IMPACTS OF GEOGENIC AND ANTHROPOGENIC ACTIVITIES ON GROUNDWATER QUALITY IN COASTAL ALLUVIAL AQUIFERS OF OGUN WATERSIDE, OGUN STATE, NIGERIA

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Abstract
Groundwater contamination is a growing concern in coastal areas due to both natural and human activities. This study examined the influence of lithological variation on surface water quality by analysing eleven physicochemical parameters across different geological formations. Purposive sampling was performed across 25 hand-dug wells in four principal villages, focusing on residential and agricultural zones based on lithological variations; samples were obtained using pre-treated polypropylene containers and examined for physicochemical parameters. Statistical evaluations including descriptive statistics, Pearson correlation, and one-way ANOVA were employed. Descriptive results showed high variability, particularly in EC, TDS, and nitrate concentrations. Correlation analysis revealed a significant positive relationship between sodium and prevailing human activity ($r = 0.544$, $p<0.005$), suggesting anthropogenic influence. ANOVA results indicated that pH ($p = 0.017$) and EC ($p = 0.005$) varied significantly across lithological classes, while sulphate, carbonate, and TDS showed near-significant differences. Other parameters such as calcium, nitrate, and potassium did not differ significantly, implying a uniform distribution or influence from external sources. These findings explain the dual influence of geology and human activity on water chemistry. It is recommended that lithology be integrated into water quality monitoring frameworks to improve source attribution and to guide sustainable watershed management practices.

Keywords: *Groundwater contamination, hydrochemistry, anthropogenic activities, natural factors, Ogun Waterside.*

INTRODUCTION

Groundwater serves as a vital water source in many regions, especially where surface water is limited or contaminated (Lewandowski *et al.,* 2020; Wang *et al.,* 2020). In coastal alluvial aquifers, water quality is influenced by natural geological formations and human activities such as agriculture, waste disposal, and industrial discharges. The need for good water quality has been of growing concern in Nigeria and worldwide as anthropogenic activities are fast degrading most water bodies (Badmus *et al.,* 2020), these activities which include agricultural practices, human domestic activities and dredging, all result in pollution of the natural habitats of aquatic organisms (Egbinola and Amanambu, 2014; Thomas, 2023). The prevalence of groundwater contamination and the quality of groundwater have become major issues and threat to the well-being of humans. The World Health Organization's 2017 estimates showed that more people die each year from the consequences of unsafe or inadequate water supplies than from all forms of violence (WHO, 2017).

Ground water contamination has become one of the main environmental issues and a challenge to the world population. The occurrence of contaminants in ground water that is either from natural origin or anthropogenic activities is said to be influenced by changes in season (Harkness *et al.,* 2017; Cangemi *et al.,* 2019). According to Emenike *et al.,* (2018), the levels of physicochemical parameters of ground water being above the permissible guidelines have resulted to health problems among the water users especially in rural areas of the developing countries where a significant number of serious human health problems have been reported to have occurred as a result of contamination of ground water (Badmus *et al.,* 2020; Iwar *et al.,* 2021). Furthermore, Boopathiraj *et al.* (2022)

revealed that contaminated water and sanitation problems accounts for 80% of all illness in developing countries. Yet the ground water contamination is ignored based on the general belief that it is self-purifying, thus, safe with minimum treatment, hence, termed as clean and safe for drinking (Emenike *et al.,* 2019, 2020).

In coastal alluvial aquifers such as those found in Ogun Waterside, Ogun State, groundwater is increasingly threatened by contamination from agricultural runoff, domestic effluents, and industrial discharges. While groundwater is typically regarded as a naturally filtered and safe water source, emerging studies have reported elevated concentrations of pollutants—often surpassing WHO and national drinking water standards—particularly in rural and peri-urban regions (Adimalla, 2020; Olalekan *et al.,* 2022). The situation is exacerbated by seasonal fluctuations that influence the mobility and concentration of contaminants. In many developing countries, including Nigeria, groundwater-related illnesses and waterborne diseases persist as significant contributors to public health burdens due to inadequate water quality monitoring and limited access to safe water (WHO, 2022). The progressive degradation of groundwater resources, coupled with insufficient community awareness and lack of effective treatment systems, underscores the urgent need for detailed groundwater quality assessment and sustainable management strategies in vulnerable regions.

Therefore, this study aims to investigate the influence of geological formations (lithology) and human activities on groundwater quality. By identifying key geogenic and anthropogenic factors affecting water quality, this research seeks to provide critical data to inform strategies for protecting and improving groundwater resources in Ogun Waterside.

MATERIALS AND METHOD

The Study Area

Ogun Waterside lies within the easternmost part of Dahomey basin and adjoined by Lagos State in the south, Ondo State in the north and Ijebu East Local Government in the west. More than half of the entire LGA is encircled by water stretching from Lagos through Ondo State (Odebiyi *et al.,* 2013). The mainland can be assessed by a few motorable roads and several feeder roads and footpaths. The area is bounded by the following coordinate: longitude 46^0E and 434^0E and latitudes 622^0N and 636^0N (Figure 1). The LGA covers an area extent of about 1000 km^2 with a population of about 72,935 inhabitants as at the end of 2006 census (Idowu et al., 2012).

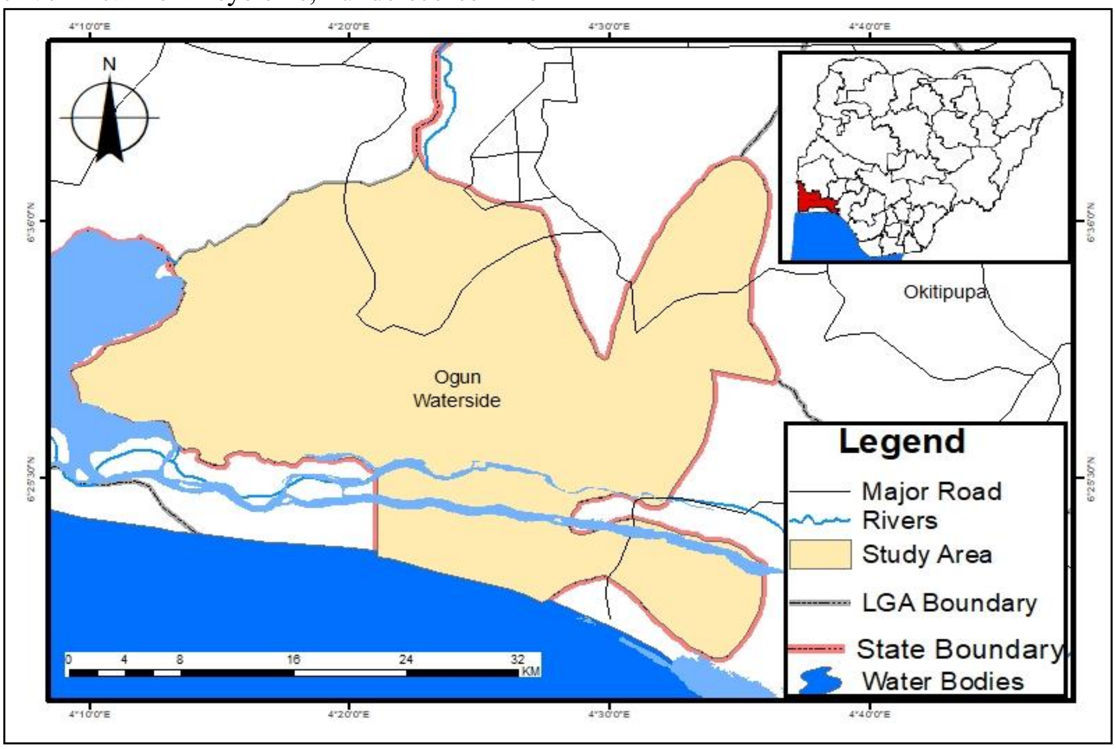

Figure 1: Ogun Waterside and Nigeria Showing Ogun Waterside.
Source: Adapted from NGSA data.

Ogun Waterside has a tropical climate starting with the wet season in March running through October and the dry season starts in November and ends in February (Ojelade *et al.,* 2021). The average yearly rainfall is about 1300 mm while the mean monthly temperature ranges from 23°C to 32°C (Amujo *et al.,* 2022). Major agricultural products in the study area are fish, cassava, rubber, maize and rice (Olaoye *et. al.,* 2012). Ogun Waterside was chosen for this study because it is relatively endowed with complex network of streams, rivers and brackish water (Figure 1).

Ogun Waterside lies within the Nigerian section of the Dahomey basin. The basin spans through four countries, stretching from south-eastern Ghana in the west through Togo and the Republic of Benin to the western part of Niger Delta in Nigeria (Jones and Hockey 1964). The basin is adjoined by the Precambrian basement complex rock in the north and in the south by the Atlantic Ocean christened the Bight of Benin (Falufosi & Osinowo, 2021). The basin came into existence as a result of the detachment of the African plate from the South American plate during the Mesozoic era (Burke *et. al.,* 1971). Fakolade and Obasi (2012) remarked that the general stratigraphic succession in the Dahomey basin from the bottom begins with the Abeokuta Group, Ewekoro Formation, Akinbo Formation, Oshosun Formation, Ilaro Formation, and Benin Formation (Coastal Plain Sands and Alluvium). The prevailing Formation in the study area has been identified to be the Coastal Plain Sands which is predominantly occupying the central, western, eastern and part of the north-western flank of the study area (Figure 2).

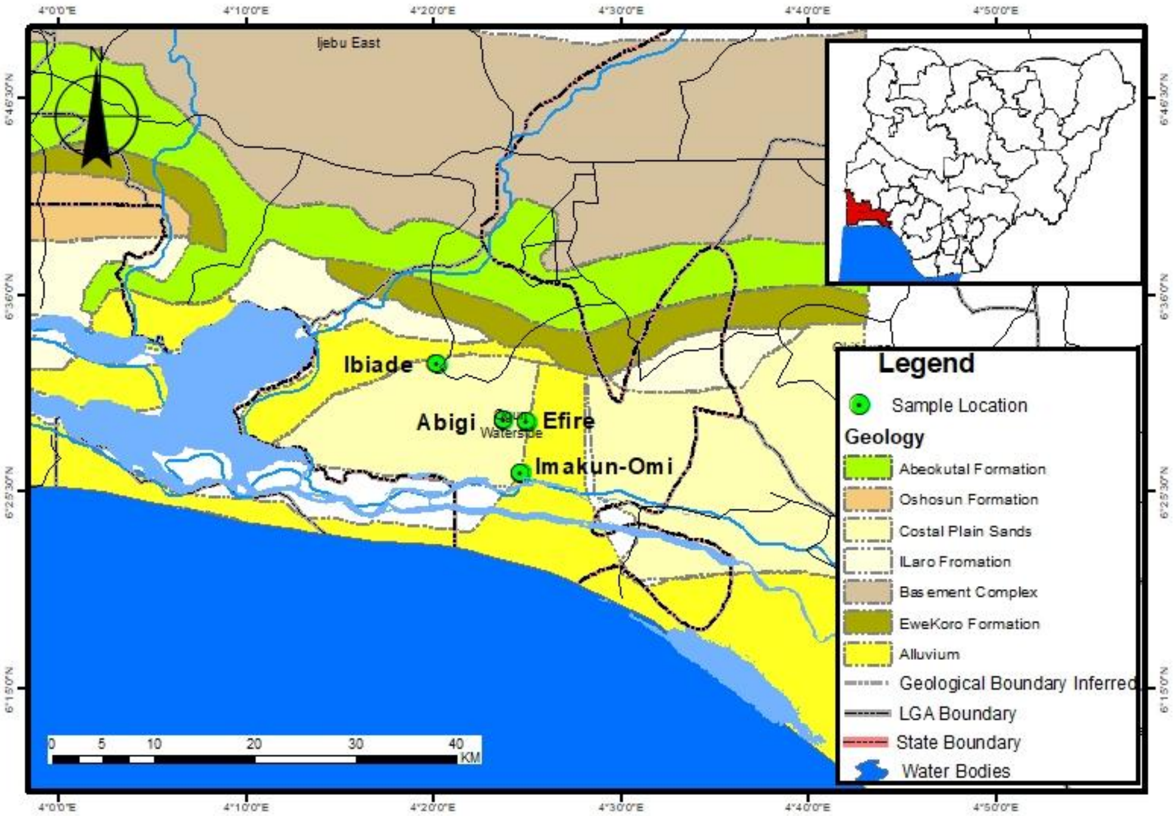

Figure 2: Geology of the Ogun Waterside.
Source: Adapted from NGSA data.

The Coastal Plain Sands Formation is considered permeable as it consists of alternation of sands and clay. The Coastal Plain Sands form a multi-layered aquifer system with three aquifer horizons which are separated by silty/clayey layers and are exploited by deep bore wells (Oteri and Atolagbe 2003). Furthermore, the north- central, north-east, southern and part of the eastern flank of the study area comprise of Alluvium (sand, silt and clay). The Alluvial deposits form an unconfined aquifer (ranging from 2 m to 15 m depth below the surface) which is exploited by dug wells (Ayolabi *et. al.,* 2013). Other Formations like; Ilaro Formation (sandstone and limestone), Ewekoro/Akinbo Formation (shale and limestone) and Abeokuta Group (sand, clay, and shale) trend towards the northern part of the study area. The Abeokuta Group forms boundaries with the

Coastal Plain Sands and Alluvium towards the eastern part of the study area, while it occupies the north-east and forms another boundary with Alluvium and Ewekoro Formation towards the north-western flank. The groundwater occurrence and movement in the study area are mainly controlled by geology.

Methodology

In order to achieve a desired output and conduct a thorough study, the researcher used the four major villages in Ogun waterside (Fig. 2). The sampling technique employed for this research is the purposive sampling technique, because sampling site for well water sample collection was purposively chosen. Sample collection was in June-July (raining season).

To assess the level of groundwater contamination, Sampling of groundwater was done from hand dug well located in residential and agricultural areas. Good quality narrow mouth screw-capped polypropylene bottles of two-litre capacity were used to collect the sample. Bottles were first washed with dilute nitric acid then thrice with DM water (Demineralized) before the samples were collected. Water samples were collected from 25 sites across four (i.e. 6 per village) villages based on the differing lithological classifications, and analysed for physicochemical parameters, including pH, electrical conductivity (EC), total dissolved solids (TDS), cations (Na^+, K^+, Mg^{2+}, Ca^{2+}), and anions (Cl^-, SO_4^{2-}, HCO_3^-, NO_3^-). ANOVA and the Mann-Whitney U test were applied to assess statistical significance, while Kriging interpolation in ArcGIS was used for spatial mapping.

Every sample was labelled adequately by permanent marker, also all the information regarding name of the sampling location, source and date of collection were recorded in field book to avoid any confusion and error. Sample bottles were rinsed thrice with the water to be collected and then filled completely to avoid encroachment of air bubble. Sample bottles screw-caped tightly and brought to the laboratory. The samples were preserved in refrigerator at 40C. The analysis of pH was made in field with the help of Systronic portable pH meter.

Groundwater samples of various locations were analysed for determination of degree of contaminants with respect to the following physicochemical parameters. The standard laboratory analysis was used in collaboration with the benchmark standard of WHO and the NSDWQ to assess water quality from hand dug wells in Ogun watersides. The anions and cations parameters were calcium, sodium, magnesium, iron, potassium, nitrate, sulphate, carbonate, chloride and bicarbonate. pH was measured in-situ using a PH meter, Electrical Conductivity and TDS were measured in-situ as well using a multi-meter.

RESULTS AND DISCUSSION

General Hydrochemistry

The hydro-chemical analysis of water samples from 25 stations reveals a generally stable pH environment, with values ranging from 6.70 to 7.01 and a mean of 6.84, indicating slightly acidic to neutral conditions. This range aligns well with the World Health Organization (WHO) guideline of 6.5–8.5 for drinking water, suggesting suitability for consumption. The low standard deviation (0.095) and slight positive skew (0.689) indicate consistent pH levels, with a few samples slightly above the mean. Electrical Conductivity (EC) showed significant variability, ranging from 270 to 1870 µS/cm with a mean of 974.38 µS/cm and a high standard deviation (431.23). Although WHO does not set a specific EC limit, elevated values suggest higher dissolved ion concentrations, potentially affecting taste, with levels above 1000 µS/cm warranting further investigation. The slight positive skew (0.291) indicates some samples had higher salinity, possibly due to pollution or geological influences. Total Dissolved Solids (TDS) varied widely from 142 to 1720 mg/L, with a mean of 667.88 mg/L and a high standard deviation (391.30), exceeding WHO's optimal threshold of 600 mg/L for palatability and, in some cases, the upper limit of 1000 mg/L. The strong positive skew (1.385) suggests a few samples with very high TDS, potentially indicating anthropogenic pollution or mineral-rich environments aligning with reports of Pushpalatha *et al.,* (2022). Potassium levels ranged from 31.25 to 99.05 mg/L (mean: 61.52 mg/L), with moderate variability (SD: 18.06) and a positive skew (0.855), possibly linked to fertilizer runoff or wastewater as opined by Adegbola *et al.,* (2022). While WHO does not specify a potassium limit, these elevated levels may affect water quality. Sodium concentrations were consistent, ranging from 40.31 to 59.52 mg/L (mean: 46.51 mg/L, SD: 5.77), well below WHO's 200 mg/L taste-based guideline, with a slight positive skew (0.714) indicating minor outliers likely from domestic effluents.

Magnesium and calcium levels were stable and low, with magnesium ranging from 3.73 to 7.15 mg/L (mean: 5.41 mg/L, SD: 0.57) and a nearnormal distribution (skew: 0.168), and calcium ranging from 2.54 to 7.37 mg/L (mean: 4.98 mg/L, SD: 1.11) with a negative skew (-0.736). Neither parameter has WHO health-based limits, and their consistency suggests minimal anthropogenic influence (Mooney *et al.,* 2020). Chloride concentrations, however, showed significant variability, ranging from 57.60 to 525.60 mg/L (mean: 203.29 mg/L, SD: 121.30), with a strong positive skew (1.195). While the mean is below WHO's 250 mg/L guideline, the maximum exceeds it, indicating potential contamination from industrial or agricultural runoff or seawater intrusion in some samples.

Sulphate levels were low and consistent, ranging from 0.75 to 2.66 mg/L (mean: 1.49 mg/L, SD: 0.43), well below WHO's 250 mg/L guideline, with a slight positive skew (0.536), posing no concern. Carbonate concentrations varied from 100.50 to 290.85 mg/L (mean: 183.22 mg/L, SD: 50.02), with a significant positive skew (0.929), likely due to geological influences like limestone. WHO does not set a carbonate limit, but high levels may affect hardness and taste. Nitrate levels ranged from 0.88 to 6.09 mg/L (mean: 1.90 mg/L, SD: 1.22), with a high positive skew (2.421) indicating a few elevated outliers, possibly from agricultural runoff. These levels are well below WHO's 50 mg/L guideline, but outliers suggest localized pollution requiring monitoring (Al-Saffawi & Al-Shaker, 2023).

Overall, most parameters meet WHO drinking water standards, particularly pH, sodium, magnesium, calcium, sulphate, and nitrate, indicating general suitability for consumption. However, elevated TDS (mean above 600 mg/L, max exceeding 1000 mg/L) and chloride (max above 250 mg/L) raise concerns about taste and potential contamination in some samples. The high variability and positive skewness in TDS, chloride, and nitrate point to localized pollution sources, such as agricultural runoff, industrial discharge, or seawater intrusion, which should be further investigated to ensure consistent water quality across all stations.

Table 1: Descriptive statistics for Groundwater Hydrochemistry

Parameter	N	Min.	Max.	Mean	Std. Deviation	Skewness	
	Statistic	Statistic	Statistic	Statistic	Statistic	Statistic	Std. Error
pH	25	6.70	7.01	6.8392	.09539	.689	.464
EC	25	270.00	1870.00	974.3804	431.22951	.291	.464
TDS	25	142.00	1720.00	667.8840	391.30201	1.385	.464
Potassium	25	31.25	99.05	61.5196	18.05878	.855	.464
Sodium	25	40.31	59.52	46.5096	5.76947	.714	.464
Magnesium	25	3.73	7.15	5.4128	.57451	.168	.464
Calcium	25	2.54	7.37	4.9804	1.11302	-.736	.464
Chloride	25	57.60	525.60	203.2908	121.29829	1.195	.464
Sulphate	25	.75	2.66	1.4920	.42711	.536	.464
Carbonates	25	100.50	290.85	183.2232	50.01665	.929	.464
Nitrates	25	.88	6.09	1.9020	1.22461	2.421	.464

Source: Field Survey, (2025).

Groundwater Hydrochemistry and Lithology

A one-way Analysis of Variance (ANOVA) was conducted to evaluate whether the mean concentrations of key physicochemical parameters varied significantly across different lithological classes within the study area (Table 2). Lithological class refers to the dominant geological formations or rock types present at the sampling sites, which can influence water chemistry through natural weathering processes, mineral dissolution, and interactions between

The analysis revealed that pH and Electrical Conductivity (EC) differed significantly across lithological classes, indicating that geological factors play a measurable role in shaping these water quality parameters; pH exhibited a statistically significant difference between lithologies, with an F-value of 6.607 and a p-value of 0.017. This suggests that the acidity or alkalinity of the water is strongly influenced by the mineral composition of the underlying rock. For example, carbonate-rich formations such as limestone or dolomite may buffer acidity and increase pH, while silicate or sulphide-bearing rocks may contribute to more acidic conditions through mineral hydrolysis or oxidation reactions. Electrical Conductivity (EC) also showed a significant variation across lithologies ($F = 9.853$, $p = 0.005$). As EC reflects the total ionic content of water, this result implies that certain lithologies release more soluble ions into the water column. This may be attributed to the weathering of ion-rich minerals in sedimentary rocks or evaporites, which tend to elevate conductivity levels, compared to more resistant igneous or metamorphic formations.

Three parameters—sulphate, carbonate, and total dissolved solids (TDS)—approached statistical significance, indicating possible trends associated with geological differences; Sulphate showed a near-significant variation across lithologies ($F = 3.836$, $p = 0.062$), potentially reflecting the presence of gypsum, pyrite, or other sulphur-bearing minerals in certain formations that undergo weathering or oxidation. Carbonates also exhibited borderline significance ($F = 4.008$, $p = 0.057$), possibly due to variations in carbonate rock content (e.g., limestone, marl) that directly influence bicarbonate and carbonate ion concentrations through dissolution reactions. TDS, while not statistically significant ($F = 1.985$, $p = 0.172$), still showed variation across lithological groups, suggesting that the total mineral content in the water may be partially controlled by the geological substrate, with some rocks contributing more solutes than others.

Conversely, other water quality parameters—including potassium, sodium, magnesium, calcium, chloride, and nitrate—did not exhibit statistically significant differences across lithological classes. This suggests a more uniform distribution of these parameters across the geological units studied, or possibly that their concentrations are more influenced by non-geological factors such as land use, anthropogenic inputs, or hydrological conditions. Sodium ($p = 0.372$) and potassium ($p = 0.416$) may originate from both geological sources and external inputs like agricultural runoff. Magnesium ($p = 0.380$) and calcium ($p = 0.897$), although typically associated with mineral weathering, did not differ significantly, perhaps due to the presence of these ions across all formations in relatively balanced proportions. Chloride ($p = 0.466$) and nitrate ($p = 0.845$) are often linked to surface contamination sources rather than underlying geology, which may explain the lack of significant variation.

In essence, the ANOVA results demonstrate that geology exerts a significant influence on certain aspects of water chemistry, particularly pH and EC, which are responsive to the mineralogical and chemical characteristics of different rock types. The near-significance observed for sulphate, carbonate, and TDS also highlights the potential role of lithological variability in modulating water quality. These findings suggest that lithological mapping and geological context should be integrated into water quality monitoring and interpretation, especially in regions where water-rock interactions are dominant controls of hydrochemistry. In more practical terms, understanding lithological influences helps differentiate between natural background levels of water quality parameters and those altered by anthropogenic activity. Future research should consider stratifying samples by additional geological features—such as soil cover, rock porosity, or weathering state—and incorporating longer-term data to capture seasonal or climatic effects on geochemical fluxes

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Table 2: Variation in Groundwater Hydrochemistry across lithology.

		Sum of Squares	df	Mean Square	F	Sig.
pH	Between Groups	.049	1	.049	6.607	.017
	Within Groups	.170	23	.007		
	Total	.218	24			
EC	Between Groups	1338523.915	1	1338523.915	9.853	.005
	Within Groups	3124489.438	23	135847.367		
	Total	4463013.352	24			
TDS	Between Groups	291932.517	1	291932.517	1.985	.172
	Within Groups	3382881.796	23	147081.817		
	Total	3674814.314	24			
Potassium	Between Groups	226.369	1	226.369	.685	.416
	Within Groups	7600.500	23	330.457		
	Total	7826.869	24			
Sodium	Between Groups	27.754	1	27.754	.828	.372
	Within Groups	771.128	23	33.527		
	Total	798.883	24			
Magnesium	Between Groups	.267	1	.267	.802	.380
	Within Groups	7.655	23	.333		
	Total	7.922	24			
Calcium	Between Groups	.022	1	.022	.017	.897
	Within Groups	29.709	23	1.292		
	Total	29.731	24			
Chloride	Between Groups	8246.169	1	8246.169	.550	.466
	Within Groups	344872.451	23	14994.454		
	Total	353118.621	24			
Sulphate	Between Groups	.626	1	.626	3.836	.062
	Within Groups	3.752	23	.163		
	Total	4.378	24			
Carbonates	Between Groups	8910.530	1	8910.530	4.008	.057
	Within Groups	51129.435	23	2223.019		
	Total	60039.965	24			
Nitrate	Between Groups	.061	1	.061	.039	.845
	Within Groups	35.931	23	1.562		
	Total	35.992	24			

Source: Field Survey, (2025.

Groundwater Hydrochemistry and Human Activity

To evaluate the potential influence of anthropogenic activities on water chemistry, Pearson correlation analysis was conducted between prevailing human activity and selected physicochemical parameters of the water samples. The results (table 3) reveal varying degrees of association, with only a few parameters exhibiting statistically significant relationships at the 0.05 level.

A statistically significant negative correlation was observed between human activity and pH (r = -0.413, p = 0.040). This indicates that increased levels of human activity are associated with a slight reduction in pH values across the sampled locations. Such a trend suggests that anthropogenic inputs, potentially from domestic waste, industrial effluents, or agricultural runoff, may be contributing to acidification of the water bodies.

Sodium exhibited a significant positive correlation with human activity (r = 0.544, p = 0.005), indicating that sodium concentrations increased in areas with higher levels of human activity. This relationship is consistent with known sources of sodium enrichment in aquatic systems, such as the discharge of sewage, the use of detergents, road de-icing salts, and leaching from urban soils. The strong statistical significance underscores the potential of sodium as a tracer for human-induced salinization in the study area.

Electrical conductivity (r = -0.378, p = 0.063) and sulphate (r = -0.389, p = 0.055) both demonstrated moderate negative correlations with human activity, though neither reached statistical significance. These near-significant values may indicate emerging trends or subtle influences not fully captured by the sample size or temporal scope of the study. Further investigation with a larger dataset or over an extended period may help clarify these relationships.

Total dissolved solids (TDS) showed a weak, non-significant positive correlation with human activity (r = 0.322, p = 0.116), implying that there may be an increase in overall dissolved ion concentration in more impacted areas, although the effect was not statistically verified. A similar pattern was observed for chloride (r = 0.328, p = 0.110), which may also reflect anthropogenic contributions, such as urban runoff or domestic discharges.

Other parameters, including potassium (r = -0.111, p = 0.597), magnesium (r = -0.273, p = 0.187), calcium (r = 0.033, p = 0.874), nitrates (r = 0.033, p = 0.874), and carbonates (r = -0.006, p = 0.979), exhibited negligible to weak correlations with prevailing human activity, none of which were statistically significant. These findings suggest that the concentrations of these parameters are not strongly influenced by human activities in the sampled areas or may be governed more by natural geochemical processes than by anthropogenic inputs.

In summary, the analysis indicated that human activity has a significant impact on specific water quality parameters—particularly pH and sodium—while other parameters appear less affected. These results showed the importance of continuous monitoring, especially in regions experiencing increased urbanization or agricultural intensification, where water quality can be subtly but progressively altered by human influence.

Table 3: Correlation between prevailing human activity and water quality

		Prevailing Human Activity
pH	Correlation Coefficient	-.413
	Sig. (2-tailed)	.040
EC	Correlation Coefficient	-.378
	Sig. (2-tailed)	.063
TDS	Correlation Coefficient	.322
	Sig. (2-tailed)	.116
Potassium	Correlation Coefficient	-.111
	Sig. (2-tailed)	.597
Sodium	Correlation Coefficient	.544
	Sig. (2-tailed)	.005
Magnesium	Correlation Coefficient	-.273
	Sig. (2-tailed)	.187
Calcium	Correlation Coefficient	.033
	Sig. (2-tailed)	.874
Chloride	Correlation Coefficient	.328
	Sig. (2-tailed)	.110
Sulphate	Correlation Coefficient	-.389
	Sig. (2-tailed)	.055
Carbonates	Correlation Coefficient	-.006
	Sig. (2-tailed)	.979
Nitrate	Correlation Coefficient	.033
	Sig. (2-tailed)	.874

Source: Field Survey, (2025).

The correlation analysis between prevailing human activity and water quality parameters provides valuable insights into the extent of anthropogenic influence on the aquatic environment within the study area. The findings have several critical implications for water resource management, public health, and environmental sustainability.

The significant negative correlation between human activity and pH suggests that increased anthropogenic presence may contribute to water acidification. Lower pH levels, even if still within the neutral range, can affect the solubility and mobility of heavy metals and nutrients, altering aquatic ecosystem dynamics. Acidic conditions can also pose risks to aquatic life, especially sensitive species such as fish and amphibians, by disrupting metabolic functions and reproductive cycles. From a human health perspective, reduced pH may also influence the taste of water and the corrosiveness of plumbing systems, potentially increasing the leaching of metals like lead and copper.

The strong positive correlation between sodium concentrations and human activity is of particular concern. Elevated sodium levels in water can originate from a variety of human-related sources including domestic wastewater discharge, road de-icing, and agricultural runoff. High sodium concentrations in drinking water pose potential health risks, especially for individuals with hypertension or cardiovascular conditions. Additionally, increased sodium levels can impact soil structure and fertility if such water is used for irrigation, leading to long-term degradation of agricultural lands.

Although not statistically significant, the moderate positive relationships observed for chloride and total dissolved solids (TDS) hint at cumulative impacts from diffuse pollution sources. These parameters are often associated with salinization processes and urban runoff, and their gradual increase could be indicative of early stages of water quality decline. Persistent exposure of water bodies to such pollutants can lead to long-term ecological degradation and reduced suitability for domestic, agricultural, and industrial use.

On the other hand, the lack of significant correlations for parameters such as nitrate, calcium, and magnesium, suggests that their concentrations may be influenced more by natural geological conditions or controlled anthropogenic input, possibly due to effective land-use practices or environmental regulations in the area. However, the unexpected absence of a strong correlation between nitrates and human activity despite their known link to agricultural practices may warrant further investigation, perhaps through seasonal monitoring or land-use-specific sampling.

The findings emphasize the need for targeted environmental management strategies. For instance, interventions should prioritize areas showing increased sodium or reduced pH levels, particularly in zones of high human activity. Efforts such as improved wastewater treatment, buffer zones around water bodies, and sustainable agricultural practices can help mitigate the observed impacts. Additionally, regular water quality monitoring programs should be instituted to track changes over time and guide evidence-based policy decisions.

Ultimately, the results highlight the complex interplay between human activity and water chemistry. While only a few parameters exhibited statistically significant changes, the emerging trends accentuate the importance of proactive management to prevent subtle degradation from becoming irreversible. Sustainable urban planning, pollution control, and public education on water conservation are essential for safeguarding both ecosystem health and human well-being in the face of growing anthropogenic pressures.

CONCLUSION AND RECOMMENDATIONS

This study assessed the influence of lithological variation on selected physicochemical parameters of surface water across different geological formations. Using statistical analyses, particularly Analysis of Variance (ANOVA), the research established that certain water quality parameters are significantly affected by the underlying geology of the sampled locations. The results indicate that pH and Electrical Conductivity (EC) varied significantly across lithological classes, with p-values of 0.017 and 0.005, respectively. These findings suggest a strong geogenic control over these parameters, particularly due to variations in mineral composition and weathering potential of different rock types. For instance, carbonate-bearing lithologies likely contributed to higher pH values due to their buffering capacity, while formations rich in soluble minerals (e.g., halite, gypsum) influenced EC through ion dissolution.

Parameters such as sulphate, carbonates, and total dissolved solids (TDS) exhibited near-significant variation among lithological classes, hinting at underlying geological influences that could become more apparent with a larger sample size or more detailed lithological stratification. The presence of sulphate and carbonate ions, for example, is consistent with the weathering of specific rock minerals like pyrite or dolomite, further reinforcing the role of lithology in shaping water chemistry. Other parameters, including potassium, sodium, magnesium, calcium, chloride, and nitrate, did not show statistically significant differences across lithological classes. This suggests that while geology plays a foundational role, other environmental factors such as land use, hydrology, anthropogenic inputs, or biological uptake may exert more influence over the spatial distribution of these parameters.

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