Assessment of Water Quality and Emerging Contaminants in Kura LGA, Kano State, Nigeria

Khadija Sule Kura
Department of Public Health Technology

Sani Tajo Tukur
Department of Science Laboratory Technology

Kamilu Ishaq
Department of Public Health Technology
Federal University of Science and Technology Kabo, Kano

Abstract
This study evaluated the suitability of groundwater for domestic use in Kura Local Government Area of Kano State, Nigeria, between October 2025 and January 2026. Water samples were collected from boreholes and hand-dug wells across ten wards using standard sampling procedures. The samples were analyzed for physicochemical characteristics, including pH, temperature, electrical conductivity, turbidity, total dissolved solids, dissolved oxygen, biochemical oxygen demand, nitrates, phosphates, and hardness, as well as for microbial indicators such as Escherichia coli and total coliforms. In addition, the presence of emerging contaminants (pesticide residues, fertilizer residues, and microplastics) and heavy metals (Cu, Pb, Cd, Zn, and Br) was assessed. The results showed that groundwater pH values (6.4–7.3) were slightly below the recommended range of the World Health Organization for drinking water, while most other physicochemical parameters and heavy metal concentrations were within permissible limits. Microbial analysis revealed the presence of E. coli (8–150 CFU/100 mL) and total coliforms (40–400 CFU/100 mL), indicating varying degrees of microbial contamination, particularly in well water sources. Emerging contaminants were detected at low but notable levels, including pesticide residues (0.02–0.09 mg/L), fertilizer residues (0.6–1.6 mg/L), and microplastics (4–20 particles/L). Seasonal variations were evident, with higher turbidity, nutrient concentrations, microbial loads, and contaminant levels observed during the late rainy season (October), largely due to agricultural runoff and surface infiltration. These parameters declined towards the dry season (December–January), while dissolved oxygen levels increased. Wells consistently showed higher contamination levels compared to boreholes. Correlation analysis further revealed strong relationships among turbidity, nutrient levels, and microbial indicators. Overall, the findings indicate that while groundwater in the study area is generally within acceptable limits for most chemical parameters, microbial contamination and emerging pollutants pose potential health risks. The study underscores the need for regular monitoring, improved sanitation practices, and protection of groundwater sources to ensure safe and sustainable domestic water supply.

Keywords: Microplastics, pesticide residues, heavy metals, water quality, emerging contaminants, Kura Local Government Area

1.0 Introduction

Background

Water is a fundamental resource that sustains life, underpins agricultural productivity, and supports the integrity of natural ecosystems; nevertheless, its quality across Nigeria is increasingly compromised by human-driven pressures. Recent rapid industrial expansion, uncontrolled urban growth, intensified farming practices, inadequate waste management, artisanal and large-scale mining, and petroleum sector activities have collectively contributed to the introduction of contaminants into both surface and groundwater supplies (Adeyemi et al., 2024; Bello & Musa, 2025).

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A worldwide problem of water pollution in freshwater habitats by an intricate blend of new contaminants has come to be regarded as a hallmark of the Anthropocene, threatening aquatic life and human well-being all around the planet (Teiba et al., 2024). Microplastics, pesticide waste, and heavy metals are some of the most alarming of these pollutants, which may co-exist in surface waters and have synergistic interactions that lead to their respective toxicities being further compounded (Fang et al., 2025). Their occurrence is especially severe in areas experiencing a rapid increase in agricultural intensity and urbanization, where there is a lack of waste control and industrial regulation, and they find their way into the environment (Gani et al., 2024). This paper will look at the surface water of Kura Local Government Area in Nigeria which is a representation of these pressures to explore the phenomenon and possible interaction of these three types of pollutants. Microplastics, which are defined as the plastic particles less than 5 mm, have become a common contaminant in the waters of every corner of the world (Migwi, Ogunah, and Kiratu, 2020). They can be various, such as the direct release of primary microplastics of personal care products and industrial abrasives, or the breakage of larger plastic debris due to physical, chemical, and biological mechanisms (Gani et al., 2024). As soon as they enter the surface waters, microplastics are not inert; their small size and high surface area-to-volume ratio precondition them as the best vectors of other environmental contaminants (Naqash et al., 2020). This is an important vector effect since microplastics are capable of sorbing and accumulating hydrophobic organic and soluble metals in the surrounding water (pesticides and the metal in the water) (Kinigopoulou et al., 2022). According to recent research, this synergistic form of pollution may cause more drastic ecological effects as compared to single pollutants (Ling et al., 2026; Kumar et al., 2025). Another key group of contaminants in farming areas such as Kura is pesticide residues, which they widely apply in order to boost the yield of their crops (Githaiga et al., 2023). All these compounds comprising insecticides, herbicides, and fungicides may reach the surface water bodies in different ways such as through run-offs in farmlands, atmospheric deposition, and disposing of containers carelessly (Picco et al., 2020). It is also alarming when pesticides are co-occurring with microplastics because research has shown that the latter can alter the environmental fate and bioavailability of the former (Li et al., 2020). As an example, the presence of microplastics can affect the kinetics of degradation of pesticides, which may result in their accumulation and movement to greater distances (Sarkar et al., 2021). Heavy metals lead, cadmium, mercury, chromium, among others, are natural materials in the crust of earth, but have been highly mobilized by human anthropogenic activity: mining, industrial discharge, and agricultural practices (Ahmad et al., 2022). Direct toxicities of these metals to aquatic organisms, in surface waters, and can segment through food web, eventually to humans (Das et al., 2025). Recently, much attention has been paid to the interaction between heavy metals and microplastics, as it has been demonstrated that microplastics may serve as an efficient carrier of metals, transforming their speciation, distribution, and toxicity in aquatic environments (Ta & Babel, 2023; Patidar et al., 2023). Moreover, the strategies of sorption of microplastics to heavy metals may depend on numerous factors such as plastic age, the presence of biofilms, or even on environmental factors, including pH and salinity (Zhang, Guo, and Wang, 2022). The coexistence of microplastics, pesticide residues, and heavy metals in surface water can pose complex pollution situations, which are not comprehensively grasped yet (Gao et al., 2024). The studies have revealed that these pollutants have not only independent actions but also can be interactively mobile, persistent, and toxic (Fang et al., 2025). As an example, microplastics have the ability to accumulate pesticides as well as heavy metals on its surfaces, forming local hotspots of contamination that can be absorbed by aquatic organisms (Kumar et al., 2025). The synergistic effects of these combined exposures are that the total effects may be stronger than the sum of each contaminant effects (Ling et al., 2026). These interactions are critical to comprehend in order to make correct risk evaluation and devise effective management strategies. The Kura Local Government Area, which is situated in Kano State in Nigeria, is an essential case study to explore this multi-contaminant pollution. The area is characterized by intensive agricultural

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activities, including irrigation farming along the Watari River, which supplies water for crop production throughout the year (Ahmad etal.,2022).

Agriculture activities in the area entail use of different pesticides to combat disease and pests and also use of fertilizers which can possess small traces of heavy metal (Githaiga et al., 2023). Besides, microplastic pollution also occurs due to the use of plastic materials in agriculture: irrigation pipes, mulching films, fertilizer bags, etc. (Li et al., 2020). Urban and domestic runside flows of adjacent settlements also contribute to the contaminant load into the surface waters (Das et al., 2025). Although it is officially acknowledged that multi-contaminant interactions can take place in freshwater systems, there is still a considerable gap in the existing knowledge about the nature of microplastics, pesticide residues, and heavy metals occurrence, as well as their concomitant effects in Nigerian surface waters (Gani et al., 2024). The prior research has concentrated on individual types of contaminants or has been carried out in other areas with varying environmental factors and sources of pollution (Migwi et al., 2020; Picó et al., 2020). Minimal available studies in West Africa underscore the importance of implementing more in-depth evaluations that will address the co-occurrence of various pollutants and how they might interact (Teiba et al., 2024). This research will seek to fill this gap by offering baseline information on the incidence and spread of these three classes of contaminants in the surface water at Kura Local Government Area hence providing a more comprehensive picture of the issues surrounding the water quality of the region and future monitoring and management strategies. The increasing pollution of freshwater by microplastics, pesticides and heavy metals is a serious environmental disaster with serious consequences on the health of the ecosystem and human well-being, especially in the agricultural intensive areas in developing countries. Although there has been an increasing literature on the individual contaminants in the aquatic environment, a serious gap exists between the simplistic, one-pollutant studies and the real-life situation of multi-contaminants associated with the actual pollution scenarios.

Existing research has found the prevalence of microplastics in African freshwater systems, but these studies have mainly been done in Eastern and Southern African water bodies, in other regions of the West Africa, a severe knowledge gap exists. The distribution of microplastics in Lake Naivasha, Kenya has also been thoroughly captured by Migwi, Ogunah, and Kiratu (2020), and offers important preliminary data into the morphology of particles and the patterns of distribution, but was restricted to only one type of pollutant in one East African lake, and did not acknowledge the coexistence nature of chemical pollution like pesticides or heavy metals that may interact with the Likewise, Githaiga et al. (2023) decadal evaluated the occurrence of contaminants of emerging concern in the surface waters in Kenya, including the presence of microplastics, pharmaceuticals, and pesticides, but it was a literature review that examined the country of Kenya in particular and did not present primary empirical data regarding the prevalence of contaminants in the Nigerian aquatic systems with varying agricultural activities Although these are foundational studies to the region, they still do not discuss the particular contamination profile of the surface waters of Northwestern Nigerian where intensive river irrigation agriculture mediates current and singular mobilization of contaminants in rivers such as the Watari River. Studies comparing the presence of microplastics and heavy metals have made major progress in Asian and European settings and it is unclear whether the same studies can be generalized to the contexts of Nigeria because of the variation in geology and industrial processes and waste management facilities. Kumar et al., (2025) studied the, distribution and influencing factors of microplastics and heavy metals in a fresh water lake system in the Indian Himalaya, which revealed significant correlations between plastic abundance and metal concentrations, but their study was set in a high-altitude tourism affected environment that has little similarity to the lowland agricurally dominated landscape of northern Nigeria. Ta and Babel (2023) investigated how land use and population density impact microplastic pollution in a tropical river, which showed that urban and agricultural lands are important sources of combined pollutions, but were located in the Southeast Asian region and did not consider the regimes of pesticide

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application typical in Nigerian agriculture. Patidar et al,. (2023) examined microplastics as heavy metal vectors within freshwater settings; contributing to an understanding of patterns of distribution and health hazards but not measured against organic pollutants such as pesticides which often accompany metals in agricultural runoff. Such geographical and environmental constraints imply that the particular interactions of the contaminants in the conditions of the Nigerian environment, with unique seasonal hydrology, soil types, and agricultural activities, are not yet studied.

Statement of problem

The presence of intensive agricultural practices, urban development, and other anthropogenic stressors in Kano State and especially Kura Local Government Area (LGA) has significantly contributed to the susceptibility of groundwater sources, such as wells and boreholes to contamination (Amponsah et al., 2024; Bello and Musa, 2025). Although research has identified isolated cases of heavy metals and microbial pollution in some regions of the Kano State, systematic and location-specific research on this issue in Kura LGA is missing, limiting insights into the true water quality situation in the region (Ibrahim et al., 2024). As the local population depends on the untreated groundwater, both directly and indirectly, they are vulnerable to both traditional contaminants (ex: heavy metals) and new ones (ex: pesticides, fertilizers, and microplastics) and susceptible to health hazards (Chukwu and Eze, 2024; Olajide et al., 2024). The presence of seasons, physicochemical characteristics and interactions of these contaminants further complicate risk assessment, but are not well documented on this locality. In the absence of extensive data, policy-makers and water resource managers do not get the information they require to provide safe water supply, reduce the ecological effects, and the Sustainable Development Goal number 6 (Clean Water and Sanitation) (Peters and Okafor, 2025). In particular, none of the prior studies have fully characterized the presence, spatial distribution patterns, and possible relationship of microplastics, pesticide remnants, and heavy metals in the surface waters of the Kura Local Government Area even though it is an area with very high agricultural outputs and with high irrigation demands and domestic usage of the Watari River. The confluence of factors in this region such as high prevalence of plastic irrigation piping, use of various pesticid formulations, closeness to urban settlements, and the semi arid climate with wet and dry seasons, presents a contamination situation, which cannot be satisfactorily elucidated by extrapolation of research carried out in other environmental and socioeconomic setting. Moreover, the possibility of the microplastics to become a carrier whereby both pesticides and heavy metals would be concentrated in this particular environment is completely untested and local communities, environmental managers, as well as policymakers would lack scientific evidence as to the risks or how best mitigation efforts would be applied. Therefore, the research is original in that it was the first to present integrative, empirical evidence of simultaneous existence of these three classes of critical contaminants in the surface waters of the Kura Local Government Area and as such, it established a form of understanding on the characteristics of multi-pollutant occurrences under different geographical conditions, and this also factored in the wider stake in defining emergent contaminant hazards. Thus, systematic evaluation of physicochemical parameters, the levels of heavy metals and the new contaminants in the ground water sources in the Kura LGA is required, to ensure informed decision-making, safeguard the community, and devise more efficient water treatment methods.

Objectives of the study were to:

1. Determine level of physicochemical and microbial water quality in wells and boreholes.
2. Determine levels of emerging contaminants.
3. Determine level of heavy metals
4. Analyze seasonal trends and correlations among water quality parameters.

Null Hypotheses

1. H_{01}: There is no significant difference in the physicochemical and microbial water quality parameters of water from wells and boreholes compared to standard permissible limits.
2. H_{02}: There is no significant presence of emerging contaminants in water from wells and boreholes.

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3. H_{03}: There is no significant concentration of heavy metals in water from wells and boreholes beyond acceptable guideline limits.
4. H_{04}: There are no significant seasonal variations or correlations among water quality parameters in wells and boreholes.

Methodology

Study Area

The research was carried out in Kura Local Government Area, which is a large-scale production of rice in the Sudan savannah zone of southern Kano state. It is a majorly bifid (two-season) region with a wet season (May-October) and dry season (November- April). The main source of supply of domestic consumption is groundwater, especially wells and boreholes. Nevertheless, intensive farming, the excessive use of fertilizers and pesticides cause the risk of groundwater contamination and the appearance of new contaminants. Ten wards make up Kura LGA with a pacific climate of rainy and dry seasons. The economic activity is mainly agriculture which is favorable due to favorable environmental conditions and the supply of ground water in large quantities through hand dug wells, boreholes and the likes. The sample was determined by a longitudinal design aimed to measure seasonal changes in the water quality and sampled were taken during 4 months (October 2025 to January 2026), covering both rainy and dry season. The study had 10 wards (Kura, Karfi, Danhassan, Dalili, Kurunsumau, Dukawa, Kosawa, Gundutse, Tanawa and Rigar Duka) with 2 sampling points per wards common hand-dug and a borehole.

Sample Collection

The two sources of water would be sampled twice a month and in 10 wards with a sample of 160 water samples four months later. Physicochemical analysis was done in clean opaque bottles and microbiological testing in sterile bottles in accordance with standard procedures. Sampling was done in the morning and boreholes pumped 3-5 minutes prior to sampling. Samples were kept in ice and brought to lab to be analyzed. The parameters assessed in the study included physicochemical parameters (pH, temperature, TDS, EC, salinity, hardness), nutrients and agrochemicals (nitrate, phosphate, fertilizer residues), heavy metals (Pb, Cd, Cu, Zn, Br), organic pollution parameters (BOD, DO), emerging contaminants (pesticides, microplastics), and microbiological indicators (E, coli and total coliform)

Laboratory Analysis

All the analyses have been performed as per the standard procedures as are suggested by the American Public Health Association (APHA, 2017) and other internationally accepted guidelines.

Physicochemical Parameters

In temperature studies, T in the furnace were carried out with a calibrated thermometer. A digital pH meter was used to measure the pH with standard buffer solutions (pH 4, 7, and 10). The conductivity and TDS meters were used to measure electrical conductivity (EC) and total dissolved solids (TDS), respectively. A DO meter was used to determine the dissolved oxygen (DO) and EDTA titrometric method was used to measure the total hardness (APHA, 2017; WHO, 2017). The samples were of a freshwater nature which led to the derivation of salinity using the conductivity value.

Nutrients and Agrochemicals

It determined the nitrate (NO 3 -) and phosphate (PO 4 -) methods through standard colorimetric techniques of nitrate and phosphate respectively with UV -vis spectrophotometry. Standard solutions were used to prepare the calibration curves, and readings were obtained at wavelengths of interest (APHA, 2017; Baird and Bridgewater, 2017). Similar spectrophotometric methods were used to determine the fertilizer residues.

Heavy Metals

Before analysis, digested water samples were analyzed with concentrated nitric acid. The concentrations of lead (Pb), cadmium (Cd), copper (Cu), zinc (Zn), and bromine (Br) were measured by Atomic Absorption Spectrophotometry (AAS). Calibration using standard solutions was done, and the background contamination was corrected using reagent blanks (APHA, 2017; Skoog et al., 2014).

Organic Pollution Indicators

The method of 5 days incubation at 200 C was used to obtain the biochemical oxygen

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demand (BOD 5) by observing the difference between initial and final dissolved oxygen levels. A DO meter was used to measure the dissolved oxygen (APHA, 2017; Sawyer et al., 2003).

Emerging Contaminants

Gas Chromatography (GC) or High-Performance Liquid Chromatography (HPLC) was used in analyzing pesticide residues after proper extraction processes. Microplastics could be detected with the help of filtration, visual sorting and the help of a microscope, and then characterized, where needed (li et al., 2018; WHO, 2019).

Microbiological Parameters

The membrane filtration technique was used to identify Escherichia coli and total coliform. The samples were filtered using membrane filters with a diameter of 0.45 μm and incubated at 37C on selective medium containing total coliform and at 44.5C on E. coli selective media and results were expressed in colony-forming units (CFU/100 mL) (APHA, 2017; WHO, 2017).

Quality Control and Assurance.

Analytical grade of all chemicals were used and the glass wares were washed with 5% HNO 3, filtered with deionized water and equilibrated with the sample or reagent. Blank samples were studied together with the test samples to reduce contamination. The quality assurance procedures included, calibration of the instruments, use of blanks and standards, duplication of analysis and strict sterile conditions in microbiological testing.

Presentation of Results

Research Question 1: What is the level of physicochemical and microbial water quality in wells and boreholes?

Table 1: Physicochemical Characteristics of Groundwater

Parameter	Range Observed	WHO Standard	Status
Ph	6.4 – 7.3	6.5 – 8.5	Slightly below standard
Temperature (°C)	24 – 29	Ambient	Acceptable
Electrical Conductivity (µS/cm)	230 – 340	1000	Within limit
Total Dissolved Solids (mg/L)	160 – 220	500	Within limit
Turbidity (NTU)	2 – 14	5	Above limit in some samples
Dissolved Oxygen (mg/L)	5.6 – 7.5	≥5	Acceptable
Biochemical Oxygen Demand (mg/L)	1.5 – 4.5	≤5	Within limit
Nitrate (mg/L)	3.8 – 9.0	50	Within limit
Phosphate (mg/L)	0.9 – 2.3	5	Within limit
Hardness (mg/L)	50 – 150	200	Within limit

Table 1.1: Microbial Quality of Groundwater

Parameter	Range Observed	WHO Standard	Status
E. coli (CFU/100 mL)	8 – 150	0	Contaminated
Total Coliform (CFU/100 mL)	40 – 400	0	Contaminated

Interpretation

The findings have shown that the groundwater in Kura Local Government Area has an average acceptable quality in regard to the physicochemical properties but presents serious concerns as regards to microbiological safety. All physicochemical measured parameters are within the allowable limits suggested by World Health Organization (WHO, 2017), making the water appear to be chemically fit to use at home.

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In other samples, the pH (6.4 -7.3) was below the recommended lower limit (6.5) by a slight margin which implies slightly acidic conditions that might positively affect solubility and mobility of some metals in the ground water. Temperature (24-29o C) levels were within the ambient tropical environment and they are unlikely to have a direct impact on water quality.
The conductivity of the electric (230-340 mS/cm) and TSS (160-220 mg/L) were quite small in comparison with the norm, which pointed to low levels of mineralization and high palatability of water. Nevertheless, the turbidity (2 to 14 NTU) in other samples was greater than recommended (5 NTU) which can be explained by suspended solids, organic materials or improper well construction and maintenance.
Turbidity can also be elevated and act as a medium on which microbes can grow and therefore diminish the effectiveness of disinfection processes. Dissolved oxygen (5.6 7.5, mg/L) and biochemical oxygen demand (1.5-4.5, mg/L) indicate low organic contamination meaning there was little biologic degradation of organic matter. The level of nitrate (3.839 mg/L) and phosphate (0.923mg/L) was within acceptable levels but contributes to the effect brought about by agricultural operations, especially the use of fertilizers in this rice-heavy region. Otherwise, an indication (hardness, 50-150 mg/L) demonstrates that water is moderately soft to hard; this is suitable to consume at home.
However, on the contrary, microbiological quality of groundwater is of extreme concern. Escherichia coli (8-150 CFU/100 mL) and total coliform (40-400 CFU/100 mL) levels are much higher than the WHO recommendation of zero CFU/100 mL in potable water (WHO, 2017). The appearance of E. coli in particular suggests recent fecal pollution, and is probably caused by lax hygienic standards, seepage of septic systems, and surface runoff into shallow ground water, such as hand-dug wells.
These results are indicative of an important public health hazard, because the ingestion of untreated contaminated water may cause water-borne illnesses like diarrhea, cholera, and typhoid fever. These findings therefore indicate that, though there are no major issues on groundwater in the Kura LGA on a chemical basis, microbiologically, it cannot be consumed without proper treatment.

Research Question Two: What are the levels of emerging contaminants in groundwater?

Table 2: Levels of Emerging Contaminants in Groundwater

Emerging Contaminant	Range Observed	Unit	WHO/Reference Standard	Status
Pesticide Residues	0.02 – 0.09	mg/L	0.1 mg/L (guideline)	Within limit
Fertilizer Residues (Nutrients)	0.6 – 1.6	mg/L	10 mg/L (for nitrates proxy)	Within limit
Microplastics	4 – 20	particles/L	No established standard	Emerging concern

Interpretation

Evaluation of emerging contaminants in ground water in the Kura Local Government Area demonstrates that there are some traces of pesticide residues, fertilizers derived compounds, and microplastics in different concentrations.
The pesticide residue level measured between 0.02 and 0.09 mg/L, which is less than the recommended guideline level of 0.1 mg/L, which means that the pesticide contamination level at present is within acceptable safety limits.
Their occurrence, however, indicates continued farming effects on the quality of groundwater. Residues of fertilizers (0.6-1.6mg/L) are also within acceptable limits compared to the common nitrate standards. Nevertheless, their identification indicates that there is leaching of nutrients due to the agricultural practices that have the potential to degrade the quality of ground water over the long term in case they are not well controlled.
The concentrations of microplastics were found to be between 4 and 20 particles/liter. Despite the fact that no standard set of

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regulatory guidelines on microplastics in drinking water is in place at the
Numerous micro plastics are detected meaning that surface activities are contaminated, perhaps by runoff and poor management of waste. Seasonal fluctuation also contributed to the degree of contaminants, with elevated levels of contaminants being recorded during the rainy season because of escalated surface runoffs, leaching to the farmlands, and groundwater leaching. Moreover, the level of contamination in hand-dug wells was relatively high in comparison with boreholes, probably because they are much closer to the surface and because the surface pollutants are much more exposed. In general, the levels of emerging contaminants in the environment are acceptable or unregulated; however, their constant presence informs of potential risks that may be involved in the long-term exposure and accumulations. This highlights the importance of constant surveillance, better farming methods, and better strategies of refuse management in order to protect the quality of ground water.

Research Question 3: What is the level of heavy metals in groundwater?

Table 3: Heavy Metal Concentrations in Groundwater

Heavy Metal	Range Observed (mg/L)	WHO Standard (mg/L)	Status
Copper (Cu)	0.02 – 0.05	2.0	Within permissible limit
Lead (Pb)	0.005 – 0.02	0.01	Slightly above limit in some samples
Cadmium (Cd)	0.001 – 0.002	0.003	Within permissible limit
Zinc (Zn)	0.05 – 0.12	3.0	Within permissible limit
Bromine (Br)	0.01 – 0.04	Not specified	No standard guideline

Interpretation

The analysis of heavy metals in groundwater indicates generally low concentrations across the study area. Most metals, including copper, cadmium, and zinc, were well within the permissible limits recommended for drinking water, suggesting minimal risk from these elements. However, lead (Pb) showed values that slightly exceeded the recommended limit (0.01 mg/L) in some locations, raising concerns due to its toxic nature even at low concentrations. The presence of bromine was detected, although no specific WHO guideline exists for comparison. Overall, the heavy metal contamination level is low, but the occasional elevation of lead suggests potential localized pollution sources and possible health risks, particularly with prolonged exposure.

Research Question 4: What are the seasonal trends and correlations among water quality parameters?

Table 4: Seasonal Variation in Groundwater Quality Parameters

Parameter	Rainy Season (October)	Dry Season (Dec–Jan)	Trend
Turbidity (NTU)	High	Low	Decreases
Nitrates (mg/L)	High	Lower	Decreases
Phosphates (mg/L)	High	Lower	Decreases
Microbial Load (CFU/100 mL)	High	Lower	Decreases
Emerging Contaminants	Higher	Lower	Decreases
Dissolved Oxygen (mg/L)	Lower	Higher	Increases

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Table 4.1: Correlation among Key Water Quality Parameters

Parameters Compared	Relationship	Strength
Turbidity vs Microbial Load	Positive	Strong
Nutrients (Nitrate, Phosphate) vs Microbial Load	Positive	Strong
Turbidity vs Nutrients	Positive	Moderate to Strong
Dissolved Oxygen vs Microbial Load	Negative	Moderate

Interpretation

The findings indicate the presence of apparent seasonal differences in the quality of groundwater. Most contamination indicators (turbidity, nutrient concentrations, microbial load and emerging contaminants) were higher during the rainy season (October). This is mostly explained by run offs of the surface, agricultural practices and a higher rate of contaminant penetration in ground water bodies. On the contrary, the quanta of these parameters were lower in the dry season (December- January), which presents less external inputs of contamination, and greater quantities of dissolved oxygen as a result of the stable state of the waters and decrease in organic load.

Correlation analysis indicated a positive close relationship between turbidity, nutrients and microbial indicators, indicating that higher nutrient concentrations and suspended particles enhance growth of microorganisms. Dissolved oxygen, on the other hand, had a negative correlation with microbial load meaning that an increased microbial activity decreases oxygen in water.

Generally, these results underscore the effects of the seasonal variation on groundwater quality and the sensitivity of the wells, as opposed to the boreholes, to contamination especially during the rainy season.

Ethical Considerations

The samples were collected with the consent of the local governments and the local people. The research made sure that no harm to the environment or local source of water was caused during all the activities.

Recommendtaions

The findings have given a recommendation that the groundwater sources within Kura LGA should be broken down into regular monitoring of their physicochemical, microbiological and emerging contaminants to ensure health water quality. Laws to minimize microbial pollution by adequate protection of the wells, safe location of latrines and regular disinfection should be implemented. To reduce the leaching of nutrients, heavy metals and pesticides to ground water, the agricultural activities require sustainable methods such as integrated pest management and less use of chemicals. There should be public awareness campaigns that train the residents on how to handle water safely, maintain hygiene and dangers of using untreated water. Furthermore, novel contaminants, including microplastics need to be addressed by proper management of plastic waste and specific mitigation measures. Empowered local water laws and more study on the sources of contaminants and the health hazards will help in implementing the evidence-based policies that will help maintain the groundwater quality and safeguard the lives of the populace in the area.

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