanko, ¹Aji Gani Mairiga, ¹Tundeno Barde Danfulloh, ¹Abdulkarim Hashim, ¹Ibrahim Danazumi Abdul, ¹Ugwu Immaculata Chidiebere, ¹Inuwa Calvin Chitwas

¹Department of Biological Sciences, Faculty of BioSciences, Federal University Wukari, Taraba State, Nigeria

*Corresponding authors' email: maryobioha202@gmail.com Phone: +2349063209740

ABSTRACT

Water plays many different roles in daily life and is a vital component of human nutrition, either directly as drinking water or indirectly as a component of food. Water contamination poses a serious threat to the wellbeing of people globally. In Nigeria, there have been increasing cases of waterborne diseases owing to water contamination, thus becoming public health concerns. This study was carried out to investigate the physicochemical and bacteriological quality of well water samples in Gindin Dorowa community, Wukari local Government Area of Taraba State. Nine Well water samples were collected from three different locations (three samples from each location) and subjected to standard bacteriological and physicochemical analysis. The result for coliform count of the bacterial isolate revealed high levels of bacterial contamination across all samples. Well water samples showed higher contamination levels in two locations, with Angwan Burofi and Angwan Sabon Kasuwa both recording 2.7×10^6 cfu/ml, while Angwan CRCN Hospital recorded 1.2×10^6 cfu/ml. A total of 36 bacterial isolates were identified and *Pseudomonas auroginosa* had the highest occurrence of 12 while *Shigella* showed the least occurrence with 2 isolates. Among the locations, Angwan Burofi recorded the highest total bacterial occurrence, accounting for 15 out of 36 isolates (41.7%) followed by Angwan Sabon Kasuwa with 13 isolates (36.1%), while Angwan CRCN Hospital had the lowest occurrence with 8 isolates (22.2%). The results of the physicochemical parameters in the three different locations (Angwan CRCN Hospital, Angwan Burofi and Angwan Sabon Kasuwa) showed; Temperature 30.2°C, 30.4°C, and 30.0°C respectively; pH ranging from 5.7 to 6.4; electrical conductivity, 81.9 S/m, 121.2 S/m, and 46.9 S/m; turbidity ranged from 56.0 NTU to 63.0 NTU, dissolved oxygen, 8.7 mg/L, 9.8 mg/L, and 8.7 mg/L respectively. These results highlight the fact that well water in Gindin Dorowa community is not safe for drinking without proper treatment such as boiling or disinfection and this could lead to outbreak of water borne diseases.

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INTRODUCTION

Water plays many different roles in daily life and is a vital component of human nutrition, either directly as drinking water or indirectly as a component of food. It is also an essential parameter in the public health due to possibility of transmitting water borne diseases and a major contributor to infant mortality in many developing nations (Al-Khatib *et al.*, 2023). The World Health Organization (WHO) has asserted that safe drinking-water is a human right and the source of drinking-water for a significant proportion of the global population ranges from individual household wells to piped supplies (WHO 2024). The quality of water has been continuously threatened by the rapid rise in industrialization, urbanization, increase in human population, various anthropogenic activities and the effects of climate change. These factors have led to a high demand for good quality water for home, recreational, industrial, and other applications (Tsor *et al.*, 2022). Physicochemical properties affect the type and amount of nutrients in surface and ground water. The nutrient levels in surface or groundwater can impact on the growth of microscopic plants and consequently affect the pollution status of drinking water. Some common physicochemical properties of water are pH, turbidity, dissolved oxygen (DO), total dissolved solids (TDS), electrical conductivity (EC),

temperature, Biochemical oxygen demand, biochemical oxygen demand (BOD), chloride, nitrate, sulphate amongst others. Temperature is a measure of degree of heat or coolness of any solution, and it impacts on the equilibrium and the pH. A reduction in pH of about 0.45 is apparent when temperature of pure water is increased by 25°C. Temperature effects becomes even more amplified in water with buffering capacity because of the presence of bicarbonate, carbonate and hydroxyl ions (Kebede *et al.*, 2018). The measure of the hydrogen ion concentration is described as pH. The activity of the hydrogen ion in diluted solutions is very nearly equivalent to its concentration. Low pH appears to enhance the corrosion of metals and consequently may lead to poisoning of drinking water (WHO 2009). The lives of bacteria and the availability of other contaminants in water may be impacted by pH, thereby making the water unpleasant for certain purposes. At elevated pH, metals tend to precipitate while other chemicals such as ammonia become toxic to aquatic life (Ewusi *et al.*, 2021). At low pH, solubility of metals tends to be high, chemicals like cyanide and sulphide become more toxic (Melecki *et al.*, 2017). The determination of pH may perhaps serve as a sensitive indicator for contamination. Conductivity is influenced by the presence of dissolved inorganic solids while organic substances have poor conductivity when in water.

Conductivity is a non-specific measurement of the ionic species available in the water sample, which can be used in screening tools for brewery water. Total dissolved solids (TDS) consist of mainly inorganic salts and lesser amount of organic matter dissolved in water. Increased level of TDS above 600 mg/L may be objectionable to the users because of increasing scaling in water pipes, heaters, boilers and household appliances. There is dearth of information as pertain to the proposed health-based guideline value for TDS (Ewusi *et al.*, 2021). The degree of the turbidity of water is generally presumed to be equivalent to the level of pollution. Nevertheless, this assertion may be misleading especially when the water is colourless but contaminated by acids, toxic metals or other substances that do not necessarily cause turbidity. Water can be objected for aesthetic value at turbidity levels above the maximum permissible limits of 5NTU (WHO 2009).

The provision of safe drinking water, particularly in poor nations like Nigeria has not been adequate (Imam *et al.*, 2023). Due to lack of clean water many households in North-central and Far-Northern Nigeria depend entirely on well water, springs, streams, ponds, rivers, dams, and rainwater for their domestic needs (Shar *et al.*, 2021). These sources are more likely to experience deficiencies in terms of water safety, which can result in water-related illness as well as adverse social and economic impacts ((WHO 2024).). Gindin Dorowa suffers portable water shortage and rely mostly on hand dug water wells for household needs including drinking, cooking, and washing. This has necessitated research to ascertain the physicochemical characteristics of the well water in three different parts of Gindin Dorowa with high utilization of well water.

MATERIALS AND METHODS

Study Area

The study was conducted in Gindin Dorowa, Wukari Local Government Area of Taraba State, Nigeria. Central coordinate: Latitude 7.87040° N, Longitude 9.77851° E. Tropical continental climate, wet season April-October (1000-1500 mm rainfall), dry season November-March, temperature 20-40°C. Water samples were collected from three borehole locations (Angwan Burofi- N07°52'15.3" E009°47'12.1", Angwan CRCN Hospital- N07°52'21.8" E009°47'18.6" and Angwan Sabon Kasuwa – N07°52'28.4" E009°47'25.2") in Gindin Dorowa.

Sample Collection

The water samples were collected from the selected sites into clean, transparent amber bottles by first rinsing the bottles with the water samples and were labeled properly. All the water samples were collected by early hours (between 7 a.m. and 9 a.m.) of the day in triplicate. Some physicochemical parameters, which include pH, temperature, total dissolved solids, and electrical conductivity, were determined at the point of collection and were later transferred into ice-pack and transferred later to the laboratory for an immediate analysis.

Bacteriological Analysis

Bacteriological analysis of the water samples involved standard microbiological methods according to the method described by Nicholas *et al.* (2022) for determination of total heterotrophic bacterial count, total coliform count and total faecal coliform count. One milliliter (1 mL) each of the well water samples was pipette into 9 mL of sterile physiological saline and thoroughly mixed by swirling. The mixtures were diluted decimally until appropriate dilution was obtained. The spread plate method was used in inoculating aliquot portion

(0.1 mL) of appropriate dilution into a sterilized nutrient agar medium. Plates were incubated at 37 °C for 24 to 48 hours for heterotrophic bacteria and the colonies obtained after incubation were counted and expressed as colony forming units per milliliter of water (CFU/mL-1). The physiological characteristics of the colonies and their number on the culture plates were used as the basis for the counting, taking into consideration their dilution number. Counts were made from the plates containing 30-300 colonies. The isolates were aseptically sub-cultured into fresh nutrient agar after counting and incubated at a temperature of 37 °C for 24 hours to obtain pure cultures of the isolates.

Preliminary identification of isolates was based on colony morphology, including colony size, shape, color, pigmentation, and elevation. Microscopic examination was carried out after Gram staining to differentiate Gram-positive and Gram-negative bacteria. Further identification was achieved using the following standard biochemical tests;

Catalase Test

Using sterile glass rod, suspected colonies were immersed in tube containing 2 ml of 3% hydrogen peroxide. Presence of bubbles indicates a positive result (Cheesbrough, 2009; Collee *et al.*, 2016).

Coagulase Test

1ml of human plasma were added to test tubes and a loopful of the bacteria isolates inoculated. The test tubes were incubated at 37°C for 1 hour in a water bath to observe for presence of clouding and clotting. Interpretation: A positive coagulase test is represented by any degree of solid clotting.

Indole Test: Isolated colonies were inoculated in peptone water, which contains amino acid tryptophan and incubated at 37°C for 24 hours. After incubation, Kovac's reagent was added and the test tube was shaken gently. The test tube was allowed to stand for 2 minutes. Interpretation: Formation of a red or pink colored ring at the top of the test tube is a positive result. This indicates the presence of tryptophase enzymes

Methyl red (MR) Test: The isolated colonies were inoculated into glucose phosphate broth, which contains glucose and a of the medium was tested by the addition of 5 drops of methyl red reagent. Interpretation: Development of red color is a positive result. Gram Negative bacteria produce yellow color.

Citrate Utilization Test: Isolated bacterial colonies were picked with a sterile inoculating loop and inoculated into slants of Simmon's citrate agar and incubated 24 to 48 hrs at 37°C. Interpretation: If the organism has the ability to utilize citrate, the medium changes its color from green to blue. This means the organism can utilize citrate as a sole carbon source and the result indicate that it helps identify the organism.

Physicochemical Analysis

The following physicochemical properties of the water samples were determined following standard analytical procedures of APHA (1995).

pH Value

The pH was determined using the pH meter (PHS-3E, Labo Hub instrument). Buffer solutions of different pH were used to standardize the pH meter.

Turbidity

The turbidity was measured by the use of turbidity meter (BEP-TB100, Infitec); the meter contains a bottle in which

the water samples were induced. The bottle was inserted into a cavity hole on the turbidity meter which was allowed to read for 30 seconds, there after the reading was recorded.

Electrical Conductivity

Electrical conductivity of the water samples was estimated by the use of a conductivity meter (INE-EC110B, mrc instrument). The conductivity meter was standardized with buffer solution and temperature of different samples before the steady readings were noted.

Temperature

The temperature of each water sample was determined through the use of a mercury-bulb thermometer by immersing the bulb vertically into the samples and allowing it to stand until a steady temperature was achieved.

Total Dissolved Solids (TDS)

An empty beaker was weighed, and 50 ml of the water sample was measured into it and filtered into another beaker. The filtrate was heated to dryness, cooled, and reweighed until a constant mass was obtained. The value of the mass was recorded using the expression $TDS = \frac{W1-W2}{V} \times 1000$ sample volume (ml).

Dissolved Oxygen (DO)

The dissolved oxygen content of the water samples was measured by using a waterproof meter according to standard method of APHA (1995).

Statistical Analysis

Data generated from the microbiological and physicochemical analyses were summarized using descriptive statistics. Differences among sampling locations

and water sources were evaluated using one-way analysis of variance (ANOVA), while frequency of occurrence of bacterial isolates was expressed as percentages. Statistical analyses were performed using the Statistical Package for the Social Sciences (SPSS) version 31, and statistical significance was considered at $P < 0.05$.

RESULTS AND DISCUSSION

Table 1 presents the total viable counts (TVC) of bacteria in colony-forming units per milliliter (cfu/ml) for well water samples collected from three areas in Gindin Dorowa. The results reveal high levels of microbial contamination across all samples. Well water samples showed higher contamination levels in two locations, with Angwan Burofi and Angwan Sabon Kasuwa both recording 2.7×10^6 cfu/ml, while Angwan CRCN Hospital recorded 1.2×10^6 cfu/ml. These values far exceed the recommended limits by World Health Organization (WHO) and the Standard Organization of Nigeria (SON), which typically stipulate that drinking water should contain zero coliforms and have heterotrophic plate counts below 1×10^2 cfu/ml for treated water. The magnitude of these counts indicates that well water samples are heavily contaminated and pose a significant public health risk to consumers. Obuekwe *et al.* (2021) reported highest bacterial counts from water in animal farm area (1.2 ± 1.05 to $4.80 \pm 0.10 \times 10^4$ CFU/mL) followed by agricultural area (1.4 ± 0.22 to $3.1 \pm 1.16 \times 10^4$ CFU/mL), but was least in residential area (1.01 ± 0.10 to $1.80 \pm 0.89 \times 10^4$ CFU/mL). The high counts in well water can be attributed to their shallow depth and greater susceptibility to surface runoff, anthropogenic activities, and contamination from domestic waste, animal feces, and inadequate sanitary infrastructure (Kwikima, 2025).

Table 1: Total Viable Counts of Bacteria in Colony forming Unit Per Milligram (cfu/ml) of Well Water Samples from the Selected Areas in Gindin Dorowa

Sample location	Sample	Total counts in cfu/ml
Angwan Burofi	Well water	2.7×10^6
Angwan CRCN Hospital	Well water	1.2×10^6
Angwan Sabon Kasuwa	Well water	2.7×10^6
WHO		0.00

The biochemical characterization in Table 2 confirmed the identification of the bacterial isolates derived from the water samples. Among the Gram-positive bacteria, *Staphylococcus aureus* was identified by its positive catalase and coagulase reactions, the latter being a key virulence factor that distinguishes it from other coagulase-negative staphylococci (França *et al.*, 2021). In contrast, *Bacillus subtilis*, while also catalase-positive, tested negative for coagulase and exhibited a unique profile of citrate utilization without the production of indole or a positive methyl red reaction, consistent with its saprophytic nature. These enzymatic profiles not only validated the Gram stain observations but also highlighted the metabolic diversity between these two Gram-positive genera. For the Gram-negative isolates, the biochemical test battery effectively differentiated the enteric bacteria from non-fermenters. *Escherichia coli* was identified by its classic pattern of being indole-positive, methyl red-positive, and citrate-negative, which is consistent with its role as a fecal indicator bacterium (Caramujo *et al.*, 2026). *Shigella* spp.,

while sharing the methyl red-positive trait, was distinguished from *E. coli* by its negative indole reaction, confirming its identity as a non-motile, non-lactose fermenting pathogen. The presence of these bacteria in the water samples is particularly significant as they are directly associated with fecal contamination and pose serious gastrointestinal health risks (Khan and Gupta, 2020). *Pseudomonas aeruginosa* stood out with a distinctly different biochemical fingerprint, being oxidase-positive and citrate-positive while negative for indole and methyl red. The positive oxidase test is a hallmark of this non-fermentative, aerobic rod. The ability of *Pseudomonas* to thrive in diverse environments, coupled with its resistance to many antimicrobial agents, makes its prevalence in well and borehole water a major public health concern (Serwecińska, 2020). Obuekwe *et al.* (2021) reported the presence of four (4) Gram positive bacteria; *Bacillus cereus*, *Staphylococcus aureus*, *Micrococcus* sp. and *Bacillus subtilis* and three (3) Gram negative bacteria; *Shigella* sp., *Salmonella* sp. and *E. coli*.

Table 2: Biochemical Reactions of Bacteria Isolated from Well Water Samples from Different Locations in Gindin Dorowa

Bacteria	Catalase test	Coagulase test	Indole test	Methyl red test	Citrate test	Oxidase test	Gram reaction
Bacillus subtilis	+	-	-	-	+	-	+Rod
Escherichia coli	+	-	+	+	-	-	-Rod
Pseudomonas aeruginosa	+	-	-	-	+	+	-Rod
Shigella spp	+	-	-	+	-	-	-Rod
Staphylococcus aureus	+	+	-	+	+	-	+Cocci

Table 3 reveals a marked variation in the occurrence of bacterial isolates across the three selected areas in Gindin Dorowa. Among the locations, Angwan Burofi recorded the highest total bacterial occurrence, accounting for 15 out of 36 isolates (41.7%) followed by Angwan Sabon Kasuwa with 13 isolates (36.1%), while Angwan CRCN Hospital had the lowest occurrence with 8 isolates (22.2%). The high bacterial load observed at Angwan Burofi is particularly concerning, as it suggests that water sources in a healthcare-associated environment may be heavily contaminated. The presence of *Pseudomonas aeruginosa* and *Staphylococcus aureus* at this location shows the potential for waterborne transmission in a setting where vulnerable individuals are present.

The chi-square analysis yielded a value of 6.05 with a corresponding p-value of 0.041, which is less than the 0.05 level of significance. This implies that the variation in contamination levels is not due to random chance but likely

reflects differences in environmental sanitation, well construction, proximity to contamination sources, or human activities at each site (Kubicz et al., 2018). *Pseudomonas aeruginosa* was the most frequently isolated organism overall (12 isolates), with the highest counts recorded at Angwan Burofi (6 isolates), suggesting possible biofilms or persistent contamination in that area. *Shigella spp.* was isolated only at Angwan Sabon Kasuwa, indicating localized fecal contamination. Obuekwe et al. (2021) found that *Shigella sp.* was the most occurring bacterial isolate (23.29%) while *Salmonella sp.* was the least (7.2%). The highest contamination at Angwan Burofi is alarming, as hospitals require high-quality water to prevent the spread of infections among patients and staff. The presence of multiple bacterial species across all locations suggests that well water sources in the study area are unsafe for direct consumption without treatment (Nwandkor and Ifeanyi, 2015).

Table 3: Occurrence of Bacteria Isolated from well Water Samples from the Selected Areas in Gindin Dorowa

Bacteria	Angwan CRCN Hospital	Angwan Burofi	Sabon Kasuwa	Total
Bacillus subtilis	4	2	2	8
Escherichia coli	-	3	1	4
Pseudomonas aeruginosa	2	6	4	12
Shigella spp	-	-	2	2
Staphylococcus aureus	2	4	4	10
Total	8 (22.2%)	15 (41.7%)	13 (36.1%)	36

$\chi^2 = 6.05$, Mean = 8.95, P-value = 0.041

From table 4, the pH mean value ranged between 6.7 to 6.9. The results showed that lowest pH mean value of 6.7 was observed at Angwan Burofi, and the highest pH mean value 6.9 was observed in Angwan Sabo Kasuwa. The present study agrees with Akani et al. (2021) that reported a pH range of 6.3 to 6.9 for well water samples from Ido community in River state. Furthermore, the present study agrees strongly with the report of Igwe et al. (2021) whose investigation obtained a range of values between 6.8 to 6.9 while the control samples had a range from 6.0 to 7.1. In a related study, Ocheli et al. (2020) reported ranges between pH 6.6 and 8.3 for shallow well and pH 6.5 and 8.4 for borehole water while WHO permissible limit of 6.5–8.5. However, Nduka et al. (2008) observed a low pH of 5.0 for Udu well water which is located in Delta State, Nigeria. pH is generally considered to have no direct impact of humans. The lower pH in well water could suggest that shallow groundwater sources are more susceptible to infiltration of acidic surface runoff, possibly from organic decomposition or atmospheric precipitation. Low pH water is often corrosive, potentially leaching heavy metals such as lead, copper, and zinc from plumbing materials and storage containers, thereby introducing additional health hazards (Gonzalez et al., 2013).

Well water samples showed temperatures of 30.2°C, 30.4°C, and 30.0°C, respectively. The WHO (2017) guideline suggests an ambient temperature range, typically around 29°C for tropical climates. Temperature constitutes an important physicochemical variable that is often used to evaluate the quality of water used for human consumption (Tula et al., 2022). All the chemical and biological processes in a living organism, including increases in color and taste of water, and alkalinity, acidity, pH and dissolved oxygen of water, are regulated by temperature (Nigam et al., 2013). The temperature values recorded in this study were slightly higher than the temperature range of well water (22.63–26.57 °C and 19.25–21.25 °C) for both dry and rainy seasons in Adamawa North senatorial zone, Nigeria which was documented by Tula et al. (2022), Abeokuta, Ogun State (Nigam et al., 2013), sampled hand-dug well water in Ilorin (Kolawole et al., 2017), Ido community, River state (Akani et al., 2021). This variation could be due to differences in geographical location. This corroborates the result of previous studies in Maiduguri, Borno State (Elemile et al., 2019). Nonetheless, a previous study in Maiduguri metropolis by Abubakar et al. (2018) recorded temperature values above WHO standards. According to that study, a higher temperature beyond the WHO acceptable limit does not imply impurities, but could

adversely impede the dissolution of oxygen, accelerate chemical reactions, and cause thermal pollution. These might adversely affect aquatic life, increase metabolic activities of microorganisms and intensify taste and odor due to anaerobic reaction, which consequently will render the water unacceptable for domestic use.

Well water samples showed even higher turbidity, ranging from 56.0 NTU to 63.0 NTU. All recorded values far exceeded the WHO (2017) and SON standard of 5 NTU, indicating severe particulate contamination. The higher turbidity in well water suggests that open or poorly protected wells are more vulnerable to surface runoff intrusion, soil erosion, and direct introduction of particulate matter from surrounding activities. High turbidity water is often unacceptable to consumers due to its appearance, and more importantly, it compromises disinfection processes (Zimoch and Paciej, 2020).

Well water samples showed higher concentrations of DO levels 8.7 mg/L, 9.8 mg/L, and 8.7 mg/L respectively. All values fell within or above the WHO (2017) and SON recommended range of 6.5–8.0 mg/L. The higher DO levels in well water may be attributed to greater air-water interaction at the surface of open wells. Adequate dissolved oxygen levels indicate that the water sources are not overloaded with

organic pollutants that would otherwise deplete oxygen through microbial decomposition (Singh et al., 2021).

Well water samples showed higher and more variable values for electric conductivity: 81.9 S/m, 121.2 S/m, and 46.9 S/m. All values remained well below the WHO (2017) guideline of 1000 S/m and the SON standard of 1500 S/m, indicating that the water is not excessively mineralized and is acceptable from a salinity perspective. The conductivity in well water may reflect greater surface influence, including contributions from agricultural activities, domestic waste, or evaporation-concentration effects in shallow wells. Higher conductivity may suggest the infiltration of wastewater or leachate from nearby anthropogenic activities (Mosuro et al., 2017). The relatively low conductivity across all samples indicates that the water does not contain excessive salts that would cause taste issues or gastrointestinal disturbances (Dietrich and Devesa, 2019).

Well water samples showed lower and more variable concentrations of TDS: 294.6 mg/L, 207.1 mg/L, and 315.5 mg/L respectively. All values were within the WHO (2017) and SON acceptable limit of 500 mg/L, indicating that the water is not excessively mineralized. Elevated TDS can affect taste acceptability and may contribute to scaling in pipes and appliances (Dietrich and Devesa, 2019).

Table 4: Physicochemical Analysis of Well Water Samples from the Three Selected Areas in Gindin Dorowa

Parameters	Angwan Burofi	Angwan CRCN Hospital	Angwan Sabon Kasuwa	WHO	SON
pH	6.7	6.98	6.9	6.5-8.5	6.5-8.5
Temperature	30.2°C	30.4°C	30.0°C	29°C	Ambient
Turbidity NTU	61.5	63.0	56.0	5	5
Dissolved Oxygen Mg	8.7	9.8	8.7	6.5-8	6.5-8
Conductivity S/m	81.9	121.2	46.9	1000	1500
Total dissolved solids Mg/l	294.6	207.1	315.5	500	500
Mean	80.4	72.9	77.3		
Std. Dev	109.1	78.4	118.4		
C.V	135.6	107.6	153.3		
P.value	< 0.037				

CONCLUSION

This study has shown that there is a high incidence of contamination of well waters by potential pathogens. The wells used by the residents of the three different locations in Gindin Dorowa community cannot therefore be considered as good sources of water for human consumption. Access to good quality or potable drinking water and efficient sanitary practices are fundamental to human health and economic development. To reduce the widespread incidence of contamination of well water, it is advocated that wells dug must be deep and covered adequately.

REFERENCES

- Abubakar, B. S., Abdullah, A., Jones, A. N., & Hussaini, M. (2018). Assessment of public boreholes water quality in Maiduguri Metropolis. *Arid Zone Journal of Engineering, Technology and Environment*, 14(4), 639-637.
- Akani, N. P., Amadi, L. O. and Amafina, I. M. (2021). Assessment of physicochemical and bacteriological quality of well water samples in Ido community, Nigeria. *Microbiology Research Journal International*, 31(1), 1-10. DOI: <https://doi.org/10.9734/MRJI/2021/v31i130284>
- Al-Khatib, I. A., Al-Jabari, M., & Al-Oqaili, M. (2023). Assessment of bacteriological quality and physicochemical parameters of domestic water sources in Jenin governorate: a case study. *Journal of Environmental and Public Health*, 2023(1), 8000728. <https://doi.org/10.1155/2023/8000728>.
- Caramujo, S., Abreu, R., Pereira, G., Cunha, E., Tavares, L., McFarlane, E. and Oliveira, M. (2026). Antimicrobial Resistance in *Escherichia coli* from Captive Wild Felids: Associations with Host and Management Factors. *Veterinary Sciences*, 13(2), 124. <https://doi.org/10.3390/vetsci13020124>
- Cheesbrough, M. (2006). District laboratory practice in tropical countries (2nd ed., Chapter 7, pp. 62–70). New York, USA.
- Cheesbrough, M. (2009). District laboratory practice in tropical countries (2nd ed., Chapter 7, pp. 132–304). New York, USA.
- Collee, J. G., Barrie, P. M., Andrew, G. F. and Anthony, S. (2016). Mackie McCartney practical medical microbiology (4th ed., pp. 254–413). Singapore.

- Dietrich, A. M. and Devesa, R. (2019). Characterization and removal of minerals that cause taste. *Taste and odour in source and drinking water: causes, controls, and consequences*, 113-142. https://doi.org/10.2166/9781780406664_0245
- Elemile, O. O., Raphael, D. O., Omole, D. O., Oloruntoba, E. O., Ajayi, E. O., & Ohwavorua, N. A. (2019). Assessment of the impact of abattoir effluent on the quality of groundwater in a residential area of Omu-Aran, Nigeria. *Environmental Sciences Europe*, 31(1), 16. <https://doi.org/10.1186/s12302-019-0201-5>
- Ewusi A., Ahenkorah I., and Aikins D. (2021). Modelling of total dissolved solids in water supply systems using regression and supervised machine learning approaches. *Applied Water Science*, 11(2), 334–625. <https://doi.org/10.1007/s13201-020-01352-7>
- França, A., Gaio, V., Lopes, N. and Melo, L. D. (2021). Virulence factors in coagulase-negative staphylococci. *Pathogens*, 10(2), 170. <https://doi.org/10.3390/pathogens10020170>
- Garba, Y. I., Gano, U. T., Yusuuf, M. S. and Musa, D. M. (2018). Assessment of physicochemical and microbiological quality of borehole water in Dutse Metropolitan Jigawa State, Nigeria. *Science World Journal*, 13(3), 1-5.
- Gonzalez, S., Lopez-Roldan, R. and Cortina, J. L. (2013). Presence of metals in drinking water distribution networks due to pipe material leaching: a review. *Toxicological & Environmental Chemistry*, 95(6), 870-889. <https://doi.org/10.1080/02772248.2013.840372>
- Igwe, O., Ngwoke, M., Ukah, B. U., & Ubido, O. E. (2021). Assessment of the physicochemical qualities of groundwater and soils around oil-producing communities in Afam, area of Porthacourt, Niger Delta Nigeria. *Applied Water Science*, 11(4), 1-13. <https://doi.org/10.1007/s13201-021-01393-6>
- Imam, N., Abdurrahman, N., Isah, L.A. and Lawal, O.S. (2023) Progress on Drinking Water Quality Monitoring in the Northern Part of Nigeria: A Catalyst to Achieving Sustainable Development Goals. *FUDMA Journal of Sciences*, 7(2): 152 - 158 <https://doi.org/10.33003/fjs-2023-0702-1472>
- Kebede N. M., Mathapelo P. S., Ntebogeng S. M., Robert M. C., & Amjad A. S. (2018). Assessment of microbiology, physicochemical, water-soluble anions and elemental contents of water sediments of Bon Accord Dam, South Africa. *Cogent Chemistry*, 4(1), 2. <https://doi.org/10.1080/23312009.2018.1560858>
- Khan, F. M. and Gupta, R. (2020). *Escherichia coli (E. coli) as an Indicator of Fecal Contamination in Groundwater: A Review*. In *International Conference on Sustainable Development of Water and Environment* (pp. 225-235). Cham: Springer International Publishing.
- Kolawole OM, Afolayan O. Assessment of Groundwater quality in Ilorin, North Central Nigeria. *Arid Zone J Eng, Technol Environ*. 2017;13(1):111-126. 12.
- Kubicz, J., Pawelczyk, A. and Lochyński, P. (2018). Environmental health risk posed by contamination of the individual water wells. *Chemosphere*, 208, 247-256. [10.1016/j.chemosphere.2018.05.182](https://doi.org/10.1016/j.chemosphere.2018.05.182)
- Kwikima, M. M. (2025). Analyzing the presence of microbial contaminants in water sourced from shallow wells within Dodoma city, Tanzania. *International Journal of Energy and Water Resources*, 9(1), 1-12. <https://doi.org/10.1007/s42108-024-00278-z>
- Malecki K. M., Schultz A. A., Severtson D. J., Anderson H. A., and VanDerslice J. A. (2017). Private-well stewardship among a general population-based sample of private well owners. *Science of the Total Environment*. 601, 1533–1543. [10.1016/j.scitotenv.2017.05.284](https://doi.org/10.1016/j.scitotenv.2017.05.284)
- Mosuro, G. O., Omosanya, K. O., Bayewu, O. O., Oloruntola, M. O., Laniyan, T. A., Atobi, O. and Adekoya, F. (2017). Assessment of groundwater vulnerability to leachate infiltration using electrical resistivity method. *Applied Water Science*, 7(5), 2195-2207. <https://doi.org/10.1007/s13201-016-0393-4>
- Nduka, J. K. C., Orisakwe, O. E., Ezenweke, L. O., Ezenwa, T. E., Chendo, M. N., & Ezeabasi, N. G. (2008). Acid rain phenomenon in Niger delta region of Nigeria: economic, biodiversity, and public health concern. *The Scientific World Journal*, 8(1), 811-818. <https://doi.org/10.1100/tsw.2008.47>
- Nigam, V., Behl, N., and Kanchan, M. C. (2013). Physicochemical parameters for testing of water-a review. *Int J Pharmacy Biological Sci*, 3(3), 523-527.
- Nwandkor, U. U. and Ifeanyi, O. E. (2015). Bacteriological assessment of different borehole drinking water sources in Umuahia Metropolis. *International Journal of Current Microbiology and Applied Sciences*, 4(5), 1139-1150.
- Obuekwe, I. S., Oshoma, C. E. and Omorogbe, J. N. (2021). Evaluation of Physicochemical and Bacteriological Properties of Borehole Water in Selected Areas of Benin City, Edo State. *Nigerian Journal of Life Sciences* 11(1 & 2), 10-17. <https://doi.org/10.52417/njls.v11i1%20&%202.59>
- Ocheli, A., Otuya, O. B., and Umayah, S. O. (2020). Appraising the risk level of physicochemical and bacteriological twin contaminants of water resources in part of the western Niger Delta region. *Environmental Monitoring and Assessment*, 192(5), 1-16. <https://doi.org/10.1007/s10661-020-08302-5>
- Tula, M. Y., Enabulele, O. I., Ophori, E. A., and Aziegbemhin, A. S. (2022). A comprehensive study on the physicochemical characteristics of two water sources from the Adamawa North senatorial zone, Nigeria. *Public Health Toxicology*, 2(4), 1-13. DOI: <https://doi.org/10.18332/pht/158012>
- Tsor, J. O., Biam, J. T., Terver, D., Shimlumun, A.P. and Jombo, G.T.A. (2022). Assessment of Physico-chemical Parameters and Heavy Metal Concentrations in Well Water of Logo-2 Area of Makurdi, Nigeria. *Nigerian Annals of Pure and Applied Sciences*, 5(1):137-148 <https://doi.org/10.5281/zenodo.6905019>
- Serwecińska, L. (2020). Antimicrobials and antibiotic-resistant bacteria: a risk to the environment and to public

health. *Water*, 12(12),
<https://doi.org/10.3390/w12123313>

Shar, A.T., Onekutu, A.A., Ebah, E.E., and Olasan, J.O. (2021) Assessment of Seasonal Variation in Relation to Physicochemical Properties of Water from Hand Dug Wells near Soakaway Pits in Vandeikya, Benue State, Nigeria. *International Journal of Research Publication and Reviews* 2(7):1960-1965

Singh, G., Singh, A., Singh, P., Shukla, R., Tripathi, S. and Mishra, V. K. (2021). The fate of organic pollutants and their microbial degradation in water bodies. *Pollutants and water management: resources, strategies and scarcity*, 210-240. <https://doi.org/10.1002/9781119693635.ch9>

3313. World Health Organization (WHO) (2009). Global health risk: Mortality and burden of disease attributable to selected major risks. Geneva: WHO. Available: http://www.who.int/healthinfo/global_disease/GlobalHealthRisks-report_full.pdf

WHO (2024) Guidelines for drinking-water quality: small water supplies. Geneva: World Health Organization; icence: CC BY-NC-SA 3.0 IGO, p viii - 175

World Health Organization (2017). Guidelines for drinking-water quality. WHO Press, Geneva. Switzerland, 4th edition.

Zimoch, I. and Paciej, J. (2020). Use of water turbidity as an identifier of microbiological contamination in the risk assessment of water consumer health. *Desalination and Water Treatment*, 199, 499-511. [10.5004/dwt.2020.26426](https://doi.org/10.5004/dwt.2020.26426)



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