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Assessment of groundwater contamination from industrial effluents along Challawa River, Kano State, Nigeria

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Abstract:
Industrial effluents released into surface and subsurface environments pose a serious threat to groundwater quality, particularly in urban industrial corridors.This study investigates the extent of groundwater contamination arising from the discharge of industrial effluents into the Challawa River, Kano State, Nigeria. Water samples were collected from boreholes, hand-dug wells, and river points and analyzed for physico-chemical and heavy metal parameters following APHA standards. The results showed turbidity levels ranging from 320 to 1,050 NTU, total dissolved solids (TDS) from 850 to 1,600 mg/L, and electrical conductivity from 1,200 to 2,500 µS/cm. Heavy metals including chromium (0.28–0.35 mg/L), iron (1.2–2.4 mg/L), and sulphate (190–340 mg/L) exceeded WHO minimum standard and Nigerian Industrial Standards (NIS) limits. The findings indicate significant infiltration of effluents into shallow aquifers, posing health and environmental risks. Effective industrial waste management, routine groundwater monitoring, and strict regulatory enforcement are recommended to safeguard water resources and public health. The detected levels of heavy metals and other physicochemical parameters beyond permissible limits serve as evidence-based guidance for regulators to establish stricter effluent discharge limits for industries operating along the Challawa Industrial Estate. Such data also support the design of groundwater protection policies and land-use zoning regulations to prevent borehole drilling and agricultural irrigation near polluted zones. Furthermore, the study outcomes can aid in developing continuous groundwater-quality monitoring frameworks that ensure early detection of contamination plumes and safeguard potable water supplies. The results provide a scientific foundation for remediation programmes and the polluter-pays enforcement principle implemented by NESREA, while also guiding public awareness campaigns to encourage responsible waste-disposal practices in surrounding communities. In summary, the study contributes directly to evidence-based environmental decision-making, public-health protection, and sustainable water-resource management in Kano State and other industrial regions of Nigeria.

Keywords: *Challawa river, Groundwater, Pollution, Heavy metals.*

1. Introduction

Groundwater serves as a vital resource for domestic, agricultural, and industrial use across developing nations. However, increasing industrialization without effective effluent management has led to widespread contamination of both surface and subsurface water resources (Edmunds and Smedley, 2019; Musa, *et al.,* 2021). Globally, untreated industrial waste discharge contributes significantly to groundwater pollution, especially in urban and peri-urban environments (WHO, 2022). In Nigeria, the situation is particularly critical due to rapid urban expansion, weak environmental governance, and poor wastewater management (Ishaku and Ajayi, 2020). The Challawa Industrial Estate in Kano State is one of Nigeria's most active industrial clusters, hosting tanneries, textile, and food processing industries that discharge untreated effluents directly into the Challawa River. Previous studies Adelana, 2005 and Aremu, *et al.* (2011) reported elevated heavy metal concentrations in surface water near this area, but limited work has quantitatively assessed how these contaminants affect groundwater quality and public health. This study bridges that gap by integrating field sampling and laboratory analysis to evaluate the spatial variation of contamination and its implications for sustainable groundwater management.

2. Methodology

2.1 Study Area Description

The study area lies within the Challawa Industrial Estate, Kano State, located between latitudes 11°55'–12°05'N and longitudes 8°25'–8°35'E. The region falls within the Sudan Savanna climatic zone, characterized by distinct wet (May–October) and dry (November–April) seasons. Annual rainfall averages 800–1,000 mm, while mean annual temperature ranges between 27°C and 30°C. Topography is generally flat to gently undulating, and drainage is dominated by the Challawa River system, which serves as the principal surface water body receiving industrial effluents. The geology comprises Precambrian Basement Complex rocks overlain by alluvial deposits along the river channels. Soils are mainly sandy-loam with moderate permeability, enhancing the potential for pollutant infiltration into shallow aquifers. Vegetation is dominated by short grasses and shrubs typical of the Sudan Savanna zone. Socio-economically, the area supports both industrial and residential communities, where groundwater from boreholes and wells is the major water source for domestic and agricultural use. Figure 1 shows the location of the study area.

2.2 Samples location and sampling

A total of fifteen (15) water samples were collected from boreholes, hand-dug wells, and river sites at varying distances from industrial discharge points. Sampling coordinates were recorded using a Garmin eTrex 32x GPS. Samples were collected in pre-cleaned 1-liter polyethylene bottles, preserved at 4°C, and transported to the laboratory within 24 hours.

Standard procedures described in APHA (2017) were used. Physico-chemical parameters such as pH, turbidity, electrical conductivity (EC), and total dissolved solids (TDS) were determined using a portable multi-parameter meter (Hanna HI98194). Heavy metals including chromium (Cr), iron (Fe), and sulphate (SO_4^{2-}) were analyzed using Atomic Absorption Spectrophotometry (AAS, Model AA-7000, Shimadzu).

Quality assurance included the use of field blanks, duplicate analyses, and calibration with standard reference materials. Data were statistically analyzed using mean, standard deviation, and Pearson correlation to identify relationships among parameters and contamination trends. Figure 2 shows the groundwater sampling points along Challawa River.

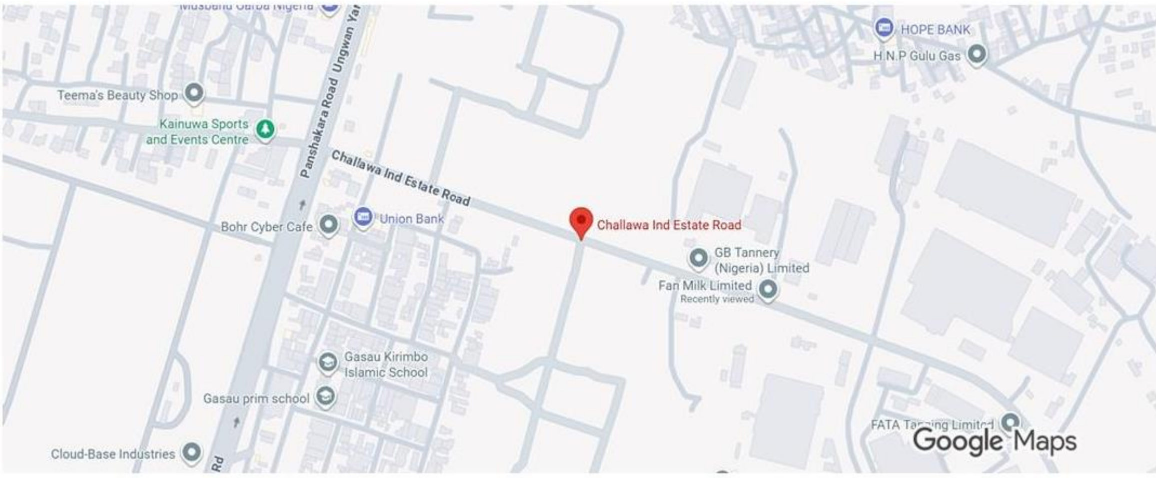

Figure 1: Location map of the study area

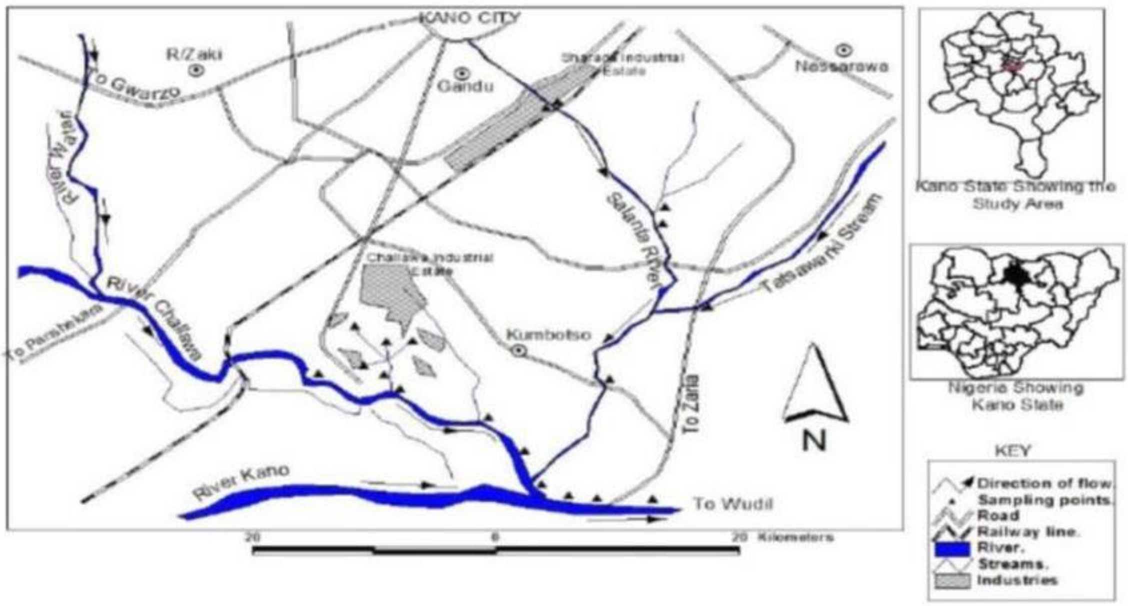

Figure 2: Groundwater sampling points along Challawa River

3. Results and discussion

3.1 Physico-chemical parameters

Table 1 summarizes the physico-chemical characteristics of groundwater samples. Most samples recorded elevated values near effluent discharge points, indicating contamination. Turbidity values ranged from 320–1,050 NTU, exceeding the WHO (2022) limit of 5 NTU. Electrical conductivity varied between 1,200–2,500 µS/cm, while TDS ranged from 850–1,600 mg/L, surpassing the NIS guideline of 500 mg/L. The high values reflect substantial leaching of dissolved solids and industrial waste into aquifers.

3.2 Heavy Metal Concentrations

Table 2 and Figure 3 present the heavy metal analysis results.

Table 1: Physico-chemical parameters of groundwater samples

Parameter	Minimum	Maximum	Average	WHO/NIS Limit
pH	6.1	7.4	6.8	6.5–8.5
Turbidity (NTU)	320	1,050	685	5
Electrical Conductivity (µS/cm)	1,200	2,500	1,850	1,000
Total Dissolved Solids (mg/L)	850	1,600	1,225	500

Table 2: Heavy-Metal Concentrations in Groundwater Samples

Parameter	Minimum	Maximum	Average	WHO/NIS Limit
Chromium (Cr)	0.28	0.35	0.32	0.05
Iron (Fe)	1.2	2.4	1.8	0.3
Sulphate (SO_4^{2-})	190	340	265	200

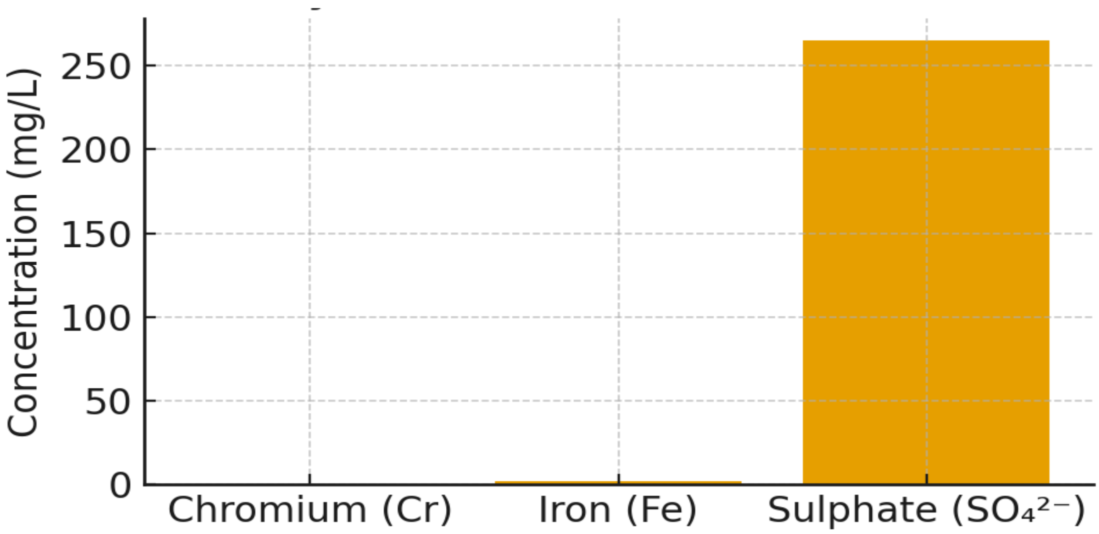

Figure 3: Variations of Heavy Metal Concentrations in Water Samples

Chromium concentrations (0.28–0.35 mg/L) were 6–7 times higher than the WHO permissible limit (0.05 mg/L). Iron ranged between 1.2–2.4 mg/L, above the WHO limit of 0.3 mg/L, while sulphate levels (190–340 mg/L) exceeded the 200 mg/L threshold. These results suggest direct infiltration of untreated industrial effluents into shallow groundwater systems.

Strong positive correlations ($r > 0.75$) between TDS, EC, and heavy metal concentrations indicate a common pollution source — mainly industrial discharges. Similar contamination patterns were observed by Olabode and Adewumi (2018) in Kaduna and Afolabi, *et al.* (2022) in Lagos.

3.3 Environmental and health implications

The elevated concentrations of chromium and iron pose serious public health risks, including renal impairment, dermatological disorders, and carcinogenic effects upon long-term exposure (WHO, 2022). Use of contaminated groundwater for irrigation can lead to heavy metal accumulation in crops and subsequent entry into the food chain, endangering human and animal health (Yahaya, *et al.,* 2021).

Ecologically, persistent contamination alters soil chemistry, reduces microbial activity, and deteriorates riverine ecosystems (Ezeh, *et al.,* 2020).

4. Conclusion

This study confirms that groundwater along the Challawa River Basin is significantly contaminated by industrial effluents. Physico-chemical and heavy metal concentrations exceeded both WHO (2022) and Nigerian standards, indicating effluent infiltration into shallow aquifers. This contamination poses serious health risks to residents who depend on groundwater for drinking and domestic use. Prolonged exposure to elevated levels of heavy metals such as lead, cadmium, and chromium can lead to neurological disorders, kidney and liver damage, and an increased risk of cancer. The findings therefore underscore the urgent need for effective groundwater protection, regular monitoring, and public health awareness to prevent long-term health complications in affected communities.

Recommendations

To protect groundwater quality and public health, the following measures are recommended:

a. Establishment of centralized effluent treatment plants (CETPs) for all industries.
b. Routine monitoring of groundwater using integrated geophysical and geochemical approaches.
c. Enforcement of strict environmental compliance by regulatory agencies.
d. Public education on groundwater protection and pollution prevention.
e. Further research on temporal pollution dynamics and contaminant transport modeling.

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