Assessment of Physico-Chemical Parameters and Water Quality in communities in Abia State, Nigeria

ABSTRACT

Background: Worldwide, there has been increased contamination of water bodies, affecting their quality and making them unsafe for human use. This study aims to assess the physico-chemical parameters and water quality in communities in Abia State, Nigeria.

Materials and Methods: This study was carried out in communities in Umuahia South, Arochukwu, and Bende Local Government Areas in Abia State. The communities were selected through random sampling of balloting. A cross-sectional analytical study design was used for this study. One (1) liter plastic bottle was used to collect water samples from the borehole/tap, spring, and stream in the communities. Water samples collected in sterile (1) liter plastic bottles were stored in iced-lined coolers and then transported to the laboratory for analysis. Laboratory data was entered into, and analysed with Statistical Package for Social Sciences (SPSS) software version 25.

Result: This study revealed that the pH of the boreholes/ tap water in Arochukwu and Umuahia LGAs in dry and rainy seasons was below the WHO standard. In Bende LGA, the pH was within the WHO standard during the dry season whereas in the rainy season, it was below the WHO standard of 7.0 - 8.9mg/l. There was a statistically significant difference between the pH of borehole water during the dry and rainy seasons (p=0.004). A statistically significant difference was observed between zinc in the borehole water during the dry and rainy seasons (p=0.002). Also, Cadmium in the borehole water had a statistically significant difference during the dry and rainy seasons (p=0.001).

Conclusion: Generally, the study highlights the poor water quality in different locations and seasons, with several parameters falling below WHO acceptable standards. Community leaders should collaborate with the government to provide safe and quality drinking water.

Keywords: Physico-chemical, Parameters, Water, Quality, Abia State, Nigeria.

INTRODUCTION

“World Health Organization reported that more than 1 billion people in developing countries, including Nigeria, lack access to safe water for drinking” (Alkire et al., 2020). Worldwide, there has been increased contamination of water bodies, affecting their quality and making them unsafe for human use (Karri et al., 2021). “Despite the amount of water available in Nigeria, about 66.3 million Nigerians do not have access to safe drinking water and instead drink poor-quality water” (Ighalo, &Adeniyi, 2020). It is documented that most of the drinking water in

Nigeria is unpurified groundwater containing pollutants and chemical contaminants such as heavy metals responsible for causing waterborne diseases such as cholera and typhoid (Pandit, & Kumar, 2019).

“Water is the most crucial liquid for maintaining life on Earth. Only 3% of the water in the oceans is fresh water, and over 97% of it is not good for human consumption”(Mishra, 2023).“The water quality is described as the state of the water, including its chemical, physical, and biological qualities, typically about how suitable it is for drinking, cooking, swimming, etc”. (Akter et al., 2016). “The quality of drinking water indicates its acceptability for human consumption. Water quality depends on water composition, which is influenced by natural processes and human activities” (Akter et al., 2016). However, in developing countries such as Nigeria, the drinking water is continuously polluted with hazardous substances as a result of an increase in the number of persons, development, urbanization, industries, and dumping of waste and chemical effluents into water bodies (Onyemesili, et al., 2022). In many parts of Nigeria including Abia State, residents in several regions of Nigeria indiscriminately dump municipal solid wastes into rivers and streams, endangering the quality of the surface water (Onyemesili, et al., 2022).

Groundwater is the primary source of water in Nigeria used for home and occasionally industrial needs (Danert, & Healy, 2021). These are frequently extracted through shallow wells and boreholes and used right away without any sort of quality control or treatment (Misstear, 2017). Rural residents typically believe that groundwater is pure and safe for human consumption (Masoud et al., 2018). In Nigeria, 72% of urban regions have access to drinking water, compared to 54% of rural areas (Simelane et al., 2020). In northern Nigeria, where only 30% of the population has access to safe drinking water and proper sanitation, the problem of access to safe water is reportedly particularly significant (Raimi et al., 2019). The sources of drinking water in Abia State are tap, boreholes, rivers, streams, rainfalland dug wells. Water is mostly obtained from reserves during dry seasons, and the sources of water change depending on the season (Enyidi, 2017). Majority of the water sources in the Abia State are contaminated rendering the water unsafe, unclean and poor in quality for drinking and domestic uses. It is reported that most of the rural communities in developing countries experience difficulty in accessing safe drinking water (Chowdhury et al., 2016).

The increasing problem of unsafe and poor quality of water in rural communities in Nigeria including Abia State has been well documented (Elum et al., 2016). “Studies show the policy gaps in the water supply sector of the country, and measures in order to improve water supply sustainability in the country is deficient” (Leflaive et al., 2020). There has been continuous lack of water service provision to rural communities in Abia State and other communities in Nigeria. There are sufficient data on this problem, with little or no effort made to mitigate the challenge and its associated health impacts. Another study, reported that community-based service providers are constrained by several policy gaps that negatively impact on the quality and sustainability of rural water in the state and the country as a whole.

Physico-chemical parameters: The qualities and composition of water can be evaluated by measuring and analysing its physicochemical parameters (Cai et al., 2017). These variables offer crucial details regarding the physical and chemical characteristics of water (Rocha et al., 2015). The parameters assist in the assessment of its suitability for a range of uses, such as industrial processes, drinking, and aquatic ecosystems(Rocha et al., 2015). The physicochemical characteristics includes; pH stands for hydrogen ion concentration. The acidity or alkalinity of a water is determined by pH, which runs from 0 to 14 (Neina, 2019). An alkaline pH is greater than 7, while an acidic pH is less than 7, and a neutral pH is seven. However, the it has been reported that pH influences chemical reactions of water and it is essential for aquatic life (Neina, 2019). The solubility of gases, chemical processes, and the metabolic rates of aquatic creatures are all impacted by water temperature (Boscolo-Galazzo et al., 2018).
According to (Rusydi, 2018), the degree of temperature is important in measuring the hotness or coldness of the water. It is reported that the health of aquatic habitats can be impacted by temperature fluctuations(Rusydi, 2018). The concentration of dissolved ions in water affects conductivity, which is a measurement of the water's capacity to conduct an electric current. Elevated conductivity could suggest the existence of dissolved ions or salts. According to (Boyd, & Boyd, 2020), the total dissolved solids (TDS) in water is the sum of all the inorganic and organic materials, including salts, minerals, and other chemicals. Water taste and quality may be impacted by high TDS levels (Boyd, & Boyd, 2020).
The cloudiness or haziness of water due to suspended particles is measured by turbidity. Excessive turbidity can have an effect on aquatic species and light penetration in aquatic ecosystems (Hill, 2017). The amount of oxygen dissolved in water, which is necessary for aquatic creatures to survive, is measured by (DO). Hypoxia brought on by low DO levels can harm fish and other aquatic life (Li et al., 2018). The COD method quantifies the quantity of oxygen needed to oxidise both organic and inorganic materials in water (Jouanneau et al., 2014). It serves as a gauge for both the degree of pollution in the water and its capacity to sustain aquatic life. The amount of oxygen used by bacteria in water during the breakdown of organic matter is measured by BOD. High BOD levels to serve asa sign of pollution and have an effect on aquatic environments (Rusydi, et al., 2018).

Phosphorus and nitrogen are vital elements for aquatic plant growth(Rathore et al., 2016). The concentration of dissolved salts in water is measured by salinity. It is an essential criterion for determining whether water is suitable for drinking and other applications. The ability of water to withstand pH fluctuations is measured by its alkalinity. It has an impact on the hydroxide, bicarbonate, and carbonate ions present and is crucial for buffering against acidity (Middelburg et al., 2020).The hardness measures the concentration of calcium and magnesium ions in water. It can impact the taste of water, the effectiveness of soaps, and the formation of scale in pipes and appliances.TSS measures the concentration of particles that are suspended in water but not dissolved (Das, 2023).Elevated total suspended solids (TSS) can impact water quality and cause turbidity. Anthropogenic pollution or naturally occurring organic materials are frequently the cause of colour in water (Madhav et al., 2020). The presence of pollutants may be indicated by elevated colour levels. In order to protect human populations and aquatic ecosystems from harm, as well as to comply with environmental rules, these physicochemical parameters are regularly checked during water quality evaluations (Madhav et al., 2020). Monitoring these parameters promotes efficient water management techniques and aids in the identification of possible sources of pollution.The selection of these parameters permits for a comprehensive assessment of water quality, comprising aspects related to organic and inorganic pollution, water stability, and suitability for various uses. Also, to identify the potential health and environmental risks associated with the parameters.

MATERIALS AND METHOD

Study Area

This study was carried out in communities in Abia State. The communities are in Umuahia South Arochukwu, and Bende Local Government Area in Abia State. Abia State is one the 36 states in Nigeria, with its capital being Umuahia. Abia is a major commercial city in Abia, State and one of the most populated areas in Nigeria. Umuahia South is a Local Government Area of Abia State, Nigeria. Its headquarters is at Apumiri in Ubakala(Okereke et al., 2022). There 9 communities Umuahia South which includes; Amakama, Ubakala, Nsirimo, Ezeleke, Ogbodiukwu, Ohiaocha, Omaegwu, Old Umuahia and UmuahiAhiaukwu. Arochukwu is made up of 19 villages with a general leader referred to as EzeAro. Arochukwu is a main famous town in Igbo land. These communities are Ugwuakuma, Agbagwu, Utughugwu, Amsnmsgwu, Ujari, Amasu, Ibom, Oro, Obinkita, Amoba, Amankwu, Ugbo, Amukwa, Atani, Isinkpu, Ugwuafor, Amangwu, Asaga, and Amuvi. Bende has boundary with Cross River State, Afikpo and Ohaozara in Ebonyi State in the North, and Arochukwu and Ohafia in the South. It is made up of thirteen (13) communities which includes; Bende, Ozuitem, Uzuakoli, Item, Itumbauzo and

Ntalakwu, Umu-imenyi, Umuhu-Ezechi, Igbere, Ugwueke, Ezukwu, Nkpa and Alayi(Ngah, &Abam, 2016).The residents of these LGAs get their daily water supply from streams, springs, rain, and boreholes and also from commercial water vendors using motorized or manual trucks. There have been reports of incident of waterborne diseases (Ngah, &Abam, 2016). This has prompted interest to understudy the physico-chemical contents and water quality in different water sources used by the people of in the communities.

Study Design/Sampling method

A cross-sectional analytical study design was adopted for this study. The study design determined level of chemical contamination of the water in communities and health implications of the contamination of the water in communities. The study design was analytical because there were basic comparisons made between the outcome variables in the study using a standard acceptable level.The following samples were collected from public tap water, spring water and stream used by public for drinking/domestic use in the community. Simple random sampling was used to select one community from each of the three LGAs (Umuahia South, Arochukwu and Bende Local Government Area).

Study tool and Validation

The laboratory equipment used were pH meter (Extech product) with buffer solution, reagent and a colour coded chat, DR/890 Colorimeter, ASTM D (1868), Nephelometer (Hach 2100Q portable turbidimeter),Copper/Iron metal test strip kit, Durhams tube and Atomic Absorption Spectrophotometer (AAS) (Parkin Elmer 5100 PC). The laboratory equipment was ensured to be in a good condition and was calibrated for accurate measurement.

Data analysis and interpretation

The laboratory data was entered and analyzed with Statistical Package for Social Sciences (SPSS) software version 25. Descriptive statistics was performed to report variables in frequency and percentages. Also, inferential statistic such as ANOVA was performed to compare parameters in dry and rainy seasons.

Results

Table 1: Phyisco-Chemical analysis of water sample during dry season

S/N	Parameters	AROCHUKWU			UMUAHIA			BENDE			WHO
		BH	Spring	Stream	BH	Spring	Stream	BH	Spring	Stream	
1.	pH	6.98	6.42	6.98	6.59	6.77	7.76	7.16	7.43	7.60	7.0 - 8.9
2.	Conductivity (μs/cm)	25	30	9	103	32	71	461	17	59	400
3.	Total Suspended Solids, TSS (mg/l)	4	0	16	0	4	1	0	0	3	5
4.	Turbidity (NTU)	2	1	20	0	1	2	0	0	8	5
5.	Chemical Oxygen Demand, COD (mg/l)	0.75	1.13	0.81	0.38	0.88	0.31	0.44	0.63	0.50	>250
6.	Biochemical Oxygen Demand, BOD (mg/l)	0.50	0.75	0.54	0.25	0.58	0.21	0.29	0.42	0.33	< 5.0
7.	Alkalinity (mg/l)	2	2	1	6	3	5	10	1	4	100
8.	Total Hardness (mg/l)	5	7	2	20	8	15	70	4	18	100
9.	Total Dissolved Solids, TDS (mg/l)	14	17	5	57	18	39	254	10	33	50-150
10.	Sulphate, SO_4^{2-} (mg/l)	1	2	0	10	2	6	10	0	2	200
11.	Nitrate, NO_3^- (mg/l)	0.5	0.7	0.3	1.5	0.8	1.2	2.0	0.7	1.2	10
12.	Phosphate, PO_4^{3-} (mg/l)	0.36	0.21	0.16	0.57	0.20	0.19	1.40	0.08	0.45	0.005 - 0.05
13.	Salinity (mg/l)	12	14	4	42	16	34	225	7	29	≤600
1-4.	Chloride, Cl^- (mg/l)	7	8	3	25	10	21	136	4	18	250.0
15.	Carbonate (mg/l)	1	2	1	4	2	3	5	0.6	2	61 - 120
16.	Temperature (^{O}C)	27.7	27.7	27.5	27.5	27.7	27.7	28.7	28.8	28.7	25–50
17.	Lead, Pb (mg/l)	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.01 - 0.015
18.	Zinc, Zn (mg/l)	0.011	<0.001	0.013	0.053	0.084	0.047	<0.001	<0.001	<0.001	5
19.	Copper, Cu (mg/l)	<0.001	<0.001	0.141	<0.001	<0.001	<0.001	<0.001	<0.001	0.158	2.0
20.	Mercury, Hg (mg/l)	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.001
21.	Cadmium, Cd (mg/l)	<0.001	<0.001	0.036	<0.001	<0.001	0.055	<0.001	0.016	<0.001	0.003
22.	Arsenic, As (mg/l)	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	10
23.	Chromium, Cr (mg/l)	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.019	0.05
24.	Nickel, Ni (mg/l)	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.02
25.	Iron, Fe (mg/l)	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.3
26.	Manganese, Mn (mg/l)	0.060	0.067	0.026	0.093	0.011	0.069	0.097	0.027	<0.001	0.05

Table 2: Chemical analysis of water sample during rainy season

S/N	Parameters	AROCHUKWU			UMUAHIA			BENDE			
		BH	Spring	Stream	BH	Spring	Stream	BH	Spring	Stream	WHO
1.	pH	5.4	6.2	5.0	4.8	5.0	6.4	5.2	6.4	5.4	7.0 - 8.9
2.	Conductivity (μs/cm)	17	26	27	33	48	84	91	22	65	3.32 - 3.98
3.	Total Suspended Solids, TSS (mg/l)	2	13	0	3	2	8	0	1	3	5
4.	Turbidity (NTU)	2	18	0	2	1	14	0	2	4	5
5.	Chemical Oxygen Demand, COD (mg/l)	0.76	0.85	0.55	0.65	0.75	0.48	0.68	1.08	0.86	>250
6.	Biochemical Oxygen Demand, BOD (mg/l)	0.51	0.57	0.37	0.43	0.50	0.32	0.45	0.72	0.57	< 5.0
7.	Alkalinity (mg/l)	2	3	3	4	6	8	10	2	7	100
8.	Total Hardness (mg/l)	4	8	8	10	13	20	25	5	16	100
9.	Total Dissolved Solids, TDS (mg/l)	9	14	15	18	26	46	50	12	36	50-150
10.	Sulphate, SO_4^{2-} (mg/l)	0	0	0	0	0	0	0	0	0	200
11.	Nitrate, NO_3^- (mg/l)	0.1	0.2	0.3	0.5	0.6	1.2	1.8	0.1	1.0	10
12.	Phosphate, PO_4^{3-} (mg/l)	0.10	0.24	0.28	0.31	0.36	0.53	1.78	0.16	0.49	0.005 - 0.05
13.	Salinity (mg/l)	7	12	12	16	24	42	45	10	33	≤600
14.	Chloride, Cl^- (mg/l)	4	7	7	10	15	25	27	6	20	250.0
15.	Carbonate (mg/l)	0	1	1	1	2	3	5	0	2	61 - 120
16.	Temperature (^OC)	29.0	28.8	28.8	28.8	28.9	28.8	29.1	29.0	29.0	25–50
17.	Lead, Pb (mg/l)	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.01 - 0.015
18.	Zinc, Zn (mg/l)	0.486	0.526	0.484	0.530	0.478	0.482	0.536	0.456	0.472	5
19.	Copper, Cu (mg/l)	0.556	<0.001	0.063	<0.001	0.300	0.057	0.038	0.454	0.523	2.0
20.	Mercury, Hg (mg/l)	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.001
21.	Cadmium, Cd (mg/l)	0.009	0.006	0.091	0.010	0.004	0.072	0.010	0.007	0.070	0.003
22.	Arsenic, As (mg/l)	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	10
23.	Chromium, Cr (mg/l)	<0.001	0.046	<0.001	<0.001	<0.001	0.096	<0.001	<0.001	<0.001	0.05
24.	Nickel, Ni (mg/l)	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.02
25.	Iron, Fe (mg/l)	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.3
26.	Manganese, Mn (mg/l)	<0.001	0.049	0.079	0.127	0.041	0.164	0.187	0.099	0.024	0.05

Tables (1 and 2) shows that the value of heavy metals in borehole waters from Arochukwu, Umuahia and Bende.The pH of the boreholes/ tap water in Arochukwu and Umuahia in dry and rainy season are below the WHO standard while in Bende during the dry season is within the WHO standard whereas in the rainy season it is below the WHO standard of 7.0 - 8.9mg/l. The value of conductivity in Arochukwu and Umuahia are below the WHO standard while in Bende during the dry season the tap water conductivity is higher than the WHO acceptable limit whereas in the rainy season the water conductivity is below the WHO standard. The total suspended solids and turbidity of the borehole water of the three communities (Arochukwu, Umuahia and Bende) are below WHO acceptable limit of 5.

The table also shows that the chemical oxygen demand of borehole/tap water in Arochukwu, Umuahia and Bende are below WHO standard of >250mg/l. biochemical oxygen demand of the tap water are less than the WHO acceptable limit of <5.0, alkalinity and total hardness are below the acceptable WHO limit of 100mg/l. The TDS of borehole water of Arochukwu is below WHO acceptable limit in the dry and rainy season, while in Umuahia TDS of borehole water was within the WHO standard in the dry season with 57mg/l and below the standard in the rainy season with 18mg/l and in Bende, during the dry season the TDS of borehole water was above the WHO standard and in the rainy season Bende tap water has a TDS that is of WHO acceptable standard.

The value of Sulphate, and Nitrate during the dry and rainy season the three communities (Arochukwu, Umuahia and Bende) are below WHO acceptable limit of 200 and 10 respectively. Also, the table further reveals that the Phosphate, salinity, Chloride, and Carbonate value of borehole waters in Arochukwu, Umuahia and Bende are below WHO acceptable limit of 0.005 - 0.05, ≤600, 250.0 and 61 – 120mg/l correspondingly.

The value of temperature of borehole water in the Arochukwu, Umuahia and Bende are within the acceptable WHO standard of 25–50^{o}c. the table reveals that the values of borehole water in the three communities (Arochukwu, Umuahia and Bende) are below WHO acceptable limit for Lead, Zinc, Copper, and Mercury separately. The value of Cadmium found in borehole water in Arochukwu during the dry season is less than WHO acceptable limit while in the rainy season Cadmium is above WHO standard of 0.003. In Umuahia and Bende during the dry season the Cadmium value are below WHO standard while in the rainy season it is found to be above the WHO acceptable limit in both communities (Umuahia and Bende).

Arsenic, Chromium, Nickel, and Iron value for borehole water in Arochukwu, Umuahia and Bende are below WHO acceptable limit of 10, 0.05, 0.02 and 0.3mg/l respectively. From the borehole water at Arochukwo, the value of Manganesewas above WHO standard in the dry season and less than WHO standard in the rainy season, at Umuahia and Bende the values of Manganese was higher than WHO acceptable limit.

Cadmium value is below WHO standard while in the rainy season it is found to be above the WHO acceptable limit in both communities (Umuahia and Bende).Arsenic, Chromium, Nickel, and Iron value for spring water in Arochukwu, Umuahia and Bende are below WHO acceptable limit of 10, 0.05, 0.02 and 0.3mg/l respectively. From the spring water at Arochukwo, the value of Manganese was above WHO standard in the dry season and less than WHO standard in the rainy season, at Umuahia the value of Manganese in the dry and rainy season are below the WHO acceptable limit while the values of Manganese was low in the dry season in Bende whereas in the rainy season was higher than WHO acceptable limit.

Table 3: Comparison of the Borehole Water during the Dry and Rainy Seasons

Parameters	Mean	Std. Deviation	t-test	df	p-value
pH Dry – pH Rainy	1.776667	.190351	16.166	2	.004*
Conductivity Dry – Conductivity Rainy	149.333333	193.600964	1.336	2	.313
Total. Suspended Solids Dry- Total. Suspended. Solids Rainy	-.333333	2.516611	-.229	2	.840
Turbidity Dry- Turbidity Rainy	-.666667	1.154701	-1.000	2	.423
Chemical. Oxygen. Demand Dry - Chemical. Oxygen. Demand Rainy	-.173333	.142244	-2.111	2	.169
Biochemical. Oxygen. Demand Dry- Biochemical. Oxygen. Demand Rainy	-.116667	.092916	-2.175	2	.162
Alkalinity Dry – Alkalinity Rainy	.666667	1.154701	1.000	2	.423
Total. Hardness Dry - Total. Hardness Rainy	18.666667	23.245071	1.391	2	.299
Total. Dissolved. Solids Dry- Total. Dissolved. Solids Rainy	82.666667	106.444039	1.345	2	.311
Sulphate Dry – Sulphate Rainy	7.000000	5.196152	2.333	2	.145
Nitrate Dry – Nitrate Rainy	.533333	.416333	2.219	2	.157
Phosphate Dry- Phosphate Rainy	.046667	.369504	.219	2	.847
Salinity Dry- Salinity Rainy	70.333333	95.552778	1.275	2	.330
Chloride Dry- Chloride Rainy	42.333333	58.045959	1.263	2	.334
Carbonate Dry – Carbonate Rainy	1.000000	2.645751	.655	2	.580
Temperature Dry – Temperature Rainy	-1.000000	.519615	-3.333	2	.079
Zinc DRY- Zinc Rainy	-.496000	.034655	-24.790	2	.002*
Copper Dry – Copper Rainy	-.198000	.310619	-1.104	2	.385
Cadmium Dry – Cadmium Rainy	-.009667	.000577	-29.000	2	.001*
Manganese Dry – Manganese Rainy	-.021333	.075798	-.487	2	.674

Statistically significant ($p \leq 0.05$)

Table 3showed that there was statistically significant difference between pH of borehole water during the dry and rainy seasons (p=0.004). The table revealed that statistically significant difference exists between zinc in the borehole water during the dry and rainy seasons (p=0.002). Also, Cadmium in the borehole water had a statistically significant difference during the dry and rainy seasons (p=0.001).

Table 4: Comparison of the Spring Water during the Dry and Rainy Seasons

Parameters	Mean	Std. Deviation	t-test	df	p-value
pH Dry – pH Rainy	1.006667	.775263	2.249	2	.153
Conductivity Dry – Conductivity Rainy	-5.666667	10.016653	-.980	2	.430
Total. Suspended Solids Dry- Total. Suspended. Solids Rainy	-4.000000	7.937254	-.873	2	.475
Turbidity Dry- Turbidity Rainy	-6.333333	9.291573	-1.181	2	.359
Chemical. Oxygen. Demand Dry - Chemical. Oxygen. Demand Rainy	-.013333	.385530	-.060	2	.958
Biochemical. Oxygen. Demand Dry- Biochemical. Oxygen. Demand Rainy	-.013333	.253246	-.091	2	.936
Alkalinity Dry – Alkalinity Rainy	-1.666667	1.154701	-2.500	2	.130
Total. Hardness Dry - Total. Hardness Rainy	-2.333333	2.309401	-1.750	2	.222
Total. Dissolved. Solids Dry- Total. Dissolved. Solids Rainy	-2.333333	5.507571	-.734	2	.539
Sulphate Dry – Sulphate Rainy	1.333333	1.154701	2.000	2	.184
Nitrate Dry – Nitrate Rainy	.433333	.208167	3.606	2	.069
Phosphate Dry- Phosphate Rainy	-.090000	.065574	-2.377	2	.141
Salinity Dry- Salinity Rainy	-3.000000	5.000000	-1.039	2	.408
Chloride Dry- Chloride Rainy	-2.000000	3.000000	-1.155	2	.368
Carbonate Dry – Carbonate Rainy	.533333	.503322	1.835	2	.208
Temperature Dry – Temperature Rainy	-.833333	.550757	-2.621	2	.120
Zinc DRY- Zinc Rainy	-.458667	.066040	-12.030	2	.007*
Copper Dry – Copper Rainy	-.251333	.230879	-1.885	2	.200
Cadmium Dry – Cadmium Rainy	-.000333	.008145	-.071	2	.950
Chromium Dry – Chromium Rainy	-.015333	.026558	-1.000	2	.423
Manganese Dry – Manganese Rainy	-.028000	.045033	-1.077	2	.394

Statistically significant (p ≤ 0.05)

Table 4showed that there was statistically significant difference between zinc in the spring water during the dry and rainy seasons (p=0.007).

Table 5: Comparison of the Stream Water during the Dry and Rainy Seasons

Parameters	Mean	Std. Deviation	t-test	df	p-value

pH Dry – pH Rainy	-.480000	3.936902	-.211	2	.852
Conductivity Dry – Conductivity Rainy	-12.333333	6.027714	-3.544	2	.071
Total. Suspended Solids Dry- Total. Suspended. Solids Rainy	3.000000	11.789826	.441	2	.702
Turbidity Dry- Turbidity Rainy	4.000000	16.000000	.433	2	.707
Chemical. Oxygen. Demand Dry - Chemical. Oxygen. Demand Rainy	-.090000	.317648	-.491	2	.672
Biochemical. Oxygen. Demand Dry- Biochemical. Oxygen. Demand Rainy	-.060000	.209523	-.496	2	.669
Alkalinity Dry – Alkalinity Rainy	-2.666667	.577350	-8.000	2	.015*
Total. Hardness Dry - Total. Hardness Rainy	-3.000000	4.358899	-1.192	2	.355
Total. Dissolved. Solids Dry- Total. Dissolved. Solids Rainy	-6.666667	3.511885	-3.288	2	.081
Sulphate Dry – Sulphate Rainy	2.666667	3.055050	1.512	2	.270
Nitrate Dry – Nitrate Rainy	.066667	.115470	1.000	2	.423
Phosphate Dry- Phosphate Rainy	-.166667	.155349	-1.858	2	.204
Salinity Dry- Salinity Rainy	-6.666667	2.309401	-5.000	2	.038*
Chloride Dry- Chloride Rainy	-3.333333	1.154701	-5.000	2	.038*
Temperature Dry – Temperature Rainy	-.900000	.529150	-2.946	2	.098
Zinc DRY- Zinc Rainy	-.459333	.021079	-37.743	2	.001*
Copper Dry – Copper Rainy	-.114667	.227060	-.875	2	.474
Cadmium Dry – Cadmium Rainy	-.047333	.027319	-3.001	2	.095
Chromium Dry – Chromium Rainy	-.025667	.061647	-.721	2	.546
Manganese Dry – Manganese Rainy	-.057333	.035698	-2.782	2	.109

Statistically significant ($p \leq 0.05$)

Table 5 showed that there was a statistically significant difference between the alkalinity of stream water during the dry and rainy seasons (p=0.015). The table revealed that a statistically significant difference exists between salinity in the stream water during the dry and rainy seasons (p=0.038). Also, Chloride in the stream water had a statistically significant difference during the dry and rainy seasons (p=0.038). There was a statistically significant difference between Zinc in the stream water during the dry and rainy seasons (p=0.001).

Discussion

The finding shows the value of heavy metals in borehole waters from Arochukwu, Umuahia, and Bende. The pH of the boreholes/ tap water in Arochukwu and Umuahia in the dry and rainy seasons were below the WHO standard while in Bende during the dry season is within the WHO standard whereas in the rainy season, it is below the WHO standard of 7.0-8.9mg/l. The value of conductivity in Arochukwu and Umuahia are below the WHO standard while in Bende during the dry season the tap water conductivity is higher than the WHO acceptable limit whereas in the rainy season, the water conductivity is below the WHO standard. The total suspended solids and turbidity of the borehole water of the three communities (Arochukwu, Umuahia, and Bende) are below the WHO acceptable limit of 5.

According to the findings chemical oxygen demand of borehole/tap water in Arochukwu, Umuahia, and Bende is below the WHO standard of >250mg/l. the biochemical oxygen demand of the tap water is less than the WHO acceptable limit of <5.0, and alkalinity and total hardness are below the acceptable WHO limit of 100mg/l. The TDS of borehole water of Arochukwu is below the WHO acceptable limit in the dry and rainy season, while in Umuahia TDS of borehole water was within the WHO standard in the dry season with 57mg/l and below the standard in the rainy season with 18mg/l and in Bende, during the dry season the TDS of borehole water was above the WHO standard and in the rainy season Bende tap water has a TDS that is of WHO acceptable standard. The value of Sulphate, and Nitrate during the dry and rainy seasons in the three communities (Arochukwu, Umuahia, and Bende) are below WHO's acceptable limit of 200 and 10 respectively. Also, the table further reveals that the Phosphate, salinity, Chloride, and Carbonate values of borehole waters in Arochukwu, Umuahia, and Bende are below WHO acceptable limit of 0.005 - 0.05, ≤600, 250.0, and 61 – 120mg/l correspondingly.

The value of the temperature of borehole water in the Arochukwu, Umuahia, and Bende are within the acceptable WHO standard of 25–50oc. the table reveals that the values of borehole water in the three communities (Arochukwu, Umuahia, and Bende) are below the WHO acceptable limit for Lead, Zinc, Copper, and Mercury separately. The value of Cadmium found in borehole water in Arochukwu during the dry season is less than the WHO acceptable limit while in the rainy season, Cadmium is above the WHO standard of 0.003. In Umuahia and Bende during the dry season, the Cadmium value is below WHO standard while in the rainy season it is found to be above the WHO acceptable limit in both communities (Umuahia and Bende).

The result showed that Arsenic, Chromium, Nickel, and Iron values for borehole water in Arochukwu, Umuahia, and Bende are below WHO acceptable limits of 10, 0.05, 0.02, and 0.3mg/l respectively. From the borehole water at Arochukwo, the value of Manganese was above the WHO standard in the dry season and less than the WHO standard in the rainy season, at Unuahia and Bende the value of Manganese was higher than the WHO acceptable limit. Also, the study revealed the value of heavy metals in spring water from Arochukwu, Umuahia, and Bende. The pH of the spring water in Arochukwu and Umuahia in the dry and rainy seasons are below the WHO standard while in Bende during the dry season is within the

WHO standard whereas in the rainy season, it is below the WHO standard of 7.0 - 8.9mg/l. The value of conductivity in Arochukwu, Umuahia, and Bende are below the WHO standard. The total suspended solids and turbidity value of spring in Arochukwu during the dry season is below WHO standard while in the rainy season it is above WHO acceptable limit, Umuahia and Bende have a value of TSS less than the WHO acceptable limit of 5. It is revealed chemical oxygen demand of spring water in Arochukwu, Umuahia, and Bende is below the WHO standard of >250mg/l. The biochemical oxygen demand of the spring water is less than the WHO acceptable limit of <5.0, and alkalinity and total hardness are below the acceptable WHO limit of 100mg/l. The TDS of spring water of Arochukwu, Umuahia, and Bende is below the WHO acceptable limit in the dry and rainy season of 50-150mg/l.

The value of Sulphate, and Nitrate during the dry and rainy seasons in the three communities (Arochukwu, Umuahia, and Bende) are below WHO's acceptable limits of 200 and 10 respectively. Also, the table further reveals that the Phosphate of spring water during the dry and rainy season in ArochukwuUmuahia and Bende is above WHO's acceptable limit of 0.005 - 0.05. The salinity, Chloride, and Carbonate values of spring waters in Arochukwu, Umuahia, and Bende are below WHO acceptable limits of ≤600, 250.0, and 61 – 120mg/l respectively. The value of the temperature of spring water in the Arochukwu, Umuahia, and Bende are within the acceptable WHO standard of 25–50oc. The table reveals that the values of spring water in the three communities (Arochukwu, Umuahia, and Bende) are below the WHO acceptable limit for Lead, Zinc, Copper, and Mercury separately. The value of Cadmium found in spring water in Arochukwu during the dry season is less than the WHO acceptable limit while in the rainy season, Cadmium is above the WHO standard of 0.003.

In Umuahia and Bende during the dry season, the Cadmium value is below WHO standard while in the rainy season it is found to be above the WHO acceptable limit in both communities (Umuahia and Bende). The result indicated Arsenic, Chromium, Nickel, and Iron values for spring water in Arochukwu, Umuahia, and Bende are below WHO acceptable limits of 10, 0.05, 0.02, and 0.3mg/l respectively. From the spring water at Arochukwo, the value of Manganese was above the WHO standard in the dry season and less than the WHO standard in the rainy season, Umuahia the value of Manganese in the dry and rainy season are below the WHO acceptable limit while the values of Manganese was low in the dry season in Bende whereas in the rainy season was higher than WHO acceptable limit.

The value of heavy metals in stream water from Arochukwu, Umuahia, and Bende. The pH of the stream water in Arochukwu in the dry and rainy season are below the WHO acceptable. In

Umuahia and Bende, the value of stream water pH was in line with the WHO acceptable limit and below WHO standard in the rainy season. The value of conductivity in Arochukwu, Umuahia, and Bende are below the WHO standard. The total suspended solids and turbidity value of stream water in Arochukwu during the dry season is below WHO standard while in the rainy season it is above WHO acceptable limit, Umuahia stream water TSS in the dry season is below WHO standard while in the rainy season it is above WHO acceptable limit and Bende has a value of TSS less than WHO acceptable limit of 5.

The finding showed chemical oxygen demand of stream water in Arochukwu, Umuahia and Bende is below the WHO standard of >250mg/l. The biochemical oxygen demand of the stream water is less than the WHO acceptable limit of <5.0, and alkalinity and total hardness are below the acceptable WHO limit of 100mg/l. The TDS of stream water of Arochukwu, Umuahia, and Bende is below the WHO acceptable limit in the dry and rainy season of 50-150mg/l. The value of Sulphate, and Nitrate during the dry and rainy seasons in the three communities (Arochukwu, Umuahia, and Bende) are below WHO's acceptable limit of 200 and 10 respectively. Also, the table further reveals that the Phosphate of stream water during the dry and rainy season in ArochukwuUmuahia and Bende is above WHO's acceptable limit of 0.005 - 0.05. The salinity, Chloride, and Carbonate values of stream waters in Arochukwu, Umuahia, and Bende are below WHO acceptable limits of ≤600, 250.0, and 61-120mg/l respectively.

The value of the temperature of stream water in the Arochukwu, Umuahia, and Bende are within the acceptable WHO standard of 25–50oc. The table reveals that the values of stream water in the three communities (Arochukwu, Umuahia, and Bende) are below the WHO acceptable limit for Lead, Zinc, Copper, and Mercury separately. The value of Cadmium found in stream water in Arochukwu during the dry season is less than the WHO acceptable limit while in the rainy season, Cadmium is above the WHO standard of 0.003. In Umuahia, the value of Cadmium in the dry and rainy season are above the WHO standard, and in Bende during the dry season the Cadmium value is below the WHO standard while in the rainy season it is found to be above the WHO acceptable limit. The value of Arsenic in stream water in Arochukwu, Umuahia, and Bende is below the WHO acceptable limit of 10, Chromium was below WHO standard in Arochukwu during the dry and rainy season, in Umuahia Chromium was below WHO standards in the dry season and above the WHO acceptable limit in the rainy season and at Bende the values of Chromium were below WHO standard. Nickel, and Iron values for stream water in Arochukwu, Umuahia, and Bende are below the WHO acceptable limit of 0.02 and 0.3mg/l respectively.

From the stream water at Arochukwo, the value of Manganese was below WHO standard in the dry season and above WHO standard in the rainy season, at Umuahia the value of Manganese in the dry and rainy season is above the WHO acceptable limit while the values of Manganese were low in the dry and rainy seasons in Bende which was less than WHO acceptable limit. The finding revealed that there was a statistically significant difference between the pH of borehole water during the dry and rainy seasons (p=0.004). The table revealed that a statistically significant difference exists between zinc in the borehole water during the dry and rainy seasons (p=0.002). Also, Cadmium in the borehole water had a statistically significant difference during the dry and rainy seasons (p=0.001).

The present result indicated a statistically significant difference between zinc in the spring water during the dry and rainy seasons (p=0.007). There was a statistically significant difference between the alkalinity of stream water during the dry and rainy seasons (p=0.015). The finding revealed that a statistically significant difference exists between salinity in the stream water during the dry and rainy seasons (p=0.038). Also, Chloride in the stream water had a statistically significant difference during the dry and rainy seasons (p=0.038). There was a statistically significant difference between Zinc in the stream water during the dry and rainy seasons (p=0.001). The findings in this study are not consistent with findings in a study conducted in Abia State (Okereke et al., 2022) which reported all of the studied communities' water samples had pH values between 4.1 and 5.9, and their acidic pH levels fell outside of the 6.5-8.5 range allowed by the Nigerian Industrial Standard (NIS). However, (Okereke et al., 2022) reported similar ambient temperatures of the water sources in the chosen localities ranging from 25.8 to 31.8oC.

Similarly, water samples from all senatorial zones under investigation had an average electrical conductivity of 0.04 µS/cm and total dissolved solids of 36.4 mg/L, all of which were under acceptable limits of 1000 µS/cm and 500 mg/L correspondingly. There is an agreement between the finding in this study and the finding by (Eze, &Chigbu, 2015), a mean temperature range of 27.7oC. They showed that the six sample sites had a pH range of 6.01–7.27 which is within the WHO standard of 6.5–9.2. The result that phosphate, alkalinity, and turbidity were all within the WHO range is in line with the findings in this study. The WHO standard for recommended levels of surface water quality was exceeded by other physico-chemical parameters evaluated, such as total suspended solids (<0.001-2.23 mg/l), electrical conductivity (21.28-206.0µs/cm), biochemical oxygen demand (0.05=3.38), and chemical oxygen demand (0.10-15.0 mg/l). These parameters are not consistent with findings in this study (Eze, &Chigbu, 2015).

Similarly, Edokpayi et al., (2018) reported that water pH and conductivity values ranged between 5.5–7.3 and 24–405 μS/cm in the wet season and 5.8–8.7 and 8–402 μS/cm in the dry season. They indicated that both pH and conductivity levels were within the recommended limits of the World Health Organization (WHO) for drinking water. The results of household samples of stored water show that bacterial contamination levels ranged from no detectable colonies to the maximum detection level of our protocol of 30,000 CFU/100 mL. Fluoride concentrations ranged from below the detection limit (bdl) to 0.82 mg/L in the dry season and to 1.48 mg/L in the wet season. Fluoride levels fell below the threshold limit for fluoride in drinking water from the WHO (1.5 mg/L). Nitrates were also observed within the limit of drinking water, between bdl–17.48 mg/L and bdl–9.72 mg/L in the dry and wet seasons, respectively. Chloride, sulfate, and phosphate levels were also present in moderate levels in the various water sources; however, a relatively high concentration of chloride of 462.9 mg/L was determined in the Mutale River in the wet season. The study reported that Sodium concentrations in the range of 3.14–41.03 mg/L and 3.02–15.34 mg/L were measured in the wet and the dry seasons, respectively (Edokpayi et al., 2018). Low values of potassium, calcium, and magnesium were lower in the wet than in dry seasons. The agreement between this current finding and previous findings may be connected to the similarity in the demographic characteristics and activities around the water source.

There is consistency between the current finding and the finding in a study by (Edokpayi et al., 2018), levels of iron (Fe) varied between 37.30–1354 mg/L and 35.21–1262 mg/L in the wet and the dry seasons, respectively. Some of the sources showed high Fe concentration which exceeded the aesthetic permissible limit of WHO in drinking water. Two community-based water systems had higher levels of Fe in the wet season as well as the major river in the region (Mutale River) for which high Fe levels were observed in both seasons. One of the clinic boreholes also recorded high levels of Fe above the permissible aesthetic value of (300 mg/L) in both seasons. Temporary seasonal variation was significant only in the levels of Fe and Al. In the wet season, their levels were generally higher than in the dry season. Some other trace metals of concern like Pb, Hg, As, Cd, Cr, Ni, Cu, Mn, and Sr were all present at low levels that were below their recommended limits in drinking water for both seasons (Edokpayi et al., 2018). Marks et al., (2020) on water supply and sanitation services in small towns in rural–urban transition zones in Uganda. Among samples originating from a piped source, the mean free residual chlorine (FRC) concentration was 0.1 mg/L (SD = 0.1), below the recommended target range of 0.2–0.5 mg/L per Ugandan water quality standards (US EAS 12: 2014).

Another study conducted in Samaru community, Zaria, Northwest Nigeria by (Adesakin et al., 2020) revealed the highest pH water mean concentration was recorded from the river water sample (7.28 ± 0.16) compared with the reservoir sample (6.35 ± 0.13). The conductivity and TDS concentration ranged widely from 102- 484 (μS/cm) and 51–242 mg/L was recorded in surface water samples. The highest DO and phosphate mean concentrations (3.67 ± 0.61 mg/L and 0.049 ± 0.005 mg/L) were obtained from a water sample collected from the reservoir while the higher mean value of sulphate (0.218 ± 0.07 mg/L) was recorded from a river water sample. The highest mean concentration of total hardness was recorded in the river water sample (422.67 ± 23.79 CaCO3mg/L). The lowest mean value of alkalinity was obtained from the reservoir water sample (8.0 ± 1.49 CaCO3mg/L) while the highest was observed from the river water sample (26.33 ± 2.25 CaCO3mg/L). The highest chloride mean concentration was recorded from the reservoir water sample while a higher mean value of nitrate was obtained from a river water sample.

The TDS and conductivity values ranged from 79.0–546 mg/L and 40.0–256 μS/cm were observed from groundwater. There is a similar finding by Iwar et al., (2021) in a study conducted by Makurdi that reported that statistics observed that the water colour varied from 95 to 250 pt.co and from 160 to 425 pt. co with mean values of 172.5 ± 50.848 and 292.5 ±146.856 for the dry and wet seasons, respectively. The slim variance noticed in the colour of the water in the two seasons may be a result of the point that colour tends to change in the wet season due to raindrops, which disturb bottom sediments that rise and dissolve in the water. Turbidity varied from 20 to 531 NTU during the dry spell and from 30.1 to 455 NTU in the wet spell with average values of 275.5 ±158.602 and 242.55 ±163.110, respectively, for the dry and wet spells. In the same study, the total dissolved solids (TDS) varied from 125 to 570 mg/L with average figures of 347.5 ± 173.012 mg/L for the dry season and also varied from 150 to 600 mg/L during the wet spell with an average worth of 375 ±158.745 mg/L. Total suspended solids (TSS) varied from 33 to 377 mg/L during the dry spell with an average of 205 ±111.891 mg/L and from 37 to 385 mg/L during the wet spell with an average of 211 ± 133.164 mg/L. The pH of River Benue water showed relative variations (7.8–8.7) with an average of 8.25 ±0.267 during the dry spell. It may be inferred that the water was slightly alkaline and might be unwholesome for portable uses during this period. Conversely, the pH values during the wet spell ranged from 7.0–8.4 with an average of 7.7 ± 0.133. Electrical conductivity (EC) varied from 50 to 304 μS/cm with an average of 177 ±128.051μS/cm during the dry period and from 19 to 315 μS/cm during the wet period with an average of 167 ±92.791μS/cm (Iwar et al 2021).

The consistency between the current finding and the finding may be connected to the similarity in the demographic characteristics and activities around the water source. The research carried out by Iwar et al (2021) further shows that heavy metals like Pb, Zn, Cu, Cd, and Ni were tested and detected in the water samples during both (dry and wet) seasons. Copper (Cu) and nickel (Ni) were not detected at some time during the dry and wet seasons. The presence of lead, zinc, copper, cadmium, and nickel varied from 0.025 to 0.592, 0.097 to 3.628, 0 to 1.134, 0.058 to 0.199, 0 to 0 mg/L, with averages of 0.309 ±0.171, 1.863 ±1.445, 0.568 ±0.370, 0.129 ± 0.400 and 0 ±0.144mg/L, respectively, in dry season. Correspondingly, they were found to vary from 0.141 to 0.592, 0.595 to 0.099, 0 to 0, 0 to 0.150 and 0.201 to 0.232 mg/L with averages of 0.367 ±57.381, 0.794 ±0.302, 0 ±0.017, 0.072 ± 0.031 and 0.217 ±0.012 mg/L, respectively, during the wet spell.

Similarly, for Oparaocha et al., (2010), the pH value ranged from 6.0 to 6.9 (mean: 6.47 + 0.374) while conductivity was (mean: 47.80 + 55.65), for the sachet water whose value was short up 30µs/cm. The Total Dissolved Solid (TDS) ranged from 13.80- 119.0 mg/l with a mean of 45.45 mg/l ± 50.50, the sachet water presented the highest value (119.0mg/l) for TDS, while the lowest was from the borehole at Hall B. The chloride content ranged from 2.50 to 21.30 mg/l. The concentrations of calcium and magnesium ions in the water samples ranged from 0.72 to 2.80mg/l and 0.24mg/l to 1.50mg/l, respectively, while chloride ion content ranged from 2.50 to 21.30mg/l with a mean of 10.86 ± 8.10 mg/l. Ali et al., (2019) in a study on assessment of some chemical contaminants in river Kaduna, Nigeria. The result shows that the mean concentration of Cadmium in the River Kaduna is low (0.0129ppm). The mean concentration of Zn in River Kaduna is 0.1458ppm. Chromium in the River has a mean concentration of 0.0105ppm. The mean concentration of Pb (0.0102) is relatively low in River Kaduna. There is a considerably low concentration of Cu in this section of River Kaduna. The mean concentration of Cu is 0.0060ppm. The result also shows that Mn is high with a mean concentration of 0.07142ppm. The concentration of Ni is also high as observed from the analysis with a mean concentration of 0.0134ppm. The results of the study further show that the concentration of Fe in River Kaduna is relatively high with a mean concentration of 0.3196ppm. The mean value of TDS in the River is 216.9. The mean value of pH is 7.5, which is within the recommended limits of NIS and WHO. The mean value of Dissolved oxygen is 4.3. The result further reveals that the mean value of electrical conductivity is 349.7 (Ali et al., 2019).

In the same vein, the current finding is in line with the finding by Olawade et al., (2020) in Osun State, Nigeria who reported that temperatures of water for three out of the four villages were similar (25.2°C),Morintewo village had a slightly lower temperature of 24.6oC. The pH of the water samples was all below the WHO permissible limit. The T.D.S of the Origbo and Morintewo villages were about twice as high as that of the Atoba and Abimbola villages. The consistency between the current finding and the finding may be due to similarity in the demographic characteristics, activities around the water source, and season of the year. Based on the findings, it can be inferred that water quality is complex in different locations and seasons, with several parameters falling below WHO standards.

Conclusions

The pH levels in boreholes were often below WHO standards, and conductivity values were typically lower. Total suspended solids and turbidity were within acceptable limits. The study showed that chemical oxygen demand, biochemical oxygen demand, alkalinity, and total hardness were below WHO standards. The total dissolved solids (TDS) varied but remained within the acceptable range. Heavy metal levels, including lead, zinc, copper, mercury, cadmium, arsenic, chromium, nickel, and iron, showed mixed results.

In spring water, pH levels were often below WHO standards, with acceptable conductivity values. Total suspended solids and turbidity varied across seasons. Chemical oxygen demand, biochemical oxygen demand, alkalinity, and total hardness were below WHO standards. TDS levels remained within acceptable limits, except for some variations. Heavy metals showed mixed results, with variations in manganese levels.

Stream water had pH levels often below WHO standards, acceptable conductivity values, and variations in total suspended solids and turbidity. Chemical oxygen demand, biochemical oxygen demand, alkalinity, and total hardness were below WHO standards. TDS levels remained within acceptable limits, with variations. Heavy metal levels showed mixed results, with variations in zinc levels. Statistical analysis revealed significant differences in pH levels, zinc, and cadmium between dry and rainy seasons in borehole water. Similar significant differences were found in zinc in spring water and alkalinity, salinity, chloride, and zinc in stream water.

Ethical Approval and Consent

We got the ethical clearance for the study from the Research and Ethics Committee of the University of Port Harcourt. Consent was obtained from the community leaders and residents who were in charge of the water sources.

Recommendations

Awareness campaigns should be hosted to educate local communities on water quality, proper water usage, and the potential health risks associated with contaminated water sources.Development of strategies and preparedness plans to address seasonal variations and potential impacts on water quality.

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