

Research Article

The Impact of Abattoir Effluent Discharge on Groundwater Quality in Potiskum Residential Area, Yobe State Nigeria

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Abstract

Groundwater is the primary source of drinking and domestic water for many households in semi-urban communities in northern Nigeria. However, the siting of abattoirs within residential areas, combined with poor waste management practices, poses a serious threat to groundwater quality and public health. This study evaluated the impact of abattoir effluent discharge on groundwater quality in Potiskum Local Government Area, Yobe State, Nigeria. Three groundwater samples (A, B and C) were collected from wells and boreholes located 24.6 m, 47.8 m and 61.5 m, respectively, from the abattoir effluent discharge point. Physicochemical and microbiological parameters were analyzed using standard methods recommended by the American Public Health Association and the World Health Organization. Results showed that most physicochemical parameters, including turbidity (0.1–1.7 NTU), total dissolved solids (<1.31 mg/L) and chemical oxygen demand (34.0–34.7 mg/L), were within WHO permissible limits. However, pH values in samples B and C were slightly acidic, while biochemical oxygen demand (10.8–23.7 mg/L) indicated significant organic pollution. Microbiological analysis revealed severe contamination, with coliform counts of >1600, 34 and 1100 MPN/100 mL for samples A, B and C, respectively. Pathogenic bacteria including *Klebsiella pneumoniae*, *Shigella* spp. and *Staphylococcus aureus* were detected in all samples. The findings demonstrate that abattoir effluent has significantly compromised groundwater quality in the study area, rendering it unsafe for domestic use without treatment. Improved effluent management, routine groundwater monitoring and enforcement of sanitation regulations are therefore essential to protect public health and ensure sustainable water resources.

Keywords

Abattoir Effluents, Groundwater Quality, Potiskum, Microbial Contamination, Public Health

1. Introduction

The abattoir industry is an essential component of Nigeria's livestock sector, providing meat to millions of people and generating employment and revenue for national, state and local governments [1]. Despite its socioeconomic importance, abattoir operations across the country are frequently characterized by inadequate infrastructure and poor waste management

practices. Many slaughterhouses lack basic amenities such as functional effluent treatment systems, proper flooring, drainage, and hygienic facilities, resulting in the indiscriminate discharge of wastewater and solid wastes into the surrounding environment [2, 3].

Effluents generated from slaughtering processes typically

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contain high loads of organic matter, nutrients, suspended solids, and pathogenic microorganisms [4]. When released untreated, these waste streams can degrade soil and water bodies, increasing concentrations of nitrogen, phosphorus, total solids, and microbial contaminants in receiving environments [5]. In many Nigerian towns, abattoirs are sited near residential areas and close to shallow wells or boreholes, enabling effluents to infiltrate the soil and leach into groundwater aquifers. This situation is particularly dangerous because groundwater is the primary source of drinking and domestic water for most households.

Groundwater contamination by abattoir effluents presents a critical public health threat. Polluted water sources may harbour pathogens such as *Escherichia coli*, *Klebsiella*, and *Salmonella*, which are linked to diarrheal and other enteric diseases [6]. Reports of offensive odour, discoloration, and visible pollution in water sources near abattoirs are common indicators of such contamination and suggest the infiltration of organic pollutants, nutrients, and toxic chemicals [7].

In Potiskum, Yobe State, several abattoirs operate within densely populated residential areas. Communities in these locations rely heavily on boreholes and shallow wells for their daily water needs, making them highly vulnerable to contamination arising from poorly managed abattoir wastes. Preliminary observations and complaints from residents have pointed to water quality deterioration in wells situated close to slaughterhouses, including changes in colour, odour, and overall aesthetic quality. These concerns are compounded by the absence of proper effluent treatment facilities and inadequate waste handling practices, which facilitate the direct discharge of untreated wastewater into the surrounding environment.

Given these challenges, a systematic assessment of groundwater quality around abattoirs in Potiskum is essential. Such an evaluation will determine the extent of physicochemical and microbiological contamination, provide evidence for potential health risks, and support the development of policies aimed at improving abattoir waste management. The findings will also contribute to safeguarding groundwater resources, promoting public health, and advancing environmental sustainability within Potiskum Local Government Area.

This study therefore investigates the physicochemical and microbiological characteristics of groundwater around the Central Abattoir in Potiskum. The goal is to quantify the level of pollution, identify associated public health implications, and provide data-driven recommendations for improving abattoir operations and ensuring access to safe and clean water for residents.

2. Materials and Methods

2.1. Study Area

The study was conducted at the Potiskum abattoir (popularly known as *Kwata*), located in Potiskum LGA, Yobe State, Nigeria, along Latitude: 11°42'50.08" N Longitude: 11° 04' 51.89" E (Figure 1). Potiskum has an estimated population of 205,876 [8] and serves as a major commercial hub. The abattoir comprises three operational sections: slaughtering, processing, and waste discharge.

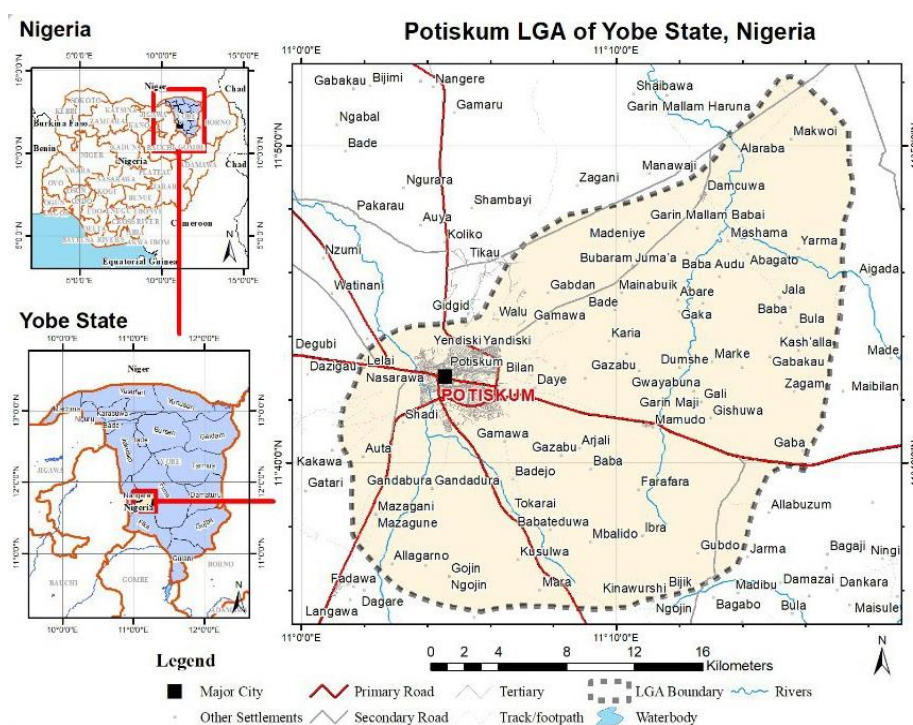


Figure 1. Map of Yobe State Showing Study Area (Potiskum).

2.2. Sample Collection

At each sampling location (A, B, and C), a composite groundwater sample was obtained to represent the site. All physicochemical and microbiological determinations were conducted in duplicate, and mean values were reported to enhance analytical reliability. Sampling, preservation, and transportation were carried out using sterile containers and aseptic

techniques to prevent external contamination.

Groundwater samples were collected from wells and boreholes located 24.6 m, 47.8 m, and 61.5 m from the effluent discharge point. Sampling was performed at approximately 06:30 h using sterile 250mL bottles, after which the samples were preserved in ice and transported to the laboratory at 0–4°C for subsequent analysis.

Table 1. Sampling Points and Collection Details.

Sample	Distance from discharge (m)	Time of Collection (a.m.)
A	24.6	06:30
B	47.8	06:33
C	61.5	06:35

2.3. Physicochemical Analysis

Parameters analyzed included temperature, turbidity, pH, total dissolved solids (TDS), total suspended solids (TSS), dissolved oxygen (DO), biochemical oxygen demand (BOD), and chemical oxygen demand (COD). Standard methods by American Public Health Association [APHA] [9] and WHO [10] were followed for measurements using calibrated probes and spectrophotometric readings.

2.4. Microbiological Analysis

The Most Probable Number (MPN) method was used to estimate total coliforms [11]. Water samples were serially diluted (10^{-1} – 10^{-5}) and inoculated in lactose broth for presumptive tests, followed by confirmatory and completed tests using EMB, MSA, and SSA agar. Isolates were identified based on morphological characteristics and biochemical reactions

(Gram stain, catalase, oxidase, indole, citrate, urease, coagulase, methyl red, and Voges-Proskauer).

2.5. Data Analysis

All physicochemical and microbiological parameters were analyzed in duplicate ($n = 2$), and results were expressed as mean $\pm$ standard deviation. Spatial variations in groundwater quality were evaluated descriptively by comparing parameter values across sampling points at increasing distances from the effluent discharge source. Microbiological data were analyzed using the Most Probable Number (MPN) method and reported as MPN per 100mL with 95% confidence limits. Results were compared with World Health Organization (WHO) guideline values for drinking water quality. Due to the limited number of sampling locations, no inferential statistical tests were applied, and interpretations were based on descriptive statistics and observed trends.

3. Results

3.1. Physicochemical Properties

Table 2. Physicochemical Parameters of Groundwater Samples (Mean $\pm$ SD, $n = 2$).

Parameter	Sample A	Sample B	Sample C	WHO Standard
Appearance	Colorless	Colorless	Colorless	-
Temperature (°C)	28.3 $\pm$ 0.0	28.0 $\pm$ 0.0	28.0 $\pm$ 0.0	Ambient
Turbidity (NTU)	1.7 $\pm$ 0.1	<0.1 $\pm$ ND	<0.3 $\pm$ ND	5

Parameter	Sample A	Sample B	Sample C	WHO Standard
pH	6.7 ± 0.1	5.1 ± 0.1	5.4 ± 0.1	6.5–8.5
DO (mg/L)	30.4 ± 0.2	42.1 ± 0.3	42.6 ± 0.3	8
BOD (mg/L)	23.7 ± 0.4	14.1 ± 0.3	10.8 ± 0.2	0
TDS (mg/L)	1.31 ± 0.02	<1.26 ± ND	<0.91 ± ND	500
TSS (mg/L)	0.4 ± 0.1	0.6 ± 0.1	<0.7 ± ND	60
COD (mg/L)	34.0 ± 0.5	34.2 ± 0.4	34.7 ± 0.6	150

Note: Values are expressed as mean ± standard deviation of duplicate laboratory analyses (n = 2). ND = standard deviation not determined due to readings below detection limit.

All samples were visually clear, with low turbidity, TDS, and TSS values indicating minimal suspended solids. However, the pH of samples B and C (5.1–5.4) was slightly below the WHO limit, suggesting mild acidity that may corrode metal pipes and affect water palatability. The elevated BOD values in all samples (10.8–23.7 mg/L) imply significant organic pollution, most likely from decomposing animal residues and blood entering the groundwater. The unusually high dissolved oxygen (DO) values recorded in all samples may

partly reflect aeration during sampling and handling rather than true in-situ oxygen conditions. However, the absence of field and laboratory blanks limits confirmation of this effect. Future studies should incorporate simple QA/QC procedures, such as analysing deionized water exposed to ambient conditions at the sampling site (field blanks) and deionized water retained in the laboratory (laboratory blanks), to better distinguish sampling artefacts from actual groundwater characteristics.

3.2. Most Probable Number (MPN) of Coliforms

Table 3. MPN per 100mL and Confidence Limits.

Sample	Distance from Effluent (m)	MPN/100mL	95% Confidence Limit
A	0–10	1600 ± 120	700–>1600
B	50	34 ± 6	16–80
C	100	1100 ± 95	180–4100

Note: MPN values represent the mean of duplicate analyses (n = 2). Confidence limits were determined following standard MPN probability tables.

Although coliform contamination generally declined with increasing distance from the effluent discharge point, Sample C exhibited an anomalously high MPN value (1100 MPN/100mL) compared to Sample B (34 MPN/100mL). This non-linear pattern suggests that microbial contamination in groundwater does not strictly follow distance-dependent attenuation. Possible contributing factors include localized human activities such as indiscriminate waste disposal, leaking septic systems, surface runoff infiltration, or variations in sub-surface permeability that facilitate preferential microbial transport. In addition, the inherent statistical variability of the MPN method may contribute to fluctuations in estimated bacterial counts. While the inclusion of 95% confidence limits

satisfies methodological requirements, replicate field sampling would further strengthen interpretation of spatial trends, particularly where deviations occur.

Note: All physicochemical and microbiological analyses were conducted in duplicate, and results are presented as mean ± standard deviation (n = 2). Where duplicate readings were identical or below detection limits, the standard deviation was negligible or not determinable. The inclusion of duplicate analyses improves analytical reliability, while 95% confidence limits were applied to MPN results in accordance with standard statistical requirements.

3.3. Bacterial Load

Table 4. Bacterial Load (cfu/mL) at Various Dilutions.

Sample	10^{-1}	10^{-3}	10^{-5}
A	13.4	0.08	No growth
B	11.6	0.08	1.6
C	7.4	0.04	No growth

Sample A exhibited the highest bacterial density, consistent with its proximity to the abattoir. Sample B showed moderate persistence of bacteria even at high dilutions (10^{-5}), suggesting the presence of resistant strains or denser microbial colonies.

The gradual decline in bacterial load with distance reflects the natural filtration capacity of soil and aquifer media but confirms significant microbial penetration.

3.4. Morphological Identification of Isolates

Table 5. Morphological Appearance of Bacterial Isolates.

Sample	Observation on Selective Media	Identified Organism
A	Pink mucoid colonies on MAC; golden yellow on MSA; colorless on SSA	<i>Klebsiella spp.</i> , <i>Staphylococcus spp.</i> , <i>Shigella spp.</i>
B	Same as A	Same as A
C	Same as A	Same as A

The uniform occurrence of *Klebsiella*, *Shigella*, and *Staphylococcus* species in all samples indicates consistent microbial infiltration from the abattoir effluent. These bacteria are asso-

ciated with gastrointestinal, urinary, and skin infections, highlighting the public health implications of consuming or using contaminated groundwater.

3.5. Biochemical Confirmation

Table 6. Biochemical Test Results for Isolates.

Organism	GR	MR	VP	IN	CAT	COU	OXI	URE	CIT
<i>Klebsiella pneumoniae</i>	–	+	+	–	–	–	–	+	+
<i>Shigella spp.</i>	–	+	–	+	–	–	–	–	–
<i>Staphylococcus aureus</i>	+	–	–	–	+	+	–	–	–

Biochemical reactions confirmed *Klebsiella pneumoniae*, *Shigella spp.*, and *Staphylococcus aureus* as the dominant

contaminants. *Klebsiella* and *Shigella* indicate faecal contamination, while *S. aureus* suggests contamination from human handling or animal skin contact during slaughtering.

4. Discussions

4.1. Physicochemical Parameters

The physicochemical results indicate that all water samples were clear and colorless, suggesting an absence of visible pollutants. Turbidity values (0.1–1.7 NTU) were within the WHO limit of 5 NTU, implying minimal suspended solids and limited particulate intrusion. Low turbidity is typical of groundwater due to natural filtration by soil layers; however, turbidity alone does not reflect the absence of microbial contamination [12].

The temperature of all samples (28.0–28.3°C) was consistent with ambient conditions, typical of shallow aquifers in tropical regions [13]. Water temperature influences dissolved oxygen levels and microbial activity; thus, stable readings suggest minimal external thermal input.

The pH values (5.1–6.7) revealed slightly acidic conditions in samples B and C, which fall below the WHO recommended range (6.5–8.5). The acidity could be attributed to decomposition of protein-rich organic waste, producing weak acids such as carbonic and amino acids [14]. Acidic groundwater can increase metal solubility and alter taste, making it unsuitable for long-term consumption [3].

Biochemical Oxygen Demand (BOD) levels ranged between 10.8 and 23.7 mg/L, exceeding the WHO ideal of 0 mg/L. This indicates a significant load of biodegradable organic matter originating from animal blood, fat, faeces, and other abattoir waste. Similar high BOD levels have been reported by Hassan *et al.* [15] and Mohammed & Musa [16] in abattoir-impacted water bodies. Elevated BOD values deplete dissolved oxygen (DO), affecting aquatic life and promoting anaerobic bacterial growth.

The Chemical Oxygen Demand (COD) values (34–34.7 mg/L) were well below the WHO limit (150 mg/L), suggesting moderate oxidizable organic matter. However, COD alone may underestimate pollution if the contaminants are largely biological rather than chemical in nature. Total Dissolved Solids (TDS) and Total Suspended Solids (TSS) were very low, reflecting low mineralization and good natural filtration. This observation is consistent with findings by Akpan *et al.* [17], who reported similar low TDS in rural aquifers.

Collectively, the physicochemical results suggest that while water clarity and mineral content appear acceptable, organic loading from abattoir waste has significantly compromised water quality, reflected in high BOD and low pH values.

4.2. Most Probable Number (MPN) of Coliforms

The MPN results revealed that groundwater near the abattoir was heavily contaminated with coliform bacteria. Sample A, located 24.6 m from the effluent discharge point, recorded >1600 MPN/100 mL, far exceeding the WHO permissible limit of 0 MPN/100 mL for drinking water. Samples B and

C also recorded 34 and 1100 MPN/100 mL, respectively, confirming persistent contamination even beyond 60 m.

These results align with findings by Bello and Oyedemi [18], who reported MPN values exceeding 1200/100 mL in wells located within 50 m of abattoirs. Similarly, Olugbenga *et al.* [19] documented coliform counts above 1000 MPN/100 mL in residential areas near slaughterhouses in Kwara State. The high MPN values in Potiskum indicate continuous infiltration of faecal matter from abattoir effluent into shallow aquifers.

The decreasing trend of contamination with distance (A > C > B) suggests partial attenuation through soil filtration; however, this effect is insufficient due to the shallow water table and possibly permeable sandy substrata characteristic of the region. Such groundwater vulnerability underscores the need for buffer zones between abattoirs and residential wells.

4.3. Bacterial Load and Distribution

The bacterial load data further substantiated the MPN results. Sample A recorded the highest colony count (13.4 cfu/mL at 10^{-1} dilution), indicating intense microbial activity near the discharge point. The bacterial count decreased with dilution and distance, consistent with reduced effluent influence.

The persistence of bacterial growth in Sample B at high dilution (1.6 cfu/mL at 10^{-5}) suggests the presence of resilient or sporulating species capable of surviving environmental stress. Such persistence indicates that the aquifer may serve as a long-term reservoir of microbial contaminants [6].

Similar bacterial load ranges were reported by Dauda *et al.* [20] in abattoir-contaminated waters (2.16×10^7 to 5.82×10^5 cfu/mL). Elevated microbial populations in this study point to continuous organic enrichment and lack of effective waste containment.

The observed decline in BOD with increasing distance from the abattoir reflects progressive reduction of biodegradable organic matter through dilution and natural attenuation. However, the persistence of high microbial counts at Sample C indicates that microbial contamination does not necessarily mirror organic load. Groundwater microorganisms may originate from multiple sources, including nearby sanitation facilities, surface runoff, or human activities independent of the abattoir. Furthermore, the MPN technique is inherently probabilistic and subject to variability, particularly at high contamination levels. Consequently, conclusions regarding distance-dependent microbial reduction should be interpreted cautiously, and corroborated through replicate sampling and complementary microbiological indicators in future studies.

4.4. Bacterial Identification and Public Health Implications

The morphological and biochemical analyses identified

Klebsiella pneumoniae, *Shigella* spp., and *Staphylococcus aureus* as the dominant isolates across all samples. The uniform presence of these pathogens in samples A, B, and C indicates extensive microbial dispersion in the groundwater system.

Klebsiella pneumoniae and *Shigella* spp. are enteric bacteria typically associated with faecal pollution. Their presence implies contamination by animal excreta and blood-laden effluents seeping from the abattoir. These bacteria are known to cause gastrointestinal disorders, dysentery, and urinary tract infections [21]. *Staphylococcus aureus*, on the other hand, often originates from human skin or nasal flora and may have entered through abattoir workers' contact during slaughtering and washing operations.

The detection of multiple pathogenic species mirrors findings by Amoo *et al.* [5] and Nafarnda *et al.* [6], who reported similar bacterial assemblages in groundwater near abattoirs in Kaduna and Abuja. Such microbial diversity reflects poor sanitary conditions, lack of wastewater treatment, and inadequate drainage design.

The coexistence of high BOD and high bacterial density further indicates a direct relationship between organic loading and microbial growth. The biological activity of decomposing matter supports pathogenic survival and proliferation. Consequently, residents consuming such water are at risk of infections including gastroenteritis, diarrhea, and typhoid fever.

4.5. Comparative Analysis and Environmental Implications

When compared with related studies in Nigeria and other developing countries, the results from Potiskum show similar patterns of effluent-induced groundwater contamination. For instance, Mohammed and Musa [16] reported comparable BOD and coliform values in the Landzu River, Bida, while Singh and Sharma [7] observed identical contamination profiles around Indian slaughterhouses lacking effluent treatment.

The slightly better results in Sample C confirm natural attenuation at distances greater than 50 m but highlight that contamination remains substantial even beyond WHO-specified safety perimeters. This suggests that soil permeability and the absence of concrete drainage channels allow direct percolation of effluents into groundwater.

The long-term environmental implication is the progressive deterioration of groundwater quality, which may render wells unsafe for domestic use. Such deterioration can also affect soil microbiota, nutrient balance, and nearby vegetation due to accumulation of organic residues and nitrogen compounds [22].

4.6. Implications for Water Safety and Management

The results underscore the urgent need for wastewater management reforms at the Potiskum abattoir. Although the physicochemical indicators might suggest acceptable quality, the microbial parameters demonstrate serious health hazards. The

consistent detection of coliforms and pathogenic bacteria invalidates the potability of the water, emphasizing the necessity for water treatment before human consumption.

Regulatory agencies should enforce environmental sanitation standards, establish effluent treatment systems, and ensure minimum buffer distances between abattoirs and residential areas. Public education on household-level water disinfection (e.g., boiling or chlorination) is also essential to mitigate health risks.

5. Conclusion

The study established that groundwater around the Potiskum abattoir is significantly affected by effluent discharge. Although most physicochemical parameters such as turbidity, COD, and TDS were within World Health Organization (WHO) limits, the elevated biochemical oxygen demand (BOD) and slightly acidic pH indicate organic pollution and chemical alteration of the aquifer.

Microbiological analysis revealed severe contamination, with Most Probable Number (MPN) values far exceeding WHO standards for potable water. The presence of pathogenic bacteria, including *Klebsiella pneumoniae*, *Shigella* spp., and *Staphylococcus aureus*, confirms faecal and organic waste infiltration from the abattoir, posing serious environmental and public health risks.

Contamination levels declined with distance from the abattoir, reflecting the spatial influence of effluent seepage. However, the persistence of microbial indicators beyond 60 meters demonstrates continued infiltration into subsurface water and highlights the vulnerability of shallow aquifers in poorly regulated semi-urban areas.

The groundwater in the study area is microbiologically unsafe for domestic use without proper treatment. Immediate interventions are required to mitigate effluent discharge, safeguard public health, and prevent further environmental degradation.

6. Recommendations

1) Recommendations Effluent Treatment and Waste Management:

Abattoir operators should install functional wastewater treatment systems such as sedimentation tanks, anaerobic digesters, or constructed wetlands to treat effluents before discharge. Proper containment structures and lined drainage channels should be incorporated to prevent seepage into groundwater.

2) Regulatory Enforcement:

The Yobe State Environmental Protection Agency (YOSEPA) and local authorities should enforce existing environmental regulations governing abattoir operations. Regular inspections, licensing, and environmental audits are essential to ensure compliance and reduce uncontrolled waste disposal.

3) Groundwater Quality Monitoring:

Routine monitoring of borehole and well water within the abattoir vicinity should be conducted to assess changes in physicochemical and microbial quality. Periodic assessments will help detect contamination early and guide appropriate remediation.

4) Safe Water Supply and Community Awareness:

Residents relying on nearby groundwater sources should be educated on the risks of consuming untreated water. Public health campaigns should promote safe household treatment methods, such as boiling, chlorination, or filtration, while government and NGOs provide access to safer alternative water sources.

5) Sustainable Abattoir Design and Siting:

New abattoirs should be located at least 100 meters away from residential and groundwater recharge zones. Existing facilities should be redesigned to include impermeable floors, soak-away pits, and controlled drainage systems to limit environmental contamination.

6) Policy Integration and Further Research:

Abattoir waste management should be integrated into urban water safety and sanitation policies. Further research is recommended on heavy metal accumulation, antibiotic resistance, and seasonal variations in groundwater contamination to provide a more comprehensive risk assessment.

Abbreviations

APHA	American Public Health Association
WHO	World Health Organization
MPN	Most Probable Number
BOD	Biochemical Oxygen Demand
COD	Chemical Oxygen Demand
DO	Dissolved Oxygen
TDS	Total Dissolved Solids
TSS	Total Suspended Solids
NTU	Nephelometric Turbidity Unit
CFU	Colony Forming Unit
MAC	MacConkey Agar
EMB	Eosin Methylene Blue Agar
MSA	Mannitol Salt Agar
SSA	Salmonella-Shigella Agar
GR	Gram Reaction
MR	Methyl Red Test
VP	Voges-Proskauer Test
IN	Indole Test
CAT	Catalase Test
OXI	Oxidase Test
URE	Urease Test
CIT	Citrate Utilization Test
LGA	Local Government Area
YOSEPA	Yobe State Environmental Protection Agency

Author Contributions

Abdullahi Hassan Gana: Conceptualization, Data curation, Formal Analysis, Funding acquisition, Investigation

Yusuf Abdullahi: Methodology, Project administration, Resources, Supervision

Abba Idris Sa'id: Validation, Visualization, Writing – original draft, Writing – review & editing

Conflicts of Interest

The authors declare no conflicts of interest.

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