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Research Article

Comparative Assessment of Bacterial Contamination in Institutional Tap Water and Vended Water (Meruwa) in Ogbia, Bayelsa State, Nigeria

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Abstract

Background: Safe drinking water is essential for human health, yet bacterial contamination remains a pervasive challenge in resource-limited settings. In many Nigerian communities, households supplement or replace tap water with water purchased from informal vendors, often referred to as Meruwa, under the assumption that vended water is safer. However, no prior study has systematically compared bacterial contamination in both institutional tap water and informal vended water in this region. **Objective:** This study compared contamination levels and bacterial species distribution between institutional tap water and vended water in Ogbia, Bayelsa State, Nigeria, and assessed compliance with World Health Organization drinking water standards. **Methods:** A total of 47 water samples were analyzed, comprising 23 tap water samples from six campus points and 24 vended water samples from vendors in Ogbia Main Town. Total bacterial counts and total coliform counts were determined using the plate count method on nutrient agar and MacConkey agar, respectively. Bacterial isolates were identified through Gram staining and biochemical characterization. Compliance was assessed against WHO guidelines of 0 CFU/100 mL for coliforms and less than 500 CFU/mL for heterotrophic bacteria. **Results:** All samples exceeded WHO standards. Tap water total bacterial counts ranged from 3.50×10^6 to 5.00×10^6 CFU/mL with a mean of 4.32×10^6 CFU/mL, and total coliform counts ranged from 3.00×10^6 to 3.80×10^6 CFU/mL with a mean of 3.21×10^6 CFU/mL. Vended water total bacterial counts ranged from 3.50×10^6 to 5.30×10^6 CFU/mL with a mean of 4.24×10^6 CFU/mL, and total coliform counts ranged from 3.00×10^6 to 4.00×10^6 CFU/mL with a mean of 3.21×10^6 CFU/mL. No significant difference was observed between water sources for total bacterial counts ($p = 0.642$) or total coliform counts ($p = 0.981$). Tap water isolates included *Escherichia coli* at 28.0%, *Staphylococcus aureus* at 28.0%, *Pseudomonas aeruginosa* at 20.0%, *Klebsiella pneumoniae* at 12.0%, and *Enterobacter aerogenes* at 12.0%. Vended water isolates comprised *E. coli* at 33.3%, *Salmonella typhi* at 25.0%, *K. pneumoniae* at 20.8%, and *Citrobacter freundii* at 20.8%. Species distribution differed significantly between sources ($\chi^2 = 24.18$, $p = 0.0005$). Compliance with WHO standards was 0% for both sources. **Conclusion:** Both water sources are universally contaminated with faecal and opportunistic pathogens, including *S. S. typhi*. The assumption that vended water is safer is unfounded. Routine monitoring, mandatory treatment of both sources, vendor certification, and targeted hygiene interventions are urgently needed.

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1. Introduction

Access to safe drinking water is a fundamental determinant of human health, yet microbial contamination of water supplies remains a persistent challenge in resource-limited settings [1–3]. In Nigeria, despite national and international efforts to expand water supply infrastructure, many communities continue to rely on unsafe or inadequately treated water sources, contributing to a sustained burden of waterborne diseases [4–6]. The Niger Delta region, including Bayelsa State, faces compounding challenges from aging distribution infrastructure, environmental degradation, and inconsistent water quality monitoring, which collectively heighten the risk of exposure to pathogenic microorganisms [5, 7–9]. Waterborne illnesses, including acute gastroenteritis, cholera, typhoid fever, and dysentery, are frequently linked to consumption of water contaminated with faecal coliforms, *Escherichia coli*, and other enteric pathogens [10–12]. In institutional settings such as schools and colleges, where populations are concentrated and water consumption is high, contaminated water poses particular risks for outbreaks and endemic transmission [13–16].

Moreover, in many Nigerian communities, households supplement or replace tap water with water purchased from informal vendors, often referred to as Meruwa, under the assumption that vended water is safer [4, 17, 18]. However, limited empirical data exist to support this assumption, and the relative microbial quality of institutional tap water versus vended water remains poorly characterized in many parts of the Niger Delta. Environmental contamination from sewage discharge, agricultural runoff, and unregulated waste disposal further compromises water safety by introducing faecal matter into both surface and groundwater sources [11, 15, 16, 19]. These pressures are particularly acute in the Niger Delta, where urbanization, industrial activity, and inadequate sanitation infrastructure converge to elevate microbial loads in water supplies [20–23]. Consequently, drinking water in this region frequently exceeds WHO guideline values for total coliforms and heterotrophic bacteria, indicating widespread non-compliance with international safety standards [24–27].

Despite growing recognition of water quality challenges in Bayelsa State, critical knowledge gaps persist. Specifically, no prior study has systematically characterized and compared bacterial contamination in both institutional tap water and locally vended water (Meruwa) within Otuogidi-Ogbia and Ogbia Main Town. Furthermore, the spatial distribution of contamination across multiple campus tap points and the diversity of bacterial species in vended water have not been comprehensively documented. These gaps hinder evidence-based policy formulation, limit the ability of regulatory authorities to enforce water safety standards, and leave consumers without reliable guidance on water treatment practices. To address these gaps, this study was designed to compare contamination levels and bacterial species distribution between institutional tap water and vended water, to evaluate compliance with WHO drinking water quality standards, and to provide evidence-based recommendations for improving water safety. Using standard microbiological techniques including total bacterial and coliform enumeration on nutrient and MacConkey agar followed by morphological and biochemical characterization of isolates, this study provides a comprehensive assessment of microbial water quality that integrates both institutional and informal water sources. The findings are intended to inform water safety interventions, strengthen regulatory oversight of the vended water sector, and contribute to the broader evidence base on drinking water quality in the Niger Delta region.

2. Materials and Methods

2.1. Study Area and Design

A descriptive cross-sectional study was conducted at Bayelsa State College of Health Technology, Otuogidi-Ogbia, and among water vendors in Ogbia Main Town, Ogbia Local Government Area, Bayelsa State, Nigeria. The college is located at approximately 4°39′00″N and 6°16′00″E within the low-lying Niger Delta environment [2, 3, 28, 29].

2.2. Sampling and Sample Size

A total of 47 water samples were examined, comprising 23 institutional tap-water samples and 24 vended-water (Meruwa) samples. The 23 tap samples represented all accessible campus sampling points: Boys' Hostel (n=5), Water Board/point of entry (n=5), Girls' Hostel A (n=5), Girls' Hostel B (n=5), Library (n=2), and Community Health Hall (n=1). Two originally planned points were inaccessible during sampling. All 24 registered active vendors identified through the Ogbia Main Town Development Association were included. Vendor water sources comprised borehole (n=16), municipal supply (n=5), and surface water (n=3); storage containers comprised plastic jerry cans (n=18) and metal drums (n=6).

2.3. Sample Collection and Transport

Approximately 100 mL of each sample was collected aseptically into sterile 100-mL screw-capped containers. Tap outlets were allowed to run for 2 minutes before collection. For vended water, storage containers were gently mixed, outlets were disinfected with 70% ethanol and allowed to flow for 30 seconds, and one container was randomly selected where multiple containers were available. Samples were labelled appropriately, transported in a cool box at approximately 4°C, and processed within 24 hours. Tap-water sampling was conducted over one week (Monday–Saturday).

2.4. Microbiological Analysis

Serial ten-fold dilutions (10^{-1}–10^{-6}) were prepared from each sample. Total bacterial counts (TBC) were determined on nutrient agar, while presumptive total coliform counts (TCC) were determined on MacConkey agar using the spread-plate method. For each dilution, 0.5 mL was spread aseptically over the agar surface and plates were incubated at 37°C for 24–48 hours. Plates containing 30–300 colonies were used for enumeration, and counts were expressed as CFU/mL using the standard plate-count formula.

Representative colonies were characterized by colony morphology and Gram staining. Pure isolates were subjected to catalase, coagulase, oxidase, citrate, urease, indole, Kligler iron agar, and motility tests using standard microbiological procedures. Presumptive coliforms were further assessed on eosin methylene blue agar and in EC broth at 44.5°C. The original study protocol identified *Escherichia coli* using the

indole reaction.

2.5. Quality Control

Media sterility was checked using uninoculated plates. Reference strains of *Escherichia coli* ATCC 25922, *Staphylococcus aureus* ATCC 25923, and *Pseudomonas aeruginosa* ATCC 27853 were used as positive controls, while sterile distilled water served as a negative control. Analyses were performed in duplicate, and 10% of samples were re-plated to assess reproducibility; reported coefficients of variation were below 10%.

2.6. Data Analysis and Ethical Considerations

Data were entered in Microsoft Excel 2021 and analysed using SPSS version 27.0. Means, standard deviations, medians, interquartile ranges, and ranges were calculated. Differences in TBC and TCC between tap and vended water were assessed using independent-samples t-tests or Mann–Whitney U tests according to distributional assessment. One-way ANOVA with Tukey post-hoc testing was used for comparisons across tap-water sampling points where applicable. Associations between water source and bacterial species were assessed using the chi-square test. Statistical significance was set at $p < 0.05$. Compliance was assessed against the benchmarks specified in the original study protocol [30]. Ethical approval was obtained from the Bayelsa State College of Health Technology Research Ethics Committee (BAYCHT/ERC/2024/017), and vendor consent and data anonymization procedures were applied.

3. Results

In Table 1 A total of 47 water samples were analysed, comprising 23 tap-water samples and 24 vended-water samples. Tap-water TBC ranged from 3.50×10^6 to 5.00×10^6 CFU/mL and TCC from 3.00×10^6 to 3.80×10^6 CFU/mL. Vended-water TBC ranged from 3.50×10^6 to 5.30×10^6 CFU/mL and TCC from 3.00×10^6 to 4.00×10^6 CFU/mL. No significant difference was reported between sources for TBC (p=0.642) or TCC (p=0.981).

Table 1: Descriptive statistics of total bacterial count (TBC) and total coliform count (TCC) in tap and vended water

Water source	n	Statistic	TBC (CFU/mL)	TCC (CFU/mL)
Tap water	23	Mean ± SD	$4.32 \times 10^6 \pm 0.54 \times 10^6$	$3.21 \times 10^6 \pm 0.24 \times 10^6$
		Median (IQR)	4.40×10^6 ($3.80–4.80 \times 10^6$)	3.20×10^6 ($3.00–3.40 \times 10^6$)
		Range	$3.50–5.00 \times 10^6$	$3.00–3.80 \times 10^6$
Vended water	24	Mean ± SD	$4.24 \times 10^6 \pm 0.68 \times 10^6$	$3.21 \times 10^6 \pm 0.31 \times 10^6$
		Median (IQR)	4.05×10^6 ($3.80–4.80 \times 10^6$)	3.15×10^6 ($3.00–3.35 \times 10^6$)
		Range	$3.50–5.30 \times 10^6$	$3.00–4.00 \times 10^6$
p-value			0.642	0.981

Note: p-values are those reported in the source manuscript. The original table described use of independent-samples t-test and Mann–Whitney U test according to distribution.

As shown in Table 2, *Escherichia coli* was the overall dominant species across both sources (30.6%, n=15), followed by *Klebsiella pneumoniae* (16.3%) and *Staphylococcus aureus* (14.3%). Tap water was primarily contaminated with *E. coli*, *S. aureus* (28.0% each), and *Pseudomonas aeruginosa* (20.0%), whereas vended water exclusively harbored Salmonella *S. typhi* (25.0%) and *Citrobacter freundii* (20.8%). A Chi-square test revealed a highly significant association between the type of water source and the distribution of bacterial species (χ^2 =24.18, p=0.0005), demonstrating distinct microbial profiles between tap and vended water.

Table 2: Comparative distribution of bacterial isolates by water source

Bacterial species	Tap water (n=25 isolates)	Vended water (n=24 isolates)	Combined (n=49 isolates)
Escherichia coli	7 (28.0%)	8 (33.3%)	15 (30.6%)
Staphylococcus aureus	7 (28.0%)	0 (0%)	7 (14.3%)
Pseudomonas aeruginosa	5 (20.0%)	0 (0%)	5 (10.2%)
Klebsiella pneumoniae	3 (12.0%)	5 (20.8%)	8 (16.3%)
Enterobacter aerogenes	3 (12.0%)	0 (0%)	3 (6.1%)
Salmonella S. typhi	0 (0%)	6 (25.0%)	6 (12.2%)
Citrobacter freundii	0 (0%)	5 (20.8%)	5 (10.2%)

Chi-square test for association between water source and bacterial species distribution: $\chi^2(6)$=24.18, p=0.0005.

As demonstrated in Table 3, both tap and vended water samples failed to meet World Health Organization (WHO) safety standards, exhibiting 0% overall compliance across all microbial parameters. Total coliform counts for tap (3.00–3.80×106 CFU/mL) and vended water (3.00–4.00 $\times 10^6$ CFU/mL), alongside heterotrophic plate counts (3.50–5.30 $\times 10^6$ CFU/mL), exceeded the WHO benchmark thresholds (0 CFU/100 mL and $<$ 500 CFU/mL, respectively) by several orders of magnitude. Furthermore, the detection of faecal coliforms (*Escherichia coli*) in 30.4% (7/23) of tap water and 33.3% (8/24) of vended water samples confirms widespread, active faecal contamination across both supply chains.

Table 3: Comparison of microbial contamination with the WHO benchmarks reported in the study

Parameter	Tap water (n=23)	Vended water (n=24)	WHO benchmark	Compliance
Total coliforms	3.00–3.80 × 10^6 CFU/mL	3.00–4.00 × 10^6 CFU/mL	0 CFU/100 mL	0%
Faecal coliforms[1]	Present	Present	0 CFU/100 mL	0%
Heterotrophic plate count	3.50–5.00 × 10^6 CFU/mL	3.50–5.30 × 10^6 CFU/mL	<500 CFU/mL	0%

[1]*Escherichia coli* was used as the indicator of faecal contamination; it was detected in 7/23 (30.4%) tap-water samples and 8/24 (33.3%) vended-water samples.

4. Discussion

The finding that total bacterial and coliform counts in both tap and vended water universally exceeded WHO drinking water guidelines by factors of 10^4 to 10^5 aligns with evidence documenting pervasive microbial contamination of drinking water in resource-limited settings [16, 31, 32]. Comparable exceedances have been reported in sachet and bottled water in Makurdi and in tap water from university hostels in Abuja, demonstrating that water supplies across Nigeria face systemic microbial quality challenges [4, 32].

The absence of significant difference in contamination levels between tap and vended water corroborates findings from Côte d'Ivoire, where household stored drinking water exhibited bacterial loads comparable to tap water [33]. This challenges the widespread consumer assumption that vended water is safer, a misconception also noted by Olalekan et al. [7] and Nicholas and Raimi [5, 27]. The finding that 0% of vended water samples met WHO standards indicates critically deficient regulatory oversight of the informal water sector.

The uniform contamination across all six campus tap water sampling points, with no significant differences between the Water Board which served as the point of entry and terminal taps, suggests that contamination occurs upstream or at the treatment stage rather than accumulating through distribution. This pattern is consistent with biofilm formation within pipes, as documented by Destiani and Templeton [34], and with observations that drinking water challenges in the Niger Delta are systemic rather than localized [7]. The detection of *Pseudomonas aeruginosa* at both the Water Board and Community Health Hall supports the hypothesis of established biofilms, as this organism is a recognized biofilm former capable of persisting despite intermittent disinfection [9, 35].

The identification of five bacterial species in tap water and four in vended water reveals distinct contamination pathways. The detection of *S. aureus* exclusively in tap water at 28% of isolates indicates point-of-use contamination through human handling, as this organism is a commensal shed from skin and mucous membranes [10, 18], consistent with studies attributing its presence to inadequate hygiene practices [12, 36]. Conversely, the exclusive recovery of *S. typhi* from vended water at 25% of isolates indicates faecal contamination at the source or during storage and distribution. This prevalence is notably higher than the 10 to 15% range reported in sachet water from Yenagoa [35], suggesting that Meruwa vendors face particular vulnerabilities. The presence of *P. aeruginosa* exclusively in tap water further supports the biofilm hypothesis, as this organism colonizes plumbing systems and resists routine disinfection [9, 34]. The significant difference in species distribution between sources with $\chi^2 = 24.18$ and $p = 0.0005$ confirms that these microbial communities reflect fundamentally different contamination pathways, a distinction with important implications for intervention targeting.

The detection of *E. coli* in 28% of tap water isolates and 33% of vended water isolates, coupled with the presence of other coliforms and *S. typhi*, provides compelling evidence of widespread faecal contamination across both sources [24, 25]. The co-occurrence of multiple enteric pathogens in vended water suggests contamination through faecal intrusion from inadequately treated source water, unsanitary storage containers, or cross-contamination during handling, rather than through biofilm-associated pathways. This is supported by Seki et al. [33], who found that household stored water exhibited higher coliform counts than source water, and Ulla et al. [37], who documented water quality deterioration during storage. The absence of *S. aureus* and *P. aeruginosa* from vended water further supports the hypothesis that vended water contamination is primarily faecal in origin.

The detection of *Salmonella typhi* in 25% of vended water isolates represents the most clinically significant finding of this study. Typhoid fever is a systemic illness with case fatality rates of 10 to 20% in untreated patients and the potential for chronic carriage and sustained community transmission [38–42]. The presence of this pathogen in water sold to consumers under the assumption of safety constitutes a preventable public health crisis. The prevalence observed here is among the highest documented in vended water [1, 43], and the detection of *S. typhi* exclusively in vended water suggests that the informal water sector may represent a disproportionately important transmission route for typhoid fever. The co-occurrence of *S. typhi* with *E. coli* and *K. pneumoniae* indicates that consumers are exposed to a mixture of pathogens capable of causing both acute gastroenteritis and systemic illness. From a health systems perspective, the presence of *S. typhi* in one-quarter of vended water isolates suggests that typhoid fever is likely endemic in the study population, contributing to preventable morbidity and antimicrobial use that strain limited resources [5, 14, 44]. The absence of molecular confirmation represents a limitation, as biochemical identification of *S. typhi* is presumptive, though the characteristic H_2S production and biochemical profile are highly specific [16].

Synthesizing the findings, while tap and vended water harbor quantitatively similar levels of bacterial contamination, their qualitative risk profiles differ substantially. For tap water, the presence of *S. aureus, P. aeruginosa*, and enteric pathogens indicate multiple barriers to safety, with source water quality, distribution system integrity, and consumer hygiene all contributing. For vended water, the exclusive presence of enteric pathogens including *S. typhi* suggests a simpler but more clinically severe contamination pathway involving faecal contamination at the source, during storage, or through handling. This distinction has important implications for intervention design, as strategies effective for tap water may be less relevant for vended water, where source water treatment and container sanitation are paramount. The comparable contamination levels underscore that neither source can be considered safe without treatment, and the detection of *S. typhi* in vended water represents a sentinel event that should prompt immediate public health action [9, 29, 45, 46].

Study Limitations

This study has several limitations. The single-week sampling period captured only a snapshot of water quality and did not account for seasonal variability. Bacterial identification relied on morphological and biochemical methods, which provide presumptive identification without molecular confirmation, and the plate count method detects only culturable bacteria. These findings should therefore be interpreted

as conservative estimates, and future studies should incorporate longitudinal sampling and molecular techniques.

Recommendations

Mandatory chlorination of vended water should be implemented with subsidized chlorine tablets for vendors, alongside emergency disinfection of high-risk taps and distribution of household water treatment supplies. Routine microbial monitoring of sentinel taps and all vendors should be conducted monthly with results reported publicly, and vendor certification with hygiene training should be established. In the medium term, rehabilitation of campus water storage and treatment facilities, installation of point-of-use filtration infrastructure, and formation of a Water Safety Committee should be pursued. In the long term, distribution system rehabilitation, centralized treatment upgrades, integration of vended water into formal regulatory oversight, and community-based surveillance with longitudinal research should be developed.

5. Conclusion

Both institutional tap water and vended water (Meruwa) in the study area are universally and heavily contaminated with bacterial pathogens, with no sample meeting WHO drinking water standards. While contamination levels were quantitatively similar, the pathogen profiles differed significantly: tap water harbored a mix of faecal, biofilm-associated, and human-handling-related organisms, whereas vended water contained *Salmonella typhi* in one-quarter of samples. The assumption that vended water is safer is unfounded. Immediate point-of-use treatment for all consumers, mandatory microbial testing of vended water with specific screening for *S. typhi*, targeted disinfection of high-risk campus taps, and sustained investment in water safety infrastructure are urgently needed.

Article Information

Ethical Approval: Ethical approval was obtained from the Bayelsa State College of Health Technology Research Ethics Committee (BAYCHT/ERC/2024/017), and vendor consent and data anonymization procedures were applied.

Data Availability: The datasets generated and/or analyzed during the current study are available from the corresponding author upon reasonable request.

Conflict of Interest: The authors declare that they have no conflict of interest.

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References

[1] M. O. Raimi, T. K. Pigha, and E. O. Ochayi. Water-related problems and health conditions in the oil-producing communities in central senatorial district of Bayelsa State. *Imperial Journal of Interdisciplinary Research*, 3(6), 2017.

[2] R. M. Olalekan, A. O. Omidiji, A. F. Abdulraheem, and E. O. Ochayi. A survey of hand-washing behaviour and awareness among health care workers in health care facilities in Kubwa District of Bwari Area Council F. C. T. Abuja, Nigeria. *Annals of Ecology and Environmental Science*, 2(2):14–31, 2018. URL https://doi.org/10.22259/2637-5338.0202003.

[3] R. M. Olalekan, A. O. Omidiji, D. Nimisngha, O. E. Odipe, and A. S. Olalekan. Health risk assessment on heavy metals ingestion through groundwater drinking pathway for residents in an oil and gas producing area of Rivers State, Nigeria. *Open Journal of Yangtze Gas and Oil*, 3(3):191–206, 2018. URL https://doi.org/10.4236/ojogas.2018.33017.

[4] L. Agbendeh and I. Ogbonna. Bacteriological and physicochemical assessment of sachet and bottled drinking water sold in Makurdi Metropolis, Benue State, Nigeria. *Asian Journal of Emerging Research*, 3(1):88–93, 2022. URL https://doi.org/10.3923/ajerpk.2021.88.93.

[5] D. O. Nicholas and M. O. Raimi. Groundwater Contamination in Bayelsa's Oil-Producing Communities: Physico-Chemical Quality, WHO Standards, and Health Implications. JMIR Preprints, 2025. URL https://doi.org/10.2196/preprints.82921.

[6] O. W. Iyoha, A. J. Omotoso, B. E. Usiobafio, M. O. Raimi, and T. N. Ofor. Beyond the tap: Water insecurity, environmental contamination, and health inequities in uselu, benin city. JMIR Preprints, 2025. URL https://doi.org/10.2196/preprints.86938.

[7] R. M. Olalekan, E. O. Dodeye, H. A. Efeqbere, O. E. Odipe, N. S. Deinkuro, A. Babatunde, et al. Leaving no one behind? Drinking-water challenge on the rise in Niger Delta region of Nigeria: A review. *Merit Research Journal of Environmental Science and Toxicology*, 6(1):31–49, 2020.

[8] M. O. Raimi and H. O. Sawyerr. Preliminary study of groundwater quality using hierarchical classification approaches for contaminated sites in indigenous communities associated with crude oil exploration facilities in Rivers State, Nigeria. *Open Journal of Yangtze Gas and Oil*, 7(2):124–148, 2022. URL https://doi.org/10.4236/ojogas.2022.72008.

[9] M. O. Raimi, H. O. Sawyerr, I. C. Ezekwe, and S. Gabriel. Many oil wells, one evil: Comprehensive assessment of toxic metals concentration, seasonal variation and human health risk in drinking water quality in areas surrounding crude oil exploration facilities in Rivers State, Nigeria. *International Journal of Hydrology*, 6(1):23–42, 2022.

[10] S. C. Edberg, P. Gallo, and C. Kontnick. Analysis of the virulence characteristics of bacteria isolated from bottled, water cooler, and tap water. *Microbial Ecology in Health and Disease*, 9(2):67–77, 1996.

[11] O. E. Odipe, M. O. Raimi, and F. Suleiman. Assessment of heavy metals in effluent water discharges from textile industry and river water at close proximity: A comparison of two textile industries from funtua and zaria, north western nigeria. *Madridge Journal of Agriculture and Environmental Sciences*, 1(1):1–6, 2018. URL https://doi.org/10.18689/mjaes-1000101.

[12] M. O. Raimi and C. E. Sabinus. An assessment of trace elements in surface and ground water quality in the Ebocha-Obrikom oil and gas producing area of Rivers State, Nigeria. *International Journal for Scientific and Engineering Research*, 8(6), 2017.

[13] C. H. Justice-Alucho, E. E. Mike-Anosike, and W. Braide. Molecular Characterization of Bacteria Isolated from Some Seafoods in Nembe Community, Bayelsa State, Nigeria. *Asian Journal of Applied Sciences and Technology (AJAST)*, 5(3):68–79, 2021.

[14] C. Oyibo, B. Authority, C. Eze, and O. R. Morufu. Physicochemical and microbiological assessment of sachet water stored under different conditions in yenagoa metropolis, nigeria. *Authorea*, 2025. URL https://doi.org/10.22541/au.176781783.37074336/v1.

[15] A. J. Omotoso, M. O. Ojile, and O. R. Morufu. Uncovering the hidden burden: Water, sanitation, and hygiene (wash) gaps and their impact on health and learning outcomes in secondary schools, ede south lga, nigeria. *Authorea*, 2025. URL https://doi.org/10.22541/au.176038377.77904469/v1.

[16] L. Fekeda and K. Gutema. Assessment of physicochemical and bacteriological quality of drinking water from source to household tap in Ayana Town, Western Ethiopia. *Trends in Environmental Sciences*, 1(1):31–44, 2025.

[17] E. C. Catherine, N. K. Emeka, A. Emeka, O. R. Michael, F. Ngozi, J. C. Happiness, and C. I. Aliyu. Impact of municipal solid waste on the water quality of Otamiri River in Owerri, South-Eastern Nigeria. *World Journal of Biology Pharmacy and Health Sciences*, 7(3):65–72, 2021. URL https://doi.org/10.30574/wjbphs.2021.7.3.0103.

[18] S. E. Bear, T. Waxenberg, C. R. Schroeder, and J. J. Goddard. Bottled water, tap water and household-treated tap water-insight into potential health risks and aesthetic concerns in drinking water. *PLOS Water*, 3(9):e0000272, 2024.

[19] Hameda Khadem Zgair. Indication of heavy metals and coliform bacteria in tap water of Al-Karkh side hospitals-Baghdad, Iraq. *World Journal of Experimental Biosciences*, 12(1):7–10, 2024.

[20] I. Clinton-Ezekwe, M. O. Raimi, I. C. Ezekwe, C. I. Osu, and B. Ordinioha. From oil to health: Groundwater quality and its potential health effects in Mgbede oil fields of South-South Nigeria. *Open Journal of Yangtze Oil and Gas*, 9:95–118, 2024.

[21] I. Clinton-Ezekwe, M. O. Raimi, I. C. Ezekwe, C. I. Osu, and B. Ordinioha. Ensuring safety: Groundwater quality and its potential health effects in the Mgbede oil fields environment of South-South Nigeria. JMIR Preprints, 2024.

[22] O. Raimi, C. Ezekwe, A. Bowale, and T. Samson. Hydrogeochemical and multivariate statistical techniques to trace the sources of ground water contaminants and affecting factors of groundwater pollution in an oil and gas producing wetland in Rivers State, Nigeria. *Open Journal of Yangtze Oil and Gas*, 7:166–202, 2022. URL https://doi.org/10.1101/2021.12.26.21268415.

[23] C. E. Ifeanyichukwu, L. O. Christian, O. R. Morufu, and A. A. Iyingiala. Hydrocarbon-based contaminants in drinking water sources and shellfish in the Soku oil and gas fields of South-South Nigeria. *Open Journal of Yangtze Gas and Oil*, 7(4):247–268, 2022. URL https://doi.org/10.4236/ojogas.2022.74012.

[24] T. A. Adesakin, A. T. Oyewale, U. Bayero, et al. Assessment of bacteriological quality and physico-chemical parameters of domestic water sources in Samaru community, Zaria, Northwest Nigeria. *Heliyon*, 6(8):e04612, 2020.

[25] M. O. Raimi, H. O. Sawyerr, I. C. Ezekwe, and S. Gabriel. Toxicants in water: Hydrochemical appraisal of toxic metals concentration and seasonal variation in drinking water quality in oil and gas field area of Rivers State, Nigeria. *Environmental Impact and Remediation of Heavy Metals*, pages 1–33, 2022. URL https://doi.org/10.5772/intechopen.102656.

[26] M. H. Lateefat, A. O. Opasola, B. Y. Adiama, A. Ibrahim, and O. R. Morufu. Elixirs of life, threats to human and environmental well-being: Assessment of antibiotic residues in raw meat sold within Central Market Kaduna Metropolis, Kaduna State, Nigeria. bioRxiv.

[27] D. O. Nicholas and M. O. Raimi. Silent contamination beneath: Groundwater quality, health risks, and policy implications in Bayelsa's oil-producing communities. *Open Journal of Physical Chemistry*, 15(3):41–73, 2025. URL https://doi.org/10.4236/ojpc.2025.153004.

[28] R. M. Olalekan, O. T. Vivien, O. O. Adedoyin, et al. The sources of water supply, sanitation facilities and hygiene practices in oil producing communities in central senatorial district of bayelsa state, nigeria. *MOJ Public Health*, 7(6):304–312, 2018. URL https://doi.org/10.15406/mojph.2018.07.00265.

[29] S. Kader, M. O. Raimi, V. Spalevic, A. A. Iyingiala, R. W. Bukola, L. Jauer, et al. A concise study on essential parameters for the sustainability of Lagoon waters in terms of scientific literature. *Turkish Journal of Agriculture and Forestry*, 47(3), 2023. URL https://doi.org/10.55730/1300-011X.3087. Article 3.

[30] World Health Organization. Drinking water, 2022. URL https://www.who.int/news-room/fact-sheet/detail/drinking-water.

[31] A. Getachew, A. Tadie, D. H. Chercos, and T. Guadu. Level of faecal coliform contamination of drinking water sources and its associated risk factors in rural settings of North Gondar Zone, Ethiopia: A cross-sectional community based study. *Ethiopian Journal of Health Sciences*, 28(2):227–234, 2018.

[32] S. Mohammed, H. Hassan, A. Omotosho, and A. Ndanusa. Physicochemical and bacteriological quality assessment of selected tap water from male and female hostels within Nile University of Nigeria, Abuja. *FCT. Nile Journal of Engineering and Applied Science*, 1:1–12, 2023. URL https://doi.org/10.5455/NJEAS.147489.

[33] T. Seki, Djedjro Meless, Sawa Kpaibé, and N. Amin. Quality control of tap water and factors determining bacterial contamination of households' stored drinking water in the town of Aboisso (Côte d'Ivoire). *International Journal of Nutrition and Food Sciences*, 13(3): 102–113, 2024.

[34] R. Destiani and M. R. Templeton. The antibiotic resistance of heterotrophic bacteria in tap waters in London. *Water Science and Technology: Water Supply*, 18(6):1987–1995, 2018.

[35] M. O. Raimi, A. S. Oyeyemi, K. G. Mcfubara, G. T. Richard, I. Austin-Asomeji, and A. O. Omidiji. Geochemical background and correlation study of ground water quality in Ebocha-Obrikom of Rivers State, Nigeria. *Trends in Applied Sciences Research*, 18(1): 149–168, 2023.

[36] B. D. A. Abdu, D. J. Egbagba, and G. D. B. Fente. Identification and antimicrobial susceptibility profile of bacterial pathogens isolated from wound infections in a tertiary hospital, Bayelsa, South southern, Nigeria. *Tropical Journal of Pathology and Microbiology*, 5(2): 966–975, 2019.

[37] S. N. Ulla, S. A. Shuchi, A. Ashraf, and S. Siddiqua. Bacteriological quality assessment of drinking water from different sources within Khulna University. *Khulna University Studies*, 22(2):16–24, 2025. URL https://doi.org/10.53808/KUS.2025.22.02.1327-ls.

[38] R. A. Gift and R. M. Olalekan. Access to electricity and water in Nigeria: A panacea to slow the spread of Covid-19. *Open Access Journal of Science*, 4(2):34, 2020.

[39] R. A. Gift, R. M. Olalekan, O. E. Owobi, R. M. Oluwakemi, B. Anu, and A. A. Funmilayo. Nigerians crying for availability of electricity and water: A key driver to life coping measures for deepening stay at home inclusion to slow covid-19 spread. *Open Access Journal of Science*, 4(3):69–80, 2020.

[40] S. Petterson, Q. Li, and N. Ashbolt. Screening level risk assessment (SLRA) of human health risks from faecal pathogens associated with a natural swimming pond (NSP). *Water Research*, 188:116501, 2021. URL https://doi.org/10.1016/j.watres.2020.116501.

[41] S. Hejazi Dehaghani, H. Q. Raheem, M. Latifpour, and M. Hallaji. Antibiotic resistance and virulence patterns of o25 and o16 serogroups in uropathogenic escherichia coli. *BMC Research Notes*, 18(1):157, 2025.

[42] C. O. Elemuwa, M. O. Raimi, U. G. Elemuwa, and T. C. Adias. Genomic and phylogenetic analysis of E. coli O157:H7: Towards improved surveillance and public health response. *Nature and Trends in Science and Technology*, 1(1), 2025. URL https://doi.org/https://doi.org/10.69798/71081461.

[43] A. S. Enoch. Comparative evaluation of enterotoxigenic bacteria in Kunu and Zobo drinks in Bayelsa. *Annals of Advanced Biomedical Sciences*, 4(2), 2021. URL https://doi.org/10.23880/aabsc-16000171.

[44] A. J. Gbeghebo, A. A. Dominic, P. C. Ada, and I. Best. Geohelminth contamination of fruits and vegetables sold in selected markets within Yenagoa Metropolis, Bayelsa State. *International Journal of Pharmaceutical and Bio-Medical Science*, 3(11), 2023. URL https://doi.org/10.47191/ijpbms/v3-i11-04.

[45] R. M. Olalekan, A. F. Abdulraheem, I. Major, O. E. Odipe, H. M. Isa, and C. Onyeche. The sources of water supply, sanitation facilities and hygiene practices in an island community: Amassoma, Bayelsa State, Nigeria. *Public Health Open Access*, 3(1):000134, 2019.

[46] A. J. Gbeghebo, A. A. Dominic, N. O. Elechi, and I. G. Ghandi. Prevalence of intestinal protozoa among primary school-aged children in selected communities in yenagoa metropolis, bayelsa state. *International Journal of Medical Science and Clinical Research Studies*, 3(7), 2023. URL https://doi.org/10.47191/ijmscrs/v3-i7-09.