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HYDROGEOCHEMICAL INVESTIGATION OF SURFACE AND GROUNDWATER QUALITY OF PAGO, NORTH CENTRAL NIGERIA

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ABSTRACT
This study investigated the hydrogeochemical characteristics of surface and groundwater in Pago, North Central Nigeria, a region characterized by Precambrian Basement Complex rocks. Water samples collected from wells and streams were analysed using Atomic Absorption Spectrometer (AAS) to analyse for major ions and heavy metals in the water samples. The water quality of the study region was evaluated using hydrogeochemical indices. The hydrogechemical analysis shows that most of the analysed parameters fell within WHO permissible limits, elevated COD levels in some samples indicate potential organic pollution, which may pose risks to human health and aquatic ecosystems. The CF shows low concentrations (<1) of SO_4^{2-}, Cl^-, Ca^{2+}, Mg^{2+}, Pb and Zn, and high concentrations (>1) of COD. The values of PLI were generally low, indicating minimal pollution. The WQI showed samples with excellent (<50) ratings. These results underscore the new regular water quality monitoring and targeted remediation strategies to ensure the safety of surface and groundwater in the region. The assessment indicates that the water in the study area is generally safe for drinking and other domestic purposes.

Keywords: Quality investigation, Surface and Groundwater, Pollution Indices, North central Nigeria

INTRODUCTION

This research focuses on a hydrogeochemical investigation, evaluating the surface and ground water quality in the regions spanning from Chanchaga to Pago through a comprehensive analysis. The Pago region in North-Central Nigeria faces significant challenges in water quality management due to increasing anthropogenic pressures. Despite its importance, limited studies have comprehensively examined the interplay between geology, chemical processes, and human activities in shaping water quality in this area. The geological formations in Pago region are known to influence water chemistry through processes such as mineral dissolution and ion exchange. Understanding these processes is critical for managing water resources in light of growing urban and agricultural demands. This study aims to characterize the hydrogeochemical properties of surface and groundwater in Pago, identify potential sources of contamination, and evaluate the implications for water resource management. Water resources' quality is essential in assessing their suitability for various uses and guaranteeing the well-being of both human and environmental systems (Ojo *et al.* 2020; Hunt *et al.* 2013). However, the increasing pressures on water sources due to population growth, urbanization, industrialization, and agricultural practices have raised concerns about water quality degradation worldwide (Kopittke *et al.* 2019).

Previous studies have highlighted the role of geological formations in shaping water quality (Boyd 2019) but little is known about how this dynamics operate in the Pago region (Akhtar *et al.* 2021; Amadi *et al.* 2015; Zhu *et al.* 2011). Understanding the origins of various water elements, locating potential sources of contamination, and distinguishing between natural changes in water quality and human-caused effects all depend on an understanding of these geological and chemical processes (Hamid *et al.* 2020). Furthermore, studying the interactions between water and geological elements can provide insight into the interactions between water and rock as well as the buffering capacity of aquifers, both of which are critical for preserving water quality throughout time. (Gaur *et al.* 2022). The selection of this study area provides representative coverage of hydrogeological conditions and water resources in Niger State, contributing to a comprehensive investigation of surface and underground water quality.

The Study Area's Geological Setting and Location

The research region is part of Minna Sheet 164SW, and spans between latitude N09^{0}28' - N09^{0}30' of the Equator and longitude E06^{0}35' - E06^{0}39' of the Greenwich Meridian, on a scale of 1: 50,000. The study is convenient accessible via well-connected road networks, including major highways such as Minna-Abuja. The study area experiences a specific climate and supports distinct vegetation types. Understanding the climate and vegetation characteristics of the study area is essential for comprehending the hydrogeological processes and water quality dynamics.

The research region has distinct wet and dry seasons and is located in a tropical climate zone. The region experiences a monsoon-influenced climate, with the rainy season typically occurring between May and October. During this period, the area receives substantial rainfall of about 1200 mm, with a low temperature of 26 °C and a maximum temperature of 34 °C, contributing to the recharge of surface and underground water sources (Taylor and Richard 2013). The dry season, which spans from November to April, is characterized by lower precipitation and higher temperatures of 23^0 C (Taylor 2002). The climate of the study area is influenced by the Guinea Savanah climatic zone, which is characterized by a transition between Sudan and Sahel savannah.

Acacia species, Combretum species, and grasses like Hyparrhenia and Anthropogony are commonly found in the savannah woodlands of the area, which are mainly composed of grass land and savannah woodland ecosystems. The predominant vegetation types in the vegetation study area are grasses, scattered trees, and shrubs that are adapted to the climate and soil conditions of the region (Mengist 2019).

Among the significant ecosystem services that the vegetation offers are wildlife habitat, water management, and soil stabilization. The research region's vegetation and climate have an effect on the hydrological processes and water quality indicators. Seasonal changes in temperature and precipitation, as well as vegetation cover, influence nutrient cycling, infiltration rates, and surface runoff, which in turn affects the availability and quality of surface and subsurface water sources.

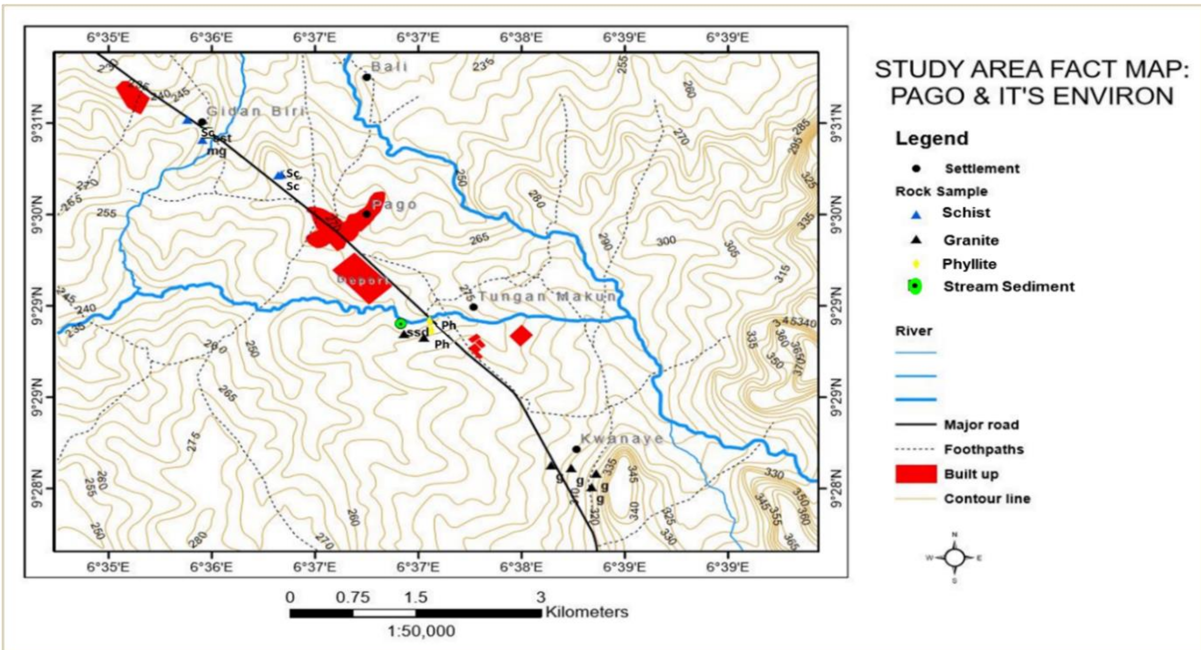

Figure 1: Location of the study area and sampling points

MATERIALS AND METHODS

Hydro geochemical and Physical Properties of Water

For this study, both surface and groundwater samples were collected from hand dug wells, streams, and boreholes within the study region. At each sampling location, the following activities were carried out: taking of the geographical co-ordinates and elevation with the aid of a Global Positioning System (GPS), noting geology of the area, assessing the state of the water and hygiene of the place. The water samples were collected using well-clean plastic bottles: one for the analysis of cations and another for the analysis of anions. These containers were rinsed with deionized water following cleaning with 0.05 M HCl and filtering through membranes with 0.45 mm pores. The water samples were acidified with concentrated nitric acid (HNO3) to homogenize the samples and prevent the metallic ions from adhering to the container walls. A multi-parameter analyzer was used to measure pH and other parameters contributing to alkalinity. Certain compounds, such as hydroxides, bicarbonates, and carbonates, are what determine how alkaline water is (Thomas *et al.* 2020). Together with the total dissolved solids, the electrical conductivity (EC) of the water samples was measured at the time of collection using the Milwaukee MW802-pH+Ec meter (TDS). Chemical oxygen demand (COD), anions, cations, and heavy metal concentrations were tested in the lab using standard procedures. The titrimetric method and the Atomic Adsorption Spectrometer model AA-7000 Shimadzu, Japan ROM version 1.01 were used to measure the cation and anion concentrations, respectively.

Evaluating the Pollution Level and Quality of Drinking Water

This study evaluates the water quality in the study region using a variety of standards. Among the measures are the pollutant load index (PLI), contamination factor, and water quality index (WQI).

WQI

The weighted arithmetic index method was used to calculate this index. The quality rating scale (q*i*) is calculated by dividing the sample concentration (C*i*) in mg/L by the relevant WHO standard (S*i*) in mg/L. The formulas known as equation (1) are obtained by multiplying the C*i*=S*i* ratio by 100. (Akakuru *et al.* 2022; Verma *et al*. 2020).

$$q_i = \frac{C_i}{S_i} \times 100 \quad (1)$$

Equation (2) provides the relative weight (Wi) of each sample, which is the inverse of the WHO standard corresponding to each of the parameters being assessed.

$$W_i = \frac{1}{S_i} \quad (2)$$

Equation (3) then provides a mathematical expression for the WQI, which is the product of Equations (1) and (2).

$$\text{WQI} = \sum qiWi \quad (3)$$

CF

Hakanson (1980) states that this index, which is presented as follows, characterizes the spectrum of metal contamination or pollution:

$$\mathbf{CF} = \frac{Cn}{Bn} \quad (4)$$

where B_n is the background/target, a reference value for the maximum permissible metal concentration, and C_n is the local metal concentration (Yahaya and Fatima 2021; Akakuru *et al.* 2022).

PLI

CF is used to calculate this index. It is computed by taking the n-root of the n-CFs for each metal in question. This index helps compare the pollution levels of different places and provides useful information on metal toxicity (Yang *et al.*

2011; Rabee *et al.* 2011). In accordance with Tomlinson *et al.* (1980), it was calculated using Equation (5).

PLI= $\sqrt[n]{CF1 \times CF2 \times \ldots \times CFn}$ (5)

Where n is the number of metals taken into consideration and CF is the contamination factor.

RESULTS AND DISCUSSION

Physical Parameters

Table 1 and Figure 2 present the findings of the physiochemical properties of the water samples. pH, EC, TDS, alkalinity, and COD were the physical and oxygen-related parameters that were taken into consideration, showing variations across the sampling points. The pH values fall within the WHO (2018) drinking water standard, with a mean of 7.08 and a range of 6.89 to 7.62. The water quality is nearly neutral, according to the average pH value (George *et al.* 2014; Olofinlade *et al.* 2018). pH controls the chemical components of metals and nutrients' solubility and biological availability. The EC of water indicates the amount of minerals, chemicals, and other compounds that are dissolved in it. The EC of the water ranges from 73.5 to 622 µ/cm, with an average of 321 µ/cm in the study region. These measurements might not have met the WHO permissible limit because of a lower concentration of dissolved solutes in the water. Low EC water is mostly corrosive and might not provide adequate safeguards against some contaminants or microbes that could damage pipes and equipment. With a mean value of 92.00 mg/L and a range of 38.00 to 122.00 mg/L, the alkalinity, a measure of how well water neutralizes acids and bases, is below the WHO standard. The low alkalinity concentration may result from the absence or minimal carbonate content in the underlying rocks. The mean alkalinity concentration was 161.62 mg/L, with values ranging from 36.90 to 312 mg/L, TDS is in the excellent and pleasant class and is within the WHO limit (Rahman et al. 2015). As stated by Akakuru *et al.* (2021) and Yetiş et al. (2019), the variation in TDS is greatly influenced by the geochemical processes and human activities that take place within groundwater repositories, as well as the groundwater's residence period within a hydrogeological unit (Alsuhaimi *et al.* 2019). With a mean of 96 mg/L and a range of 32 to 208 mg/L, the COD measures the amount of oxygen that can be consumed per volume of water. The COD levels in all of the water samples exceeded the WHO guideline because municipal and industrial pollutants break down and seep into the groundwater. There is more oxidizable organic material in the water samples, as shown by the high COD contents.

Table 1: Results of chemical composition of water samples from Pago and its Environs

PARAMETERS	L 1	L2	L3	L4	L5	NIS (2015)	WHO (2018)
pH	7.62	6.94	7.12	6.89	7.25	6.5-8.5	6.5-8.5
EC (µS/cm)	157.5	622	221	532	73.5	1000	0-1000
TA (mg/L)	80.00	120.00	100.00	122.00	38.00	50-150	200
TH (mg/L)	52.00	230	90.00	196.00	31.00	50-150	300
Ca^{2+} (mg/L)	10.51	63.08	23.13	49.20	8.41	NA	75-200
Mg^{2+} (mg/L)	6.28	17.69	7.87	17.85	2.44	0.2	0-50
TDS (mg/L)	81.2	312	111	267	36.9	500	1000
Cl^- (mg/L)	17.77	62.18	20.73	49.35	26.16	250	250
COD (mg/L)	112	208	64	32	64	NA	10
SO_4^{2-} (mg/L)	10.21	25.12	9.86	11.41	9.67	100	250-500
Pb (mg/L)	0.00	0.04	0.02	0.05	0.00	NA	1.0-3.0
Zn (mg/L)	0.05	0.75	0.02	0.61	0.04	3	3.0

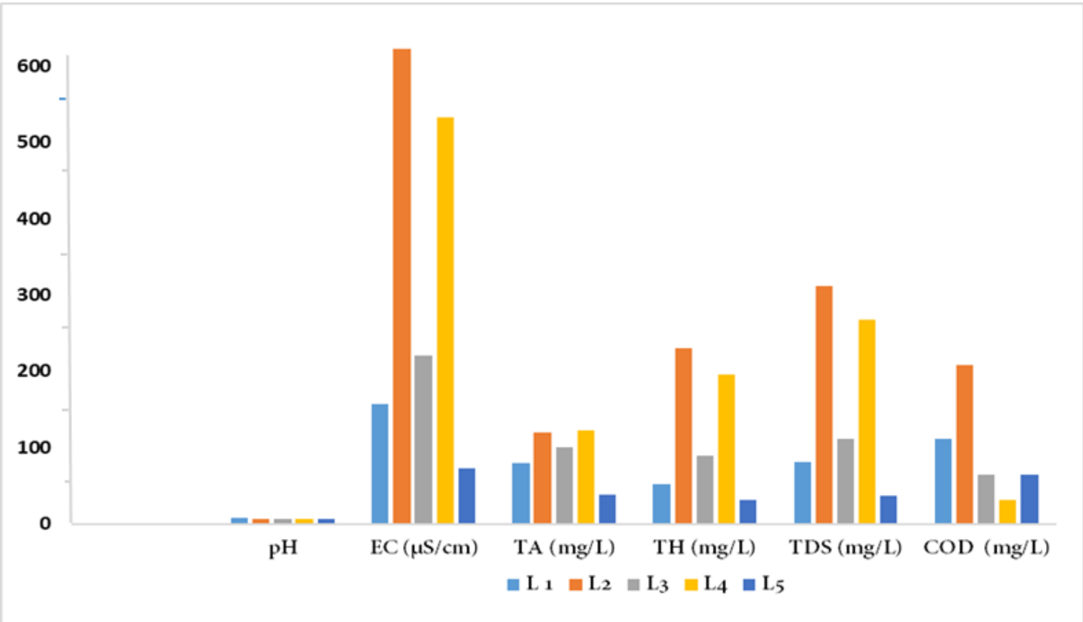

Figure 2: Distributions of the physical and oxygen-related parameters

Hydrogeochemical Parameters

With an average of 30.86 mg/L, the amount of calcium falls between 8.41 to 63.08 mg/L, which is the WHO drinking water standard range. Calcium is essential bone and dental health, and its level in drinking water generally pose no adverse health effects. Within the range of 9.67 to 25.12 mg/L, the SO_4^{2-} values had a mean of 13.25 mg/L, which was within the WHO drinking water standard. Copper pipes can be harmed by high SO_4 concentrations, and groundwater reservoirs can become harder (NIS, 2018). Lung inflammation brought on by a high SO_4^{2-} concentration can lead to lung disease. The Cl- likewise falls within the WHO-recommended limit of 250 mg/L, at an average value of 34.24 mg/L and values varies from 17.77 to 62.18 mg/L. Cl^- levels above 250 mg/L will provide a salty flavour that is unsuitable for human consumption (Rahman *et al.* 2015). The addition of chlorides from rocks, the intrusion of seawater, or contamination from home or business sewage can all contribute to the Cl^-concentration in groundwater (Saha *et al.* 2019). Mg^{2+} levels in drinking water were under the WHO permitted limit, ranging from 2.44 to 17.85 mg/L, with a mean of 10.43 mg/L. This was due to the low salinity of the water sources in the research region. Water sources that have come into contact with specific rocks and minerals, such as gypsum and limestone, contain both calcium and magnesium. These materials degrade to produce calcium and magnesium.

Heavy Metals

The water samples have Pb and Zn contents that range from 0 to 0.05 mg/L and 0.02 to 0.75 mg/L, respectively. These levels are substantially within the WHO guideline, indicating that they do not provide an immediate health danger and meet the standards for water quality assessments. Excess Pb in water harms the brain and kidneys and creates major health issues, particularly for pregnant women and children. For zinc, it causes nausea, vomiting, dizziness, and cramping in the stomach. (NIS, 2018)

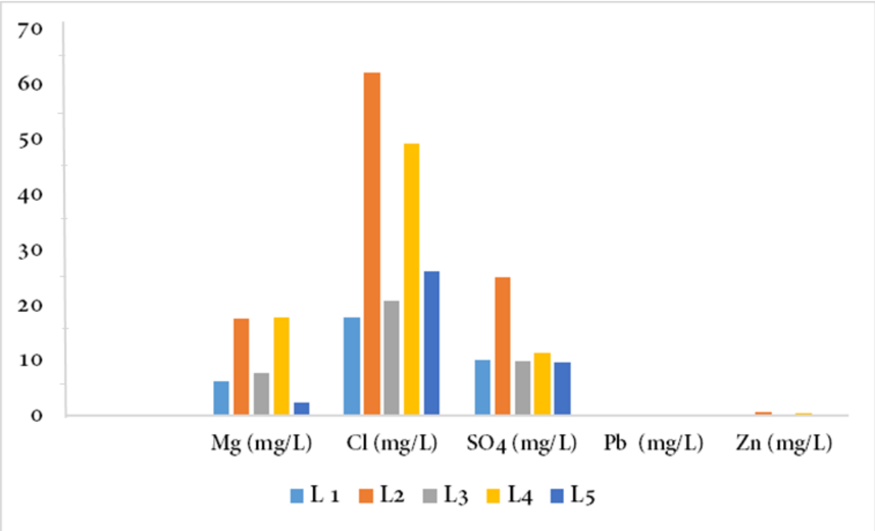

Figure 3: The concentration of ions and heavy metals in Pago and its Environs

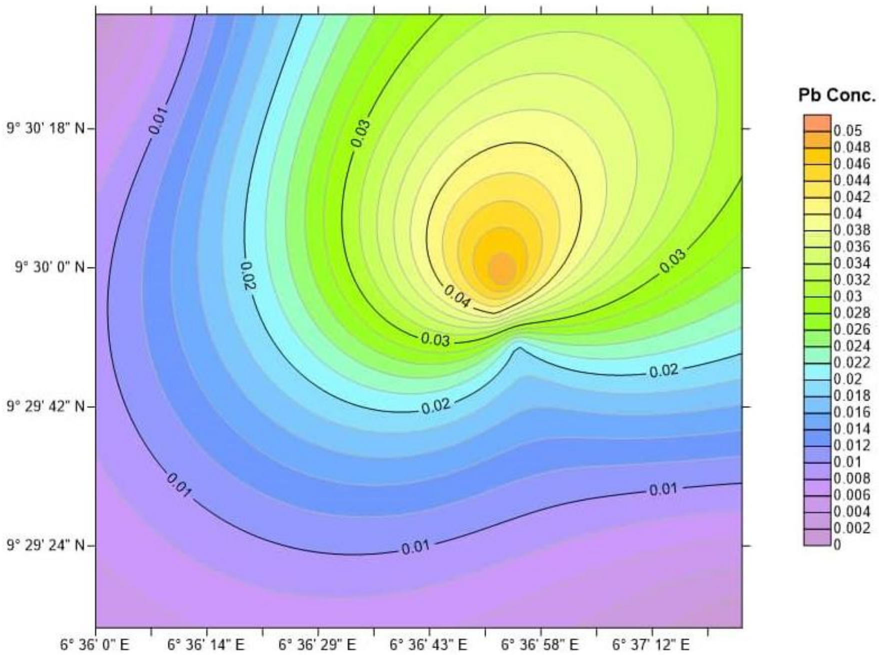

Figure 4: Concentration Map of Lead in Water from Pago and its Environs

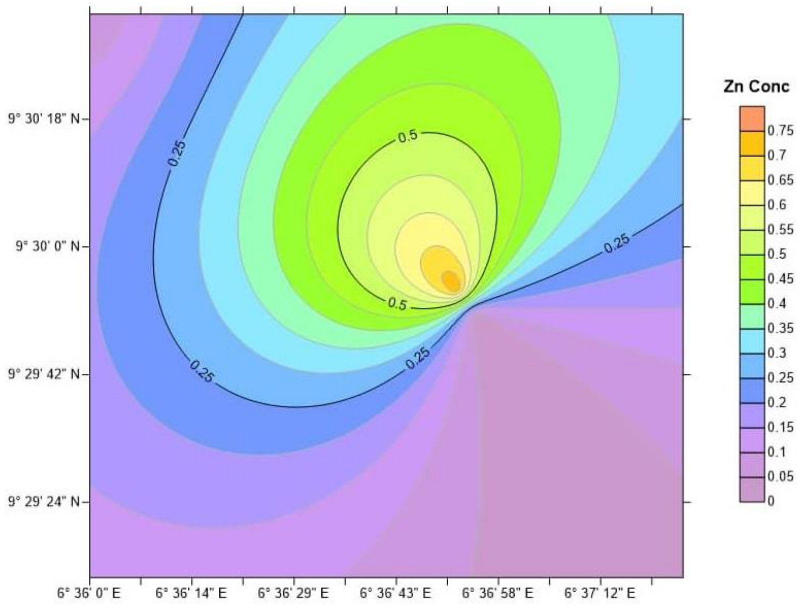

Figure 5: Concentration Map of Zinc in Water from Pago and its Environs

Contamination Factor, Pollution Load Index, Water Quality Index

The water samples' CF, WQI, and PLI were computed; the results and classification are given in Tables 2, 3, and 4, respectively. According to evaluations by Bhutian *et al.* (2017) and Akakuru (2021), the levels of Ca^{2+}, Mg^{2+}, $Cl^{-}SO_4^{2}$, Pb, and Zn in every water sample examined were found to be within the recognized standard limits. According to WHO (2018) and NIS (2018), this suggests that the levels of contaminants do not provide a serious concern to the quality of the water.

Table 2: Results of CF, PLI and WQI for the studied samples

Sample ID	Contamination factor						PLI	WQI
	Ca^{2+}	Mg^{2+}	Cl^{-}	SO_4^{2}	Pb	Zn		
L1	0.140	0.126	0.071	0.041	0.00	0.016	0.000	0.034
L2	0.841	0.354	0.349	0.100	0.04	0.250	0.219	0.278
L3	0.308	0.157	0.083	0.039	0.02	0.006	0.058	0.064
L4	0.656	0.357	0.197	0.045	0.05	0.203	0.280	3.570
L5	0.112	0.049	0.105	0.038	0.00	0.013	0.068	0.932

Table 3: Classification of water based on WQI values

S/No	WQI Value	Water Class
1	<49.99	Excellent
2	50.00-99.99	Good
3	100.00-199.99	Poor
4	200.00-399.99	Very poor
5	>400.00	Unsuitable for Domestic use

Table 4: Classification of water based on PLI

S/No	PLI Value	Rate of Pollution
1	<1	Low Pollution
2	1	Baseline level
3	>1	High Pollution

CONCLUSION

To assess how much surface and groundwater samples from Pago and the surrounding area were suitable for domestic use and human consumption, their physical and hydrogeochemical characteristics were examined. The study presents the concentrations of physical characteristics used to assess the water quality indicators, including CF, PLI, and WQI. With the exception of COD, which was found to be higher than the WHO (2018) recommendations, all water samples included levels of all physical and chemical parameters within the WHO-permitted limit for drinking water. Similarly, all water samples have very low PLI levels, indicating no pollution. According to the WQI, water samples with values less than 50 (good class) are fit for drinking and other domestic use. The assessed indices can be used as instruments to forecast whether groundwater is suitable for household and drinking uses. It is advised that additional heavy metal concentrations, salinity hazard, alkalinity, soluble sodium percentage, residual sodium bicarbonate, and permeability index be taken into account and assessed in future studies.

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