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Physicochemical and Heavy Concentration of Selected Borehole Water along Pipeline Routes in Parts of Obio/Akpor LGA, Rivers State, Nigeria

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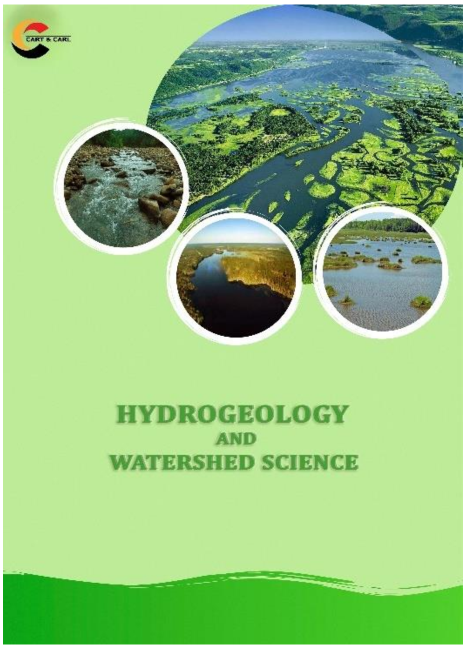

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Abstract

Various anthropogenic activities can influence groundwater quality; therefore, regular water quality monitoring is important to safeguard public health. The study examines the physicochemical and heavy concentration of selected borehole water along pipeline routes in parts of Obio/Akpor Local Government Area, Rivers State, Nigeria. Water samples (15) were sourced from communities (Rumuoke, Rumukania and Egbelu) where decommissioned pipelined pass through and analysed for physicochemical and heavy concentration following the standard methods of the American Public Health Organisation (APHA) and the American Society for Testing and Materials (ASTM). The findings revealed that the pH mean concentration was 5.34 across the study area, and all concentrations reported are within the WHO and NSDWQ allowable limits. The mean concentration of electrical conductivity (107.51 µS/cm), TDS (69.73 mg/l), NO_3^- (0.02 mg/l) and Cl^- (4.52 mg/l) reported are within the WHO and NSDWQ allowable limits. All the reported parameters tested are within the allowable limit standard of WHO; however, various human-related activities that can influence water quality must be closely monitored, and adherence to various environmental guidelines against water pollution is essential.

Keywords : Groundwater, Physicochemical, Heavy Metals, Water Quality, Rivers State

Introduction

Due to rapid industrialisation and increasing human population, the stress on natural resources is growing, and their conservation is one of the significant challenges for mankind (Kaur et al., 2016). Groundwater is a vital resource for millions of people for drinking and irrigation. Groundwater possesses some inherent valuable properties compared with surface water, and compromising these properties has implications for human health (Oladeji, 2011). Also, approximately 97% of the earth's usable fresh water is stored as groundwater, with much higher residence time within the water cycle than the more readily available surface waters (Delleur, 1999; Oladeji, 2011). The quality of groundwater is as important as its quantity because it is the primary factor in determining its suitability for drinking, domestic, irrigation and industrial purposes (Kauri et al., 2016). The concentration of chemical constituents, which is greatly influenced by geological formations and anthropogenic activities, determines the groundwater quality. The agricultural and anthropogenic activities have resulted in deterioration of water quality, posing a serious threat to human beings (Kauri et al., 2016).

Oil exploration and exploitation is a common industrial activity in the Niger Delta states which is associated with pipelines installations.

Hazardous events such as pipeline vandalism and product leakages due to corrosive pipelines (Boris, 2015; Omodanisi et al., 2015) can lead to environmental pollution, primarily underground, since most pipelines are buried under the earth. Such pollution can lead to contamination of groundwater aquifers. Corrosiveness and product leakage due to poor maintenance of pipes and vandalism can lead to groundwater pollution and go unnoticed for many years. Groundwater contamination is nearly always the result of human activity. In areas where population density is high and human use of the land is intensive, groundwater is especially vulnerable. Virtually any activity whereby chemicals or wastes may be released to the environment, either intentionally or accidentally, has the potential to pollute groundwater. When groundwater becomes contaminated, it is difficult and expensive to clean up.

Groundwater has natural deposits of contamination (Omole *et al.,*2017). However, groundwater pollution can also arise from anthropogenic activities and surface and groundwater interaction (Omole *et al*., 2017). The quality of groundwater is determined by the initial quality of water infiltrating the subsurface, its interaction with the subsurface environment and the impact of anthropogenic activities at the surface (agriculture) or in the subsurface (e.g. oil and gas exploration) (World Water Quality Alliance, 2021). Therefore, the 'governing factors' determining the potential threats to groundwater quality are the composition and reactivity of the subsurface strata (geogenic contamination) and contaminant sources from land use and other human activities (anthropogenic contamination). As a result, like surface water, there may be multiple groundwater quality challenges at any given location (World Water Quality Alliance, 2021).

Pollutants affecting drinking water sources include heavy metal pollution from manufacturing, metallurgy, paints, chemicals and other similar industrial activities (Omole *et al.,*2015). Other pollutants such as nitrates, nitrites and sulphate can affect drinking water sources because of improperly managed wastewater effluents. Therefore, regular water quality monitoring is important to safeguard public health. In Nigeria, a study conducted by Afolabi et al. (2022) and Asomaku (2023) confirmed the impact of poor waste management through the leachate on groundwater quality in their studied area. Similarly, studies such as Aderemi et al. (2011), Mokuolu et al. (2017), Nwankwoala and Mzaga (2017), Elenwo *et al*. (2019), Kenneth *et al*. (2019), Ibe et al. (2020), Ogbaran and Uguru (2021), and Abba and Abba (2022) have all considered the influence of various anthropogenic activities on groundwater quality; however, none of these studies were based on the potential impact on groundwater quality. The study examined the physicochemical and heavy metal concentration of selected borehole water along pipeline routes in parts of Obio/Akpor Local Government Area, Rivers State, Nigeria.

Materials and Methods

Study Area

The study was carried out in Rumuoke, Rumukania and Egbelu communities in Obio/Akpor LGA. Obio/Akpor LGA is one of the 23 local governments of Rivers state, found in the south southern part of Nigeria, otherwise called the Niger Delta Region of Nigeria, located approximately between latitude 4º 45" N through 4º 56" N and longitude 6º 52" E through 7º 6" E (Figure 1). Consequent to rapid urbanisation and the rising industrial and commercial growth of Port Harcourt, more goods and services are being made available, thus the springing up of fuelling stations, to meet the growing population's demand, arises. A reconnaissance survey was carried out on the 30th November, 2024, to help familiarise oneself with the study area. GARMIN Extech 76, a Global Positioning System (GPS), was deployed during the reconnaissance survey to obtain the coordinates of the sampling points in the study.

Data (Sampling) Collection and Procedure

Sampling Points/Sites

The water samples for the study were collected from boreholes (BH) around the study area (Rumuoke, Rumukania and Egbelu communities), all within Obio/Akpo local government area of Rivers State. Specifically, water samples were collected from sixteen [16] boreholes on December 21st 2024, and tested for various physicochemical and heavy metals parameters. Each sample was tagged accordingly with the generic name and symbols to prevent confusion and mix-up of the water sample.

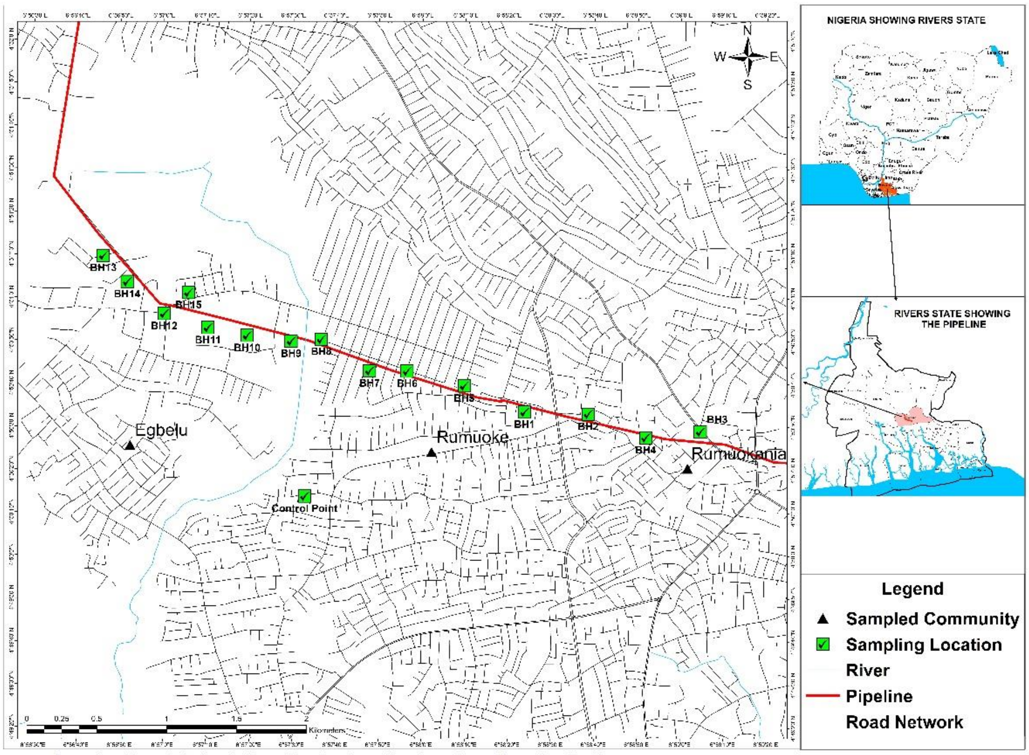
Sample Collection Procedure

Water samples were collected from various designated water sources with the aid of a labelled lucid bottle. Before the water collection, the lucid bottles were cleaned with 70% steriliser to prevent impurities and contamination. Afterwards, the water samples were collected from each designated point, and the bottles were filled to the brim. The filled bottles were immediately placed in the ice-parked cooling medium to arrest continuous microbial activities and preserve the water before being taken to the laboratory for analysis.

Data Analysis

Physicochemical and Heavy Metals

Numerous physicochemical parameters (Colour, Temperature, Turbidity, Total Dissolved Solid (TDS), Electricity Conductivity (EC), Total Alkalinity, Total Hardness, Chloride, Salinity, Dissolved Oxygen,



Location Map of the Study Area Showing Sampling Locations Along the Pipeline

Figure 1: Overview of the Study Area and Sampling Points

Bicarbonate, Sodium, Calcium, Magnesium, Potassium, Iron, Phosphate, Sulphate, Nitrate) and heavy metals (Copper (Cu), Iron (Fe), Lead (Pb), Nickel (Ni), Cadmium (Cd), Chromium (Cr), Manganese (Mn) and Zinc (Zn)) for water quality were analysed. All physicochemical parameters were analysed by following the standard methods of the American Public Health Association (APHA) and the American Society for Testing and Materials (ASTM), similar to those described by Khalid et al. (2018) and Latif et al. (2024). The acidified water samples were filtered using Whatman ashless filter paper and thereafter analysed with an Atomic Absorption Spectrophotometer (Shimadzu AA-6650) using a standard method (ASTM D1971/4691) to determine the level of heavy metals in the sample (Afolabi et al., 2022).

To ascertain the quality of the outcomes from various studies, standard procedures and laboratory quality assurance were strictly followed. Samples were analysed in triplicates, and the mean was estimated for accuracy and precision (Chiatuala et al., 2024). The resulting concentration of the parameters was analysed using descriptive statistics such as mean and standard deviation, and the results will be presented in tabular form.

Result

Physicochemical Concentration of Groundwater Quality

The physicochemical concentration of the groundwater samples collected from boreholes (BH 1-15) was analysed, and the outcome was presented in Table 1 and Figure 2.

pH: The groundwater ph ranged from 4.23 at BH12 to 6.62 at BH13, with a mean concentration of 5.34, while the control sample was 7.88. All the pH concentrations reported were below the WHO (2018) and NSDWQ (2007) allowable limit of 6.5 – 8.5, except at BH1 and BH13.

Temperature: The reported groundwater temperature ranged from 21.2 °C at BH15 to 33.8 °C at BH8, with a mean concentration of 28.39 °C, while the control sample was 29.9 °C. The concentration reported for colour was one across the sampled boreholes with no specific limit with WHO (2018) and NSDWQ (2007).

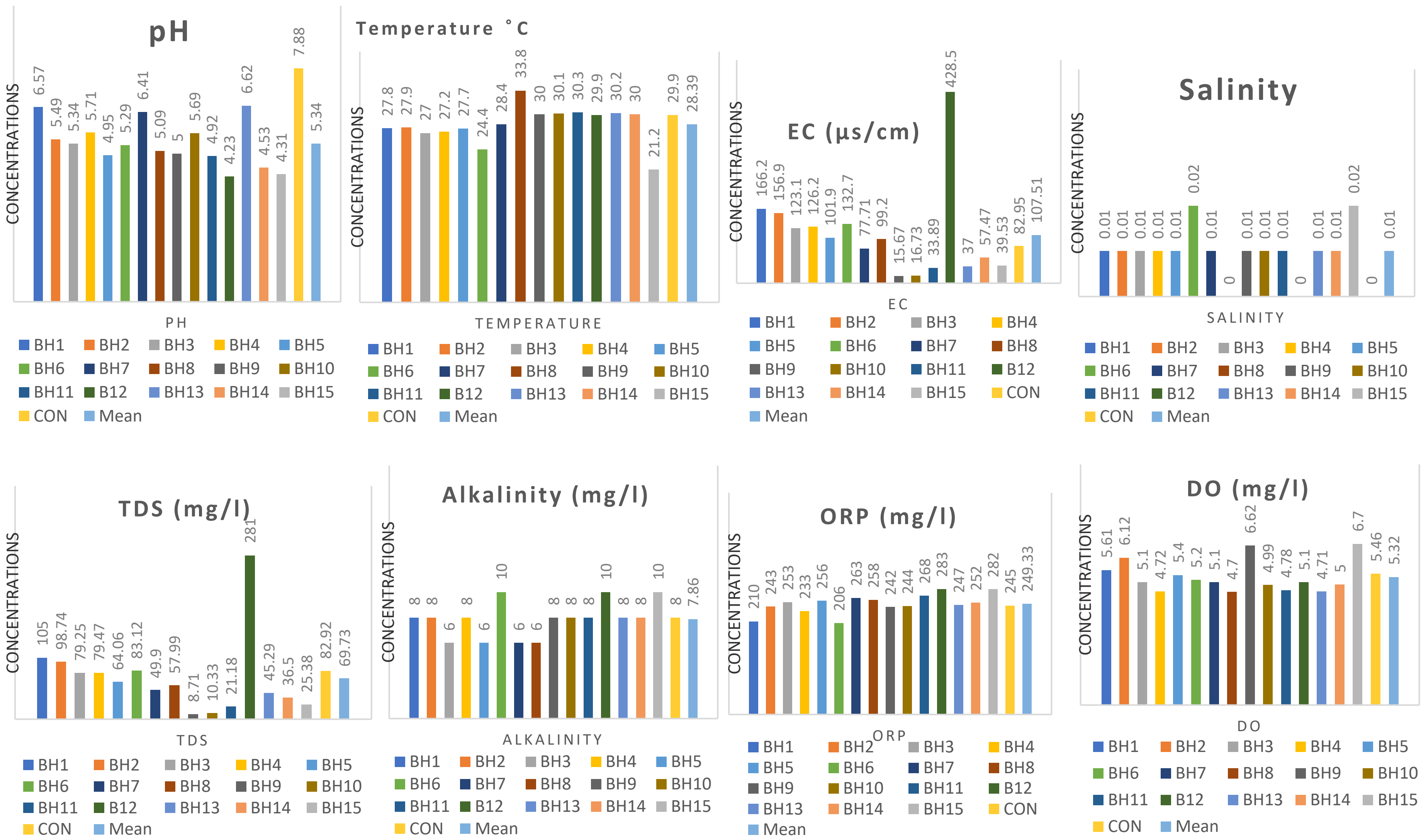
Salinity: the concentration reported for salinity was 0.1 ppm across all sampled groundwater except BH6 and BH15 at 0.02 ppm with mean concentration of 0.01 and no specific limit with WHO(2018) and NSDWQ (2007).

Electrical Conductivity (EC): The concentration reported ranged from 15.67 μS/cm at BH9 to 428.5 μS/cm at BH12 with mean concentration of 107.51 with control sample concentration of 82.95 μS/cm and all reported concentrations are below the allowable limit for WHO(2018) and NSDWQ (2007) 1000 μS/cm.

Table 1: Physiochemical Concentration of Groundwater Quality

	BH1	BH2	BH3	BH4	BH5	BH6	BH7	BH8	BH9	BH10	BH11	B12	BH13	BH14	BH15	CON	Mean	WHO	NSDWQ
PHYSIOCHEMICALS (mg/l)																			
pH	6.57	5.49	5.34	5.71	4.95	5.29	6.41	5.09	5.00	5.69	4.92	4.23	6.62	4.53	4.31	7.88	5.34	6.5 - 8.5	6.5 - 8.5
Temp ºC	27.8	27.9	27.0	27.2	27.7	24.4	28.4	33.8	30.0	30.1	30.3	29.9	30.2	30.0	21.2	29.9	28.39	Amb.	Amb.
Colour (TCU)	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.0	NS	NS
Salinity	0.01	0.01	0.01	0.01	0.01	0.02	0.01	<0.01	0.01	0.01	0.01	0.0	0.01	0.01	0.02	0.0	0.01	NS	NS
EC (µS/cm)	166.2	156.9	123.1	126.2	101.9	132.7	77.71	99.20	15.67	16.73	33.89	428.5	37	57.47	39.53	82.95	107.51	1000	1000
TDS	105.0	98.74	79.25	79.47	64.06	83.12	49.9	57.99	8.71	10.33	21.18	281.0	45.29	36.5	25.38	82.92	69.73	1500	500
Alkalinity	8.0	8.0	6.0	8.0	6.0	10.0	6.0	6.0	8.0	8.0	8.0	10.0	8	8	10	8.0	7.87	2000	NS
ORP	210	243	253	233	256	206	263	258	242	244	268	283	247	252	282	245	249.33	-	-
DO	5.61	6.12	5.1	4.72	5.4	5.2	5.10	4.7	6.62	4.99	4.78	5.10	4.71	5.0	6.7	5.46	5.32	5.0	> 4
Nitrate	0.037	0.041	0.031	0.023	0.02	0.029	0.017	0.018	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.012	<0.001	0.02	50	50
Carbonate	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.01	<0.01	<0.01	<0.01	-	NS	NS
Bicarbonate	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.01	<0.01	<0.01	<0.01	-	NS	NS
Chloride	7.99	7.99	5.99	6.99	4.99	7.99	3.99	3.99	0.99	1.99	1.99	2.99	2.99	2.99	3.99	2.99	4.52	600	100
Sulphate	0.049	0.053	0.047	0.042	0.037	0.042	0.033	0.036	0.002	0.013	0.016	0.018	0.026	0.022	0.035	0.014	0.03	400	100
Phosphate	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	-	5	5
INORGANIC ELEMENTS (mg/l)																			
Sodium	0.088	0.121	0.062	0.079	0.063	0.104	0.069	0.084	0.009	0.073	0.052	0.072	0.044	0.061	0.044	0.052	0.07	-	-
Calcium	0.221	0.285	0.211	0.279	0.187	0.192	0.203	0.211	0.048	0.076	0.061	0.052	0.061	0.082	0.077	0.081	0.15	100	-
Magnesium	0.013	0.027	0.031	0.012	0.034	0.041	0.038	0.026	0.012	0.027	0.033	0.012	0.018	0.032	0.039	0.027	0.02	50	-
Potassium	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	-	-	-

BH: Borehole, CON: Control, WHO: World Health Organisation, NSDWQ: Nigeria Standard for Drinking Water Quality, ORP: Oxidation Reduction Potential, DO: Dissolved Oxygen, UBJ: Unobjectiv


pH
CONCENTRATIONS
6.57 5.49 5.34 5.71 4.95 5.29 6.41 5.09 5 5.69 4.92 4.23 6.62 4.53 4.31 7.88 5.34
PH
BH1 BH2 BH3 BH4 BH5 BH6 BH7 BH8 BH9 BH10 BH11 B12 BH13 BH14 BH15 CON Mean
Temperature °C
CONCENTRATIONS
27.8 27.9 27 27.2 27.7 24.4 28.4 33.8 30 30.1 30.3 29.9 30.2 30 21.2 29.9 28.39
TEMPERATURE
BH1 BH2 BH3 BH4 BH5 BH6 BH7 BH8 BH9 BH10 BH11 B12 BH13 BH14 BH15 CON Mean
EC (µs/cm)
CONCENTRATIONS
166.2 156.9 123.1 126.2 101.9 132.7 77.71 99.2 15.67 16.73 33.89 428.5 37 57.47 39.53 82.95 107.51
EC
BH1 BH2 BH3 BH4 BH5 BH6 BH7 BH8 BH9 BH10 BH11 B12 BH13 BH14 BH15 CON Mean
Salinity
CONCENTRATIONS
0.01 0.01 0.01 0.01 0.01 0.02 0.01 0 0.01 0.01 0.01 0 0.01 0.01 0.02 0 0.01
SALINITY
BH1 BH2 BH3 BH4 BH5 BH6 BH7 BH8 BH9 BH10 BH11 B12 BH13 BH14 BH15 CON Mean
TDS (mg/l)
CONCENTRATIONS
105 98.74 79.25 79.47 64.06 83.12 49.9 57.99 8.71 10.33 21.18 281 45.29 36.5 25.38 82.92 69.73
TDS
BH1 BH2 BH3 BH4 BH5 BH6 BH7 BH8 BH9 BH10 BH11 B12 BH13 BH14 BH15 CON Mean
Alkalinity (mg/l)
CONCENTRATIONS
8 8 6 8 6 10 6 6 8 8 8 10 8 8 10 8 7.86
ALKALINITY
BH1 BH2 BH3 BH4 BH5 BH6 BH7 BH8 BH9 BH10 BH11 B12 BH13 BH14 BH15 CON Mean
ORP (mg/l)
CONCENTRATIONS
210 243 253 233 256 206 263 258 242 244 268 283 247 252 282 245 249.33
ORP
BH1 BH2 BH3 BH4 BH5 BH6 BH7 BH8 BH9 BH10 BH11 B12 BH13 BH14 BH15 CON Mean
DO (mg/l)
CONCENTRATIONS
5.61 6.12 5.1 4.72 5.4 5.2 5.1 4.7 6.62 4.99 4.78 5.1 4.71 5 6.7 5.46 5.32
DO
BH1 BH2 BH3 BH4 BH5 BH6 BH7 BH8 BH9 BH10 BH11 B12 BH13 BH14 BH15 CON Mean

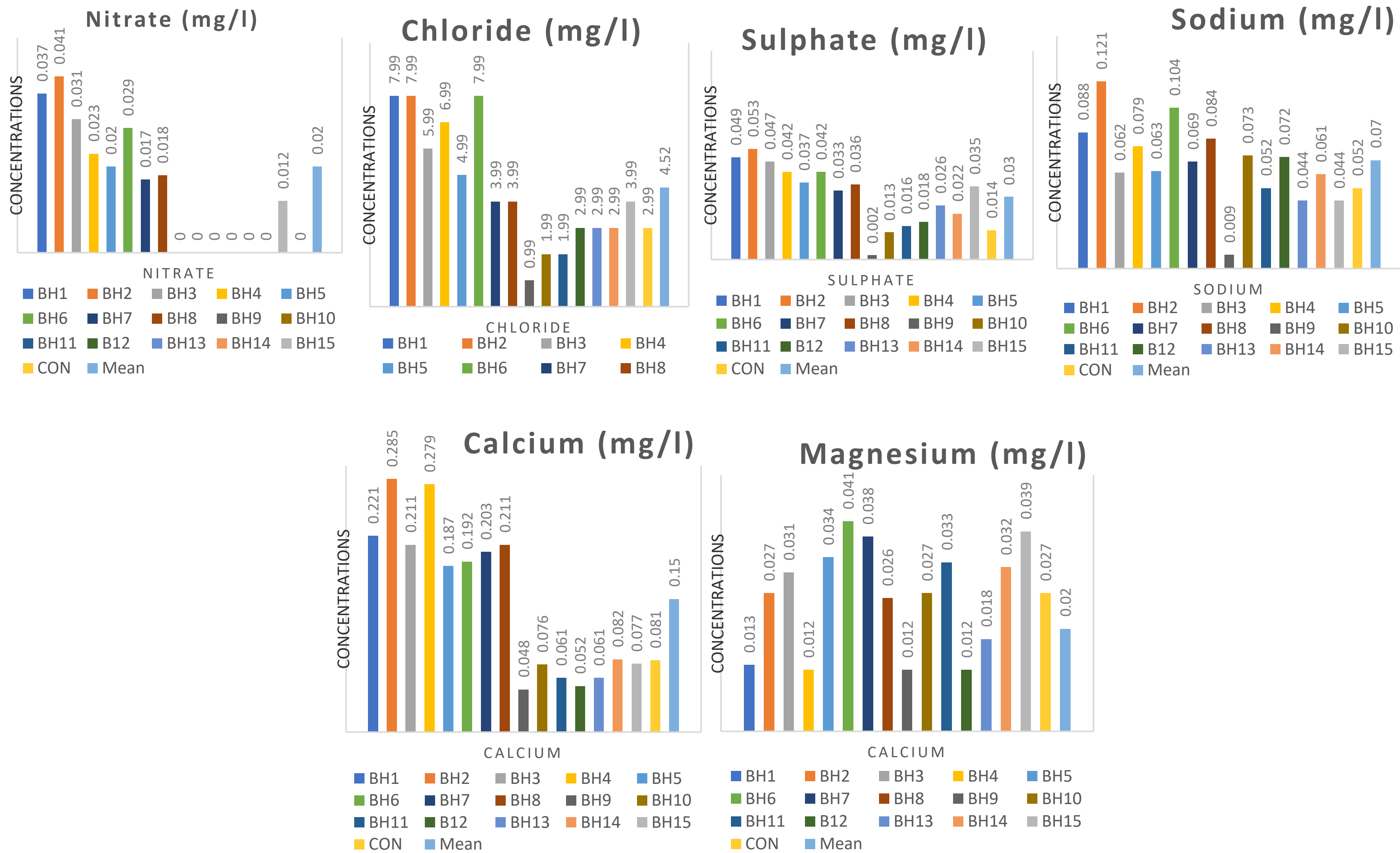


Figure 2: Physiochemical Concentration of Groundwater Quality

Total dissolve solid (TDS): The concentration of TDS in the sampled groundwater ranged from 8.71mg/l at BH9 to 281 mg/l at BH12 with mean concentration of 69.72 and control sample concentration of 82.92 mg/l while all reported concentrations are below the allowable limit for WHO (2018) and NSDWQ (2007) of 1500 mg/l and 500 mg/l respectively.

Alkalinity: The alkalinity concentration of the groundwater ranged from 6 mg/l at BH3, BH5, BH6-7 to 10 mg/l at BH10 with mean concentration of 7.87 and control sample concentration of 8 mg/l while no specific limit with WHO (2018) and NSDWQ (2007).

Oxidation Reduction Potential [ORP]: The ORP concentration of the groundwater ranged from 206 mg/l at BH6 to 283 mg/l at BH12 with mean concentration of 249.33 and control sample concentration of 245 mg/l while no specific limit with WHO (2018) and NSDWQ (2007).

Dissolved Oxygen (DO): The DO concentration of the groundwater ranged from 4.7 mg/l at BH8 to 6.7 mg/l at BH15 with mean concentration of 5.32 and control sample concentration of 5.46 mg/l while no specific limit with WHO (2018) and NSDWQ (2007) (2007).

Nitrate (NO_3^-): The nitrate (NO_3^-) concentration reported for groundwater samples ranged from <0.001 mg/l at BH9-BH15 to 0.041 mg/l at BH2 with meal concentration of 0.03 and control sample concentration of <0.001 mg/l while all concentrations were below the allowable limit of 50 mg/l for WHO (2018) and NSDWQ (2007).

Carbonate, Bicarbonate and Phosphate: All the sample concentration reported across the sampled groundwater had concentration range of <0.001 mg/l with no specific limit with WHO (2018) and NSDWQ (2007) for carbonate and bicarbonate while the reported concentrations were below the allowable limit of 5 mg/l for WHO (2018) and NSDWQ (2007).

Chloride ion (Cl^-): The concentration of Cl^- in the sampled groundwater ranged from 0.99 mg/l at BH9 to 7.99 mg/l at BH1-2 and BH6 with mean concentration of 4.52 and control sample concentration of 2.99 mg/l. All the reported concentrations are below the allowable limit of 600 mg/l and 100 mg/l for WHO (2018) and NSDWQ (2007) respectively.

Sulphate (SO_4^{2-}): The concentration of SO_4^{2-} in the sampled groundwater ranged from 0.002 mg/l at BH9 to 0.053 mg/l at BH2 with mean concentration of 0.031 and control sample concentration of 0.014 mg/l. All the reported concentrations are below the allowable limit of 400 mg/l and 100 mg/l for WHO (2018) and NSDWQ (2007) respectively.

Sodium (Na): The Na concentration ranged from 0.009 mg/l at BH9 to 0.121 mg/l at BH2 with mean concentration of 0.068 and control sample concentration of 0.052 mg/l.

Calcium (Ca): The Ca concentration ranged from 0.048 mg/l at BH9 to 0.285 mg/l at BH2 with mean concentration of 0.149 and control sample concentration of 0.081 mg/l. All the reported concentrations were below the WHO allowable limit of 100 mg/l for Ca.

Magnesium (Mg): The Mg concentration ranged from 0.012 mg/l at BH9 to 0.041 mg/l at BH6 with mean concentration of 0.026 and control sample concentration of 0.027 mg/l. All the reported concentrations were below the WHO allowable limit of 50 mg/l for Mg.

Potassium (K): all samples concentration was <0.001 mg/l across all sampled groundwater and controls sample while all concentrations are within the WHO (2018) and NSDWQ (2007) allowable limits.

Test of Significant

From Table 2, the significant difference in the physicochemical parameters' concentration was tested using the ANOVA. In explaining the outcome of the significance tests, the p-value was adopted to determine the significance levels (where $p \leq 0.05$ rejects the null hypothesis). Based on the outcome, the null hypothesis (H_0) which stated that there is no significant difference in the physicochemical parameters' concentration of the groundwater samples across the study area was accepted (where $p > 0.05$, $p = 0.983$).

Heavy Metals Concentrations

The heavy metals concentration of the groundwater samples collected from boreholes (BH 1-15) was analysed and the outcome was presented in Table 3. The Cu concentration ranged from 0.007 mg/l at BH9 to 0.027 mg/l at BH6 with mean concentration of 0.014 and control sample concentration of <0.001 mg/l. All the reported concentrations were below the WHO (2018) and NSDWQ (2007) allowable limit of 2 mg/l and 0.3 mg/l for Cu. Iron (Fe), Lead (Pb), Nickel (Ni), Cadmium (Cd), Chromium (Cr), Manganese (Mn) and Zinc (Zn): All samples concentration was <0.001 mg/l across all sampled groundwater and controls sample while all concentrations are within the WHO (2018) and NSDWQ (2007) allowable limits.

Discussion

pH: The pH mean concentration across the sampled points was 5.34 across the study area. All concentrations reported are within the WHO (2018) and NSDWQ (2007) allowable limits while the reported concentrations were within those reported by Arain et al. (2014), Khalid et al. (2018), Mengstie et al. (2023) and Addisie (2022) at 6.5 to 7.45. The finding share similarity with the study conducted by Afolabi and Adesope (2022) and Allison et al. (2020). Also, the pH is determined by the amount of dissolved carbon dioxide ($CO2$), which forms carbonic acid in water (Meride & Ayenew, 2016).

Table 2: Significant Different Analysis of Physico-chemical concentration in Groundwater

		Sum of Squares	Df	Mean Square	F	Sig.
Groundwater	Between Groups	27827.450	14	1987.675	0.363	0.983
	Within Groups	1148625.435	210	5469.645		
	Total	1176452.885	224			

Table 3: Heavy Metals Concentration of Groundwater

	BH1	BH2	BH3	BH4	BH5	BH6	BH7	BH8	BH9	BH10	BH11	B12	BH13	BH14	BH15	CON	Mean	WHO	NSDWQ
Copper	0.022	0.016	<0.001	0.009	0.016	0.027	<0.001	0.011	0.009	0.011	<0.001	0.007	0.013	0.015	<0.001	<0.001	0.014	2	0.3
Iron	<0.001	0.011	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	-	0.3	0.01
Lead	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	-	0.01	0.01
Nickel	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	-	0.07	NS
Cadmium	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	-	0.003	NS
Chromium	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	-	0.05	0.05
Manganese	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	-	0.05	0.1
Zinc	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	-	1.00	0.003

Temperature: The temperature mean concentration across the sampled points was 28.4 °C. Temperature in this study was found within permissible limit of WHO (30 °C). Ezeribe et al. (2012) reported high temperature at 29 °C for a well water in Nigeria. Temperature is one of the most significant environmental features which affects and controls behavioral characteristics of organisms, solubility of gases and salts in water (Joanne et al., 2011). Temperature affect the amount of dissolved oxygen in water which in turn influences the survival of an aquatic organisms Ojekunle and Lateef (2017). Increased in temperature affects the levels of dissolved oxygen in the water column (Rajaram, 2008).

Salinity: The salinity mean concentration across the sampled points was 0.01. Low concentration of salinity was reported across all the samples of groundwater confirm that the water bodies are fresh water. The report was similar to those reported by Emmanuel et al. (2024).

Electrical Conductivity: The EC mean concentration across the sampled points was 107.51 μS/cm. All concentrations reported are within the WHO (2018) and NSDWQ (2007) allowable limits. The concentration reported for the study lower than those reported by Meride and Ayenew (2016) and Muhammad et al. (2024). These results clearly indicate that groundwater in the study area was not considerably ionized and has the lower level of ionic concentration activity due to small dissolve solids. Pure water is not a good conductor of electric current rather a good insulator. Increase in ions concentration enhances the electrical conductivity of water (Meride & Ayenew, 2016). Generally, the amount of dissolved solids in water determines the electrical conductivity.

Total Dissolved Solid: The TDS mean concentration across the sampled points was 69.73 mg/l. All concentrations reported are within the WHO (2018) and NSDWQ (2007) allowable limits. The concentration reported for groundwater was similar for those reported by Ganiyu et al. (2018) but lower in concentration to those reported Afolabi et al. (2022) for groundwater around dumpsites. The TDS value of less than 1000mg/l implies that the water samples can be classified as freshwater (Adebayo et al., 2015; Ganiyu et al., 2018). High TDS concentration in water could lead to laxative or constipation effects (Leelavathi et al., 2016; Afolabi et al., 2021) and the concentration can be influence by anthropogenic activities such as untreated waste water and industrial discharge (Mohamed and Zair, 2017).

Alkalinity: There was no change in groundwater samples alkalinity across the study area. The concentration reported across the study areas are within the concentration WHO/NSDWQ standard while the concentrations are within the range reported by Arain et al. (2014) and Aderemi et al. (2011) for physicochemical parameters for drinking water. The concentrations reported are lower than those reported hydration, improve acid-base balance, and boost anaerobic exercise performance in combat sport athletes (Chycki et al., 2018).

Dissolve Oxygen (DO): The DO mean concentration across the sampled points are 5.01 mg/l across the study area. The DO is one of the most important physicochemical parameters used for assessing the suitability of surface water. Furthermore, DO affect the production of aquatic life in water. A DO of 5mg/l is ideal for aquatic, any value below this have detrimental effect on aquatic organisms. The higher the concentration of DO the better the water quality (Ojekunle & Lateef, 2017). Also, the concentration reported was higher than those reported by Abubakar and Yankasai (2012) and Karikari et al. (2007) at range of 5.8mg/l to 8.9mg/l.

Nitrate: The NO_3^- mean concentration across the sampled points are 0.01 mg/l across the study area. All concentrations reported are within the WHO (2018) and NSDWQ (2007) allowable limits and within the range reported by Meride and Ayenew (2016) but lower than those reported by Ibrahim et al. (2020). According to Meride and Ayenew (2016), Nitrate one of the most important diseases causing parameters of water quality particularly blue baby syndrome in infants. The sources of nitrate are nitrogen cycle, industrial waste, nitrogenous fertilizers etc.

Chloride: The Cl^- mean concentration across the sampled points are 4.52 mg/l across the study area. All concentrations reported are within the WHO (2018) and NSDWQ (2007) allowable limits. The Cl reported for this study was similar to those reported by Asaomaku (2022) while the higher than those reported by Khalid et al. (2018) and Meride and Ayenew (2016) but lower to those reported by Muhammad et al. (2024). Chloride is mainly obtained from the dissolution of salts of hydrochloric acid as table salt (NaCl), NaCO2 and added through industrial waste, sewage, sea water etc. High chloride concentration damages metallic pipes and structure, as well as harms growing plants (Meride & Ayenew, 2016).

Sulphate: The SO_4^{2-} mean concentration across the sampled point was 0.03 mg/l across the study area. All concentrations reported are within the WHO (2018) and NSDWQ (2007) allowable limits. All the reported concentrations are similar to those reported by Afolabi et al. (2022) for groundwater and Magaji (2020) for Sachet water produced.

Inorganic Element: Na, Ca, Mg and K: All the inorganic elements reported are similar in concentration across the study area while the reported concentrations are below the WHO allowable limit. The concentration reported for inorganic elements are lower to those reported by Afolabi et al. (2022). According to Adimalla and Wu (2019), inorganic elements are from natural sources, although anthropogenic activities can also increase their concentration in groundwater.

Heavy Metals: The concentration of heavy metals reported for groundwater are within the WHO and FMENV allowable limits. The outcome is similar to the concentration reported by Laniyan and Adewumi (2019), Naminata et al. (2018) and Afolabi et al. (2022) for similar heavy metals concentration for groundwater. Similar concentrations were reported for groundwater by the study conducted by Akubugwo et al. (2012), Godwin and Oborakpororo (2019), Orodu and Alalibo (2020). Cr, Ni, and Pb are metals with no biological advantage, and their high concentration in groundwater is dangerous to human health and adversely affects children in many ways (Saheed et al., 2020). Pb poisoning in humans damages the kidneys, liver, heart, brain, skeleton, and nervous system (Flora et al., 2006; Kinuthia et al., 2020). Chronic exposure to low Pb levels can limit the intelligence capacity of children (Kinuthia et al., 2020). In its compounded form, Cr, chromates of Ca, Zn, Sr, and Pb are highly soluble in water, toxic, and carcinogenic (Nwaichi et al., 2016; Afolabi, 2024). Human exposure to Ni can result in health impacts such as allergies.

Conclusion

Groundwater Quality Assessment along Pipeline Routes in parts of Obio/Akpor Local Government Area in three communities in Rivers state, Niger delta, Nigeria was carried out based on the physic-chemical, heavy metals, microbial quality and water quality index. The outcome revealed that all the parameters tested are within the allowable limit standard of World Health Organization and Nigeria Standard for Drinking Water Quality (NSDWQ). It was therefore recommended the need for continuous monitoring of the water quality in Rumuoke, Rumukania and Egbelu to improve the wellbeing and sustainable development of the people in the community. Also, various human related activities that can influence the quality of water must be closely monitored and adherence to various environmental guidelines against water pollution.

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.

Credit Authorship Contribution Statement

Elele, N: Conceptualization, Methodology, Formal analysis, Investigation, Resources, Data curation, Visualization, Project administration, Writing - original draft. **Osuji, L.C** and **Nwankwoala, H.O**: Supervision, Methodology, Validation, Formal analysis, Data curation, Visualization, Review and Editing.

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