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Evaluation of the Chemical Investigation into Surface Water Contamination (Case Study of Bangaie Abattoir River, Bida)

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Abstract: *Surface water contamination from abattoir effluents poses significant environmental and public health challenges, particularly in developing countries where wastewater treatment facilities are inadequate. This study evaluated the chemical quality of surface water along the Bangaie River adjacent to the Bangaie Abattoir in Bida, Niger State, Nigeria. Five surface water samples were collected at designated locations along the river and analysed for selected physicochemical parameters, including total hardness, pH, chlorine, acidity, and alkalinity, using standard analytical methods. The results were compared with World Health Organization (WHO) guideline values for drinking water quality. Total hardness ranged from 60 to 140 mg/L, with two sampling points recording values above the desirable guideline value of 100 mg/L. The pH ranged from 6.5 to 7.5, remaining within the WHO recommended range of 6.5–8.5. Chlorine concentrations varied between 24.81 and 50.63 mg/L, while acidity ranged from 1.88 to 3.72 mg/L and alkalinity from 50 to 100 mg/L, all of which were below the WHO maximum permissible limits where applicable. The elevated hardness observed at selected locations indicates localized contamination arising from the discharge of untreated abattoir wastes, although the river maintained near-neutral pH and moderate buffering capacity. The findings suggest that continuous disposal of untreated slaughterhouse effluents is gradually degrading the chemical quality of the river and may lead to long-term ecological deterioration and increased public health risks if not properly managed. The study recommends installing efficient wastewater treatment facilities, regularly monitoring surface water quality, strictly enforcing environmental regulations governing abattoir operations, and conducting comprehensive future investigations that incorporate heavy metals, nutrients, microbiological indicators, and seasonal variations to support sustainable management of the Bangaie River.*

Keywords: *Surface water, Abattoir effluent, Water quality, Physicochemical analysis, Bangaie River*

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1.0 Introduction

Surface water is one of the most valuable natural resources because it supports domestic water supply, agriculture, industrial production, recreation, fisheries, and the ecological balance of aquatic ecosystems. Rivers, streams, lakes, and reservoirs provide freshwater for millions of people worldwide, particularly in developing countries where a significant proportion of the population depends directly on untreated surface water for drinking, irrigation, washing, and other household activities. However, rapid

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urbanization, industrialization, population growth, and inadequate waste management practices have resulted in increasing contamination of these water bodies. The deterioration of surface water quality has become a major environmental challenge with serious implications for ecosystem sustainability, socioeconomic development, and public health.

Among the numerous anthropogenic sources of surface water pollution, abattoir activities constitute one of the most significant point sources in many developing countries. Abattoirs play an indispensable role in food security by providing meat and meat products to rapidly growing populations. During slaughtering, dressing, washing, and processing operations, however, substantial quantities of solid and liquid wastes are generated. These wastes include blood, fats, grease, intestinal contents, undigested feed materials, animal tissues, bones, hair, urine, faecal matter, detergents, disinfectants, and other organic and inorganic substances. In many developing countries, including Nigeria, these wastes are frequently discharged directly into nearby rivers, streams, drains, and surrounding lands without adequate treatment. Such practices introduce high concentrations of suspended solids, dissolved organic matter, nutrients, pathogens, heavy metals, and other pollutants into receiving water bodies, thereby altering their physical, chemical, and biological characteristics (Saidu & Musa, 2012; Tekenah et al., 2014).

The environmental consequences of untreated abattoir wastewater are far-reaching. Organic pollutants increase biochemical oxygen demand (BOD) and chemical oxygen demand (COD), reducing dissolved oxygen levels required for the survival of aquatic organisms. Nutrients such as nitrates and phosphates stimulate excessive algal growth, resulting in eutrophication, oxygen depletion, fish mortality, and loss of biodiversity. In addition, alterations in pH, hardness, alkalinity, conductivity, and total dissolved solids may reduce the suitability of water for domestic, agricultural, and industrial applications. The contamination of surface water also facilitates the transmission of pathogenic microorganisms responsible for diseases such as cholera, typhoid fever, dysentery, diarrhoea, and other waterborne infections. Consequently, the protection of surface water quality has become a major environmental and public health priority worldwide.

Recognizing the importance of clean water, the World Health Organization (WHO) and national regulatory agencies such as the Nigerian Standard for Drinking Water Quality (NSDWQ) have established permissible limits for physicochemical and microbiological parameters in water intended for human consumption. Routine monitoring of these parameters provides valuable information for assessing pollution levels, determining compliance with environmental standards, and developing appropriate management strategies. Chemical parameters such as pH, alkalinity, hardness, chloride concentration, dissolved oxygen, conductivity, biochemical oxygen demand, chemical oxygen demand, nitrate, phosphate, and total suspended solids are widely used indicators for evaluating the degree of surface water contamination because they reflect the cumulative effects of anthropogenic activities on aquatic environments.

Numerous studies have investigated the impact of abattoir effluents on surface water quality in different regions of Nigeria. One of the earliest investigations was conducted by **Saidu & Musa (2012)** on River Landzu in Bida, Niger State. Their study demonstrated that the discharge of untreated abattoir wastewater significantly increased biochemical oxygen demand, suspended solids, chemical oxygen demand, ammonia, total nitrogen, phosphorus, dissolved solids, iron, zinc, and cadmium

concentrations downstream of the discharge point compared with upstream values. Although the pH remained within acceptable limits, the observed deterioration in other water quality parameters indicated that the receiving river was unable to sufficiently dilute the pollutants, thereby posing considerable environmental and public health risks.

Similarly, Ubwa *et al*. (2013) evaluated the pollution status of surface water surrounding the Gboko Abattoir in Benue State. Their findings revealed elevated concentrations of total dissolved solids (1,026.78 mg/L), total suspended solids (565.22 mg/L), biochemical oxygen demand (484.64 mg/L), phosphate (8.89 mg/L), and several heavy metals including lead, chromium, nickel, and cadmium ||||||||||||livestock slaughter activities may have altered the chemical composition of the river over time, making previous datasets insufficient for current environmental management decisions. Consequently, there remains a need for updated site-specific information on important chemical parameters such as pH, total hardness, alkalinity, and chlorine concentration to determine the present status of surface water quality around the Bangaie Abattoir.

The Bangaie Abattoir River constitutes an important water resource for surrounding communities in Bida, serving domestic, agricultural, and economic purposes. Continuous discharge of untreated slaughterhouse wastewater into the river has the potential to compromise its chemical quality, reduce ecosystem health, and expose nearby residents to environmental and public health risks. Therefore, periodic assessment of the river's physicochemical characteristics is essential for evaluating pollution levels and providing scientific evidence for environmental regulation and remediation.

This study aims to evaluate the chemical characteristics of surface water around the Bangaie Abattoir River in Bida, Niger State. Specifically, the study determines selected physicochemical parameters, including pH, total hardness, alkalinity, and chlorine concentration, at different sampling locations and compares the measured values with established WHO guideline values to assess the extent of contamination attributable to abattoir activities.

The significance of this study lies in its contribution to understanding the chemical impacts of abattoir wastewater on surface water quality in Bida. The findings will provide updated baseline data for environmental scientists, water resource managers, public health practitioners, and regulatory agencies involved in monitoring water quality and enforcing environmental regulations. The results will also support the formulation of evidence-based waste management policies, encourage the establishment of wastewater treatment facilities in abattoirs, and contribute to the protection of aquatic ecosystems and public health. Furthermore, the study will enrich the existing literature on surface water contamination and provide a useful reference for future investigations on sustainable management of water resources in Nigeria and other developing countries.

2.0 Materials and Methods

This study employed standard field sampling and laboratory analytical procedures to evaluate the chemical quality of surface water in the Bangaaie River around the Bangaaie Abattoir, Bida, Niger State, Nigeria. Water samples were collected from selected locations along the river and analysed for selected physicochemical parameters, including pH, total hardness, chlorine concentration, and alkalinity, using standard analytical methods.

2.1 Study Area

The study was conducted along the Bangaaie River adjacent to the Bangaaie Abattoir in Bida, Niger State, Nigeria (Fig. 1). The study area is located approximately at latitude

9.0805° N and longitude 6.0131° E. The Bangaaie Abattoir is one of the major slaughter facilities in Bida, where cattle, sheep, and goats are processed daily. Large quantities of solid and liquid wastes generated during slaughtering operations are discharged into the surrounding environment, with a significant proportion entering the Bangaaie River. Consequently, the river is vulnerable to contamination from abattoir effluents, making it an appropriate location for assessing the chemical quality of surface water.

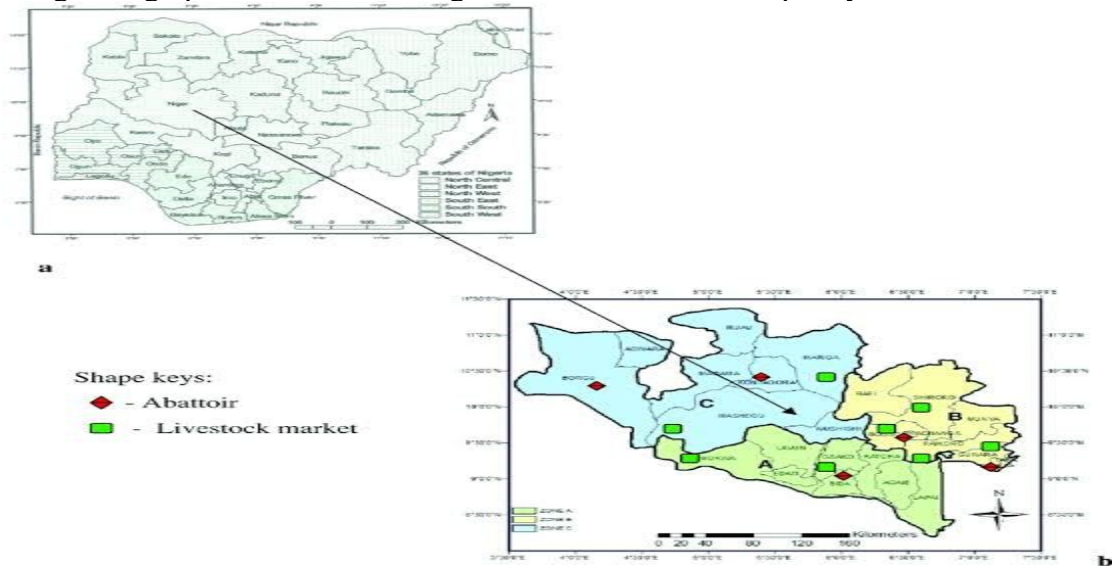

Fig. 1: Map of the Bangaaie Abattoir and the sampling locations along the Bangaaie River.

2.2 Sample Collection

Surface water samples were collected from five sampling stations established at 100 m intervals along the Bangaaie River. Sampling commenced at a point upstream of the abattoir, which served as the control location, and continued downstream through locations potentially influenced by the discharge of abattoir effluents. The sampling design was adopted to evaluate spatial variations in water quality resulting from wastewater discharge from the abattoir.

Water samples were collected in clean, sterilized polyethylene bottles that had been thoroughly rinsed with distilled water and subsequently with water from each sampling point before collection. The bottles were filled below the water surface to minimize contamination and avoid the inclusion of surface debris. Each sampling location was geo-referenced using a Global Positioning System (GPS) receiver to facilitate accurate identification and future monitoring. The collected samples were properly labelled, stored in an ice chest, and transported immediately to the laboratory for chemical analysis.

3.0 Results and Method

4.1 Chemical Characteristics of Surface Water around the Bangaie Abattoir River

The chemical characteristics of surface water collected from five sampling points along the Bangaie Abattoir River are presented in Table 1, while the graphical variations in hardness and pH are shown in Figs. 3 and 4, respectively. The assessed parameters include total hardness, pH, chlorine concentration, acidity, and alkalinity. These parameters were compared with the World Health Organization (WHO) guideline values to determine the suitability of the water and the extent of contamination resulting from abattoir activities.

Table 1. Chemical characteristics of surface water samples collected from the Bangaie River and comparison with WHO guideline values

Sampling Location	Latitude (°N)	Longitude (°E)	Total Hardness (mg/L)	pH	Chlorine (mg/L)	Acidity (mg/L)	Alkalinity (mg/L)
Bangaie River Sample A	9.08551	6.02144	140	6.5	50.63	3.04	80
Bangaie River Sample B	9.08620	6.02144	100	7.0	29.78	2.12	100
Bangaie River Sample C	9.08603	6.02038	60	7.0	24.81	3.20	50
Bangaie River Sample D	9.09026	Not recorded	140	6.5	34.74	1.88	60
Bangaie River Sample E	Not recorded	6.01989	60	7.5	39.71	3.72	80
WHO Guideline Value	—	—	100*	6.5–8.5	250	Not specified	

The results demonstrate noticeable spatial variations among the sampling locations, indicating differences in the influence of abattoir effluent on the receiving water body.

4.2 Total Hardness

The total hardness values obtained from the five sampling locations ranged from 60 to 140 mg/L (Table 1). As illustrated in Fig. 2, Samples A and D recorded the highest hardness values (140 mg/L), Sample B recorded 100 mg/L, while Samples C and E had the lowest hardness values (60 mg/L)..

The WHO recommends a desirable hardness concentration of approximately 100 mg/L for drinking water. Samples A and D exceeded this value by 40%, Sample B was equal to the guideline value, whereas Samples C and E were below the recommended limit.

The elevated hardness observed in Samples A and D may be attributed to the dissolution of calcium and magnesium salts originating from blood, bones, animal tissues, washing activities, and other abattoir wastes discharged into the river. Slaughterhouse wastewater is known to contain appreciable concentrations of dissolved minerals that contribute significantly to water hardness (Tekenah *et al*., 2014; Ogwu *et al*., 2024).

The results agree with the findings of Ogwu *et al*. (2024), who reported total hardness values ranging from 990 to 1,256 mg/L in the Iwofe River receiving abattoir wastewater, although the concentrations recorded in the present study were considerably lower. Similarly, Madukasi *et al*. (2026) reported increased alkalinity and other dissolved constituents in the Ekpan River following the discharge of untreated

slaughterhouse wastewater. In contrast, Saidu & Musa (2012) observed increases in dissolved solids and related physicochemical parameters downstream of River Landzu due to abattoir effluent discharge.

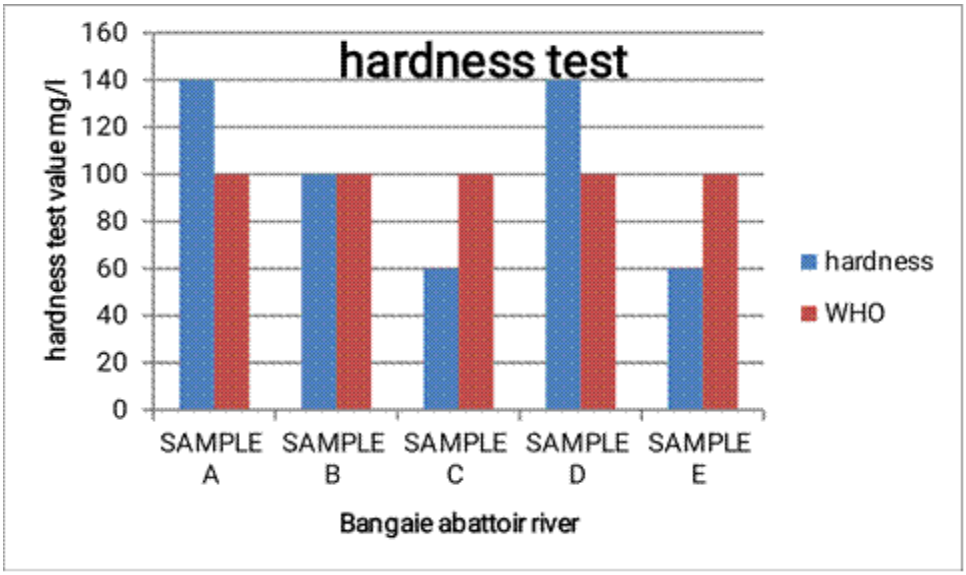

Fig. 2:Variation in total hardness of surface water samples compared with WHO guideline values

The results agree with the findings of Ogwu *et al*. (2024), who reported total hardness values ranging from 990 to 1,256 mg/L in the Iwofe River receiving abattoir wastewater, although the concentrations recorded in the present study were considerably lower. Similarly, Madukasi *et al*. (2026) reported increased alkalinity and other dissolved constituents in the Ekpan River following the discharge of untreated slaughterhouse wastewater. In contrast, Saidu & Musa (2012) observed increases in dissolved solids and related physicochemical parameters downstream of River Landzu due to abattoir effluent discharge.

Although the measured hardness values are relatively moderate compared with some previous Nigerian studies, the elevated concentrations observed at Samples A and D indicate localized contamination. Hard water is generally not considered a direct health hazard; however, prolonged consumption may result in scaling of household plumbing systems, reduced soap efficiency, increased maintenance costs, and deterioration of industrial equipment. More importantly, increased hardness may indicate the accumulation of dissolved inorganic pollutants arising from continuous waste discharge into the river.

4.3 Hydrogen Ion Concentration (pH)

The measured pH values ranged between 6.5 and 7.5 (Table 1), as illustrated in Fig. 3. Samples A and D recorded pH values of 6.5, Samples B and C recorded 7.0, while Sample E recorded 7.5.

The measured pH values fall within the WHO recommended range of 6.5–8.5, indicating that the river water remains chemically neutral to slightly alkaline despite receiving abattoir effluents.

The slightly acidic conditions observed in Samples A and D may result from the decomposition of organic wastes such as blood and animal tissues, which produce organic acids during microbial degradation. Conversely, the slightly alkaline conditions

recorded at Sample E may be associated with carbonate and bicarbonate ions released from decomposing organic materials and surrounding geological formations.

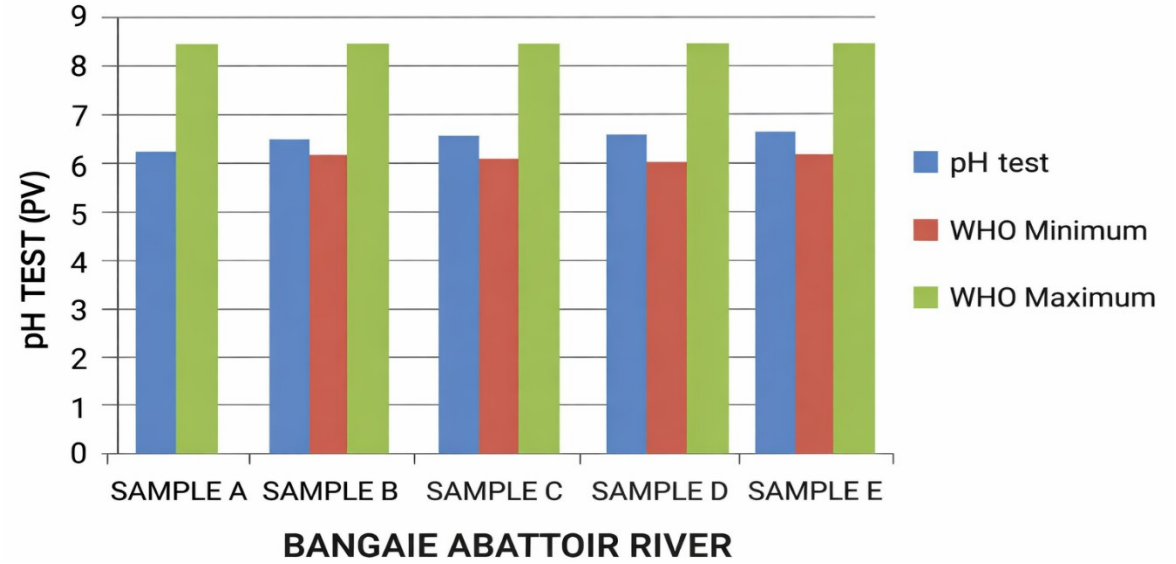

Fig. 3. Variation in pH values of surface water samples compared with WHO guideline limits

The findings are consistent with those reported by Saidu and Musa (2012), who observed pH values between 6 and 8 in River Landzu despite significant deterioration in other water quality parameters. Likewise, Ogwu *et al*. (2024) reported pH values between 7.19 and 7.36 in the Iwofe River, while Tekenah *et al*. (2014) found that pH remained relatively stable even though other physicochemical parameters indicated pollution.

The implication of these findings is that pH alone cannot be used as an indicator of water quality deterioration. A river may exhibit acceptable pH values while simultaneously containing elevated concentrations of dissolved pollutants, organic matter, and pathogenic microorganisms. Therefore, comprehensive chemical analyses remain essential for evaluating the true quality of surface water.

4.4 Chlorine Concentration

The chlorine concentrations recorded in the study ranged from 24.81 to 50.63 amu (Table 1 and Fig. 4). Sample A recorded the highest concentration (50.63 amu), followed by Samples E (39.71 amu), D (34.74 amu), B (29.78 amu), and C (24.81 amu).

The WHO guideline value for chloride in drinking water is 250 mg/L. All measured values were considerably lower than the permissible limit, indicating that chloride contamination has not yet reached concentrations capable of affecting the taste or chemical suitability of the river water.

The elevated chlorine concentration observed at Sample A may reflect direct influence from slaughterhouse washing activities, detergents, cleaning chemicals, and dissolved salts associated with fresh abattoir effluent. Chloride concentrations generally decrease with increasing distance from pollution sources due to dilution and natural dispersion processes.

The results are comparable with the observations of Tekenah et al. (2014), who reported positive relationships between chloride concentrations and biochemical oxygen demand in waters receiving abattoir discharges. Similarly, Ogwu et al. (2024) reported elevated chloride concentrations in river water impacted by slaughterhouse wastewater.

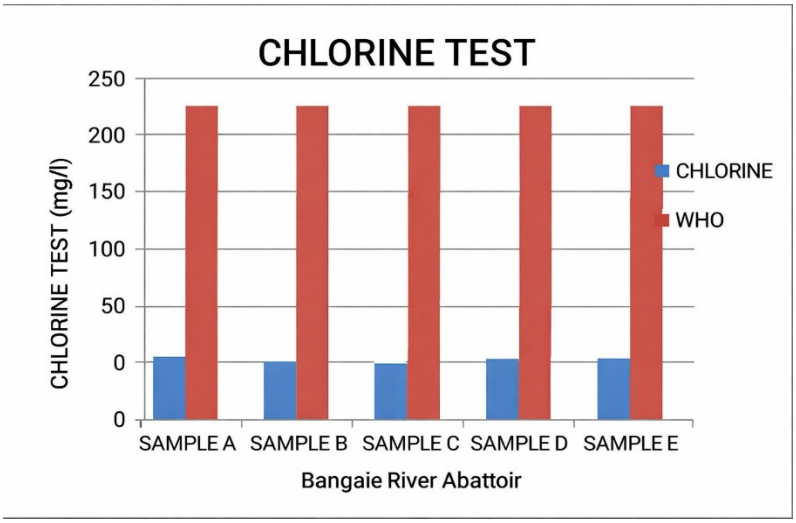

Fig. 3: Chlorine Concentration Comparison in Bangaie River Samples

Although the measured chlorine concentrations remain within WHO limits, continuous discharge of untreated wastewater may gradually increase chloride accumulation, eventually affecting water palatability, soil quality during irrigation, and freshwater aquatic organisms.

4.5 Acidity

The acidity values ranged between 1.88 and 3.72 mg/L (Table 1). Sample E recorded the highest acidity (3.72 mg/L), while Sample D recorded the lowest value (1.88 mg/L).

No WHO guideline value has been established specifically for acidity in drinking water because acidity primarily influences corrosion rather than human health.

The relatively low acidity values observed indicate that the river possesses adequate buffering capacity to resist rapid pH fluctuations. Nevertheless, localized increases in acidity may result from microbial decomposition of organic wastes discharged from the abattoir.

The measured acidity corresponds well with the near-neutral pH values obtained in this investigation, suggesting that carbonate buffering systems continue to stabilize the river water despite ongoing pollutant inputs.

Although acidity does not currently present a major concern, continuous discharge of organic wastes may eventually overwhelm the natural buffering capacity of the river, resulting in acidification and adverse ecological consequences.

4.6 Alkalinity

Alkalinity values ranged from 50 to 100 mg/L (Table 1). Sample B recorded the highest alkalinity (100 mg/L), followed by Samples A and E (80 mg/L), Sample D (60 mg/L), and Sample C (50 mg/L).

The WHO guideline value for alkalinity is approximately 200 mg/L. Therefore, all measured values fall well below the recommended maximum concentration.

Alkalinity represents the ability of water to neutralize acids and maintain stable pH conditions. The moderate alkalinity values obtained indicate that the river possesses sufficient buffering capacity against acidification. However, the relatively higher alkalinity at Sample B may indicate increased bicarbonate and carbonate concentrations resulting from decomposition of animal wastes and organic matter.

Similar observations were reported by Madukasi et al. (2026), who recorded alkalinity values of 72.23 mg/L in surface waters

receiving abattoir wastewater. Likewise, Ogwu et al. (2024) reported alkalinity values ranging from 25 to 113 mg/L in the Iwofe River.

Although the alkalinity values comply with WHO recommendations, continued discharge of untreated abattoir wastewater may gradually alter the buffering characteristics of the river and influence other important chemical parameters.

4.7 Overall Assessment of Surface Water Quality

The results clearly show that chemical analyses indicate that the Bangaie Abattoir River exhibits varying degrees of contamination associated with abattoir activities (Table 1). While pH, chlorine concentration, and alkalinity remain within WHO guideline limits, elevated hardness values at Samples A and D suggest localized accumulation of dissolved inorganic constituents originating from slaughterhouse wastes.

These findings corroborate previous studies conducted in Nigeria (Saidu & Musa, 2012; Ubwa et al., 2013; Tekenah et al., 2014; Offiono, 2023; Ogwu et al., 2024; Ayisa et al., 2025; Madukasi et al., 2026; Chilea et al., 2026), all of which demonstrated that untreated abattoir effluents significantly deteriorate the chemical and microbiological quality of receiving water bodies. Furthermore, the results complement the bacteriological investigation of Ayisa et al. (2025) conducted at the same Bangaie Abattoir, which reported bacterial contamination above permissible limits. Together, the chemical and microbiological evidence indicates that the river is under increasing environmental pressure from slaughterhouse operations.

Although most measured chemical parameters currently satisfy WHO guideline values, compliance with individual standards should not be interpreted as evidence of good water quality. Continuous discharge of untreated abattoir wastewater may lead to cumulative increases in dissolved solids, nutrients, organic pollutants, and pathogenic microorganisms over time. Consequently, the river should not be considered safe for direct domestic consumption without adequate treatment.

The findings underscore the urgent need for effective wastewater treatment facilities, strict enforcement of environmental regulations governing abattoir operations, routine monitoring of surface water quality, and public awareness programmes aimed at protecting the Bangaie River from further degradation.

4.0 Conclusion

This study evaluated the chemical quality of surface water along the Bangaie River influenced by effluent discharge from the Bangaie Abattoir in Bida, Niger State. The findings revealed spatial variations in the physicochemical characteristics of the river, indicating the influence of abattoir activities on surface water quality. Total hardness ranged from 60 to 140 mg/L, with some sampling points exceeding the desirable guideline value, suggesting localized enrichment of dissolved minerals associated with abattoir waste. The pH values (6.5–7.5) remained within the World Health Organization (WHO) recommended range for drinking water, indicating that the river has not yet experienced significant acidification or alkalinization. Alkalinity values (50–100 mg/L) were also within acceptable limits, demonstrating moderate buffering capacity. Although the measured chlorine concentrations were below the WHO guideline value for chloride, their spatial variability indicates the influence of wastewater inputs and highlights the need for continuous monitoring. Collectively, the results suggest that while some chemical parameters currently comply with international standards, untreated abattoir effluents are contributing to the gradual deterioration of surface water quality and may lead to cumulative environmental impacts if discharge continues unchecked.

The findings, together with previous studies reporting elevated microbial contamination in the same environment, demonstrate that the Bangaie River is under increasing environmental pressure and should not be considered safe for direct domestic use without appropriate treatment. There is an urgent need for the installation of effective wastewater treatment facilities at the abattoir before effluent is discharged into the river. Regulatory agencies should strengthen routine monitoring and enforce environmental standards governing abattoir operations. Improved drainage systems, proper solid waste management, and the adoption of environmentally sustainable slaughterhouse practices should also be implemented to minimize pollution. Furthermore, comprehensive studies involving seasonal monitoring, heavy metals, nutrients, organic pollutants, microbiological indicators, and ecological risk assessment are recommended to provide a more complete understanding of the long-term impacts of abattoir effluents on surface water quality, aquatic ecosystems, and public health.

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Declaration

Ethics Approval and Consent to Participate

Not applicable

Consent for Publication

All authors have read and approved the final version of the manuscript and consented to its publication.

Availability of Data and Materials

Data shall be made available upon request

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Competing Interests

The authors declare that they have no known competing financial interests or personal relationships that could have influenced the work reported in this paper.

Author Contributions

Anurunwa Nnamdi Justice conceptualized the study, conducted field sampling, laboratory analyses, data interpretation, and drafted the manuscript. Dokochi Ndanusa contributed to study design, data validation, and manuscript review. Sunday Emmanson Udo assisted with data analysis, interpretation, and critical revision. Musa Yakubu supported sample collection, laboratory investigations, literature review, and final editing. All authors approved the final manuscript.

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