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COMPARATIVE STUDY OF RIVER WATER AND GROUNDWATER QUALITY IN OZEZEBIRI, SOUTHERN-IJAW LOCAL GOVERNMENT AREA, BAYELSA STATE, NIGERIA.

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ABSTRACT

This study focuses on the comparative assessment of river water and groundwater quality in Ozezebiri, Southern Ijaw L.G.A., Bayelsa State, Nigeria. The aim was to evaluate the suitability of these water sources for domestic and irrigation use by determining physicochemical parameters and heavy metal content, and assessing water quality indices (SAR, MAR, KR, Na%). Total of three water samples were collected from river (dry and rainy seasons) and groundwater sources, analyzed for pH, NO_3^-, SO_4^{2-}, Cl^-, CO_3^{2-}, HCO_3^-, Na^+, Ca^{2+}, Mg^{2+}, K^+, and Fe concentration using APHA and ASTM methods, including in-situ pH testing and laboratory techniques like titration and atomic absorption spectrophotometry. All samples showed acidic pH (4.38–5.94), below WHO (6.5–8.5) and NSDWQ standards. Groundwater had high chloride (148 mg/L), rainy-season river water had elevated iron (0.42 mg/L) and sulfate (68.3 mg/L), while dry-season river water was less contaminated but still acidic. Irrigation indices showed low SAR (0.43–0.70) and KR (0.13–0.55), but high MAR (26–35%). The acidity likely stems from gas flaring and runoff, while high chloride and iron concentration indicates saltwater intrusion and pollution from oil activities. Low SAR and KR indicate irrigation suitability, but high MAR may harm soil over time, reflecting the region’s environmental challenges. The water sources in the study area are unsuitable for drinking without treatment due to acidity and contamination, with irrigation potential limited by magnesium hazards, necessitating urgent intervention.

KEYWORDS: Groundwater, River-water, Physicochemical-parameters, heavy-metals comparative-analysis, ozezebiri, southern-ijaw.

INTRODUCTION

Water is the foundation of life and economic vitality, essential for drinking, farming, fishing, and sustaining communities globally (Johnson et al., 1997). In the Niger Delta, particularly Ozezebiri, Southern-Ijaw L.G.A., Bayelsa State, Nigeria, river and groundwater are lifelines for a population dependent on agriculture and fishing for survival. However, these resources face severe threats from environmental degradation due to decades of oil exploration, gas flaring, and agricultural runoff (Nwankwoala & Ngah, 2014; Shaibu & Victor, 2023). This pollution introduces heavy metals, hydrocarbons, and acidic compounds, posing risks to public health, local livelihoods, and fragile wetland ecosystems (Ohimain & Angaye, 2014).

In Ozezebiri, the impact is profound where oil spills and gas flaring have contaminated surface and groundwater, while seasonal runoff worsens pollution by carrying contaminants into rivers (Ogherohwo et al., 2016). With limited access to purification systems, the community relies on untreated water, increasing exposure to health hazards (Amadi et al., 2012).

This degradation of water quality indices threatens food security by impairing soil fertility and crop yields (Paliwal, 1972) and hinders economic growth by deterring tourism and development (Adeoye et al., 2015).

Water quality in Nigeria, especially in the Niger Delta, is threatened by pollution and seasonal variability, with limited studies addressing Ozezebiri specific conditions (Adeoye et al., 2015). Oil-related activities and poor sanitation have degraded water sources, posing health risks like cholera and heavy metal exposure. This study fills the gap by analyzing seasonal water quality against WHO and NSDWQ standards to inform mitigation strategies.

The aim of this study is to conduct a comparative study of river water and groundwater quality in Ozezebiri, Southern Ijaw L.G.A., Bayelsa State, Nigeria, by evaluating physicochemical parameters for domestic use suitability and assess water quality indices (SAR, MAR, KR, Na%) for irrigation suitability. This research offers critical insights into water quality challenges in Ozezebiri, identifying health risks from acidity and contaminants. It supports decision-making for treatment and monitoring, benefiting local communities and policymakers in the Niger Delta.

Geology of the Study Area

Ozezebiri community is located in Southern Ijaw LGA, Bayelsa State, Nigeria, between latitude 6°11'35"N to 6°12'32"N and longitude 4°46'48"E to 4°47'45"E, at an elevation of approximately 10m above mean sea level, within the Niger Delta wetlands. The area has a tropical climate with a dry season (October-March) and a rainy season (April-September), receiving 2000-3000mm of rainfall annually, with temperatures of 25-30°C and high humidity (80-90%). Vegetation is dense rainforest, though degraded by oil activities and development.

Ozezebiri in Southern-Ijaw L. G. A., lies within the Niger Delta sedimentary basin, formed by sediment deposition from the River Niger since the Miocene (figure 2.1). This basin comprises three main Formations; the Benin Formation (composed of coarse sands, up to 2100m thick, hosting aquifer), the Akata Formation (interbedded sands and shales, 0-1500m thick, acting as hydrocarbon reservoir), and the Agbada Formation (marine shales, 0-200m, acting as source rock). The coastal setting of Southern Ijaw exposes aquifers to saltwater intrusions and oil pollution, influencing groundwater quality and flow. These geological features combined, shape the Hydrochemical characteristic observed in the region (Abam, 1999).

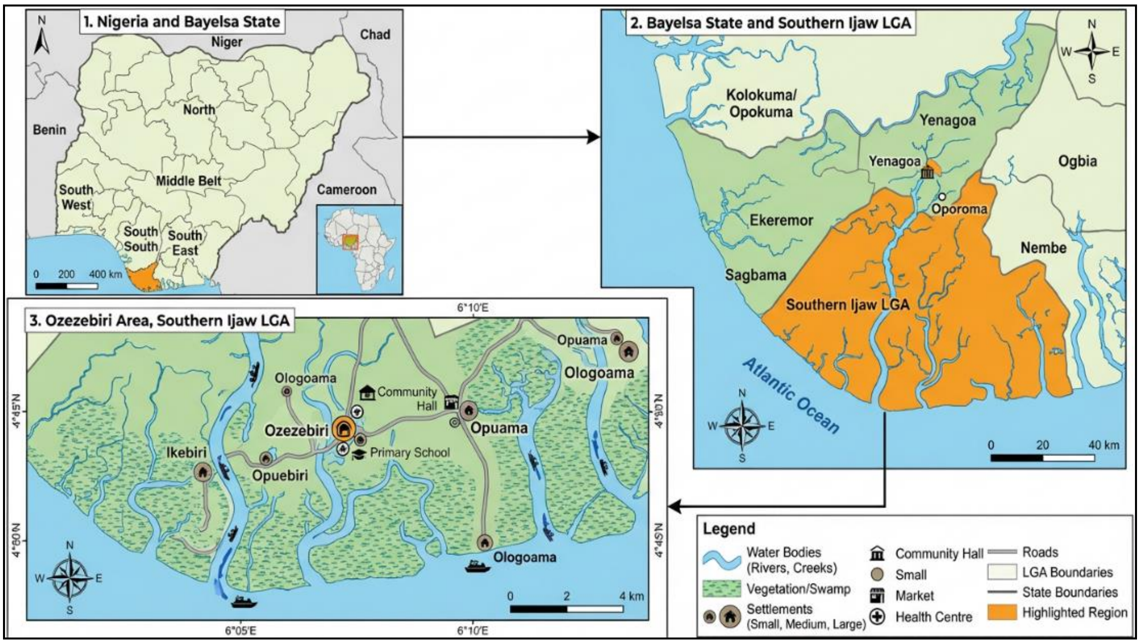

Figure 1: Geographic location Map Showing Ozezebiri, Southern-Ijaw L. G. A., Bayelsa State, Nigeria.

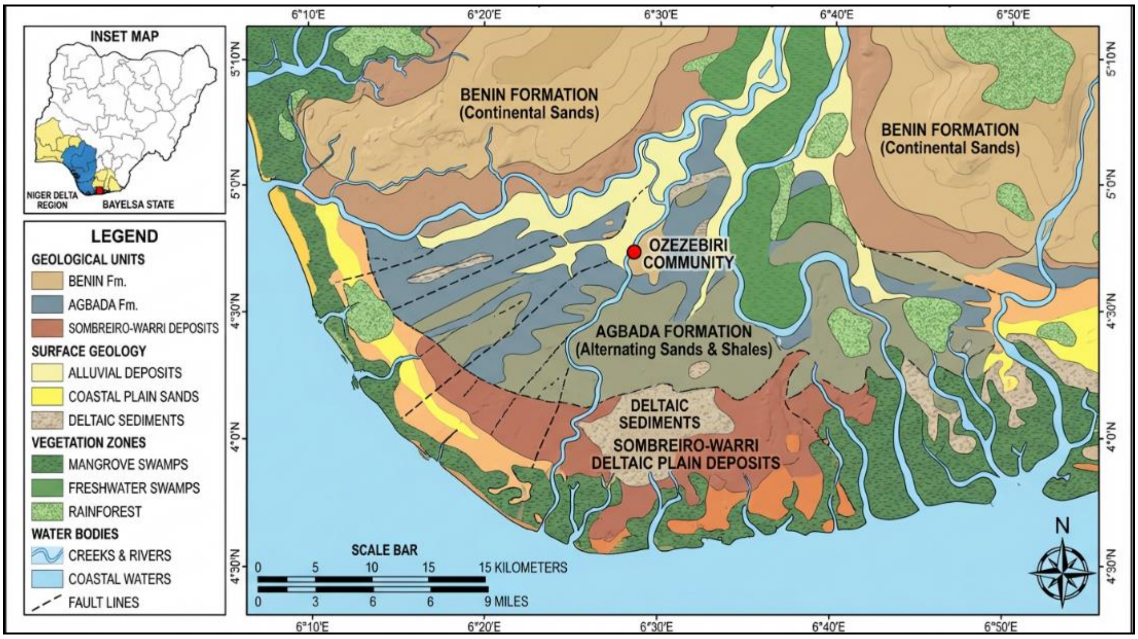

Figure 2: Geologic Map of the Study Area.

MATERIALS AND METHODS

This studies make use of three water samples collected from the study area (one from dry season river water, one from rainy season river, and one from borehole groundwater). The three water samples were analyzed for pH, Ca^{2+}, Mg^{2+}, Na^{+}, K^{+}, Cl^{-}, HCO_3^{-}, SO_4^{2-}, NO_3^{-}, CO_3^{2-}, and Fe^{2+} using standard methods. pH level of the water samples was analyzed in-situ with a portable multifunctional water tester (APHA 4500B). Laboratory analyses included titration for HCO_3^{-} and CO_3^{2-} (APHA 2320), the brucine method for NO_3^{-} (APHA 4500-NO3-B), Mohr's method for Cl^{-} (ASTM-D512), turbidimetric analysis for SO_4^{2-} (ASTM-D516), and Atomic Absorption Spectrophotometry for cations and Fe^{2+} (ASTM D511) see table 1.

Table 1: Equipment and analytical methods used.

Parameter	Unit	Type of Test	Equipment/ Analytical Method	Standard
pH		In-situ	Water quality tester	APHA 4500B
HCO_3^-	Mg/L	Laboratory	Colorimetric Method	APHA 2320
CO_3^{2-}	Mg/L	Laboratory	Colorimetric Method	APHA 2320
NO_3^-	Mg/L	Laboratory	Brucine Method	APHA 4500-NO3-B
Cl^-	Mg/L	Laboratory	Modified Moher's Method	ASTM-D512
SO_4^{2-}	Mg/L	Laboratory	Spectrophotometer	ASTM-D516
Na^+	Mg/L	Laboratory	Atomic Absorption Spectrophotometer (AAS)	ASTM D511
Ca^{2+}	Mg/L	Laboratory	Atomic Absorption Spectrophotometer (AAS)	ASTM D511
K^+	Mg/L	Laboratory	Atomic Absorption Spectrophotometer (AAS)	ASTM D511
Mg^{2+}	Mg/L	Laboratory	Atomic Absorption Spectrophotometer (AAS)	ASTM D511
Fe^{2+}	Mg/L	Laboratory	Atomic Absorption Spectrophotometer (AAS)	ASTM D511

Water quality indices such as; Kelly's ratio (KR), sodium absorption ratio (SAR), sodium percentage (Na %), and magnesium absorption ratio (MAR) were calculated to determine the groundwater suitability for agriculture and irrigation purposes using Richards, (1954) equation for sodium absorption ratio (see equation 1), palival, (1972) equation for magnesium absorption ratio (see equation 2), Kelly, (1940) equation for Kelly's ratio (see equation 3), and Wilcox, (1955) equation for sodium absorption percentage (see equation 4). All parameters were converted to Meq/L before calculations and classified the water quality for irrigation using classification scheme for water quality indicators (see table 1).

Sodium Absorption Ratio; $\boldsymbol{SAR} = \frac{Na^+}{\sqrt{\frac{Ca^{2+}+Mg^{2+}}{2}}}$ Richards, (1954) ……………...equation 1

Magnesium Absorption; **MAR**=$\left(\frac{Mg^{2+}}{Mg^{2+}+Ca^{2+}}\right) \times \mathbf{100}$ Palival, (1972) …..……….equation 2

Kelly's Ratio**; KR**=$\frac{Na^+}{(Mg^{2+}+Ca^{2+})}$ Kelly, (1940) …………………………..……..equation 3

Sodium Percentage**; Na%**=$\frac{Na^++K^+}{(Mg^{2+}+Ca^{2+}+Na^++K^+)} \times \mathbf{100}$ Wilcox, (1955) ……….equation 4

RESULTS AND DISCUSSION

The results of physicochemical and heavy metal content in river water and groundwater samples from the study area are presented in Table 2, individual parameters analyzed are presented in figure 4.1a to figure 3 to compare the concentration of the physicochemical and heavy metals in the various samples, while results of univariate statistical analysis are presented in Table 4.2 and compared with both World Health Organization (WHO, 2011) and Nigerian Standard for Drinking Water Quality (NSDWQ, 2007). Graphical presentation of pH and average physicochemical parameters along with WHO guidelines are presented in Figure 4.1 and figure 4.2. Results of water quality indices are presented in table 4.3.

Table 2: Result of the physicochemical and heavy metal Analysis of the Water Samples.

S/No.	Parameter.	Unit.	River Water (dry season)	River Water (Rainy Season)	Ground Water
1	pH		5.85	4.38	5.94
2	NO_3^-	Mg/L	1.21	12.87	1.97
3	SO_4^{-2}	Mg/L	3.96	68.3	1.68
4	Cl^-	Mg/L	12	283	148
5	CO_{3-2}	Mg/L	0	0	0
6	HCO_3^-	Mg/L	0	0	0
7	Na^+	Mg/L	6.11	17.15	13.81
8	Ca^{2+}	Mg/L	7.19	104.2	19.16
9	Mg^{2+}	Mg/L	1.54	8.53	6.27
10	K^+	Mg/L	1.96	26.47	13.81
11	Fe	Mg/L	0.054	0.42	0.01

Table 3 Statistical analysis compared with WHO (2011) and NSDWQ. (2007)

Parameter	Unit	Min	Max	Mean	S.D.	W.H.O. (2011)	NSDWQ (2007)
pH		4.38	5.94	5.39	0.87	6.5-8.5	6.5-8.5
NO_3^-	Mg/L	1.21	12.87	5.35	6.52	50	500
SO_4^{-2}	Mg/L	1.68	68.3	24.65	37.82	500	100
Cl^-	Mg/L	12	283	147.67	135.5	250	250
CO_3^{-2}	Mg/L	0	0	0	0	NA	NA
HCO_3^-	Mg/L	0	0	0	0	NA	NA
Na^+	Mg/L	6.11	17.15	12.36	5.66	200	200
Ca^{2+}	Mg/L	7.19	104.2	43.52	52.89	75	75
Mg^{2+}	Mg/L	1.54	8.53	5.45	3.57	50	30
K^+	Mg/L	1.96	26.47	14.08	12.26	200	200
Fe	Mg/L	0.01	0.42	0.2	0.22	0.3	0.3

Table 4 Results of water quality indicators in the study area.

S/No.	Parameter and Units.	River Water (Dry Season)	River Water (Rainy Season)	Groundwater
1	Sodium Absorption Ratio SAR (Ratio)	0.54	0.43	0.7
2	Magnesium Absorption Ratio MAR (%)	26.1	11.93	35.01
3	Sodium Percentage Na% (%)	39.4	19.4	39.3
4	Kelly's Ratio KR (Ratio)	0.55	0.13	0.41

Table 5: classification scheme for water quality indicators in the area.

S/N	Classification Scheme	Category	Range (mg/L)	River -Water (Dry Season)	River-Water (Rainy Season)	Groundwater
1	Sodium Absorption Ratio (SAR) modified after Richards, 1954	Excellent	<10	0.54	0.43	0.7
		Good	18-Oct			
		Fair	>18-26			
		Poor	>26			
		Hard	>200-300			
		Very Hard	>300			
2	Magnesium Absorption Ratio (MAR) modified after Palival, 1972	Excellent	Up to 20		11.87	
		Good	>20-40	26.06		35.01
		Permissible	>40-60			
		Doubtful	>60-80			
		Unsuitable	>80			
3	Sodium Percentage (Na%) modified after Wilcox, 1955	Acceptable	<50	39.37	19.42	39.3
		Unacceptable	>50			
4	Kelly's Ratio KR (Kelly, 1940)	Suitable	<1	0.55	0.13	0.41
		Unsuitable	>1			

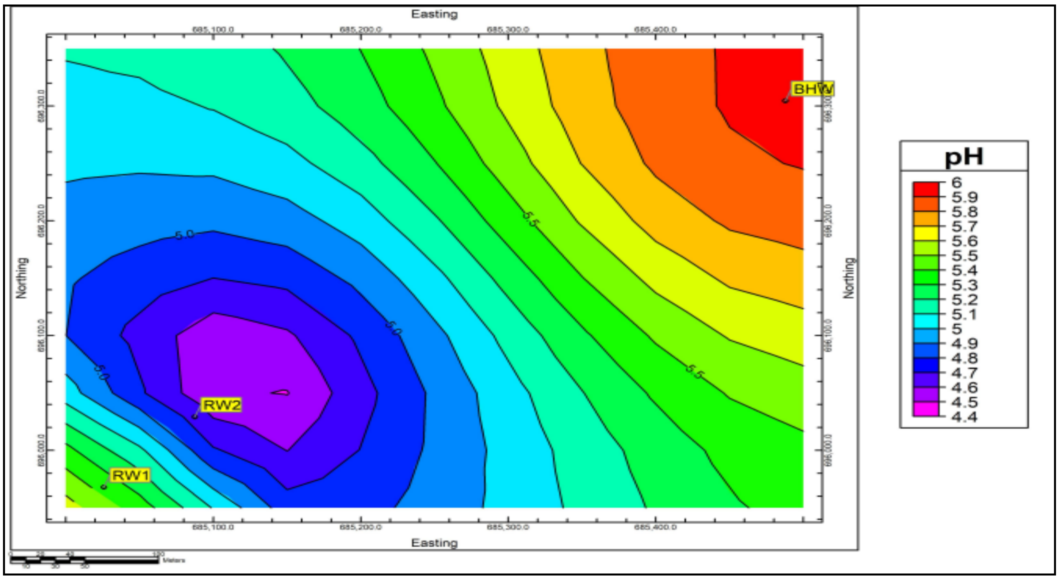

Figure 3: Comparative Analysis of pH concentration of the water samples in the study area.

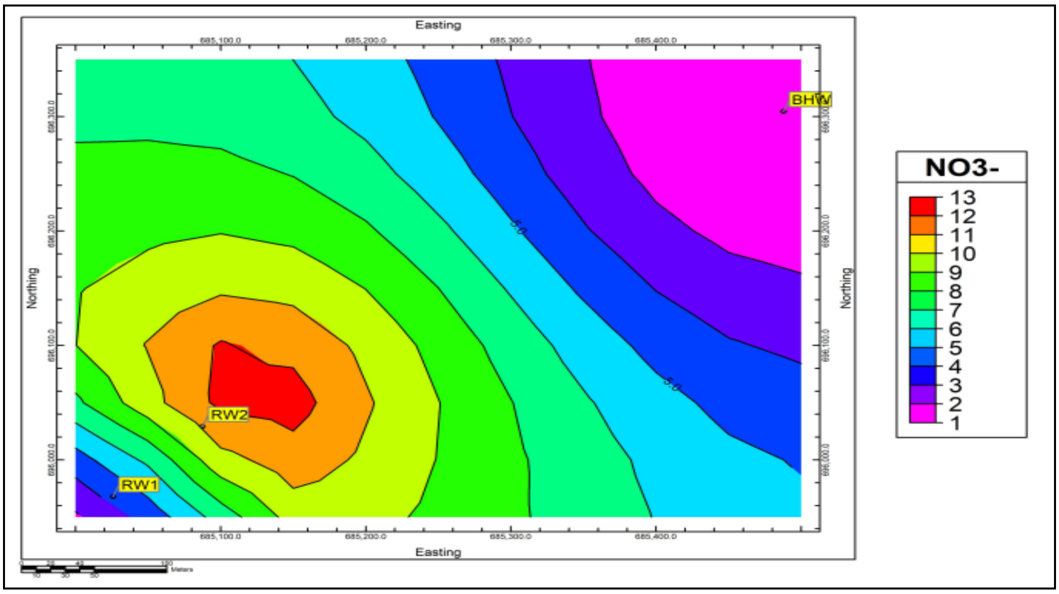

Figure 4: Comparative Analysis of NO_3^- concentration of the water samples in the study area.

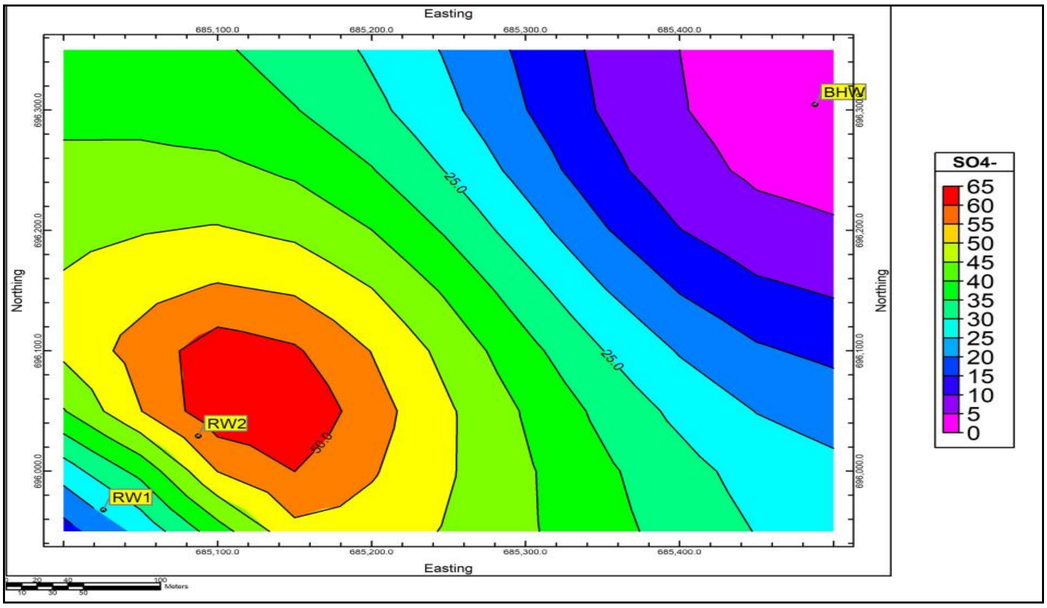

Figure 5: Comparative Analysis of SO_4^{2+} concentration of the water samples in the study area.

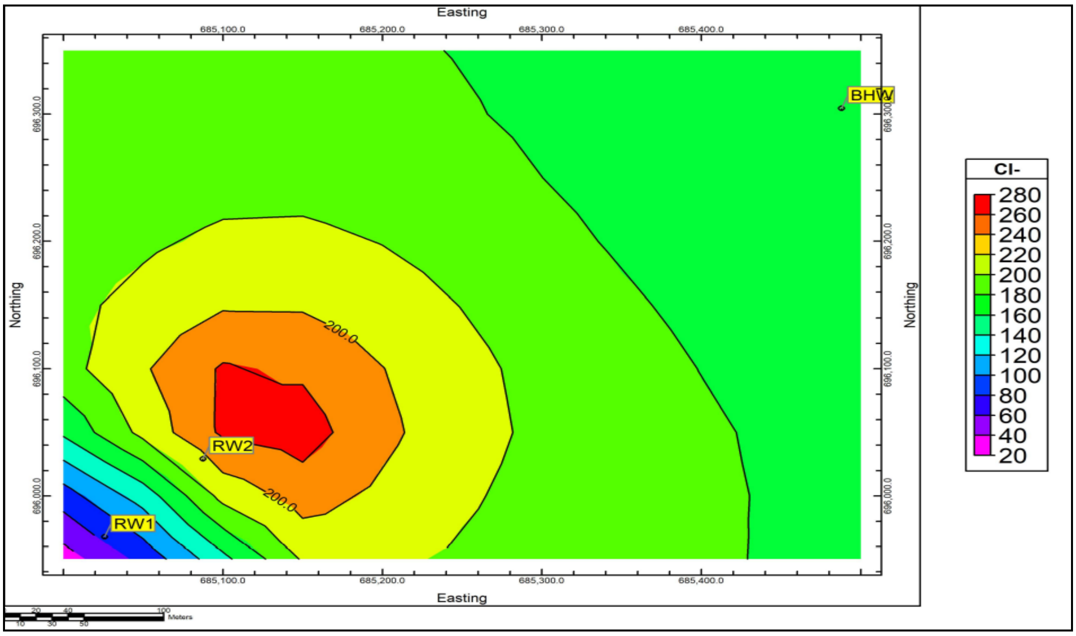

Figure 6: Comparative Analysis of Cl^- concentration of the water samples in the study area.

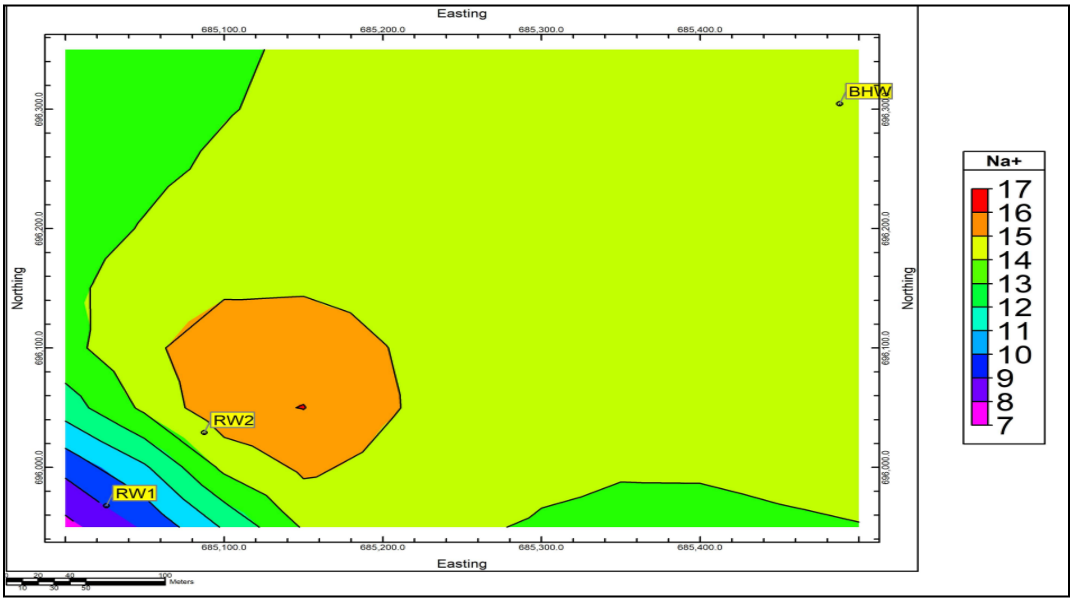

Figure 7: Comparative Analysis of Na^+ concentration of the water samples in the study area.

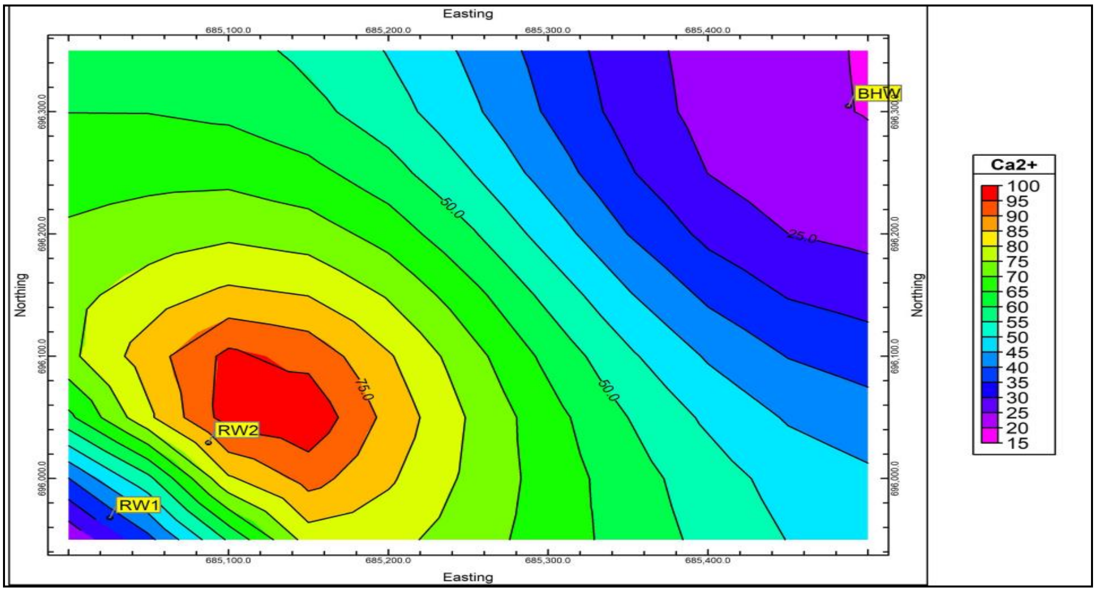

Figure 8: Comparative Analysis of Ca^{+} concentration of the water samples in the study area.

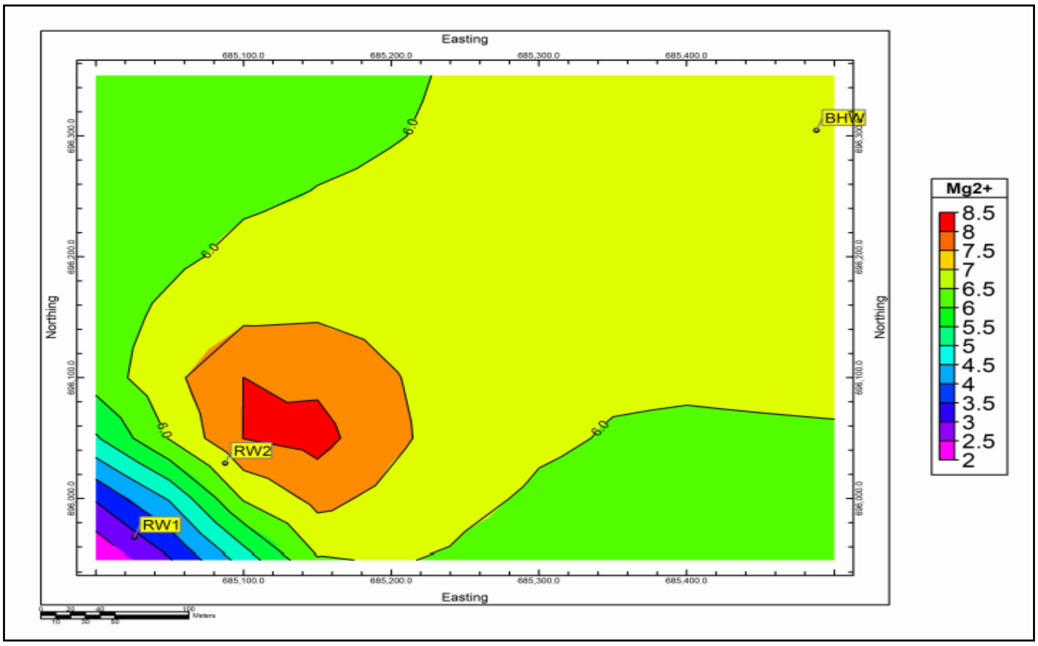

Figure 9: Comparative Analysis of Mg^{2+} concentration of the water samples in the study area.

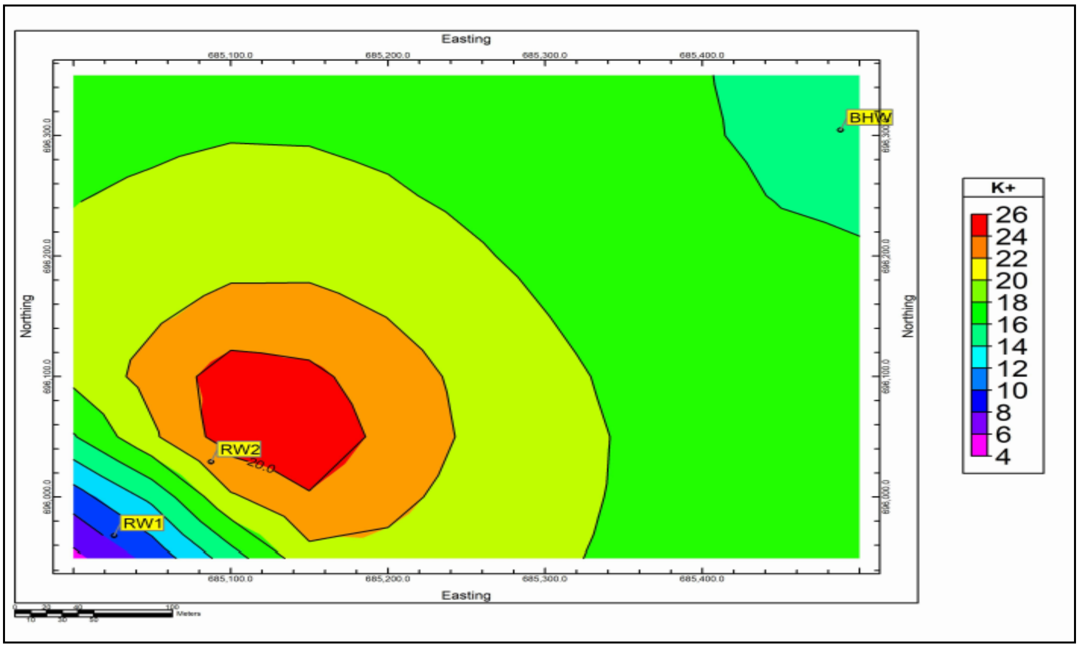

Figure 10: Comparative Analysis of K^+ concentration of the water samples in the study area.

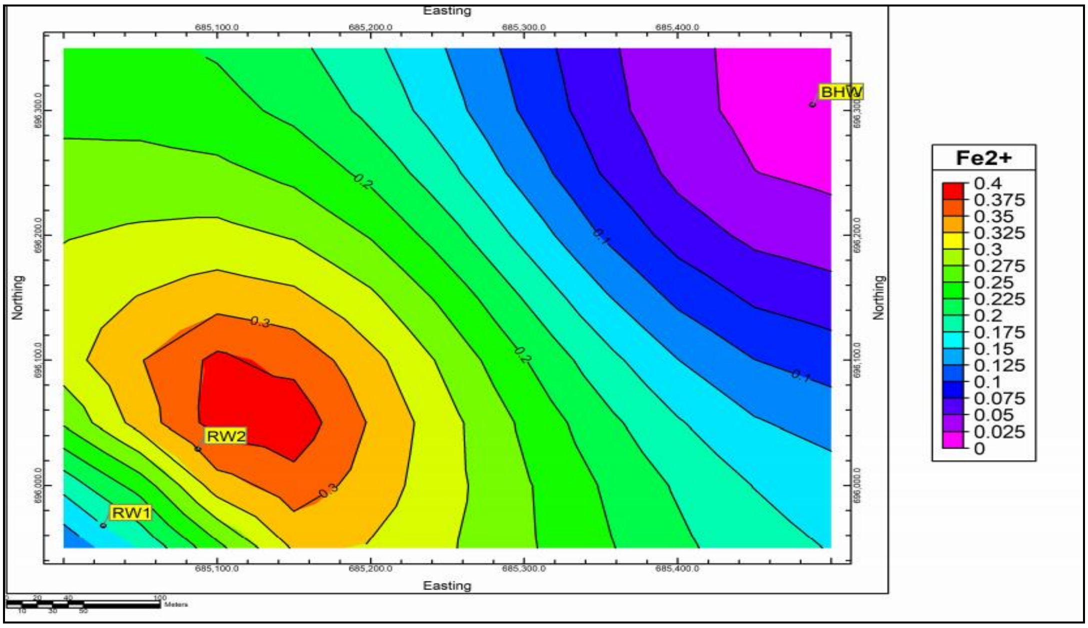

Figure 11: Comparative Analysis of Fe^{2+} concentration of the water samples in the study area

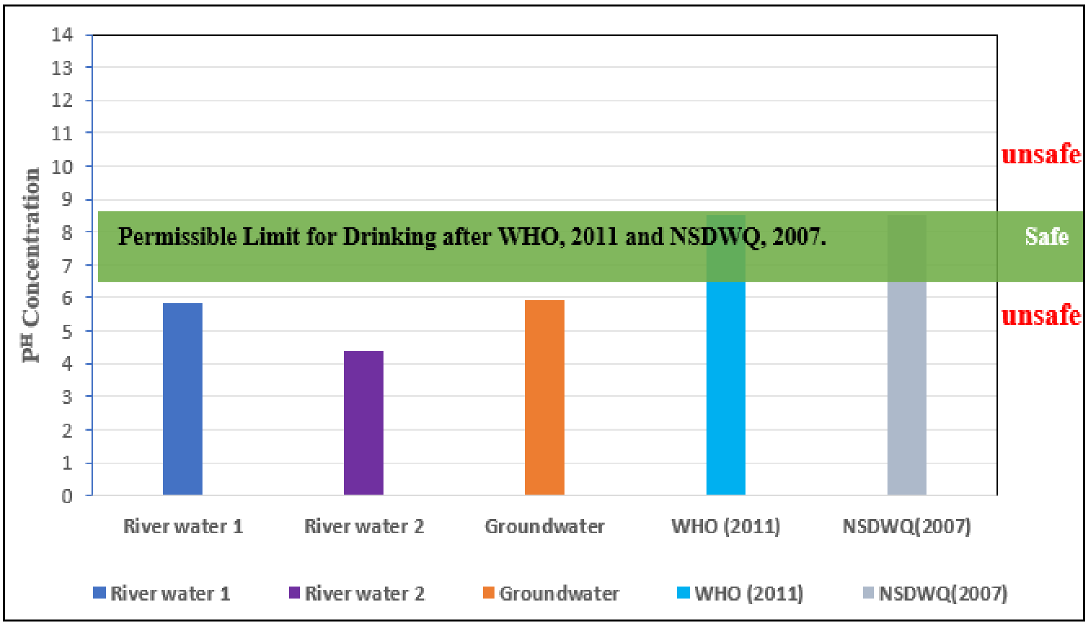

Figure 12: Comparative Analysis of pH concentration of the water samples in the study area with WHO and NSDWQ Limits.

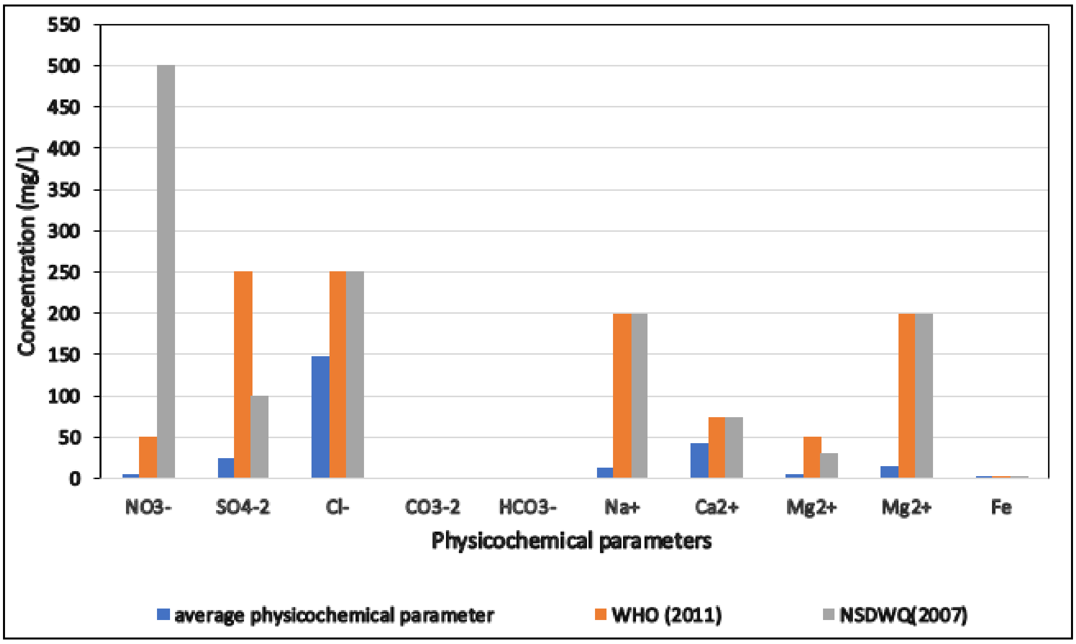

Figure 13: Average physicochemical parameters compared with WHO and NSDWQ Guidelines.

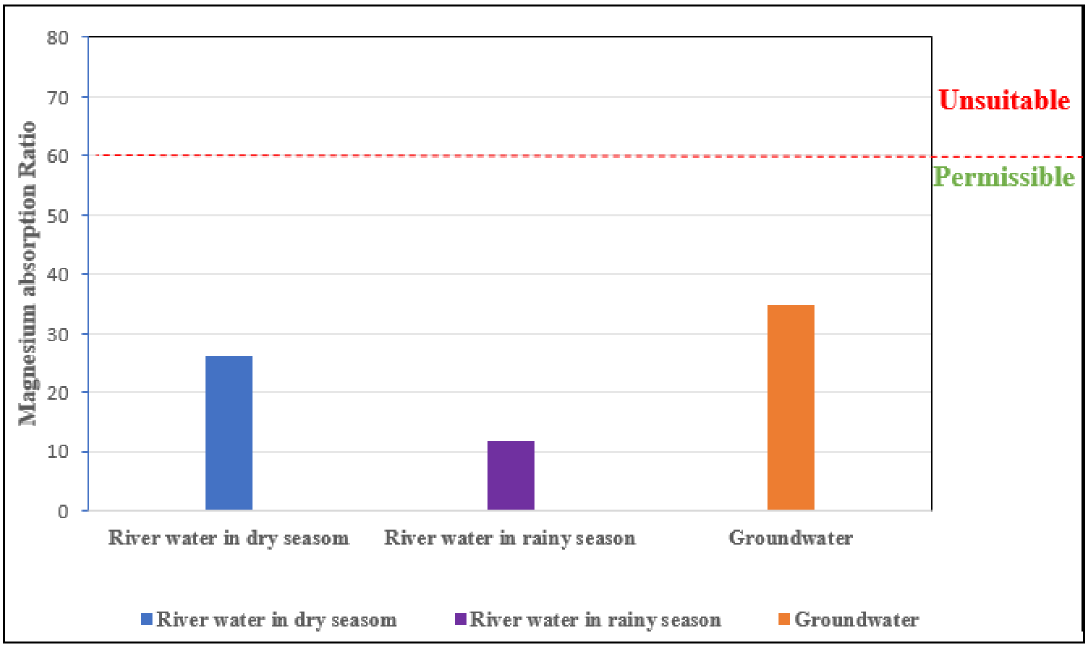

Figure 14: Magnesium Absorption Ratio in the three water sources (Palival, 1972).

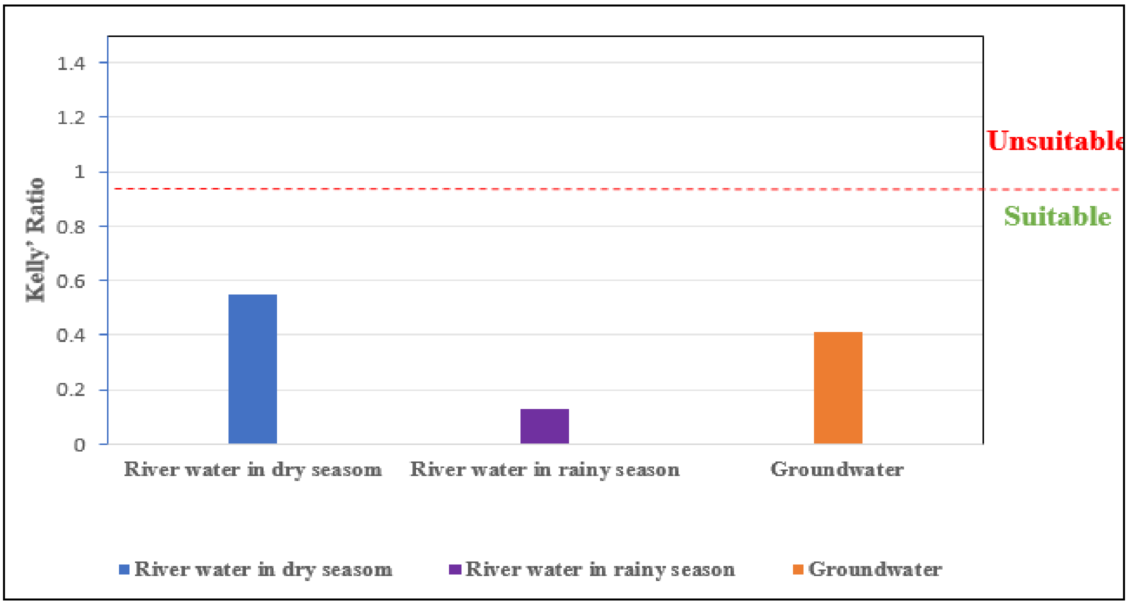

Figure 15: Kelly's Ratio in the three water samples using Kelly, (1940) Classification Model.

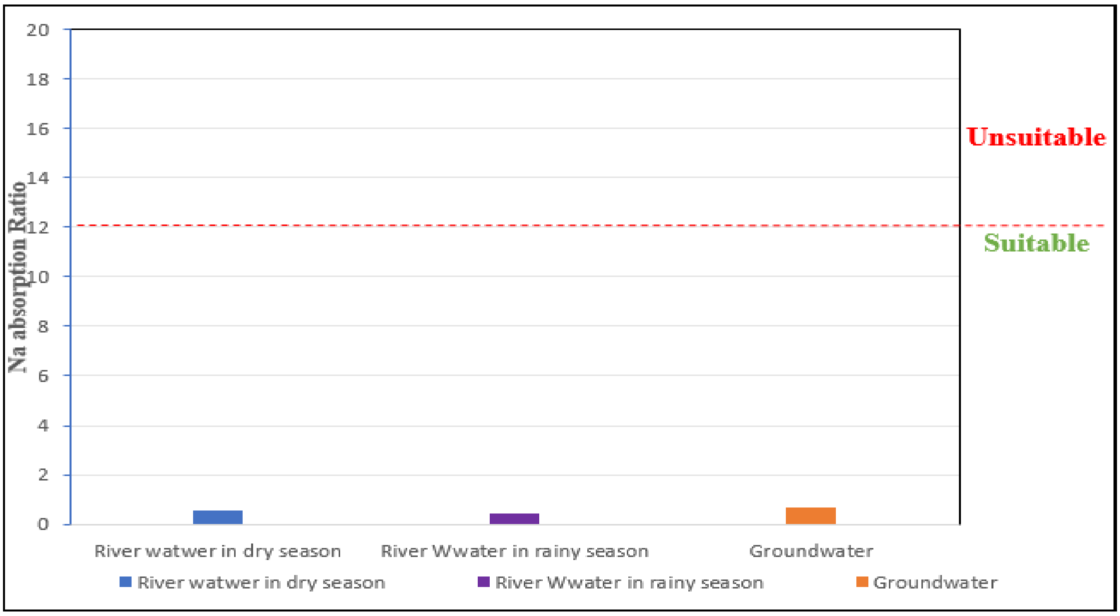

Figure 16: Sodium Absorption Ratio of the water samples using Richards, (1954) classification model.

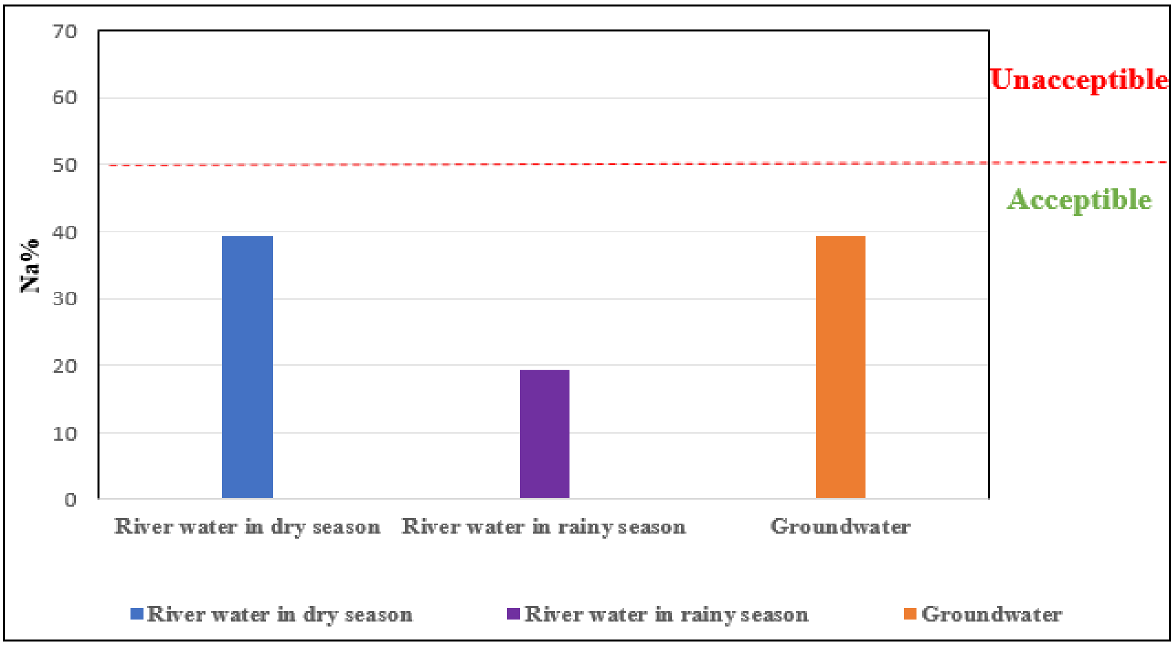

Figure 17: Sodium percentage (Na%) using Wilcox, 1955 classification model.

All samples exhibit acidic pH level of 4.38–5.94, which is below the WHO (2011) and NSDWQ (2007) permissible level of 6.5–8.5 (see table 2 & 3, figure 3 & 12). This acidity poses risks of corrosion in plumbing systems, leaching metals like lead, and reducing disinfection efficacy, making the water unsuitable for direct consumption without neutralization (e.g., lime addition). The lowest pH in rainy-season river water at 4.38 likely results from increased runoff introducing organic acids and atmospheric deposition. In the

Niger Delta, such acidity is commonly linked to acid rain caused by gas flaring from oil and gas activities, which releases SO_x and NO_x precursors that form sulfuric and nitric acids (Ogherohwo et al., 2016). Groundwater pH level at 5.94 is slightly higher, suggesting partial buffering through subsurface filtration, but still indicates regional geogenic influences like low-carbonate soils.

Chloride levels (see table 2 & 3, figure 6 & 13) are elevated in groundwater (148 mg/L) and rainy-season river water (283 mg/L), with the latter exceeding the WHO aesthetic limit of 250 mg/L, potentially imparting a salty taste and accelerating corrosion. High Cl^- in groundwater may stem from saltwater intrusion, common in coastal Niger Delta areas due to over-extraction or sea-level rise, or from anthropogenic sources like septic leakage (Ayolabi et al., 2013).

Sulfate (SO_4^{2-}) is notably higher in rainy-season river water (68.3 mg/L), possibly from agricultural runoff or industrial effluents, but remains below the 500 mg/L limit. Nitrate (NO_3^-) peaks in rainy-season river (12.87 mg/L), below the 50 mg/L health limit but indicative of fertilizer leaching during monsoons (see table 2 & 3, figure 5 & 13).

Absence of CO_3^{2-} and HCO_3^- across the water samples reflects negligible alkalinity, exacerbating acidity and vulnerability to pH shifts (see table 2 & 3, and figure 13). Cations (Na^+, Ca^{2+}, Mg^{2+}, K^+) are within permissible limits but show seasonal enrichment in river water, likely from mineral weathering intensified by rainfall (see table 2 & 3, figure 7, 8, 9, 10, & 13). Overall, these patterns highlight greater contamination in river water during wet seasons, consistent with studies in Bayelsa showing runoff-driven pollution (Ayibawari et al., 2017).

Iron (Fe) concentration is highest in rainy-season river water (0.42 mg/L), surpassing the WHO and NSDWQ aesthetic guideline of 0.3 mg/L, which could cause reddish discoloration, metallic taste, and staining (see table 2 & 3, figure 11 & 13). This elevation is attributable to sediment resuspension and runoff from iron-rich lateritic soils prevalent in the Niger Delta, mobilizing Fe concentration during high-flow periods (Nwankwoala et al., 2016). Lower Fe concentration in dry-season river (0.054 mg/L) and groundwater (0.01 mg/L) suggests dilution and natural filtration, respectively (see table 2 and figure 11). While not posing acute health risks at these levels, chronic exposure may lead to hemochromatosis. Comparative studies in the region report similar seasonal Fe spikes in rivers, underscoring the need for filtration (Akiplai & Ogherohwo, 2016).

The suitability of water for irrigation is determined by its effect on soil and plant growth, with key indicators including Sodium Absorption Ratio (SAR), Magnesium Absorption Ratio

(MAR), Sodium Percentage (Na%), and Kelly's Ratio (KR). SAR values are low 0.43–0.70 < 10 (see table 4.3, 4.4 and figure 4.4c), classifying the water sources as excellent for irrigation with no sodium hazard to soil structure (Richards, 1954). MAR is elevated in dry-season river water (26%) and groundwater (35%), exceeding the 50% threshold in some classifications, potentially reducing soil permeability and crop yields by displacing calcium (Paliwal, 1972). Rainy season river MAR (12%) is safer, reflecting diluted Mg^{2+} (see table 4.3, 4.4 and figure4.4a). Na% ranges from 19–39% <60% (see table 4.3, 4.4 and figure 4.4d), indicating permissible quality without alkali risks (Wilcox, 1955). KR values 0.13–0.55 <1 (see table 4.3, 4.4 and figure 4.4b) confirm suitability, as low sodium relative to calcium/magnesium minimizes soil solidity (Kelly, 1940; Sundaray et al., 2009). Overall, the waters are viable for irrigation but require monitoring for MAR-related soil degradation, especially in groundwater-dependent farming.

CONCLUSION

This study compared the quality of river water (dry and rainy seasons) and groundwater in Ozezebiri, Southern Ijaw LGA, Bayelsa State, Nigeria, to assess their suitability for domestic and irrigation use. Water samples were analyzed for pH, nitrate (NO_3^-), sulfate (SO_4^{2-}), chloride (Cl^-), carbonate (CO_3^{2-}), bicarbonate (HCO_3^-), sodium (Na^+), calcium (Ca^{2+}), magnesium (Mg^{2+}), potassium (K^+), and iron (Fe) using APHA and ASTM methods. Results showed acidic pH levels (4.38–5.94), below WHO and NSDWQ standards (6.5–8.5). Groundwater had high chloride (148 mg/L), rainy-season river water showed elevated iron (0.42 mg/L) and sulfate (68.3 mg/L), while dry-season river water was less contaminated but still acidic. Irrigation indices included low Sodium Absorption Ratio (SAR, 0.43–0.70) and Kelly's Ratio (KR, 0.13–0.55), but high Magnesium Absorption Ratio (MAR, 26–35%).

The water sources (river water and ground water) in Ozezebiri are unsuitable for drinking due to acidity and contamination from gas flaring, saltwater intrusion, and runoff. While suitable for irrigation based on SAR and KR, high MAR poses risks to soil health over time. The findings underscore the pervasive impact of oil-related activities and seasonal variations, necessitating urgent action to ensure safe water use.

DECLARATIONS

Ethical Approval: This study did not involve human participants or animal experimentation and therefore did not require formal ethical approval. All procedures involving data handling and analysis were conducted responsibly and in accordance with standard academic and institutional guidelines.

Disclaimer (Artificial Intelligence): Author hereby declare that no generative Artificial Intelligence (AI) technologies such as Large Language Models (ChatGPT, COPILOT, etc.) and text-to-image generators have been used during writing or editing of this manuscript.

Declaration of Conflict of Interest: The author declares that no known conflict of interest or personal relationships that could have influence the work reported in this paper.

Declaration of Data Availability Statement: Data are available upon request from the Author.

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