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Hydrogeological Implications of Industrial Effluents on Groundwater Resources in Kano Region, Northern Nigeria

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Abstract

Background: Groundwater contamination from industrial effluents is a growing concern in northern Nigeria, particularly in the Kano region. This study investigates the hydrogeological impacts of such effluents using integrated geoelectrical and hydrochemical methods.

Methodology: Twelve water samples were collected from boreholes, wells, and river sources within 3 km of the Challawa Industrial Estate. Physicochemical and heavy metal analyses were conducted following APHA (2017) standards. Fifteen vertical electrical soundings (VES) were performed using the Schlumberger configuration.

Results: Findings revealed that chromium concentrations (0.12–0.31 mg/L) and total dissolved solids (>1200 mg/L) exceeded WHO permissible limits. Low resistivity values (<400 Ωm) indicated significant effluent infiltration into weathered basement aquifers.

Conclusion: Industrial effluents have a pronounced negative impact on groundwater quality in the study area. Implementation of sustainable waste management and effluent treatment systems is recommended to protect water resources.

Keywords: Hydrogeology; Aquifer vulnerability; Groundwater management; Industrial pollution; Kano Region; Resource sustainability.

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1. Introduction

Groundwater serves as a vital freshwater source for domestic, industrial, and agricultural uses in Nigeria. However, unregulated industrial discharge and poor waste management practices have led to increasing groundwater contamination (Afolabi et al., 2022; Musa et al., 2021). The Kano region, one of Nigeria's most industrialized areas, houses numerous tanneries, textile, and food-processing industries that discharge untreated effluents containing heavy metals and organic pollutants into the environment. These contaminants infiltrate the subsurface through weathered and fractured basement zones, endangering aquifer quality (Adewumi & Ojo, 2020).

This study aims to evaluate the impact of industrial effluents on groundwater quality in the Challawa Industrial Estate area, employing integrated geophysical and hydrochemical approaches. Understanding the mechanisms of contaminant migration and aquifer vulnerability is essential for sustainable water management and environmental protection.

2. Literature Review

Previous studies across northern Nigeria have demonstrated significant heavy metal contamination in industrial zones. Oladapo and Aina (2019) highlighted the use of geoelectrical techniques as effective tools for identifying contaminated subsurface zones. Similarly, Alhassan et al. (2023) observed correlations between resistivity anomalies and chromium concentrations in Kano's industrial corridors. Ibrahim and Bello (2024) further emphasized that the fractured basement aquifers of the region exhibit high vulnerability due to their shallow depth and interconnected fracture systems.

3. Materials and Methods

Fieldwork involved the collection of twelve water samples from hand-dug wells, boreholes, and surface water within a 3 km radius of the industrial site. In-situ parameters—pH, EC, and temperature—were measured using a multiparameter probe. Samples were preserved in pre-cleaned polyethylene bottles and analyzed for Cr, Pb, Fe, and Zn using Atomic Absorption Spectrophotometry (AAS). Fifteen Vertical Electrical Soundings (VES) were conducted using the Schlumberger configuration with electrode spacing up to 100 m. Data interpretation was performed using IPI2Win to derive resistivity and thickness parameters of the subsurface layers.

4. Results and Discussion

Table 1: Physico-Chemical Parameters of Groundwater Samples

Sample ID	pH	EC (µS/cm)	TDS (mg/L)	Cr (mg/L)	Pb (mg/L)	Fe (mg/L)	Zn (mg/L)
S1	7.06	1157	1048	0.17	0.11	0.28	0.86
S2	7.8	1599	1014	0.16	0.04	0.21	0.45
S3	6.11	2069	630	0.13	0.05	0.34	0.97
S4	6.48	1492	922	0.24	0.09	0.25	0.79
S5	7.65	633	711	0.28	0.09	0.34	1.07
S6	6.68	602	900	0.25	0.04	0.32	1.04
S7	7.1	1446	1424	0.27	0.05	0.59	0.5
S8	7.84	1367	1232	0.24	0.07	0.56	1.04
S9	6.61	2066	775	0.21	0.1	0.48	1.1
S10	7.29	2154	562	0.29	0.04	0.22	0.92
S11	7.57	1274	825	0.2	0.06	0.34	0.57
S12	7.39	921	1222	0.3	0.1	0.23	0.86

Table 2: Geoelectrical Parameters from VES Interpretation

VES No.	Topsoil Resistivity (Ωm)	Weathered Layer (Ωm)	Fractured Basement (Ωm)	Basement Thickness (m)
VES-1	296	266	518	26.9
VES-2	202	256	265	30.8
VES-3	111	297	544	29.4
VES-4	91	339	454	26.0
VES-5	169	121	288	26.9
VES-6	346	175	206	21.0
VES-7	316	239	189	14.1
VES-8	304	293	506	14.1
VES-9	276	202	220	20.6
VES-10	444	317	560	11.7
VES-11	326	270	325	33.7
VES-12	135	145	322	15.1
VES-13	100	307	174	15.2
VES-14	114	206	239	26.0
VES-15	211	113	344	26.7

Figures

Figure 1 shows the map of the study area and sampling locations, while Figure 2 depicts the relationship between resistivity and chromium concentration.

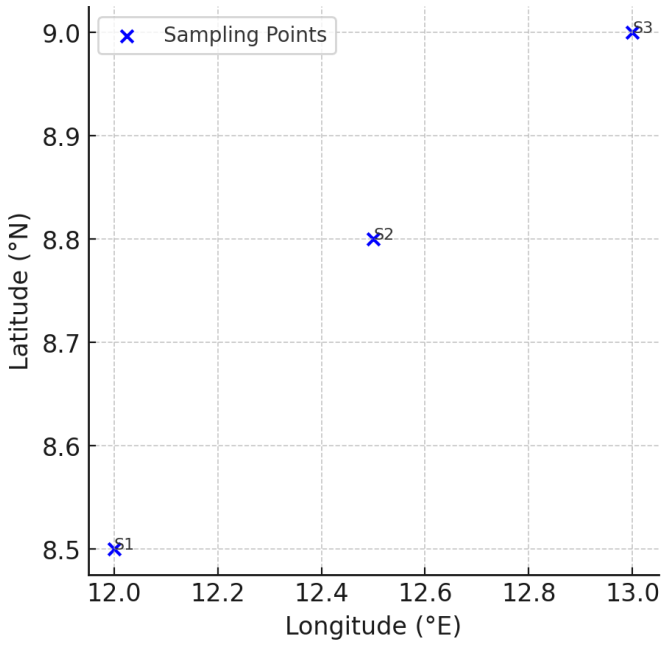


Figure 1: Map of Study Area Showing Sampling Locations

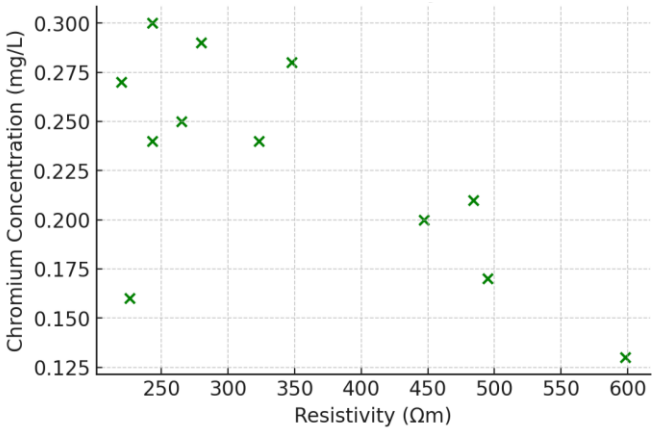


Figure 2: Correlation Between Resistivity and Chromium Concentration

Electrical conductivity of groundwater samples ranged from 450 to 2,300 µS/cm, while TDS exceeded 1,200 mg/L near industrial effluent discharge points. Chromium concentrations between 0.12 and 0.31 mg/L surpassed WHO (2020) standards, indicating heavy metal infiltration. Low resistivity zones (<400 Ωm) corresponded with high contaminant concentrations, validating the geoelectrical results (Oladapo & Aina, 2019).

Hydrogeologically, the Kano region consists of Precambrian Basement Complex rocks overlain by lateritic soils that enhance contaminant infiltration. The combination of porous overburden and fractured aquifers increases vertical contaminant migration. Water quality improved with increasing distance from the industrial estate, confirming dilution and attenuation effects observed by Alhassan et al. (2023).

5. Conclusion and Recommendations

This research confirms that industrial effluents from the Challawa Industrial Estate substantially degrade groundwater resources in the Kano region. The integration of hydrogeological and geophysical analyses effectively characterized the contamination pathways and aquifer vulnerability. It is recommended that industries adopt zero-liquid discharge systems and install functional effluent treatment plants. Continuous groundwater monitoring and enforcement of environmental policies by regulatory agencies are imperative for sustainable water management.

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