Cek ID 31091

by turnitin fmipa

Jurnal Penelitian Fisika dan Aplikasinya (JPFA)
Volume 14, Issue 02, December 2024
https://journal.unesa.ac.id/index.php/jpfa/
p-ISSN: 2087-9946
e-ISSN: 2477-1775

In-depth Examination of Physicochemical Parameters of Borehole Water Samples in Borokiri, Niger Delta

Ojo Odunayo Tope[1,a,*], Adeoye James Adejimi[2,b], Okoli Austin Emeka[3,c], and Inyang Namdie Josphe[4,5,d]

[1] Department of Geology. Faculty of Natural Sciences, Redeemer University, Ede, Osun State.
[2] Department of Geology and Mining, Faculty of Applied Sciences and Technology, Ibrahim Badamasi Babangida University, Lapai Niger State.
[3] Department of Geology, School of Physical Science, Federal University of Technology, Owerri, Nigeria.
[4] Department of Geoscience, Faculty of Science, University of Uyo, Uyo, Nigeria.
[5] Okna Geoservices Nigeria Limited, Eket, Nigeria.

e-mail: [a] ojood@run.edu.ng, [b] jamesadejimi@gmail.com, [c] emeka.okoli@futo.edu.ng, and [d] namdie007@yahoo.com
* Corresponding Author

Received: ………; Revised: ………; Accepted: ………

Abstract

This research provides an in-depth examination of the physicochemical parameters of borehole water samples in Borokiri Port Harcourt, with an emphasis on temperature, pH, conductivity, total dissolved solids (TDS), and heavy metal concentrations (lead, copper, zinc, and manganese). This research objective is to undertake a complete hydrogeochemical evaluation of groundwater quality in Borokiri, with an emphasis on determining the levels of various physicochemical parameters and heavy metal pollutants. The study included comprehensive field surveys, collecting primary data at borehole locations. Samples were gathered during the rainy season, analyzed in Borokiri's laboratory for physicochemical and microbial parameters using established international methods. Data analysis employed various geochemical techniques, ensuring a thorough assessment of groundwater characteristics and quality. The mean temperature, roughly 29.97°C, is surrounded by a tight clustering, with a modest temperature range of 6.30°C. The average pH of 8.04 shows excellent constancy, as seen by a low standard deviation and a limited range. Conductivity has a mean of 417.00 S/cm, showing significant dispersion with a wider range. The mean total dissolved solids of 199.00 mg/L demonstrate a wide range. Piper and Durov diagrams reveal ion dominance and interaction among samples, supporting judgements on water resource management. The calculated Water Quality Index (WQI) values represent the status of water quality, with most samples displaying "Good" quality and one indicating "Poor" quality due to increased parameter concentrations.
Keywords: *Physicochemical; Heavy Metal Contamination; Statistical Analysis, WQI*

How to cite: Tope OO, Adejimi AJ, Emeka OA, and Josphe IN. In-depth Examination of Physicochemical Parameters of Borehole Water Samples in Borokiri, Niger Delta. *Jurnal Penelitian Fisika dan Aplikasinya (JPFA)*. 2024; **14**(2): 125-143. DOI: https://doi.org/10.26740/jpfa.v14n2.p125-143.

INTRODUCTION

Groundwater, as a precious natural resource, is critical to a country's potential to grow, industrialize, urbanize, advance in agriculture, and improve economically overall [1,2].

Anthropogenic and geological activities have a considerable influence on certain chemical parameters in specific regions [3,4]. With a growing worldwide population, intensive agricultural methods, fast urbanization, and expanded industrial activity, the demand for freshwater in many sectors has grown dramatically [5,6,7]. Notably, groundwater supplies roughly 50% of urban water demands, 62.4% of net irrigation needs, and 85% of rural drinking water and household needs [8,9].

Groundwater has become a vital lifeline for over 1.5 billion people globally, acting as the major supply of drinking water, according to Sakram and Adimalla [7]. However, the groundwater supply has faced severe problems in recent years, particularly in urban, industrialized, and commercial regions. Because of the widespread use of agricultural chemicals such as pesticides, fertilizers, and heavy metal pollutants, groundwater has become unsafe for drinking when it comes into contact with these toxins [3,10].

Topography, rainfall, mineral composition, solubility, oxidation, ionic exchange, poor sanitary conditions, and uncontrolled application of fertilizers and pesticides, often with limited knowledge of soil chemical makeup, all have an impact on groundwater quality [8,11]. As a result, knowing the quality and hydrogeochemistry of groundwater is critical for determining its appropriateness for drinking, irrigation, and other uses. Furthermore, studying changes in groundwater quality caused by water-rock interactions or human activities is critical for long-term resource management [11,12].

Agriculture is a powerful driving force and a significant contributor to the Gross Domestic Product (GDP) in many nations throughout the world. Groundwater is critical for irrigation in Nigeria's southern area, owing to its large supplies that are available all year [6,13]. To fully realize the irrigation potential of groundwater, a coordinated effort to investigate its hydrogeochemistry and overall quality is required. Sodium percentage (%Na), Kelly's ratio (KR), total dissolved solids (TDS), sodium adsorption ratio (SAR), electrical conductivity (EC), chloro-alkaline indices (CAI), index base exchange (IBE), and magnesium hazard (MH) are all important parameters to consider [13].

Numerous research has been undertaken across the world to investigate the hydrogeochemical characteristics and irrigation suitability of groundwater. Researchers investigated groundwater in Qatar for domestic and agricultural uses [14], Tunisia for irrigation purposes, noting elevated SAR and PI levels that rendered the water unsuitable [15], and Italy, where abundant anions and cations were observed, making the water predominantly suitable for irrigation [3]. Several studies have been conducted in several countries, including Nigeria, Turkey, Pakistan, China, South Africa, Southern Mozambique, Albania, and India, to investigate groundwater quality and hydrogeochemical features impacted by both natural and human activities.

Despite several investigations in and around the research region, little or no work has been done on understanding the development and hydrogeochemical processes of the study area's groundwater systems, their effect on water geochemistry, pollution status, and suitability for irrigation purposes. The goal of this research is to fill these critical gaps and provide insight on the complicated interactions that shape groundwater quality, eventually directing sustainable irrigation techniques.It is disturbing to see how disorganized and irrational rubbish disposal practices are spreading across Borokiri. As examples, Onyeanuna et al. [16], Ejiogu et al. [17], Ibe et al. [18], and Urom et al. [19] list the uncontrolled application of artificial fertilizers and fish feeds as well as the indiscriminate placement of cemeteries, restrooms, solid waste disposal sites, and sewage eluent discharge. Unfortunately, throughout the planning and execution of these operations, geological and hydrologic issues are usually overlooked. There is growing worry about this since some of these facilities and activities may have been located close to groundwater recharge zones [20,21].

This disregard for hydrogeological elements poses serious hazards, since it is likely to result in the hydro-geo-pollution cycle. As a result, accessible water sources are vulnerable to significant contamination risks. The local population currently extensively relies on shallow groundwater sources for drinking water, making the existing water supply vulnerable to pollution [16,20]. To maintain the region's groundwater supplies and public health, there is an urgent need to solve these environmental concerns and implement more sustainable waste disposal procedures.

This investigation will concentrate on in Borokiri to assess the hydrogeochemical aspects of groundwater quality. Groundwater samples from various sites and depths will be collected for the study in order to represent distinct aquifer systems. The aim of this research is to undertake a complete hydrogeochemical evaluation of groundwater quality in Borokiri, with an emphasis on determining the levels of various physicochemical parameters and heavy metal pollutants.

MATERIALS AND METHODS

Data Collection

The study area as shown in Figure 1, underwent comprehensive field surveys, during which primary data were gathered at the designated borehole locations. Essential observations were made regarding water usage frequency, seasonal water demands, and the intervals at which sites were opened and closed. The data collected during these field surveys were meticulously recorded. Notably, specific points of interest were identified and pinpointed using a Global Positioning System (GPS). The GPS coordinates played a crucial role in determining appropriate borehole placement to ensure optimal spacing within the study area.

Water Sampling and Sampling Treatment

Samples were gathered during the rainy season and subsequently analyzed at a laboratory in Borokiri. Groundwater samples were collected in 1-liter containers that had been cleaned using water from boreholes as shown in Table 1. The collection process took place after the borehole water had been pumped for a minimum of 15 to 20 minutes. These collected samples were swiftly transported on the same day to the laboratory for both physicochemical and microbial analyses, utilizing established international standard methods that are recognized and endorsed [22].

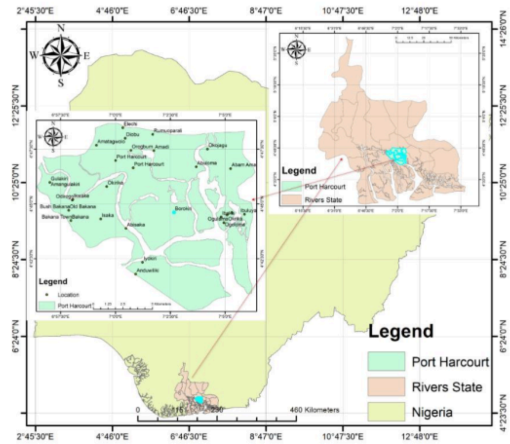

Figure 1. Map of Nigeria, Rivers State, Port Harcourt and the Study Area Borokiri

Table 1. Showing The Coordinates of Samples

Sample Location	Longitude	Latitude
GW1	7.044	4.748
GW2	7.053	4.743
GW3	7.055	4.732
GW4	7.038	4.738
GW5	7.028	4.742
GW6	7.030	4.741
GW7	7.050	4.738
GW8	7.052	4.745
GW9	7.036	4.734
GW10	7.051	4.732

Water Samples Analysis

The methodologies employed for physicochemical analysis in this study have previously been utilized in other geochemical investigations.

(a) Physical Parameters Certified international standard methods were employed to determine these parameters. Total Dissolved Solids (TDS) [22]: TDS were directly measured using a TDS meter.

(b) Chemical Parameters Various techniques were employed to analyze the chemical parameters in the laboratory, including methods outlined by APHA, [22] and WHO, [23]. These methods encompassed:

(i) Volumetric titration method [23]: Chemicals were subjected to titration with a standardized titrant, and the endpoint was indicated by a color change using an indicator.
(ii) Colorimetric method [23]: The intensity of color from target chemicals was measured, and the measured potential was logarithmically proportional to ion concentration.
(iii) UV Method [23]: Similar to the colorimetric approach, this method utilized UV light to measure the absorption of certain organic compounds, revealing a correlation between UV absorption and organic carbon content for qualitative estimation.
(iv) Atomic Absorption Spectrophotometry (AAS) Method [23]: This technique was employed for identifying metal elements.

The following chemical parameters were assessed in this study: a. Alkalinity was determined through titration using methyl orange as an indicator. b. Total hardness and calcium ion concentration were assessed via titration using standard EDTA at pH 10, with Erichrome black T as an indicator. c. Chloride content was calculated using an argentometric procedure, involving titration with standard silver nitrate and the indicator potassium chloride. d. Iron, manganese, and lead ion content were measured using Unicam 969 Atomic Absorption Spectrophotometry (AAS). e. Sulphate ion levels were determined using a colorimetric procedure [22].

The concentrations of the major constituent cations and anions were converted from milligram/liter (mg/L) to milliequivalent/liter (meq/L) and Percentage equivalent mass (% epm) using the equation 1 developed by Todd [12]

$$\text{Mean equivalent mass} = \frac{\text{Atomic weight}}{\text{Valency}} \tag{1}$$

$$\text{Concentrations}\left(\frac{\text{meq}}{\text{L}}\right) = \frac{\text{Concentrations (mg/l)}}{\text{Equivalentmass}} \tag{2}$$

$$\%\ \text{epm}=\%\ \text{epm} = \frac{\text{Concentrations (meq/l)}}{\textit{Total Cation or Anion}}\ x\ 100$$

The concentrations in meq/L were used to prepare Piper trilinear, Schoeller Semi logrithmatic, Durov and Stiff diagrams.

The total hardness as ($CaCO_3$) of the borehole water samples in Borokiri were determined using equation 3.4 developed by Todd [12]. Total hardness as

$$CaCO_3\ \text{mg/L} = 2.5\ [Ca^{2+}] + 4.1\ [Mg^{2+}] \tag{4}$$

Water Quality Index (WQI)

WQI was computed by making use of the weighted arithmetic index formula. The quality rating scale (q_i) for each parameter was obtained by dividing the sample concentration (C_i) in each groundwater sample by its respective standard (S_i). The result is then multiplied by 100 [4, 24].

$$\text{WQI} = \frac{\sum W_n Q_n}{\sum \text{W}_\text{n}} \tag{5}$$

Where W_n is the unit factor for each parameter used in the calculation and is gotten by

$$\text{W}_\text{n} = \frac{\text{K}}{S_n} \tag{6}$$

$$\text{K} = \frac{1}{{}^1/_{S_1} + {}^1/_{S_2} + {}^1/_{S_3} \ldots\ldots + {}^1/_{S_n}} = \frac{1}{\Sigma \frac{1}{S_n}} \tag{7}$$

S_n = Standard Limit of the n^{th} parameter

On summation of all the selected parameter unit weight factors, $W_n = 1$ (unity)
Q_n is the sub-index

$$Q_n = \frac{[(V_n - V_0)]}{[(S_n - V_0)]} \times 100 \quad (8)$$

Were,
Vn =mean concentration of the nth parameter
S_n = Standard Limit of the n^{th} parameter
V_0 = Actual value of the parameter in pure water (V_o =0, for most parameters except for pH

Table 2. WQI Classification and Status

WQI Classification Index	Water Quality Status
0-25	Excellent
26-50	Good
51-75	Poor
76-100	Very Poor
>100	Unfit for Consumption

Table 2 shows WQI classifications, ranging from "Excellent" (0-25) to "Unfit for Consumption" (>100), indicating varying groundwater quality across the study area.

Hydrogeochemical Plots

Commonly used graphical techniques include pie diagrams, Stiff pattern diagrams, Schoeller semi-logarithmic diagrams, Piper diagrams, Collins bar diagrams, Q-mode hierarchical cluster analysis (HCA), Principal Components Analysis (PCA), K-means clustering (KMC), and Fuzzy K-means clustering (FKM).

In this study, a relatively extensive dataset was employed to assess these techniques and to compare their effectiveness in sorting water chemistry samples into coherent groups. Specifically, the techniques of Stiff diagram, Piper diagram, Schoeller diagram, and Durov diagram were selected for this research. The main objective of comparing these techniques is to identify the chemical similarities among water samples. Samples exhibiting similar chemical patterns often share comparable hydrologic histories, including factors like recharge areas, mineral composition, infiltration routes, flow pathways in relation to climate, and time.

Piper Diagram

This refers to a graphical representation of water chemistry, depicting both positive and negative ions using distinct ternary plots. The cation plot highlights calcium, magnesium, sodium, and potassium peaks, while the anion plot showcases sulfate, chloride, carbonate, and bicarbonate peaks. Unlike the Stiff diagram, concentrations in the Piper diagram are expressed in terms of % meq/L. The Piper diagram is particularly useful for identifying water mixing and tracking changes across space and time.

Durov Diagram

The Durov diagram shows the major ions as percentages. The total cations and the total anions are set equal to 100% and the data points in the two triangles are projected onto a square grid that lies perpendicular to the third axis in each triangle. The plot establishes useful properties for large sample groups. The benefit of the Durov diagram is to elaborate clustering of data points to point out samples that have similar compositions.

RESULTS AND DISCUSSION

Results

Water quality assessment is a vital endeavor to ensure the safety and suitability of water for various applications, including human consumption and ecological preservation. The quality of water can be evaluated through the analysis of diverse physicochemical and microbiological parameters. Table 3 presents a comprehensive set of parameters measured for assessing the water quality of in ten (10) different location.

The details of the hydrogeochemical parameters carried out in the study area, shown respectively in Tables 3.

Table 3. Comparative Analysis of Water Quality Parameters

Sample	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10
Calcium (mg/L)	72.800	48.800	19.200	33.600	24.000	72.800	63.200	48.000	84.800	24.000
Magnesium (mg/L)	11.700	11.720	4.390	6.830	37.080	14.200	3.420	22.500	0.980	29.300
Chloride (mg/L)	39.000	35.900	10.900	42.900	42.900	77.900	49.900	85.900	103.000	71.000
Bicarbonate (mg/L)	46.000	18.000	20.000	20.000	38.000	28.000	40.000	22.000	56.000	98.000
Sodium (mg/L)	18.000	16.900	4.200	13.800	12.400	32.100	25.000	29.900	40.600	32.000
Potassium (mg/L)	10.300	6.800	2.000	2.100	2.500	6.800	19.100	14.200	22.200	18.400
Lead (mg/L)	0.106	0.050	0.014	0.013	0.063	0.047	0.063	0.089	0.064	0.093
Copper (mg/L)	0.312	0.276	0.204	1.101	0.113	0.155	0.180	0.151	0.177	0.177
Zinc (mg/L)	0.209	0.184	0.188	0.214	0.249	0.159	0.207	0.196	0.206	0.134
Manganese (mg/L)	0.054	0.039	0.090	0.116	0.100	0.131	0.050	0.130	0.117	0.093
Temperature (°C)	27.200	27.600	28.700	29.900	29.500	30.100	30.600	30.200	32.400	33.500
pH @ 25°C	7.900	7.800	8.000	8.600	8.200	7.800	7.800	7.900	8.200	8.200
Conductivity (μS/cm)	310.000	340.000	260.000	340.000	340.000	660.000	520.000	590.000	400.000	410.000
Total Dissolved Solids (mg/L)	140.000	160.000	120.000	160.000	160.000	330.000	250.000	290.000	180.000	200.000

Discussion of Geophysical Parameters

The provided dataset furnishes essential insights into the water quality parameters, including temperature, pH, conductivity, and total dissolved solids (TDS). These parameters play a crucial role in assessing the health and usability of water bodies [23]. The statistics presented below shed light on the central tendencies, variability, and precision of these parameters. Table 4 and Figure 2 show descriptive statistics of the physiochemical parameter.

The mean temperature recorded is approximately 29.97°C, with a narrow standard deviation of 1.94°C. This indicates that the temperature values are closely clustered around the mean. The temperature range of 6.30°C underscores a moderate variation in the dataset. The calculated standard error of 0.61°C suggests a reasonable precision in estimating the population mean. With an average pH of 8.04 and a relatively low standard deviation of 0.26, the pH values exhibit a notable consistency in the dataset. The narrow range of 0.80 further emphasizes this stability. The small standard error of 0.08 highlights the accuracy of the sample mean as an approximation of the broader population.

The mean conductivity stands at 417.00 μS/cm, accompanied by a substantial standard deviation of 130.73 μS/cm. This larger standard deviation corresponds to a significant dispersion of conductivity values around the mean. The broader range of 400.00 μS/cm reinforces this observation. The calculated standard error of 41.34 μS/cm reflects the precision of the sample mean, considering the dataset's variability.The mean total dissolved solids amount to 199.00 mg/L, with a notable standard deviation of 68.87 mg/L. Similar to conductivity, the larger standard deviation signifies a wide spread of data points. The range of 210.00 mg/L supports this notion. The standard error of 21.78 mg/L underscores the precision of the sample mean.

Table 5. Descriptive statistics of physiochemical parameters of the study area

	Temperature (°C)	pH @ 25°C	Conductivity (μS/cm)	Total Dissolved Solids (mg/L)
Mean	29.97	8.04	417.00	199.00
Median	30.00	7.95	370.00	170.00
Range	6.30	0.80	400.00	210.00
Standard Deviation	1.94	0.26	130.73	68.87
Standard Error	0.61	0.08	41.34	21.78

Table 5 provides valuable insights into the water quality parameters examined. The temperature and pH data exhibit relatively tight clustering around their means, with minimal variation. Conductivity and total dissolved solids data show more significant variability, as indicated by their larger standard deviations and ranges. These findings contribute to a better understanding of the variability and trends in these water quality parameters, enabling more informed water resource management decisions [14, 21].

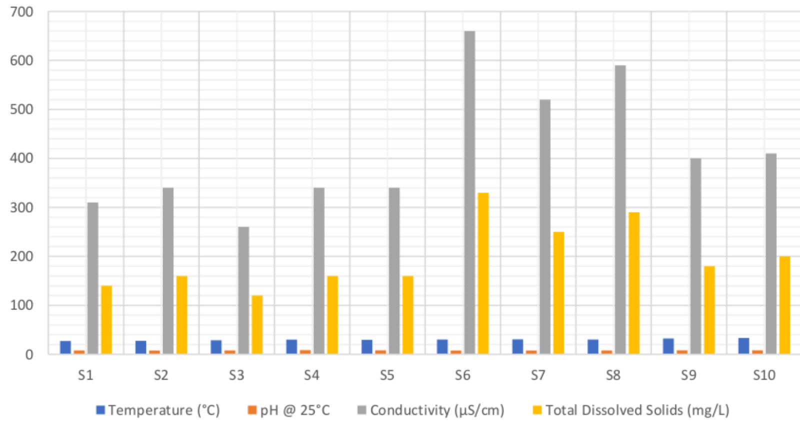

Figure 2. Comparison of Geophysical Parameters Within The Study Area

Discussion of Trace Metal Concentrations

The dataset provided offers insights into the concentrations of heavy metals as shown in Table 6 and Figure 3, namely lead, copper, zinc, and manganese, within water samples. Heavy metals, even in trace amounts, can have considerable environmental and health implications.

The mean lead concentration is 0.060 mg/L, with a slightly higher median value of 0.063 mg/L. The relatively small standard deviation of 0.031 indicates that lead concentrations are clustered closely around the mean. The range of 0.093 mg/L reveals a moderate variability in lead levels. The standard error of 0.010 suggests that the sample mean is a precise estimate of the population mean. Copper concentrations exhibit a mean of 0.285 mg/L and a median of 0.179 mg/L. The larger standard deviation of 0.293 points to a wider spread of data points from the mean. The considerable range of 0.988 mg/L signifies notable variability in copper levels within the dataset. The standard error of 0.093 indicates the precision of the sample mean.

The mean zinc concentration is 0.195 mg/L, closely aligned with the median value of 0.201 mg/L. The standard deviation of 0.031 suggests relatively low dispersion around the mean zinc concentration. The range of 0.115 mg/L reflects moderate variability in zinc levels. The standard error of 0.010 underscores the precision of the sample mean. Manganese concentrations have a mean value of 0.092 mg/L and a median value of 0.097 mg/L. The standard deviation of 0.034 indicates moderate variability around the mean manganese concentration. The range of 0.092 mg/L points to comparable variability within the dataset. The standard error of 0.011 highlights the precision of the sample mean estimation.

Metals, such as lead and manganese, exhibit relatively consistent concentrations with limited variability, others like copper and zinc display wider ranges and higher standard deviations, indicating fluctuations in their presence. The provided statistics are instrumental in assessing potential environmental impacts and guiding the implementation of effective monitoring and management strategies for heavy metal contamination in water bodies [20, 24].

Table 6. Summary of Trace Metal Concentrations in Water Samples

	Lead (mg/L)	**Copper (mg/L)**	**Zinc (mg/L)**	**Manganese (mg/L)**
Mean	0.060	0.285	0.195	0.092
Median	0.063	0.179	0.201	0.097
Range	0.093	0.988	0.115	0.092
Standard Error	0.010	0.093	0.010	0.011
Standard Deviation	0.031	0.293	0.031	0.034

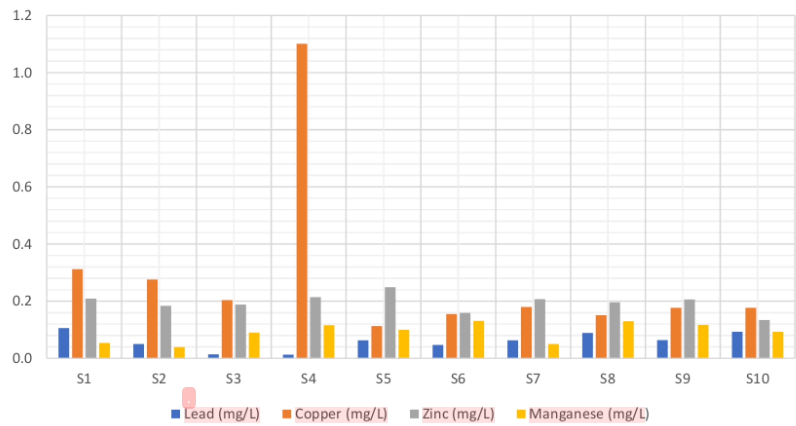

Figure 3. Comparison of Trace Elements Parameters Within the Study Area

Analysis Of Water Quality Parameters and Variability

The dataset presented offers insights into the concentrations of major ions, including calcium, magnesium, chloride, bicarbonate, sodium, and potassium, within water samples as shown in Table 7 and Figure 4. These ions play vital roles in water chemistry and can impact various environmental and industrial processes [7, 9, 23].

The mean calcium concentration is 49.12 mg/L, and the median is 48.40 mg/L. The standard deviation of 23.55 indicates considerable variability around the mean calcium concentration. The range of 65.60 mg/L suggests a broad span of calcium levels within the dataset. The standard error of 7.45 indicates the precision of the sample mean. The mean magnesium concentration is 14.21 mg/L, while the median is 11.71 mg/L. The standard deviation of 11.90 signifies moderate variability around the mean magnesium concentration. The range of 36.10 mg/L implies variability within the dataset. The standard error of 3.76 points to the precision of the sample mean estimation.

Chloride concentrations have a mean value of 55.93 mg/L and a median value of 46.40 mg/L. The standard deviation of 27.72 indicates relatively high variability around the mean chloride concentration. The range of 92.10 mg/L points to significant variability within the dataset. The standard error of 8.77 reflects the precision of the sample mean estimation. The mean bicarbonate concentration is 38.60 mg/L, closely aligned with the median value of 33.00 mg/L. The standard deviation of 24.48 indicates moderate variability around the mean bicarbonate concentration. The range of 80.00 mg/L reflects variability within the dataset. The standard error of 7.74 underscores the precision of the sample mean estimation.

Sodium concentrations exhibit a mean of 22.49 mg/L and a median of 21.50 mg/L. The standard deviation of 11.23 indicates moderate variability around the mean sodium concentration. The range of 36.40 mg/L suggests variability within the dataset. The standard error of 3.55 highlights the precision of the sample mean estimation. The mean potassium concentration is 10.44 mg/L, with a median of 8.55 mg/L. The standard deviation of 7.61 suggests variability around the mean potassium concentration. The range of 20.20 mg/L indicates variation within the dataset. The standard error of 2.41 emphasizes the precision of the sample mean estimation.

The variability in ion concentrations suggests diverse sources and processes influencing groundwater quality. High calcium and chloride levels in some areas may indicate potential contamination or natural mineral dissolution [5,9,14,20]. Variability in magnesium, bicarbonate, sodium, and potassium suggests differing geological formations and water-rock interactions [6,9]. These findings underscore the complexity of the groundwater system, necessitating tailored management strategies to address local water quality issues and ensure safe drinking water.

Table 7. Summary of Physicochemical Parameters of Water Quality

	Calcium (mg/L)	**Magnesium (mg/L)**	**Chloride (mg/L)**	**Bicarbonate (mg/L)**	**Sodium (mg/L)**	**Potassium (mg/L)**
Mean	49.12	14.21	55.93	38.60	22.49	10.44
Median	48.40	11.71	46.40	33.00	21.50	8.55
Range	65.60	36.10	92.10	80.00	36.40	20.20
Standard Deviation	23.55	11.90	27.72	24.48	11.23	7.61
Standard Error	7.45	3.76	8.77	7.74	3.55	2.41

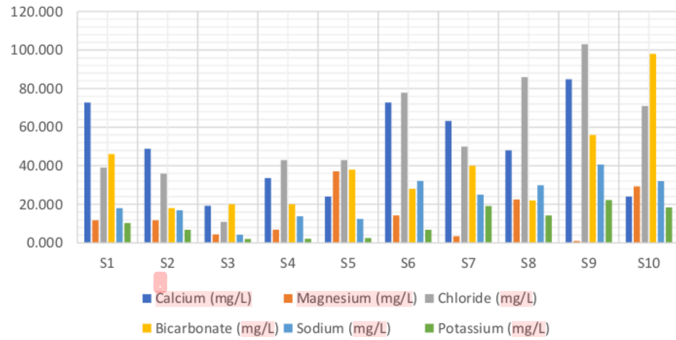

Figure 4. Comparison of physicochemical parameters within the study area

Hydrogeochemical Plots

Piper Diagram

Unlike surface-level data presentation, the Piper Trilinear plot delves into the heart of chemical similarities, surpassing the capabilities of alternative plotting techniques [25]. Consequently, it not only provides a visual representation but also facilitates a deeper comprehension of groundwater geochemistry. Figure 5 showcases the Piper Trilinear plot, which brings the prevailing ionic species into focus. Among cations, the combination of calcium (Ca) and magnesium (Mg) takes a prominent role, establishing their dominance in the cationic realm.

The prevalence of calcium and magnesium can be attributed to the dissolution of limestone and carbonate rocks within the groundwater. This dissolution process, facilitated by carbonic acid, contributes to the abundance of these ions [24]. The disintegration of calcic-plagioclase feldspars and pyroxenes adds to the presence of calcium, further highlighting its importance in the hydrogeochemical framework [15,20,22]. The high concentration of chloride ions can be attributed to multiple factors. These factors encompass the leaching of chloride-bearing rocks, the influence of evaporates, potential intrusion of seawater, the contribution of connate and juvenile water, and the impact of industrial or domestic waste contamination [8, 26]. Each of these sources leaves its distinct mark on the chloride content, underscoring the intricate interplay between natural processes and human activities.

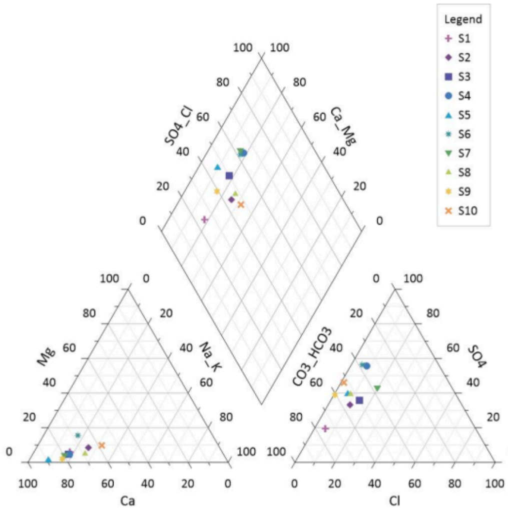

Figure 5. Piper Diagram Showing Major Cations and Anions

Figure 5, shows that**,** Samples S1, S2, S4, S6, S7, and S8 cluster around the calcium-magnesium region, indicating a prevalence of these cations in these samples. The data points for samples S4 and S5 extend into the chloride region, suggesting a notable presence of chloride ions in these samples. The majority of samples, including S1, S2, S3, S6, S7, S8, and S9, occupy the bicarbonate-sulphate portion of the diagram, signifying a balanced interplay of these ions. Manganese concentrations in samples S1, S2, S3, S4, S5, S8, S9, and S10 contribute to the distribution of data points in the vicinity of the center of the diagram.

Piper diagram offers a snapshot of the chemical composition of groundwater samples, helping to guide further analysis and decisions related to water resource management, environmental protection, and public health concerns [7]. The Piper diagram provides a powerful tool for summarizing and analyzing the hydrochemical composition of groundwater samples. Its simplicity and effectiveness in conveying complex information make it an invaluable asset for researchers seeking to gain insights into water quality characteristics and variations within the study area.

Durov Diagram

Figure 6 shows the Durov diagram, which closely mirrors the characteristics observed in the Piper plot, effectively aligning within the portable region of the graph. Operating on a foundation of percentage plotting, the Durov diagram employs a distinct methodology wherein cations and anions are allocated to separate triangles. The crux of this technique lies in extending lines from these plotted points to the central rectangular field. The convergence of these lines culminates in pinpointing a specific water type [27]. These identified positions subsequently serve as reference points from which supplementary lines are drawn to the adjacent rectangles. This process unveils the total concentration, expressed in milligrams per liter (mg/L) or grams per liter (g/L), thereby facilitating a comprehensive analysis of chemical composition and total dissolved solids.

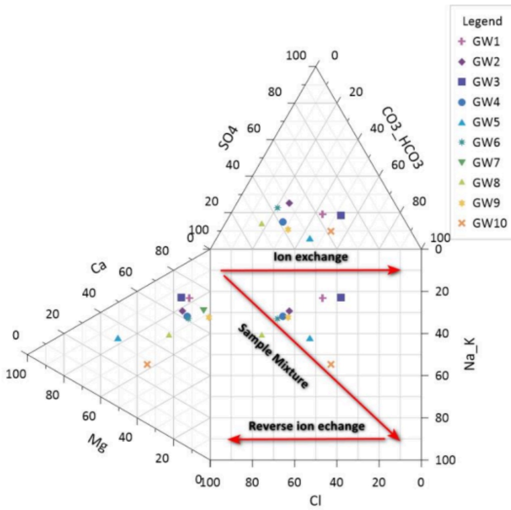

Figure 6. Durov plot showing Cations and Anions

Figure 6 shows, that Samples S1, S2, S4, S6, S7, and S8 exhibit relatively lower lead concentrations, clustering towards the lower end of the cationic triangle. Sample S4 stands out with significantly elevated copper levels, extending further into the cationic triangle compared to the other samples. Zinc concentrations in samples S1, S2, S3, S7, S8, and S9 are comparatively lower, whereas samples S4 and S5 display elevated zinc levels. Manganese concentrations in samples S1, S2, S3, S4, S5, S8, S9, and S10 are relatively similar and cluster together within the cationic triangle.

Water Quality Index

The WQI stands as a valuable tool in the realm of water assessment, offering a method to rank and categorize water quality. Groundwater quality assessment is of paramount significance, particularly in the context of evaluating its suitability for drinking, irrigation, and industrial applications [28]. In the study area, the WQI analysis performed on the groundwater samples yielded promising results, signifying their appropriateness for various uses, including drinking and industrial activities (Table 8).

Table 8. Water Quality Index Classification of Groundwater

Sample	WQI	Water Quality Status
S1	44.89	Good
S2	44.76	Good
S3	47.62	Good
S4	61.34	Poor
S5	43.90	Good
S6	46.31	Good
S7	46.92	Good
S8	45.50	Good
S9	48.54	Good
S10	45.63	Good

The calculated WQI values as shown in Table 8, for the groundwater samples provide valuable insights into the overall quality of each sample in terms of its suitability for various uses. The WQI values, along with their corresponding water quality status classifications, reflect the relative health of the water samples and their potential implications for consumption, agriculture, and environmental integrity.

Among the samples, it is evident that the majority fall within the "Good" water quality status category. Specifically, samples S1, S2, S3, S5, S6, S7, S8, S9, and S10 all exhibit WQI values that indicate good water quality. This suggests that these samples have relatively low concentrations of the assessed parameters (Lead, Copper, Zinc, and Manganese) and are generally suitable for consumption and various domestic and agricultural activities.

However, sample S4 stands out with a considerably higher WQI value, classifying it as having "Poor" water quality. This indicates that the concentration of the assessed parameters in this sample is higher compared to the other samples, potentially posing a risk to human health and suggesting that it may not be suitable for consumption without appropriate treatment.The variation in WQI values underscores the importance of thorough water quality assessment and monitoring [29]. It is crucial to consider these values alongside regulatory standards and guidelines to ensure that water resources are safe for human use and do not adversely impact the environment.

The calculated WQI values and their associated classifications provide a straightforward way to gauge the overall quality of the groundwater samples. These results serve as a valuable tool for decision-makers, researchers, and policymakers to understand and manage water quality, make informed choices regarding water usage, and implement measures to address any potential water quality concerns.

The study's limitations include a limited sample size; further research should involve more extensive sampling across different seasons to enhance data robustness. Advanced analytical methods and continuous monitoring would provide deeper insights into groundwater quality dynamics and inform better management strategies. This research provides critical insights into water's physicochemical and microbiological parameters, enhancing our understanding of water quality's impact on environmental and public health safety.

CONCLUSION

The meticulous examination of various physicochemical parameters in borehole water samples within the Borokiri region of Port Harcourt has yielded profound insights into the quality and suitability of the water for diverse purposes, particularly for drinking. Through the in-depth analysis of temperature, pH, heavy metal concentrations, and major ion concentrations, we have gained a comprehensive understanding of the hydrochemical nature of the groundwater in this area.

The study highlights the stability of temperature and pH in Borokiri's groundwater, ensuring their reliability for monitoring purposes. However, conductivity and total dissolved solids exhibited significant variability, indicating diverse mineral content. This necessitates a detailed understanding of these parameters to evaluate water quality effectively. The findings also underscore the critical implications of trace heavy metals in water. Detailed statistical analysis of lead, copper, zinc, and manganese concentrations revealed consistent lead and manganese levels but wider variability for copper and zinc. This variability emphasizes the need for ongoing monitoring and effective management strategies to mitigate environmental and health risks associated with heavy metal contamination. Further analyses are needed to identify correlations and distribution patterns within the dataset to enhance water quality assessments and ensure safety for various uses.

The examination of major ion concentrations in groundwater from Borokiri revealed varying degrees of variability, with calcium and magnesium showing substantial variations, while sodium and potassium displayed more moderate variability. These insights enhance understanding of water composition and its impact on water quality and ecosystem health. Visualization tools like Piper and Durov diagrams facilitated quick and insightful assessments of ion concentrations and water types, aiding in the interpretation of complex hydrochemical interactions. The Water Quality Index (WQI) for each sample provided a concise assessment of overall quality, with most samples indicating "Good" quality suitable for consumption and various uses. However, one sample classified as "Poor" emphasizes the need for regular monitoring to ensure water safety and mitigate health risks.

This comprehensive analysis of borehole water samples from the Borokiri region of Port Harcourt has significantly enriched our understanding of water quality and its multifaceted dynamics. The insights garnered from the evaluation of temperature, pH, heavy metal concentrations, and major ion concentrations contribute to informed decision-making in water resource management, environmental protection, and public health. This study's findings not only enhance existing knowledge but also emphasize the importance of ongoing monitoring and effective management strategies to ensure the continued safety and sustainability of groundwater resources. This study's comprehensive analysis of water quality parameters in Borokiri's borehole water paves the way for future research on hydrochemical dynamics, environmental impact, and public health implications.

The study provides novel insights into Borokiri's groundwater, revealing critical variability in physicochemical parameters, heavy metal concentrations, and major ions. Using advanced hydrochemical tools, it highlights water quality dynamics and underscores the need for regular monitoring and sustainable management to ensure safety and environmental health.Future studies should integrate real-time monitoring, isotopic analysis, and advanced geostatistical methods to explore spatial-temporal dynamics in groundwater systems, enhancing the understanding of hydrochemical interactions and improving environmental and public health strategies.

AUTHOR CONTRIBUTIONS

Ojo Odunayo Tope and Adeoye James Adejimi undertook the study's design, execution, and the compilation and interpretation of well log data. Okoli Austin Emeka and Inyang Namdie Josphe contributed to data analysis and manuscript preparation. All authors participated in thorough revisions of the manuscript for substantial intellectual contributions and endorsed the final version for publication.

DECLARATION OF COMPETING INTEREST

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

REFERENCE

[1] Akaolisa CCZ, Ibeneche W, Ibeneme S, Agbasi OE, and Okechukwu S. Enhance Groundwater Quality Assessment Using Integrated Vertical Electrical Sounding and Physio-Chemical Analyses in Umuahia South, Nigeria. *International Journal of Energy and Water Resources*. 2022; **9**: 133-144. DOI: http://dx.doi.org/10.1007/s42108-022-00219-8.

[2] Akaolisa CCZ, Agbasi OE, Okeke OC, and Okechukwu S. An Assessment of The Groundwater Potentials of The Farm with Preliminary Geophysical Method and Grain Size Analysis Prior to The Drilling of Boreholes. *HydroResearch*, 2022; **5**: 85–98. DOI: http://dx.doi.org/10.1016/j.hydres.2022.09.001.

[3] Tiwari AK, Raffaella GM, and Muriel L. Evaluation of Hydrogeochemical Processes and Groundwater Quality for Suitability of Drinking and Irrigation Purposes: A Case Study in The Aosta Valley Region, Italy. *Arabian Journal of Geoscience*. 2017; **10**: 264. DOI: https://doi.org/10.1007/s12517-017-3031-z.

[4] Akakuru OC and Akudinobi BEB. Determination of Water Quality Index and Irrigation Suitability of Groundwater Sources in Parts of Coastal Aquifers of Eastern Niger Delta, Nigeria. *International Journal of Applied and Natural Sciences (IJANS)*, 2018; **7**(1): 1-6. Available from: https://ssrn.com/abstract=3130011.

[5] Adimalla N and Venkatayogi S. Geochemical Characterization and Evaluation of Groundwater Suitability for Domestic and Agricultural Utility in The Semi-Arid Region of Basara, Telangana State, South India. *Applied Water Science*. 2018; **8**(1): 44. DOI: https://doi.org/10.1007/s13201-018-0682-1.

[6] Akakuru OC, Akudinobi BE, Nwankwoala HO, Akakuru OA, and Onyekuru SO. Compendious Evaluation of Groundwater in Parts of Asaba, Nigeria for Agricultural Sustainability. *Geoscience Journal*. 2021; **25**: 915–927. DOI: https://doi.org/10.1007/s12303-021-0010-x.

[7] Sakram G and Adimalla N. Hydrogeochemical Characterization and Assessment of Water Suitability for Drinking and Irrigation in Crystalline Rocks of Mothkur Region, Telangana State, South India. *Applied Water Science*. 2018; **8**: 143. DOI: https://doi.org/10.1007/s13201-018-0787-6.

[8] Raju NJ, Shukla UK, and Ram P. Hydrogeochemistry for The Assessment of Groundwater Quality in Varanasi: A Fast-Urbanizing Center in Uttar Pradesh, India. *Environmental Monitoring Assessment*. 2011; **173**: 279–300. DOI: https://doi.org/10.1007/s10661-010-1387-6.

[9] Mokoena P, Thokozani K, and Jan van Bever D. Hydrogeochemical Characteristics and Evaluation of Groundwater Quality for Domestic and Irrigation Purposes: A Case Study of the Heuningnes Catchment, Western Cape Province, South Africa. *SN Applied Sciences*. 2020; **2**: 1548. DOI: https://doi.org/10.1007/s42452-020-03339-0.

[10] Egbueri JC. Evaluation and Characterization of The Groundwater Quality and Hydrogeochemistry of Ogbaru Farming District in Southeastern Nigeria. *SN Applied Sciences*. 2019; **1**: 851. DOI: https://doi.org/10.1007/s42452-019-0853-1.

[11] Akakuru OC, Akudinobi BEB, and Usman AO. Organic and Heavy Metal Assessment of Groundwater Sources Around Nigeria National Petroleum Corporation Oil Depot Aba, South-Eastern Nigeria. *Journal of Natural Sciences Research*. 2017; **7**(24): 48-58. Available from: https://iiste.org/Journals/index.php/JNSR/article/view/40118.

[12] Todd DK. *Groundwater hydrology*. 2nd eds. New York: Wiley; 1980.

[13] Eyankware MO, Obasi PN, Omo-Irabor OO, and Akakuru OC. Hydrochemical Characterization of an Abandoned Quarry and Mine Water for Domestic and Irrigation Uses in Abakaliki, Southeast Nigeria. Model. Earth System and Environment. 2020; 6: 2465-2485. DOI: https://doi.org/10.1007/s40808-020-00827-5.

[14] Ahmad A., Mohammad AA, Majeda K, and Nabil Z. Hydrogeochemical Characterization and Quality Evaluation of Groundwater Suitability for Domestic and Agricultural Uses in The State of Qatar. *Groundwater for Sustainable Development*. 2020; **11**: 100467. DOI: https://doi.org/10.1016/j.gsd.2020.100467.

[15] Moussa AB, Sawsan C, Houcem M, Sarra BH, Salem, HE, Kamel Z, Amor H, and Habib M. Hydrogeochemistry and Evaluation of Groundwater Suitability for Irrigation Purpose in the Mornag Region, Northeastern Tunisia. *Environment, Development and Sustainability*. 2020; **23**: 2698-2718. DOI: https://doi.org/10.1007/s10668-020-00696-z.

[16] Onyeanuna C, Chukwuemeka PJ, and Nwankwo T. Geochemical Characterization and Assessment of Groundwater Quality in Owerri Metropolis, South-Eastern Nigeria. *Journal of Geography, Environment and Earth Science International*. 2019; **19**(1): 1-24. DOI: https://doi.org/10.9734/JGEESI/2019/32939.

[17] Ejiogu BC, Opara AI, Nwosu EI, Nwofor OK, Onyema JC, and Chinaka JC. Estimates of Aquifer Geohydraulic and Vulnerability Characteristics of Imo State and Environs, Southeastern Nigeria, Using Electrical Conductivity Data. *Environmental Monitoring and Assessment*. 2019; **191**(4): 238. DOI: https://doi.org/10.1007/s10661-019-7335-1.

[18] Ibe FC, Opara AI, and Ibe BO. Application of Pollution Risk Evaluation Models in Groundwater Systems in The Vicinity of Automobile Scrap Markets in Owerri Municipal and Environs, Southeastern Nigeria. *Scientific African*. 2020; **8**: e00450. DOI: https://doi.org/10.1016/j.sciaf.2020.e00450.

[19] Urom OO, Opara AI, Usen OS, Akiang FB, Isreal HO, Ibezim JO, and Akakuru OC. Electro-Geohydraulic Estimation of Shallow Aquifers of Owerri and Environs, Southeastern Nigeria Using Multiple Empirical Resistivity Equations. *International Journal*

of Energy, Water and Resources. 2021; **6**: 15-36. DOI: https://doi.org/10.1007/s42108-021-00122-8.

[20] Akakuru OC, Maduka EC, and Akakuru OU. Hydrogeochemical Characterization of Surface Water Sources in Owerri Capital Territory, Southeastern Nigeria. *IOSR Journal of Applied Geology and Geophysics*. 2013; **1**(2): 0123238. Available from: https://iosrjournals.org/iosr-jagg/papers/vol1-issue2/E0123238.pdf.

[21] Udoh EJ and Etim NA. Analysis of Domestic Water Consumption Pattern by Farming Households in Itu, Akwa Ibom State, Nigeria. *European Journal of Social Sciences*. 2007; **5**(2): 76–82. Available from: https://www.europeanjournalofsocialsciences.com/issues/ejss_5_2.html.

[22] APHA. *Standard Methods for Examination of Water and Wastewater*. Washington DC: APHA Press; 1998.

[23] WHO. *Guidelines for Drinking Water Quality*. Switzerland: Stanford Geneva; 2017.

[24] Gopinath SK, Srinivasamoorthy K, Saravanan RP, and Karunanidhi D. Characterizing Groundwater Quality and Seawater Intrusion in Coastal Aquifers of Nagapattinam and Karaikal, South India Using Hydrogeochemistry and Modeling Techniques. *Human and Ecological Risk Assessment*. 2019; **25**: 314-344. DOI: https://doi.org/10.1080/10807039.2019.1578947.

[25] Sakram G, Sundaraiah R, and Vishnu RS. The Impact of Agricultural Activity on The Chemical Quality of Groundwater, Karanja Vagu Watershed, Medak District. *Andhra Pradesh International Journal of Advance Science Technology and Research*. 2013; **6**(3): 769-786.

[26] Saha S, Selim R, and Mrinal KR. Hydrochemical Evaluation of Groundwater Quality of The Tista Floodplain, Rangpur, Bangladesh. *Applied Water Science*, 2019; **9**: 198. DOI: https://doi.org/10.1007/s13201-019-1085-7.

[27] Krishan G, Sejwal P, Bhagwat A, Prasad G, Yadav BK, Kumar CP, . . . Muste M. Role of Ion Chemistry and Hydro-Geochemical Processes in Aquifer Salinization—A Case Study from a Semi-Arid Region of Haryana, India. *Water*. 2021; **13**(5): 617. DOI: https://doi.org/10.3390/w13050617.

[28] Ben-Brahim F, Boughariou, E, and Bouri S. Multicriteria-Analysis of Deep Groundwater Quality Using WQI and Fuzzy Logic Tool in GIS: A Case Study of Kebilli region, SW Tunisia. *Journal of African Earth Sciences*. 2021; **180**: 104224. DOI: https://doi.org/10.1016/j.jafrearsci.2021.104224.

[29] Gao Y, Qian H, Ren W, Wang H, Liu F, and Yang F. Hydrogeochemical Characterization and Quality Assessment of Groundwater Based on Integrated-Weight Water Quality Index in A Concentrated Urban Area. *Journal of Cleaner Production*. 2020; **260**: 121006. DOI: https://doi.org/10.1016/j.jclepro.2020.121006.

[30] Rao NS, Dinakar A, Sravanthi M, and Kumari BK. Geochemical characteristics and quality of groundwater evaluation for drinking, irrigation, and industrial purposes from a part of hard rock aquifer of South India. *Environmental Science and Pollution Research*. 2021; **28**(24): 31941–31961. DOI: https://doi.org/10.1007/s11356-021-12404-z.

Cek ID 31091

ORIGINALITY REPORT

13%	10%	13%	0%
SIMILARITY INDEX	INTERNET SOURCES	PUBLICATIONS	STUDENT PAPERS

MATCH ALL SOURCES (ONLY SELECTED SOURCE PRINTED)

9%

★ Odunayo Tope Ojo, Chiaka Joy Ike, Adegoke Ige Aladeboyeje, Olayiwola Grace Olaseeni, Olumuyiwa Femi Adewumi. "Hydrochemical assessment of borehole water in Effurun, Delta state Niger Delta, Nigeria: implications for public health and safety", Discover Geoscience, 2025

Publication

Exclude quotes	On	Exclude matches	< 1%
Exclude bibliography	On		

Cek ID 31091

GRADEMARK REPORT

FINAL GRADE

/100

GENERAL COMMENTS

PAGE 1

PAGE 2

PAGE 3

PAGE 4

PAGE 5

PAGE 6

PAGE 7

PAGE 8

PAGE 9

PAGE 10

PAGE 11

PAGE 12

PAGE 13

PAGE 14

PAGE 15

PAGE 16

PAGE 17

PAGE 18

PAGE 19