



## DETERMINATION OF WATER QUALITY FROM BOREHOLE SOURCES IN OVIA NORTH EAST COMMUNITIES, EDO STATE, NIGERIA

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### Abstract

Access to clean and safe drinking water is crucial for the health and well-being of communities. This study aimed to assess the water quality from borehole sources in the Ovia North East communities of Edo State, Nigeria. The research involved collecting water samples from various boreholes within the area and analyzing them for key parameters indicative of water quality using the American Public Health Association (APHA) standard operating procedures. The test water samples' corrosiveness tendency and scaling potentials were measured using water stability indices computed from the studied physicochemical parameters like pH, temperature, TDS, EC, Ca<sup>2+</sup>, Mg<sup>2+</sup>, Cl<sup>-</sup>, SO<sub>4</sub><sup>2-</sup>, HCO<sub>3</sub><sup>-</sup> alkalinity, and total hardness. The findings of this research revealed variations in the water quality parameters across different boreholes in the study area exceeding the permissible limit of the World Health Organization. These parameters are pH, temperature, total hardness, Ca<sup>2+</sup>, and Mg<sup>2+</sup>. The result of the stability indices revealed that the test water samples in Ovia Northeast Communities had significant scaling and corrosion potential. This research contributes to the ongoing efforts to monitor and enhance water quality standards in the region, highlighting the importance of regular testing and maintenance of borehole water sources. Sustainable management practices and community awareness programs are essential to safeguarding the health of the population and promoting sustainable development in the area.

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

### Introduction

Water quality assessment is a crucial aspect of water research (Eyankware et al., 2019), playing a vital role in understanding and monitoring the health of water bodies. Researchers often utilize various methods and techniques to assess water quality, aiming to identify potential contaminants, assess the overall health of aquatic ecosystems, and ensure the safety of water for human consumption and environmental sustainability. For instance, common parameters measured in water quality assessment include pH levels, dissolved oxygen content, turbidity, and the presence of pollutants such as heavy metals and pathogens. By analyzing these parameters, researchers can draw conclusions about the quality of water and its suitability for different uses.

Research has proven that water quality depends on physicochemical parameters (Aghazadeh et al., 2017). These parameters play a crucial role in determining the overall health and safety of water sources. Indeed, pH level of water is a key physicochemical parameter that directly influences its acidity or alkalinity. In addition, the presence of heavy metals such as lead, mercury, and cadmium can significantly impact water quality and pose serious health risks to humans and aquatic life. 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 describes the potential of water to either dissolve or deposit ions. The dissolution of minerals leads to corrosion, while deposition leads to scaling. Water stability, in essence, is a critical aspect of water quality that can have significant impacts on various systems and infrastructures. When water dissolves ions, particularly minerals like calcium and magnesium, it can result in the corrosion of pipes and plumbing fixtures. Corrosion and scaling have become a global challenge in water quality for domestic and industrial uses. It may adversely affect human health, the general acceptability of the public, and 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 water distribution (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 primary 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, attention is paid to this phenomenon due to health and economic issues, 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 bioaccumulation in the human body. For instance, the high concentration of copper can cause bone toxicity in the body due to accumulation and its afterward 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 associated with corrosion and scaling is the alteration in the color 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, corrosion costs and damage are becoming more alarming (Vreeburg et al., 2008). The key parameters impacting water corrosiveness and scaling potentials are temperature, alkalinity, pH, hardness, carbon dioxide, dissolved oxygen, and total dissolved solids (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 significant 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 maintenance costs (Liang et al., 2014). With the growth of the global population, a greater demand for water 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).

Applying corrosion indices in estimating water corrosion and scaling potentials is simple. In general, this work has several indices, such as Langelier, Ryznar, Puckorius, aggressive, chloride-sulfate mass ratio, and Larson-Skold indices. Error tests have developed these indices. The sole difference between the Puckorius and Ryznar indexes 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, sulfate, and alkalinity (Omid et al., 2019). Several studies have been conducted to date on water resources' corrosiveness and scaling tendency. 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 iron level 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 tendencies. 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. The water stability status in the studied areas was revealed to be corrosion (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 caused by corrosion and scaling of water, it was therefore imperative to evaluate the quality of water in Ovia Northeast Communities through periodic assessment of water stability. No comprehensive study has been carried out on groundwater's corrosion and scaling potential in the study area. Thus, this study investigated the corrosion and scaling tendency in Ovia Northeast Communities using Langelier, Ryznar, Puckorius, Larson-Skold, Rivelle, CSMR, and Aggressive indices. Water corrosion and scaling can be predicted and assessed using water stability indices (Pietrucha-Urbanik et al., 2020; Kumar & Singh, 2021).

## Materials and Methods

The present research evaluates the corrosiveness and scaling tendency of groundwater water in some communities in Ovia Northeast of Edo State, Nigeria, using water stability indices like Larson-Skold, Langelier, Ryznar, Puckorius, Rivelle, aggressive indices, and chloride-sulfate mass ratios. Composite samples of groundwater water were collected from each of the five communities selected for this study and transported to the laboratory for analysis. The communities are Okada, Uhen, Utese, Ora, and Uhiere. 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<sup>2+</sup>, Mg<sup>2+</sup> 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 <sub>3</sub> <sup>-</sup> mg/l	Ca <sup>2+</sup> mg/l	Mg <sup>2+</sup> mg/l	Cl <sup>-</sup> mg/l
OKADA	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
UHEN	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
UTESE	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
ORA	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
UHIERE	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

**Table 2: Corrosion and scaling Indices classification and interpretation**

Indices	Equation	Index value	Status of water
Aggressive index(AI)	$AI = pH + \log((TH) \times (T. Alk))$	A<10	Highly corrosive
		10<AI<12	Moderately Corrosive
		AI>12	Scaling tendency
Chloride-sulphate mass ratio (CSMR)	$CSMR = \frac{[Cl^-]}{[SO4^{2-}]}$	CSMR <0.5	No corrosion potential
		CSMR>0.5	Corrosion potential
Langelier saturation index (LSI)	$LSI = [Cl^-] + [SO4^{2-}]/[HCO3^-]$	LSI <0	Corrosive tendency
		LSI = 0	Neutral tendency
		LSI >0	Scaling tendency
Larson-Skold index (L-S index)	$L-SI = Cl^- + SO4^{2-}/ HCO3^-$	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)	$RI = Cl^-/HCO3^-$	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)	$RSI = pH + \log (TH \times T. Alk)$	RSI < 5.5	High scaling tendency
		5.5<RSI<6.2	Scaling tendency
		6.2<RSI<6.8	Neutral tendency



Fig 1: Chart showing computed values for Langelier saturation index (LSI)

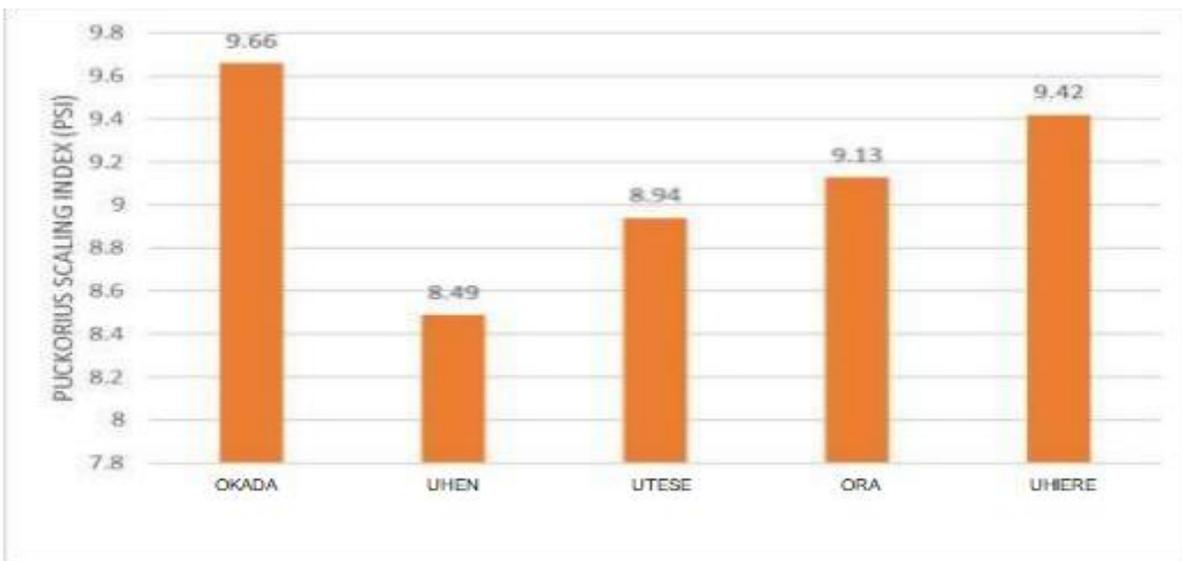


Fig 2: Chart showing computed values for Puckorius scaling index(PSI)

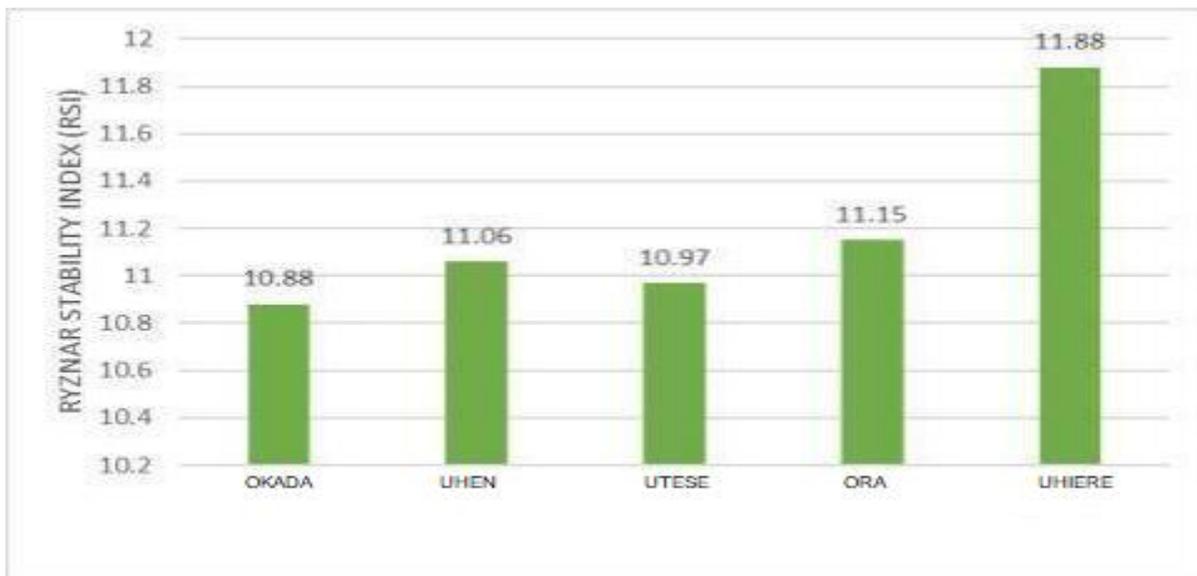


Fig 3: Chart showing computed values for Ryznar stability index(RSI)

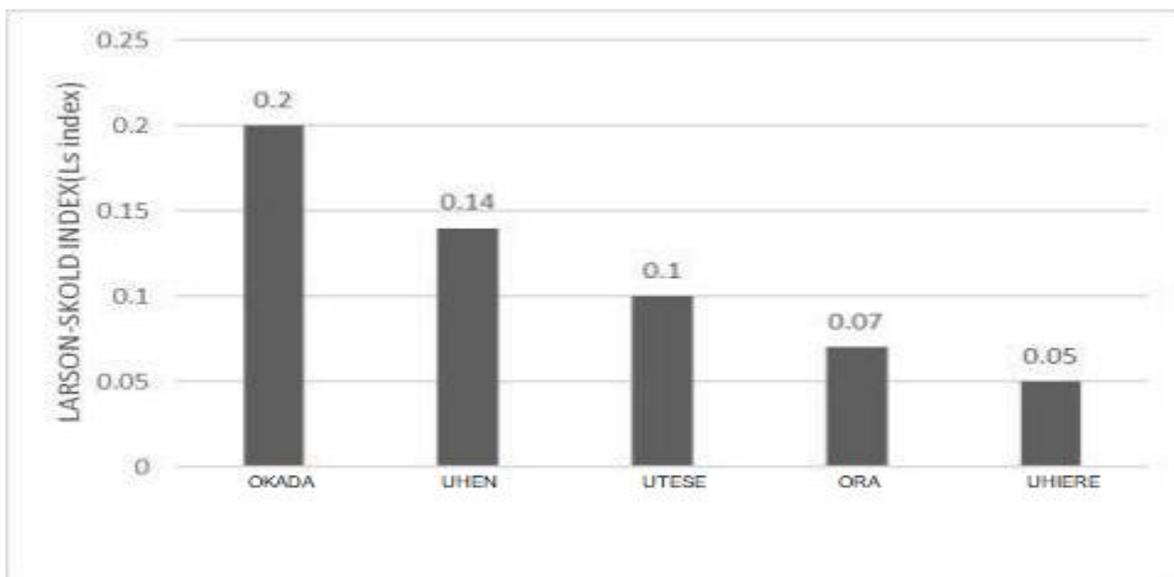


Fig 4: Chart showing computed values for Larson-Skold index (L-SI)

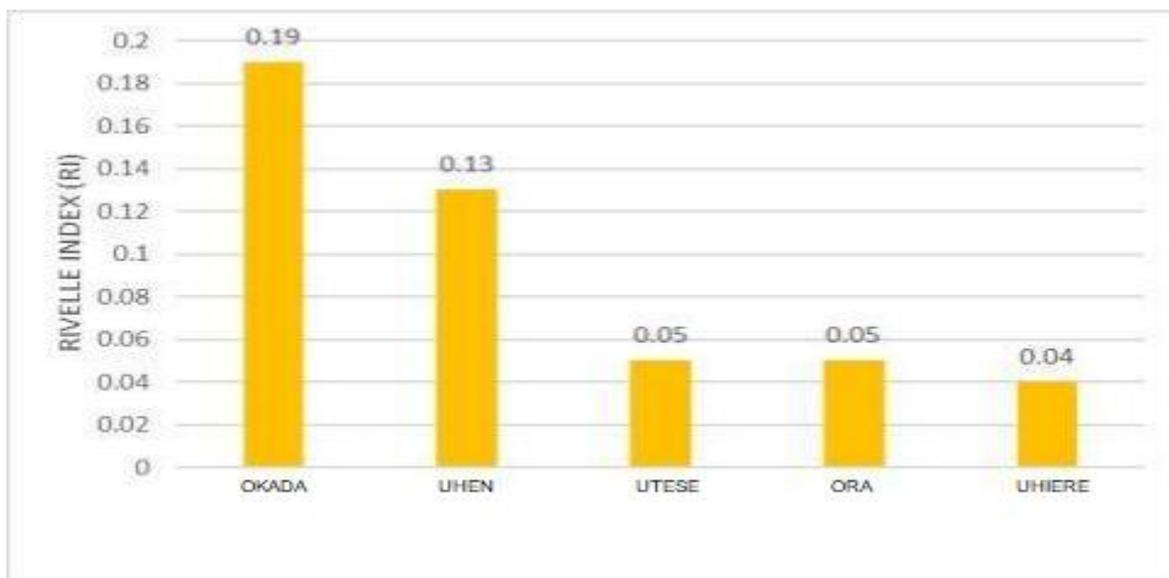


Fig 5: Chart showing computed values for Rivelle index(RI)

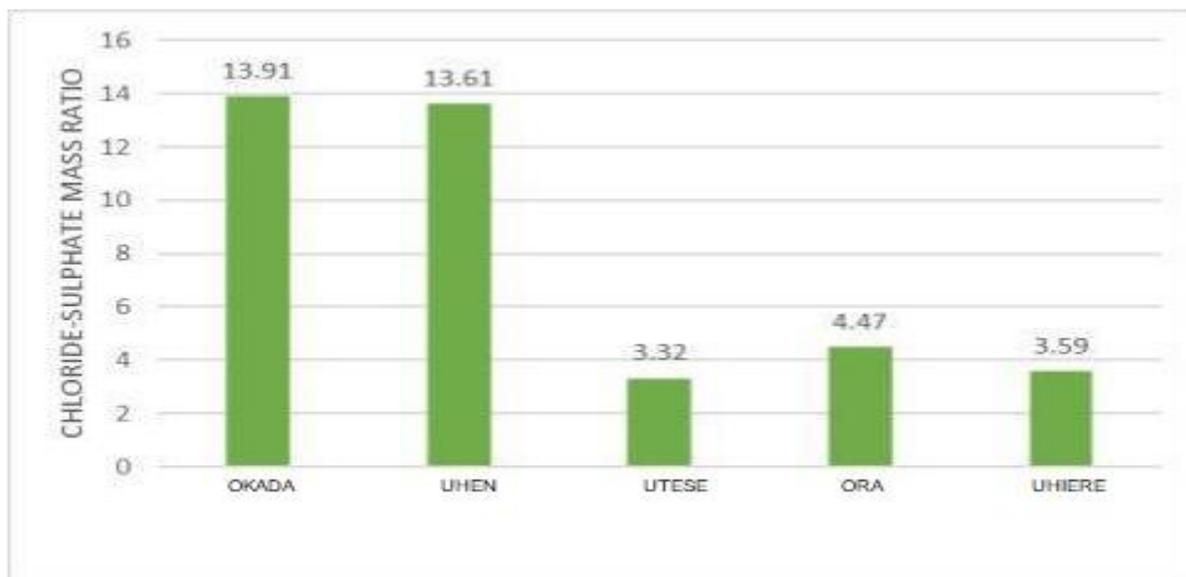
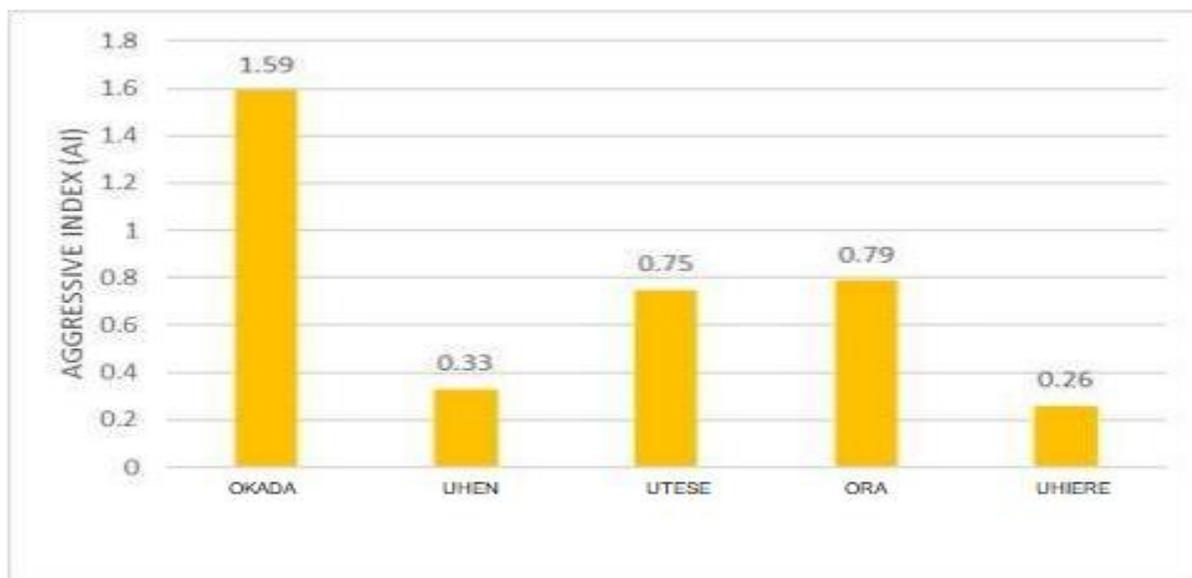


Fig 6: Chart showing computed values for chloride-sulphate mass ratio (CSMR)



**Fig 7: Chart showing computed values for aggressive index (AI)**

### Discussion

According to the study, 58.33% of the metrics examined meet the 2011 WHO recommendations. While conductivity, total dissolved solids, total alkalinity, carbonate, chloride, and sulfur values are within the allowed limits, pH levels, temperatures, total hardness,  $\text{Ca}^{2+}$ , and  $\text{Mg}^{2+}$  do not meet WHO guidelines (2011). In 100% of the samples, the acceptable values for pH, temperature, TH,  $\text{Ca}^{2+}$ , and  $\text{Mg}^{2+}$  were exceeded. According to earlier research, high TH levels in water can accumulate sediments (limescale) and eventually clog pipes, which restricts the use of this kind of water in boilers (Sharma & Patel, 2010). The findings demonstrated that chemicals in water were created by water hardness and total alkalinity. According to Yousefi et al. (2018), the corrosion and lime scaling of water samples may be exclusively caused by the effects of  $\text{Cl}^-$  and  $\text{SO}_4^{2-}$ .

The calculated Larson-Skold index for this investigation varied from 0.05 to 0.20 (Fig. 5), with Okada and Uhen exhibiting elevated L-SI values, indicating a greater propensity for corrosion relative to other stations. Research indicates that  $\text{HCO}_3^-$  influences water acidity, rendering it corrosive (Mukate et al., 2019). Likewise, the concentration of sulphate in water might expedite corrosion processes (Atasoy & Yesilnacar, 2010). A Chloride-Sulfate Mass Ratio exceeding 0.5 indicates that water facilities are deemed to contribute to the corrosion of watercourses (Mahmood et al., 2018; Omid et al., 2019). In this study, CSMR ranged from 3.32 to 13.91, with a mean of 7.78 (Figure 7). The computation of the CSMR in this study indicated that 100% of the tested water samples exhibited a CSMR over 0.5, signifying a propensity for groundwater corrosion in the studied area. This may be ascribed to seawater intrusion via springs, streams, and anthropogenic garbage originating from the region.

A similar conclusion can be drawn from the fact that Revelle Index values that are lower than 0.5 indicate that salinity does not influence the chemistry of water, corrosion vulnerability, or scale (Akoteyon, 2013). Between 0.04 to 0.19 was the range of RI values that were investigated in this study, with 0.09 being the average value (Figure 6). The RI computation that was performed because of this research further suggested that the dissolving of halite, which is a type of rock salt, is the cause of the presence of chloride in the water samples that were tested (Akoteyon et al., 2018). According to Olabaniyi and Owoyemi (2004), the low amount of chloride in groundwater may be the result of a low degree of sea salt intrusion through rivers and streams on the part of the groundwater.

The Langelier saturation index is an effective instrument for assessing the corrosiveness of water. Alam and Kumar (2023) asserted that the LSI represents the disparity between saturated pH and the measured pH. The negative mean LSI value of -3.39 indicates a corrosion tendency for the tested groundwater samples, as illustrated in Figure 1. The

results indicated that all tested water samples were corrosive and potentially unsuitable for human consumption. Additionally, Ram et al. (2021) characterized the Ryznar Stability Index as the disparity between the measured pH and double the saturation of water. The average RSI value was calculated to be 11.19 (Figure 4), indicating a significant corrosion potential of the water samples from the research area. To assess the buffering capacity and precipitation in the test water samples of this study, the Puckorius Scaling Index was calculated to estimate the overall sedimentation load when the water reaches equilibrium (Taghipour et al., 2012). PSI values span from 8.49 to 9.66, with an average PSI value of 9.13. Figure 3 indicates that all water samples exhibited susceptibility to corrosion.

According to Taghipour et al. (2012), the Aggressive index was utilized exclusively for the purpose of measuring the corrosion resistance of asbestos-cement pipes. When it comes to the selection of materials or processing processes for the purpose of controlling corrosion in water distribution channels, it is a powerful instrument that is utilized. All of the water characteristics, including total alkalinity, total hardness, and pH, were utilized in order to calculate the aggressive index expression. Figure 8 illustrates the artificial intelligence of the water samples. The average value of AI for all stations was 0.74, with values ranging from 0.26 to 1.59 out of a possible two. Based on the obtained average value, it may be concluded that the water sample exhibits a moderate sensitivity to corrosion.

## Conclusion

This study aimed to assess the quality of drinking water in Ovia Northeast, Edo State, Nigeria, by analyzing various physical and chemical parameters, and to evaluate the corrosiveness and lime scaling propensity of the water utilizing the Langelier, Ryznar, Puckorius, Larson-Skold, Rivelle, and aggressive indices, in addition to the chloride-sulphate mass ratio. It was noted that 41.67% of the parameters (pH, temperature, total hardness, calcium, and magnesium) failed to comply with the specified requirements, but 58.33% of the parameters (electrical conductivity, total dissolved solids, total alkalinity, bicarbonate, chloride, nitrate, and sulfate) adhered to the stated guidelines. The evaluation of water stability indicated that the groundwater in the chosen communities had both scaling and corrosion potential, as demonstrated by the range of values derived from the calculation of each water stability index. This study advocates for stabilization measures to mitigate the economic impact of corrosion and scaling, as well as health risks associated with lime scale in water and water corrosiveness. Recommended strategies include scale control, periodic monitoring, water treatment through liming, the use of water softeners, regular flushing of water boreholes, and educating rural populations on global best practices.

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