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Assessing Water Quality from Borehole Sources in Five Communities of Ekpeyeland in Nigeria

***Okidhika, C.U., Ekpete, O.A., & Edori, O.S.**
Department of Chemistry, Ignatius Ajuru University of Education, Port Harcourt, Nigeria

***Corresponding author email:** okidhis@gmail.com

Abstract
Corrosiveness and scaling a characteristics that are common to groundwater and are associated with the nature of underlying rocks and soils that the groundwater mixes up with. Drinking water quality is to a very large extent greatly determined by the corrosion and scaling of residential plumbing networks and rural community water schemes. This research was carried out to examine the corrosiveness and scaling tendency of groundwater in Ekpeye Kingdom, Rivers State, Nigeria. Water samples were collected from five communities in Ekpeyeland and were analysed for some physicochemical parameters using the American Public Health Association (APHA) standard operating procedures. The corrosiveness tendency and scaling potentials of the test water samples were measured using water stability indices that are computed from the studied physicochemical parameters like pH, temperature, TDS, EC, Ca^{2+}, Mg^{2+}, Cl^- SO_4^{2-}, HCO_3^- alkalinity and total hardness. The results revealed that 41.67 percent of the physicochemical parameters exceeded the permissible limit of the World Health Organization. These parameters are pH, temperature, total hardness, Ca^{2+} and Mg^{2+}. The calculated values for the indices are LSI (-2.79 to -4.03), CSMR (3.32 - 13.91), RI (0.54 - 0.19), L-SI (0.50 - 0.20), PSI (8.49 - 9.66), RSI (10.88 - 11.88), AI (0.26 - 1.59). The result of the stability indices revealed that the test water samples of Ekpeyeland had significant scaling and corrosion potential. Liming, water softeners, filter beds and corrosion inhibitors are recommended to reduce the corrosion potential as well as lowering the scaling potential of drinking water.

Keywords: Water Stability, Scaling Tendency, Corrosiveness Potential, Scaling, Corrosion indices.

Introduction

The assessment of water quality is one of the most common approaches employed in water research (Eyankware et al., 2019). Research has proven that water quality is dependent on physicochemical parameters (Aghazadeh et al., 2017). Corrosion explains the physical and chemical interaction of metals and their surroundings, which can change metal properties (Pirialam et al., 2008). Corrosion and scaling are globally observed as one of the most important water quality problems (Bangalore & Usha, 2018). Water stability refers to the potential of water to either dissolve or deposit ions. The dissolution of minerals leads to corrosion while deposition leads to scaling. Corrosion and scaling have become a global challenge in water quality for domestic and industrial uses. It may adversely affect human health and the general acceptability of the public as well as the operating costs of safe drinking water supply for consumption purposes. Physical, chemical and biological parameters, the nature and degree of scaling and corrosion substances, and the source of water related to groundwater and surface water are a yardstick for determining their suitability for domestic and industrial applications (Wekesa, 2022). The corrosion phenomenon caused by some physical and chemical reactions causes alterations in the quality and properties of metallic equipment like tanks, pipelines, control valves, and special taps used in the distribution of water (Rezaee Kalantari et al., 2013). In other words, it is known that physical and chemical reactions as well as parallel reactions that cause metal alloy dissolution are the causes of corrosion phenomena (Eslami et al., 2020). The main complications of corrosion are the formation of holes, loss of water quality, and decline in resistance and equipment durability (Majid et al., 2018). In most countries, due to health and economic issues, attention is paid to this phenomenon, while continuing inspections and monitoring of corrosive environments are poor (Gonzalez et al., 2016).

Long-standing illnesses can be attributed to heavy metals dissolution due to corrosion and bio-accumulation in the human body. For instance, the high concentration of copper can cause bone toxicity in the body due to accumulation and its afterwards impacts on the central nervous system and cognitive delay. High levels of arsenic result in high blood pressure, induce cardiovascular-related diseases and are also proven to be carcinogenic (Bazrafshan et al., 2016). Another problem that is associated with corrosion and scaling is the alteration in the colour of the water, which adds to consumer complaints and reduces citizen's trust and patronage (Mirzabeygi et al., 2017). In some studies, conducted in some countries, the cost and damage resulting from corrosion are becoming more alarming (Vreeburg et al., 2008). The temperature, alkalinity, pH, hardness, carbon dioxide, dissolved oxygen and total dissolved solids are the key parameters that impact water corrosiveness and scaling potentials (Yousefi et al., 2018). The scaling process is another problem for water equipment, as the reaction of compounds of calcium magnesium and carbon dioxide in saturated waters is very important from an economic standpoint due to the formation of deposited layers on the interior surfaces of plants and used pipes. Following the effects of scale on water supply networks, it can be argued that at the time of operation, pressure reduction, reduced inflow and obstacles in the pipes would raise additional costs of maintenance (Liang et al., 2014). With the growth of the global population, a greater demand for water in the industrially, domestically and agriculturally has resulted in the worn out of available water sources (Abbas et al. 2018; Biglari et al., 2016). Geological structures and water resources could influence the chemical quality of water, corrosion and lime scaling potentials (Vreeburg et al., 2008).

The application of corrosion indices in estimating water corrosion and scaling potentials is simple. In general, there are several indices for this work, such as Langelier, Ryznar, Puckorius, aggressive, chloride-sulphate mass ratio and Larson-Skold indices. These indices have been developed by error tests. The sole difference that exists between the Puckorius index and the Ryznar index is that equilibrium pH is used in place of the measured pH value. The Larson–Skold index came into being to address corrosion induced by chloride, sulphate and alkalinity (Omid et al., 2019). Several studies have been conducted to date on the corrosiveness and scaling tendency of water resources. A study carried out in Nigeria on the corrosiveness and scaling potentials of water used Langelier saturation, Ryznar, and Larson–Skold indices. The results showed a corrosive potential in the water sources of the studied region. The study further posited that the change in the level of iron had a strong positive correlation with these indices (Akoteyon, 2013).

In Iran, a study on the stable conditions of water was assessed using Langelier, Ryznar, Larson–Skold, Puckorius, Rivelle, and aggressive indices. Ryznar index showed that 20% of the samples were neutral to corrosion whereas 80% of the water samples studied had corrosion tendency. The Langelier saturation index showed that 6.6% of the total samples were at the neutral condition, and 93.4% had a corrosion potential (Pirialam et al., 2008). Another study has also been carried out in Iran to evaluate the stability status of groundwater. It was revealed that the water stability status in the studied areas had a corrosion tendency (Aghazadeh et al., 2017). In the city of Noor Abad, Lorestan, research was carried out to ascertain the status of the drinking water and it was discovered that all the test water samples had corrosion potentials as explained from the computation of Ryznar, Puckorius, Larson–Skold and Aggression indices (Aghazadeh et al., 2017). Following the problems from corrosion and scaling of water, it was therefore imperative to evaluate the quality of water in Ekpeyeland through periodic assessment of water stability. There had not been any comprehensive study carried out on the corrosion and scaling potential of groundwater in the Ekpeye Kingdom. Thus, the purpose of this study was to investigate the corrosion and scaling tendency in Ekpeye Kingdom using Langelier, Ryznar, Puckorius, Larson–Skold, Rivelle, CSMR and Aggressive indices. The occurrence of water corrosion and scaling can be predicted and assessed using water stability indices (Pietrucha-Urbanik et al., 2020; Kumar & Singh, 2021).

The study area

The study areas are oil bearing communities in both Ahoada -East and Ahoada -West Local Government Areas of Rivers State, Nigeria. The geographical coordinates (GPS) of Ahoada -West Local Government Area are 5°09' and 5º59' North, 6° 28' and 6°47' East respectively and Ahoada –East Local Government Area are 5°07' and 5º41' North, 6° 38' and 6°64' East respectively. Ahoada -West and Ahoada -East Local Government Areas are situated within latitudes 5º09' and 5º59' N and between longitudes 6º28' and 6º47'E and5°07' and 5º41' N, 6° 38' and 6°64' E respectively.

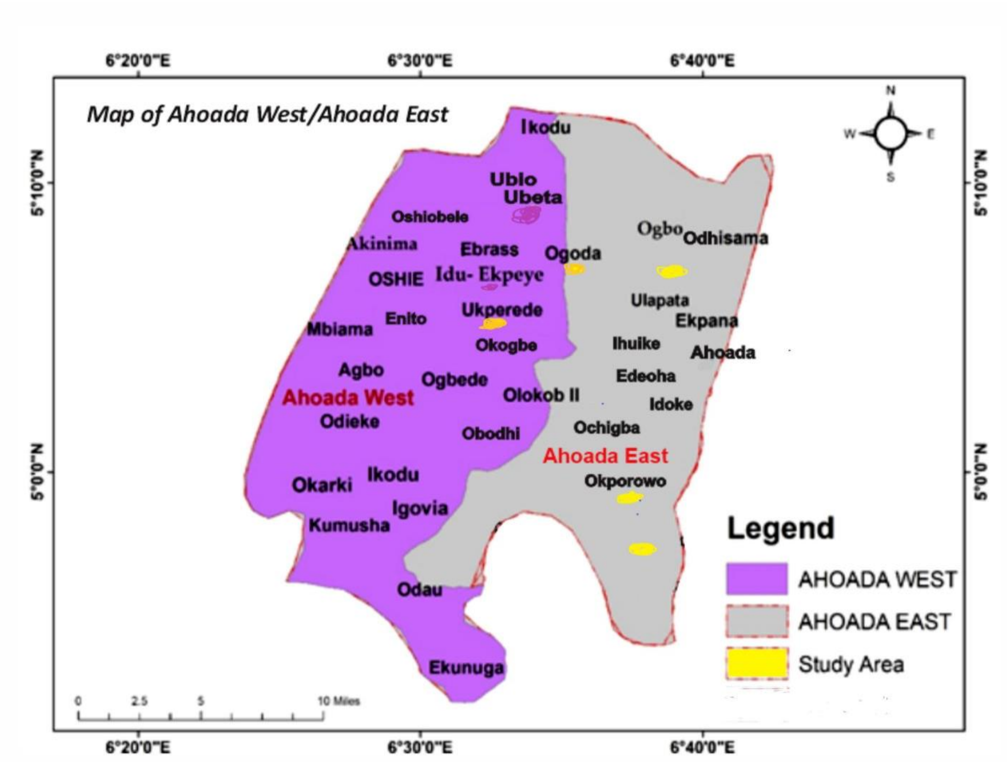

Figure 1 Map of the Study Area

Materials and Methods

The present research evaluates the corrosiveness and scaling tendency of groundwater water in some communities in Ekpeyeland using water stability indices like Larson-Skold, Langelier, Ryznar, Puckorius, Rivelle, aggressive indices and chloride-sulphate mass ratios. Composite samples of groundwater water were collected from each of the five communities of Ekpeyeland selected for this study and transported to the laboratory for analysis. The communities are Oshika, Ukpeliede, Ogoda, Ula-Ehuda and Okoma 2. To investigate the corrosiveness and scaling tendency of water samples, several water characteristics such as pH, total dissolved solids, total hardness, nitrates, chlorides, sulphate, carbonates, electrical conductivity, temperature, $Ca^{2+,}$ Mg^{2+} and total alkalinity were determined using standard operating procedures. Seven water stability indices were used to investigate the corrosion and scaling potential of drinking water. These include Langelier Saturation Index method (Alam & Kumar, 2023), Ryznar Stability Index method (Alam & Kumar, 2023), Larson-Skold Index method (Eyankware et al., 2019), Puckorius Scaling Index method (Eslami et al., 2020), Chloride-Sulphate Mass Ratio method (Eyankware et al., 2019), Aggressive Indices method (Eslami et al., 2020) and Rivelle index method (Eyankware et al., 2019).

Results

Table 1. Physicochemical result of groundwater parameters from the study area

STATIONS	Water Parameters									
	pH -	EC µS/cm	TDS mg/l	T °C	TH mg/l	T.Alk mg/l	HCO_3^- mg/l	Ca^{2+} mg/l	Mg^{2+} mg/l	Cl^- mg/l
OSHI	5.30±0.08	273.06±22.10	307.02±10.72	24.5±0.20	230.58±2.90	22.20±0.82	281.31±0.76	92.21±3.20	133.83±0.22	52.17±0.05
OGOD	4.14±0.14	440.34±28.60	441.18±21.19	22.78±0.28	213.54±3.76	29.97±0.11	260.51±0.88	85.44±1.60	124.41±0.48	34.97±0.12
UKPE	4.41±0.16	260.76±26.30	331.53±34.02	24.26±0.17	231.03±7.60	19.98±0.91	281.86±0.66	92.41±0.12	136.26±0.66	14.37±0.19
ULAE	4.35±0.52	270.60±29.40	354.57±9.60	26.51±0.28	205.92±2.81	17.48±0.25	251.22±0.84	82.30±6.80	118.62±2.30	13.78±0.57
OKOM 11	3.82±0.13	339.50±48.00	388.92±12.35	25.47±0.47	232.32±1.18	15.45±0.29	283.43±0.41	92.92±2.80	134.40±1.34	11.82±0.24
WHO, (2011)	**6.5 – 8.5**	**1250**	**500**	**20**	**200**	**200 – 600**	**600**	**75**	**50**	**250**

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OSHI = Oshika, OGOD = Ogoda, UKPE = Ukpeliede, ULAE = Ula Ehuda & OKOM 11 = Okoma 11

Table 2: Corrosion and scaling Indices classification and interpretation

Indices	Equation	Index value	Status of water
Aggressive index(AI)	AI = pH + log((TH) x (T.Alk))	A<10	Highly corrosive
		10<AI<12	Moderately Corrosive
		AI>12	Scaling tendency
Chloride-sulphate mass ratio (CSMR)	CSMR = [Cl-] / [SO42-]	CSMR <0.5	No corrosion potential
		CSMR>0.5	Corrosion potential
Langelier saturation index (LSI)	LSI = [Cl-] + [SO42-]/[HCO3-	LSI <0	Corrosive tendency
		LSI = 0	Neutral tendency
		LSI >0	Scaling tendency
Larson-Skold index (L-S index)	L-SI = $Cl^- + SO_4^{2-}$/ HCO_3-	L-SI <0.8	Scaling tendency
		0.8<L-SI<1.2	Moderate corrosive tendency
		L-SI>1.2	High corrosive tendency
Puckorius scaling index(PSI)	PSI = 2pHs - pHeq	PSI > 7	Corrosive tendency
		PSI <6	Scaling tendency
Revelle index (RI)	RI = Cl^-/HCO_3^-	RI<0.5	Unaffected by salinization
		0.5 - 6.6	Slightly affected by salinization
		RI>6.6	Strongly affected by salinization
Ryznar stability index (RSI)	RSI = pH + log (TH xT.Alk)	RSI < 5.5	High scaling tendency
		5.5<RSI <6.2	Scaling tendency
		6.2<RSI<6.8	Neutral tendency

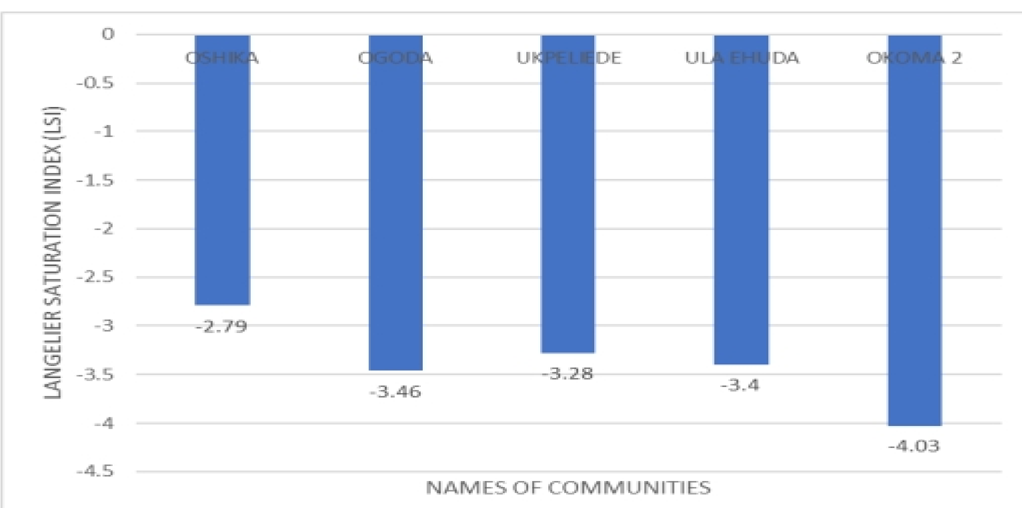

Fig 2: Chart showing computed values for Langelier saturation index (LSI)

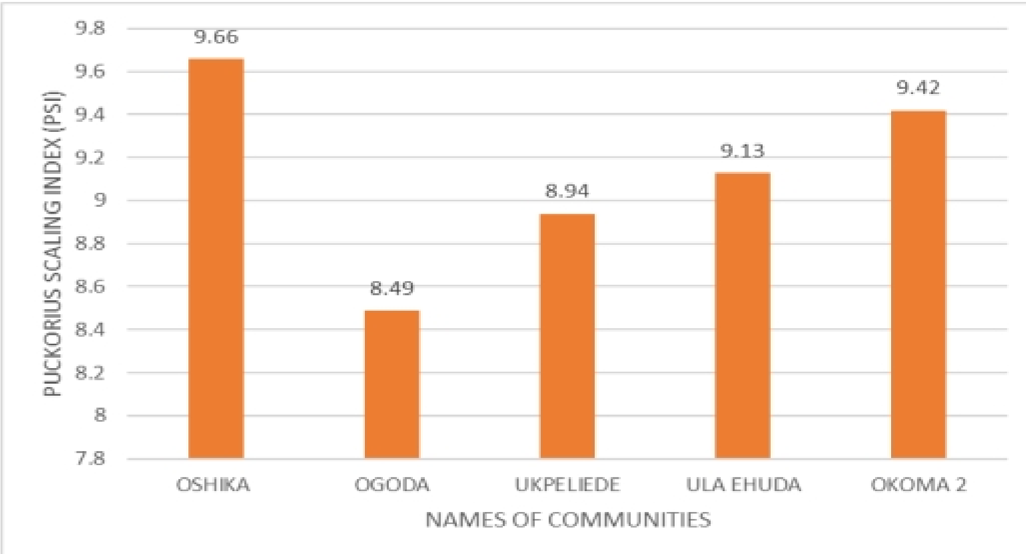

Fig 3: Chart showing computed values for Puckorius scaling index(PSI)

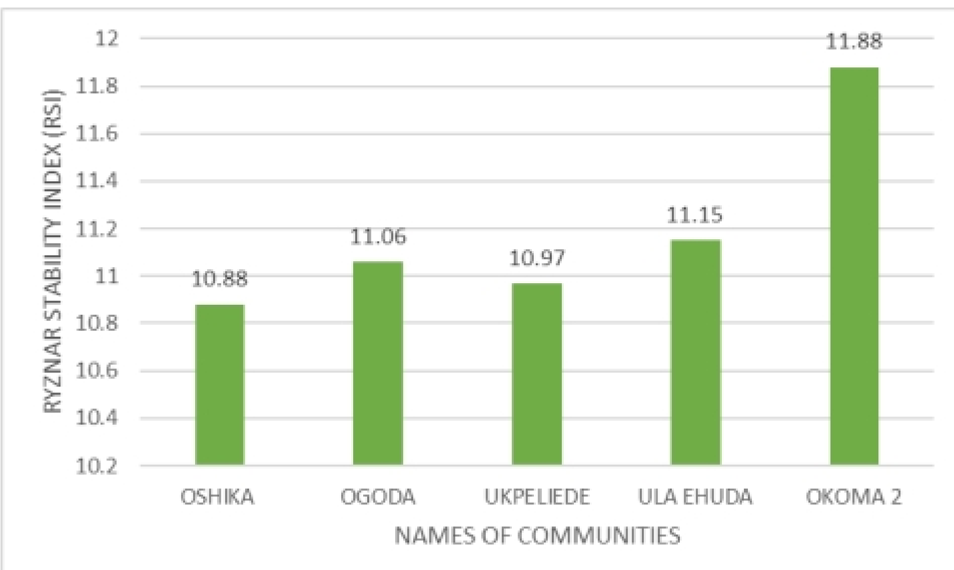

Fig 4: Chart showing computed values for Ryznar stability index(RSI)

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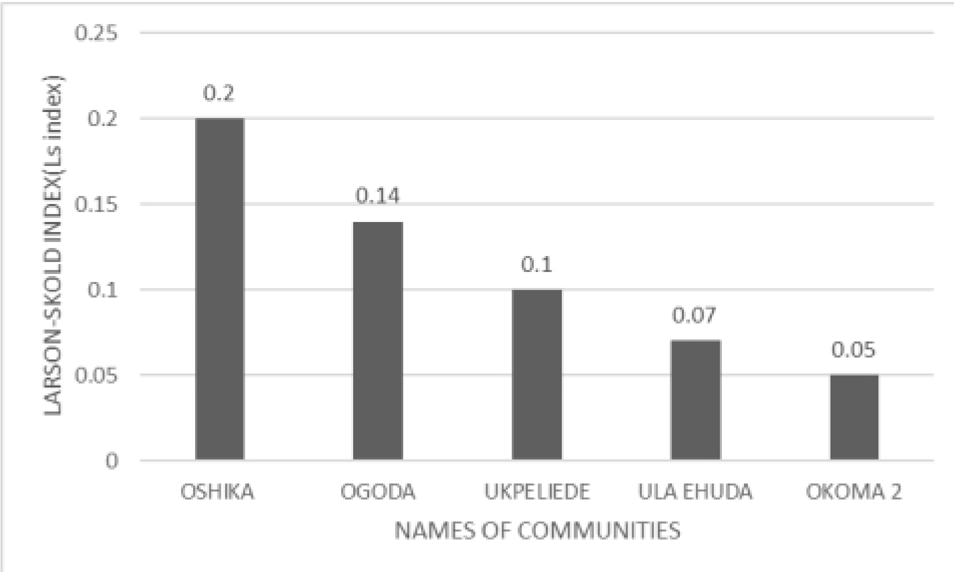

Fig 5: Chart showing computed values for Larson-Skold index (L-SI)

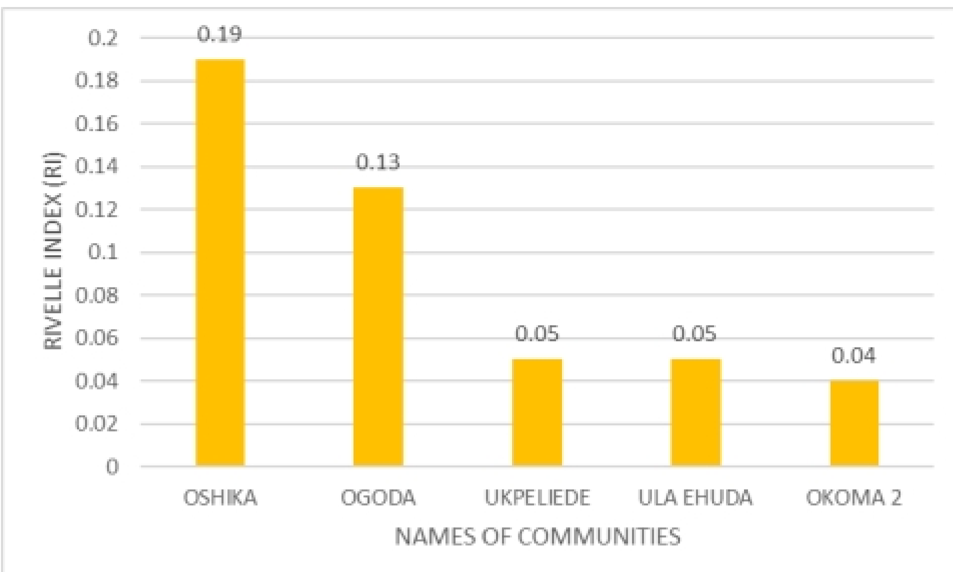

Fig 6: Chart showing computed values for Rivelle index(RI)

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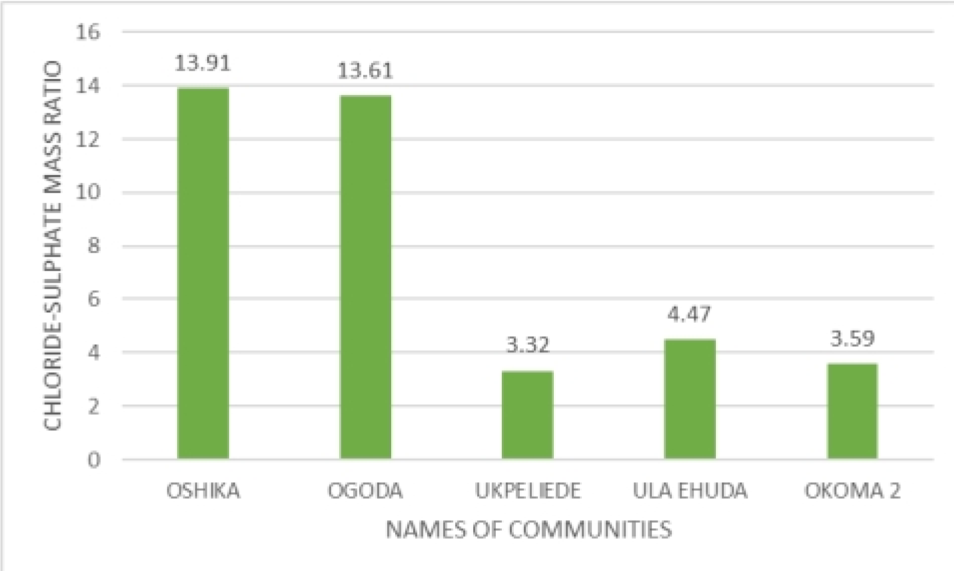

Fig 7: Chart showing computed values for chloride-sulphate mass ratio (CSMR)

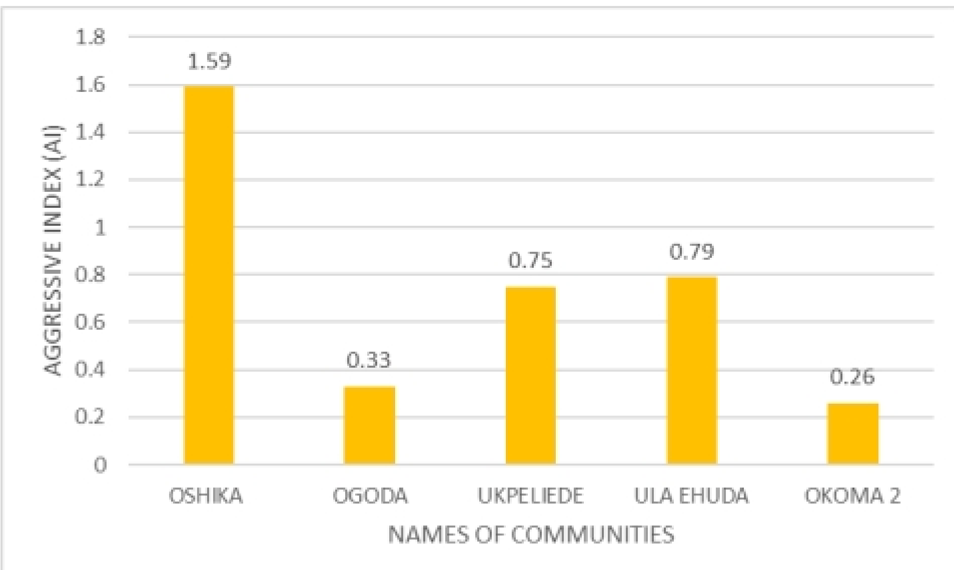

Fig 8 : Chart showing computed values for aggressive index (AI)

Discussion

The study showed that 58.33 per cent of the parameters studied comply with the WHO 2011 guidelines. However, pH levels, temperatures, total hardness, Ca^{2+} and Mg^{2+} are not consistent with WHO recommendations (2011), while the conductivity, total dissolved solids, total alkalinity, carbonate, chloride and sulphur values are within the permitted limits. pH, temperature, TH, Ca^{2+}, and Mg^{2+} in 100% of samples exceeded the permissible limits. Previous studies have found that high TH levels in water can build up sediments(limescale) and eventually cause obstruction of pipes, thereby limiting the using this type of water in boilers (Sharma & Patel, 2010). The results showed that water hardness and total alkalinity produced substances in water. The impact of Cl^{-} and SO_4^{2-} could be attributed to be the sole reason for the corrosion and lime scaling of water samples (Yousefi et al., 2018).

The computed Larson-Skold index result of this study ranged from 0.05 to 0.20 (Fig. 5), with Oshika and Ogoda showing higher L-SI values thus signifying high corrosion tendency compared to other stations, Studies have shown that HCO^- affects water acidity thus making it corrosive (Mukate et al., 2019). Similarly, the sulphate level of water can accelerate corrosion activities (Atasoy & Yesilnacar, 2010). Chloride-Sulfate Mass Ratio above 0.5 implies that water facilities are considered to be contributing to the corrosion of the watercourses (Mahmood et al., 2018; Omid et al., 2019). In this study, CSMR varied from 3.32 - 13.91, with a mean of 7.78 (Figure 7). The computation result of CSMR of this study showed that 100% of the test water samples had CSMR above 0.5, which means that there is a tendency for corrosion of groundwater in the study area. This might be attributed to seawater intrusion through springs, waterways and man-made waste originating in the area.

In the same vein, Revelle Index values less than 0.5 suggest that the chemistry of water, corrosion vulnerability and scale are not influenced by salinity (Akoteyon, 2013). RI values in this research varied from 0.04 - 0.19, with an average value of 0.09 (Figure 6). The RI computation from this research further implied that the source of chloride in the test water samples is due to the dissolution of halite (rock salt) (Akoteyon et al., 2018). The low level of chloride in groundwater may be due to a low degree of intrusion of sea salt through rivers and streams (Olabaniyi & Owoyemi, 2004).

The Langelier saturation index is a useful tool for determining the degree of corrosiveness of water. Alam and Kumar (2023), posited that the LSI is the difference between saturated pH and the measured pH. The negative mean LSI value of -3.39 implies a corrosion trend for the test groundwater samples as displayed in Figure 1. The values obtained showed that all the test water samples were corrosive and may not be suitable for human consumption. Furthermore, Ram et al. (2021) described the Ryznar Stability Index as the difference between the measured pH and twice saturation of water. The mean RSI value was computed as 11.19 (Figure 4), thus implying a strong corrosion potential of the water samples from the study area. To validate the buffering capacity and precipitation in the test water samples in this study, the Puckorius Scaling Index was computed to speculate the overall degree of sedimentation load when the water attains equilibrium (Taghipour et al., 2012). PSI values range from 8.49 to 9.66, with a mean PSI value of 9.13. As shown in Figure 3, implying that all the water samples were susceptible to corrosion.

Finally, the Aggressive index was employed specifically to measure asbestos-cement pipe corrosion (Taghipour et al. 2012). It is a veritable tool used in the selection of materials or processing methods for the control of corrosion in water distribution channels. Aggressive index expression was derived using water parameters like total alkalinity, total hardness and pH. The AI of the water samples is shown in Figure 8. AI values varied from 0.26 - 1.59, with a mean value of 0.74 for all stations. The average value indicates that the corrosion susceptibility of the water sample is moderate.

Conclusion

This research was conducted to investigate the quality of drinking water in the Ekpeye Kingdom through the examination of some physical and chemical parameters and to evaluate the corrosiveness and lime scaling tendency of water using Langelier, Ryznar, Puckorius, Larson-Skold, Rivelle and aggressive indices as well as chloride-sulphate mass ratio. It was observed that 41.67% of the parameters (pH, Temp, TH, Ca^{2+} and Mg^{2+}) did not meet the established guidelines, while 58.33% of the parameters (EC, TDS, T.Alk, HCO_3^-, Cl^-, NO_3^- and SO_4^{2-}) met the established guidelines. In the assessment of water stability, the index results revealed that the groundwater in Ekpeye kingdom had scaling and corrosion potential as evident in the range of values obtained from the computation from each of the water stability indices. Considering the economic implication of mitigating the effect of corrosion and scaling and health damage that is caused or may be caused by lime scale in water and water corrosiveness, this study strongly recommends stabilization efforts such as scale control, periodic monitoring process and water monitoring through liming, use of water softeners, regular flushing and treatment of water boreholes, education of rural dwellers on global best practices seem inevitable.

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