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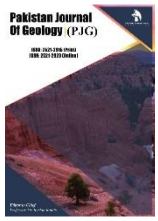

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RESEARCH ARTICLE

SEASONAL VARIATIONS OF ALKALINITY OF SURFACE WATERS IN PARTS OF AKWA IBOM STATE, SOUTH- SOUTH, NIGERIA

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ABSTRACT

Alkalinity of surface waters is a measure of the capability of water to neutralize the level of acidity of water. This is really an expression of buffering capacity of water. Alkalinity is important for fish and aquatic life because it protects or buffers against rapid pH changes. Living organisms, especially aquatic life, function best in a pH range of 6.0 to 9.0. Calcium carbonate saturation indices (Langelier) commonly are used to evaluate the scale-forming and scale-dissolving tendencies of water, and is related to alkalinity of water. Higher alkalinity levels in surface waters will buffer acid rain and other acid wastes from anthropogenic activities and prevent pH changes that are harmful to aquatic life. For protection of aquatic life the buffering capacity should be at least 20 mg/L CaCO3. This study aims at the determination of seasonal variations of total alkalinity, total hardness and langelier saturation index of surface waters in Uyo, Ikot Ekpene and Eket , by computer aided potentiometry. From the results of alkalinity determination, it is significant that all the locations have higher than 20 mg/L total alkalinity, that falls within the limit of moderate alkalinity (50 mg/L – 160 mg/L) , as the optimum alkalinity of surface waters for the protection of aquatic life and the surface waters not being negatively impacted by anthropogenic activities going on in these areas. Also, the p H of the surface waters in the studied locations in both seasons were less than 8.3, indicating that the dominant alkalinity was bicarbonate alkalinity. The total hardness determined in the surface waters of the studied locations during both rainy and dry seasons were within the water hardness classification of moderately hard (60 – 120 mg/L CaCO3) according to United State Geological Survey. The Langelier saturation index of surface waters determined in the study locations in both the rainy and dry seasons were outside the optimum range of – 0.5 to + 0.5, indicating that all the surface waters in the study areas are calcium carbonate dissolving and under -saturated with calcium carbonate, thereby have corrosive potential on metal substrates, also difficult in forming calcium carbonate scales. The seasonal variations in total alkalinity, Langelier saturation index and total hardness in the surface waters from Uyo, Ikot Ekpene and Eket were not significant at P ≤ 0.05.

KEYWORDS

Calcium carbonate saturation, Alkalinity, Surface waters, Total hardness, Corrosive Potential

1. INTRODUCTION

Environmental pollution is a growing problem worldwide as a result of contaminations which are at different levels in different parts of the world (Abioye et al., 2018). Surface waters of Europe are becoming much cleaner today because of the Urban Waste Water Treatment Directive which aims to protect the European environment from the adverse effects of discharges of urban and industrial wastewaters by ensuring adequate treatment of wastewater (EEA, 2007; Udousoro, and Umoren, 2014)

Surface waters play a fundamental role in sustaining life, ecosystems, and human civilizations. It is essential for the survival and growth of all known living organisms, from microorganisms to complex multicellular life forms (Yin et al., 2019 ; Akinro et al.,2008).

The importance of water quality is to support aquatic lives including fish is very critical in terms of the physicochemical parameters such as pH, temperature, dissolved oxygen, transparency, total alkalinity, total hardness, electrical conductivity, phosphate and sulphate. According to the study, the physico-chemical properties of water are vital for the distribution and richness of the aquatic organisms (Akpan et al., 2015).

Akwa Ibom State's abundance of surface water resources, including rivers, streams, estuaries, and its coastal border along the Atlantic Ocean, plays a central role in the state's environment, economy, and culture. These water bodies are essential for various activities, from agriculture to fisheries, and contribute significantly to the livelihoods of the local population (FAO, 2024).

The alkalinity of water is its quantitative capacity to undergo reaction with a strong acid to a designated pH (Udoh et al., 2020). Alkalinity can also be said to be a measure of an aggregate property of water and can be interpreted in terms of specific substances only when chemical compositions of the sample is known. The measured value of alkalinity of water vary significantly with the endpoint pH used , is primarily the function of carbonate, bicarbonate and hydroxide content.(Etesin et al. 2018). The pH at which water is satu rated with calcium carbonate is known as the pH of saturation. Calculation of saturation index is based on the values of pH , total alkalinity, total dissolved solids (TDS) , temperature , and total hardness as calcium carbonate (APHA, AWWA,WEF, 2005; Etesin et al., 2018). A positive saturation index is an indication of non-corrosiveness condition, whereas a negative saturation index indicates corrosive condition or corrosive possibility.

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Akwa Ibom State, located in the southern region of Nigeria, boasts a rich and diverse aquatic environment characterized by a network of rivers, estuaries, and coastal areas along the Atlantic Ocean (Chidumeje et al., 2015). These surface water bodies are vital for the state's economy, ecosystems, and the well-being of its residents. However, seasonal variations in alkalinity levels in these surface waters as a result of anthropogenic activities pose significant challenges and questions that necessitate investigation and understanding. These seasons likely influence the alkalinity of surface waters, but the extent and nature of these variations remain poorly understood. A fundamental problem is the need to document and analyze how alkalinity changes over the course of a year and across different water bodies in the state.

The seasonal variations in alkalinity could have profound consequences for the health of aquatic ecosystems, including fish populations, aquatic flora, and other wildlife. However, there is a lack of comprehensive data regarding the ecological impact of these fluctuations.

The aim of this study is to determine levels of alkalinity and calcium carbonate saturation index in surface waters within some part of Akwa Ibom State (Uyo, Ikot Ekpene, Eket) , in order to assess the seasonal variations resulting from anthropogenic activities such as massive road constructions, agricultural activities, oil explorations and exploitations that are prevalent in the study area.

2. Materials And Methods

2.1 The Study area

Akwa Ibom State lies between latitude 4.30 to 5.30 North; and Longitudes 7.30 to 8.20 East. In terms of structural make up, Akwa Ibom is triangular in shape and covers a total land area of 8,412 km2, encompassing the Qua Iboe River Basin, the western part of the lower Cross River Basin and the Eastern part of the Imo River Basin. With an ocean front which spans a distance of 129 kilometers from Ikot Abasi in the west to Oron in the east. (Figure. 1). Akwa Ibom's 6,900 sq Km land area is located between Cross River, Abia, and Rivers on the sandy coastal plain of the Gulf of Guinea. It is bordered on the south by the Atlantic Ocean which stretches from Ikot Abasi to Oron. The area has over 200 mm of rainfall per annum. The area is generally flat and lies within the beach dunes and large valleys (Etesin et al., 2021) . It is characterized by man- grove swamps, tidal creeks and brackish lagoons. The area is subjected to constant inundation by saline and brackish water.

In this study, surface water samples were collected from Uyo, Ikot Ekpene and Eket Local Government Areas of Akwa Ibom State depicted in Table 1.

Figure 1: Map of Akwa Ibom State, Nigeria showing sampling locations

Table 1: Coordinates of Sample Locations

Location	Sampling Point	Coordiantes			
Uyo	Obot Idim Nsit	04	48	341	N
		09	52	172	E
Ikot Ekpene		04	54	541	N
		09	60	352	E
Eket	Ikot Ibok River	04	39	450	N
		09	49	710	E

Akwa Ibom belongs to the area classified as coastal plain sands known as the Benin formation. The Benin formation is the upper most unit of the Niger Delta complex and overlies the Agbada formation. The coastal plain sands are made of alternating sequences of gravels and sands of different grain sizes e.g. silt, clay and alluvium. Accordingly, Benin formation comprises of sediments whose age is from tertiary to recent. Benin formation also consists of fine-medium coarse-grained sands which are sometimes poorly sorted (Chilton, 1992).

The study area is underlain by the sedimentary formation of Late Tertiary and Holocene ages (Magnus et al., 2012). Deposits of recent alluvium and beach ridge sands occur along the coast and the estuaries of the Imo and Qua Iboe Rivers and also along flood plains of creeks. The study area consists of mainly of coastal plain sands. The sands are mature, coarse and moderately sorted. The coastal plain sands, otherwise known as the Benin formation overlies the Bende-Ameki formation and dips south westward (Akankpo and Igbokwe, 2011; Mbonu and Ebeniro, 1991).

The landscape of Akwa Ibom State comprises of a generally low-lying plain and riverine areas with no portion exceeding 175 metres above mean sea level. The physiography of Eket is that of a beach ridge complex characterized by a succession of sub parallel sand ridges (Figure. 1). The physical relief of Eket, Uyo and Ikot Ekpene Local Government Areas is basically flat, though with some marshy river-washed soils around the banks of Qua Iboe River (Aluminium Smelter Co. of Nigeria, 1997). Eket Local Government falls within the tropical zone wherein its dominant vegetation is the green foliage of trees/shrubs and the oil palm tree belt. The three Local Government areas have two seasons: the wet season and the dry season. Eket has an abundant deposit of crude oil and clay.

2.2 Materials and Equipment

The materials, equipment and reagents required for the study are hereby listed:

i. Deionised water generated from Akwa Ibom State University , Chemistry Department Laboratory.
ii. 250 ml volumetric flask (10 pieces)
iii. 100 ml volumetric flask (10 pieces)
iv. 250 ml glass beakers (10 pieces)
v. 100 ml glass beakers (10 pieces)
vi. Rotary Evaporator: BUCHI Rotavapor R-215 (Switzerland)
vii. Dichloromethane (Analar grade)
viii. Separatory Funnel [500mL]
ix. Microwave Assisted Extractor [with Florisil SPE Cleanup]
x. Anhydrous sodium sulfate.(Analar grade)
xi. 500 m L polyethylene bottle (20 pieces)
xii. Hexane (analar grade)
xiii. Acetone (analar grade)
xiv. p H meter ((model: Orion Star A211),
xv. Conductivity meter (model: 4510)
xvi. Dissolved oxygen meter
xvii. Ultraviolet / visible spectrophotometer
xviii. Multimeter for alkalinity
xix. Digital Burette, Automatic Potentiometer Titrator (model: AT-710),
xx. Global positioning system (GPS).

2.3 Surface water sampling

Water samples were collected using sterilized polyethylene containers to a volume of at least two litres from the locations in Table 1 . Collected water amples were stored in ice-coolers and transported to the Central Laboratory, Akwa Ibom University for analysis. However, most physicochemical parameters were determined in-situ at the sampling locations.

The water samples were picked for May, June and July, 2024 to cover rainy season sampling and water samples were picked for January, February and March, 2025 to cover dry season sampling.

2.4 Methods of analyses

2.4.1 Total Hardness (TH)

Total hardness content of the surface waters was determined by disodium

ethylenediammine tetra acetic acid (EDTA) titration according to method No.2340 C of

APHA, AWWA.WEF (2021).

To 100 ml of water sample was added buffer solution, this is to prevent increase of pH, and about 0.5 gm of Eriochrome Black T as indicator usually in powder form which turns the sample solution into purple.

2.4.2 Calcium Hardness

Calcium content of the water was determined by Flame Atomic Absorption Spectrometer (Unicam 939/959) using nitrous oxide and acetylene flame, at a wavelength of 422.7 nm according to method of APHA, AWWA.WEF (2021), following the instrument's operational manual.

2.4.3 Determination of Conductivity

Conductivity of the surface waters was determined in situ at the sampling locations using a Multimeter (DDJ 303A)

2.4.4 Determination of Total Dissolved Solids

Total dissolved solid of the surface water samples was determined using a multi meter (DDJ 303A) according to the method by Etesin et al.(2018) and APHA, AWWA.WEF (2021),

2.4.5 Determination p H of surface waters

The p H of surface waters was determined using a p H meter (Model DDJ 303A) according to method by APHA, AWWA.WEF (2021),

2.4.6 Determination of Total Alkalinity (TA)

Total alkalinity of surface waters was determined by titrimetric method, according Method No.2320 B of APHA, AWWA.WEF (2021) In this study, since all the water samples analyzed had pH below 8.3, only total alkalinity was determined by titration as stated.

Total Alkalinity was calculated using the formula (1) provided below.

$$\text{Total Alkalinity, mg CaCO3 / L} = \frac{A \times N \times 50000}{\text{SampleSample volume (ml)}} \quad (1)$$

Where;

A = mL standard acid used

N = Normality of standard acid

2.4.7 Determination of Redox Potentials in surface waters

The redox potentials of surface waters in the study area were determined by Method of APHA, AWWA.WEF (2021) using multimeter (Model DDJ 303A) in situ during sampling.

2.4.8 Determination of Bicarbonate Alkalinity

Bicarbonate was determined according to APHA, AWWA.WEF (2005). When total dissolved solids (TDS) is less than 500 mg / L, then bicarbonate (HCO-3) was calculated using equation (2) (Etesin et al . 2018);

$$\text{Bicarbonate alkalinity (mg (CaCO3 / L)} = \frac{T - 5.0 \times 10\ (pH - 10)}{1 + 0.94 \times 10\ (\text{pH} - 10)} \quad (2)$$

Where,

T = Total alkalinity as mg $CaCO_3$ / L

The above relations are based on the ionization constants of carbonic acid at 25 oC assuming activity coefficient as 1. Also, when total dissolved solids (TDS) > 500 mg / L, then HCO_{-3} is calculated from phenolphthalein alkalinity (P mg $CaCO_3$ / L) and total alkalinity (T mg $CaCO^3$ / L) as follows;

When P = 0, HCO-3 = T, (3)

when P < 0.5 T, HCO-3 = T – 2P, (4)

when P = 0.5 T or P > 0.5 T or P = T, HCO-3 = 0.

2.4.9 Determination of Saturation p H (p Hs)

Saturation p H (p Hs) is determined by calculation as in equation 4.

pHs = (9.3 + A + B) – (C + D), according to method of APHA, AWWA.WEF (2005) .

2.4.10 Data Analysis

Microsoft Excel was used for graphical representation of data among stations and Statistical package for Social Sciences (SPSS) version 25 was employed to compute Mean, variance and standard deviation in the data. Also, one-way analysis of variance (ANOVA) and Least Significant Difference (LSD) test were employed to separate significant differences in mean values computed for stations while paired sample t-test was used to compare seasons. The probability level was set at $p \leq 0.05$.

3. Results And Discussion

3.1 Results of Physicochemical Parameters of surface waters during Rainy Season

3.1.1 Results of p H of surface waters during rainy season

The results of p H determinations of surface waters from Uyo, Ikot Ekpene and Eket , covering May, June and July, 2024 are presented in Table 2, with values ranging as follows: May, 2024 : Uyo (5.19) , Ikot Ekpene (4.44) , Eket (5.71) ; June, 2024: Uyo (5.73) , Ikot Ekpene (5.92) , Eket (5.86) ; July,2024 : Uyo (6.16) , Ikot Ekpene (5.74) , Eket (6.21)

The values of p H , TDS , alkalinity , total hardness, conductivity and redox potential of surface waters from Uyo, Ikot Ekpene and Eket in May, 2024 are represented in Fig. 2. The p H had a low value of 4.44 ± 0.05 in Ikot Ekpene to 6.21 in Eket, which indicated acidic waters. However, the p H values were below the range for water quality guideline which has p H of 6 - 9 , except in Eket (APHA, AWWA.WEF, 2021).

Table 2: Results of surface water analysis during the rainy season

RAINY SEASON		May , 2024			June, 2024			July, 2024	
UYO		IKOT EKPENE	EKET	UYO	IKOT EKPENE	EKET	UYO	IKOT EKPENE	EKET
p H	5.19	4.44	5.71	5.73	5.92	5.86	6.16	5.74	6.21
TDS (mg/L)	21.4	34.9	15.22	25.64	37.12	25.81	32.77	39.05	19.22
T. alkal. (mg/L)	70.4	61.2	64.3	78.09	81.08	69.16	76.24	54.26	71.37
T. hard. (mg/L)	72.8	66.2	69.8	81.06	60.32	76.33	79.82	70.08	56.19
Cond.(ɥS/cm)	49.4	68.5	17.94	57.08	72.75	46.47	57.05	82.12	23.75
Red. Pot. (m V)	67.1	152.4	73.4	65.16	132.8	69.53	54.84	120.5	76.45

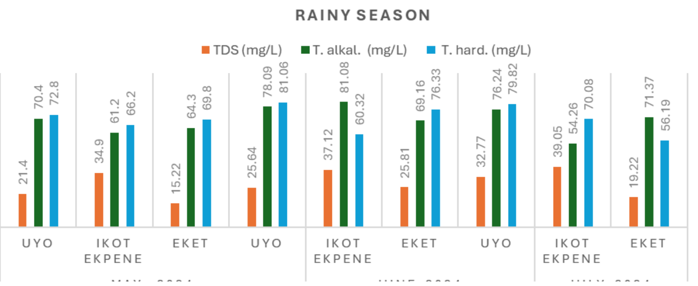

Figure 2: Results of TDS, T.alkanity and T.hardness during rainy season

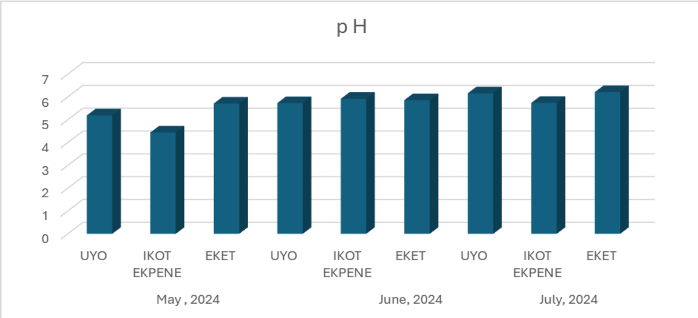

Figure 3: Representation of p H during rainy season

3.1.2 Results of TDS of surface waters during rainy season

The results of TDS determinations of surface waters from Uyo, Ikot Ekpene and Eket , covering May, June and July, 2024 are presented in Table 2, with values ranging as follows : May,2024 : Uyo (21.4 mg/L), Ikot Ekpene (34.9 mg/L), Eket (15.22 mg/L) ; June 2024: Uyo (25.64 mg/L), Ikot Ekpene (37.12 mg/L), Eket (25.81 mg/L); July,2024 : Uyo (32.77 mg/L), Ikot Ekpene (39.05 mg/L), Eket (19.22 mg/L).

The TDS had values of between 15 .22 mg/L to 39.05 mg/L at all the locations, which were far below the water quality guidelines of 250 mg/L as indicated in Fig. 2.

3.1.3 Results of Total alkalinity in surface waters during rainy season

The results of total alkalinity determinations of surface waters from Uyo, Ikot Ekpene and Eket , covering May, June and July, 2024 are presented in Table 2 and in Fig.4 with values ranging as follows : May,2024 : Uyo (70.4 mg/L), Ikot Ekpene (61.2 mg/L), Eket (64.3 mg/L); June, 2024 : Uyo (78.09 mg/L), Ikot Ekpene (81.08 mg/L), Eket (69.16 mg/L); July, 2024: : Uyo (76.24 mg/L), Ikot Ekpene (54.26 mg/L), Eket (71.37 mg/L);

The total alkalinity values were within the range of 54.26 ± 2.81 mg/L to 81.08 ± 5.02 mg/L, which are more than 20 mg/L as the least alkalinity of surface waters for the protection of aquatic life.

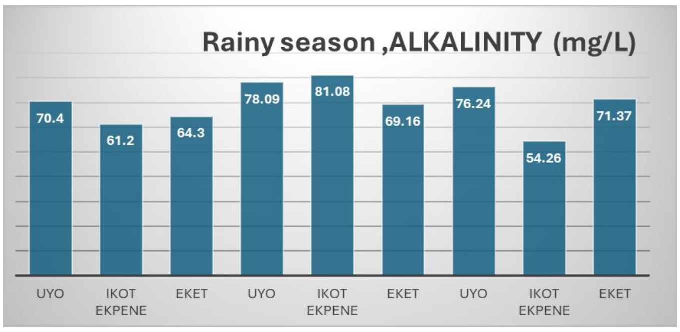

Figure 4: Results of Alkalinity at all study locations during rainy season

3.1.4 Results of total hardness of surface waters during rainy season

The results of total hardness determinations of surface waters from Uyo, Ikot Ekpene and Eket , covering May, June and July, 2024 are presented in Table 2 and Fig.5 with values ranging as follows : May,2024 : Uyo (72.8 mg/L) , Ikot Ekpene (66.2 mg/L), Eket (69.8 mg/L) ; June, 2024 : Uyo (81.06 mg/L) , Ikot Ekpene (60.32 mg/L), Eket (76.33 mg/L) ; July,2024 : Uyo (79.82 mg/L) , Ikot Ekpene (70.08 mg/L), Eket (56.19 mg/L).

The total hardness have values between 56.19 ± 3.06 to 81.06 ±3.96 mg/L $CaCO_3$ at all

locations (Fig.5) which were within the water hardness classification of moderately hard (60–120 mg/L) according to United State Geological Survey. (Cole and Fulton, 2025).

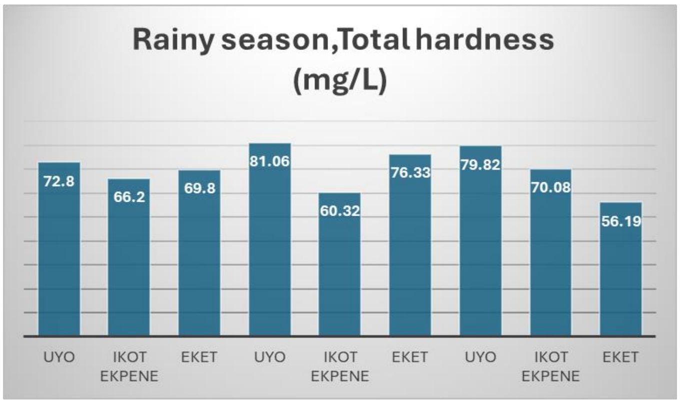

Figure 5: Results of Total hardness of surface waters during rainy season

3.1.5 Results of conductivity of surface waters during rainy season

The results of conductivity determinations of surface waters from Uyo, Ikot Ekpene and Eket , covering May, June and July, 2024 are presented in Table 2, with values ranging as follws: May , 2024 : Uyo (49.4 ᴜS/cm) , Ikot Ekpene (68.5 ᴜS/cm), Eket (17.94 ᴜS/cm) , June,2024 : Uyo (57.08 ᴜS/cm) , Ikot Ekpene (72.75 ᴜS/cm), Eket (46.47 ᴜS/cm), July,2024 : Uyo (57.05 ᴜS/cm) , Ikot Ekpene (82.12 ᴜS/cm), Eket (23.75 ᴜS/cm).

Conductivity of the surface waters have values between 17.94 ± 0.45 to 82.12 ± 6.09 u S/cm during the rainy season, at all locations, which were lower than the limit of 250 u S/cm (Etesin et al., 2021).

3.1.6 Result of Redox potential of surface waters during rainy season

The results of redox potential determinations of surface waters from Uyo, Ikot Ekpene and Eket , covering May, June and July, 2024 are presented in Table 2, with values ranging as follows, May, 2024: Uyo (67.1mV) , Ikot Ekpene (152.4 mV), Eket (73.4 mV); June, 2024 : : Uyo (65.16mV) , Ikot Ekpene (132.8 mV), Eket (69.53 mV) ; July, 2024 : Uyo (54.84mV) , Ikot Ekpene (120.5 mV), Eket (76.45 mV) .

Redox potentials of the surface waters from Ikot Ekpene have highest values of 120.5 ± 2.34 to 152.8 ± 5.43 m V during the rainy season (Fig 6)., which indicated an oxidized environment, while surface waters from Uyo had lowest values of 54.84 to 67.10 m V (Water Quality Standard, 2018).

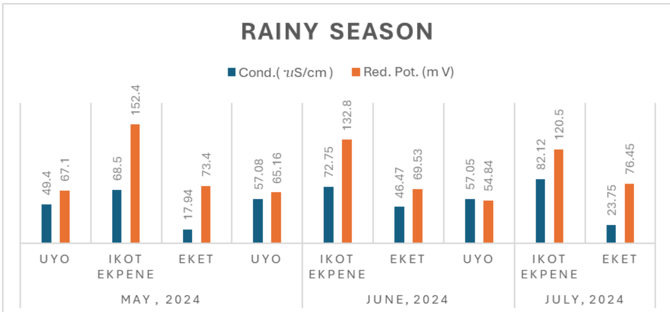

Figure 6: Conductivity and Redox potentials in surface waters during rainy season

3.2 Results of Physicochemical Parameters of surface waters during dry Season

3.2.1 Results of p H of surface waters during dry season

The results of p H determinations of surface waters from Uyo, Ikot Ekpene and Eket , covering December, 2024 January, 2025 and February, 2025 are presented in Table 3, with values ranging as follows , Dec,2024 :Uyo (6.92) , Ikot Ekpene (6.87), Eket (6.68);Jan,2025: Uyo (6.65) , Ikot Ekpene (6.79), Eket (6.54); Feb, 2025: Uyo (5.34) , Ikot Ekpene (6.21), Eket (6.52).

Table 3: Results of surface water analysis during the dry season

DRY SEASON		Dec, 2024			Jan, 2025			Feb, 2025	
UYO		IKOT EKPENE	EKET	UYO	IKOT EKPENE	EKET	UYO	IKOT EKPENE	EKET
p H	6.92	6.87	6.68	6.65	6.79	6.54	5.34	6.21	6.52
TDS (mg/L)	22.4	16.8	18.2	32.05	25.08	20.95	27.32	23.47	21.99
T. alkalinity (mg/L)	122.4	124.6	110.2	142.2	134.4	119.8	132.4	129.5	115.8
T. hardness (mg/L)	82.4	67.74	76.6	92.16	86.22	80.79	91.08	67.74	72.57
Cond. (uS/cm)	18.7	21.6	18.2	23.87	19.76	27.12	26.17	27.88	22.96
Red. Pot.(m V)	45.89	95.03	65.45	56.13	45.72	67.99	62.35	84.16	60.74

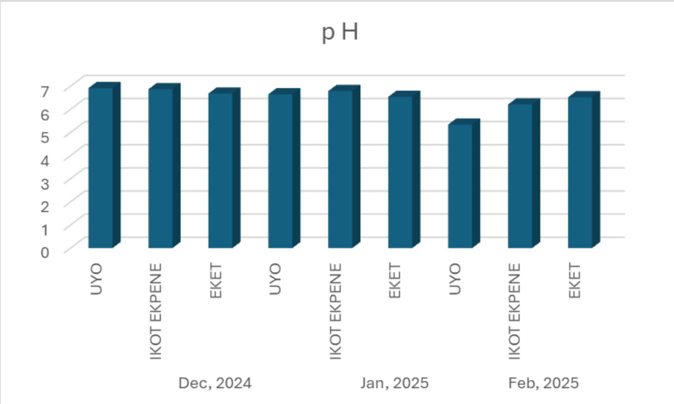

Figure 7: p H of surface waters during dry season

The p H of surface waters from the study locations had a range of 6.54 ± 0.08 in Eket to 6.79 ± 0.13 in Ikot Ekpene, which indicated a near neutral waters (Fig.7). However, the p H values were within the range for water quality guidelines of 6 - 9 , in all the locations (APHA, AWWA.WEF, 2021).

3.2.2 Results of TDS of surface waters during dry season

The results of TDS determinations of surface waters from Uyo, Ikot Ekpene and Eket , covering December,2024, January, 2025 and February, 2025 are presented in Table 3, with values ranging as follows : Dec, 2024 : Uyo (22.41 mg/L), Ikot Ekpene (16.8mg/L), Eket (18.2 mg/L); January, 2025 : : Uyo (32.05 mg/L), Ikot Ekpene (25.08 mg/L), Eket (20.95 mg/L); February, 2025 : Uyo (27.32 mg/L), Ikot Ekpene (23.47 mg/L), Eket (21.99 mg/L).

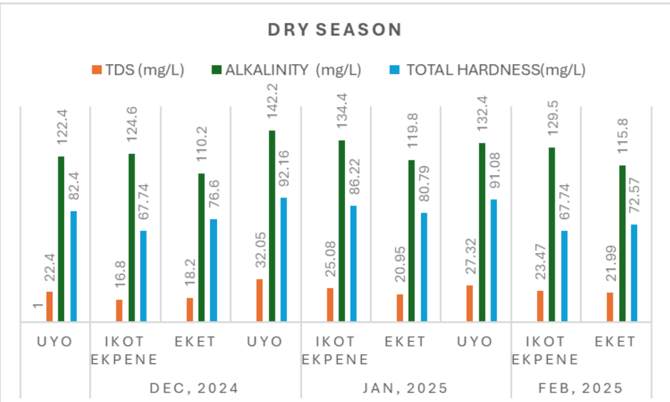

Figure 8: Results of TDS, T.alkanity and T.hardness during dry season

The TDS had values of between 16.8 ± 0.87 to 32.05 ± 0.45 mg/L at all the locations, which were far below the water quality guidelines of 250 mg/L TDS (WHO , 2011), as indicated in Figure 8.

3.2.3 Results of Total alkalinity in surface waters during dry season

The results of total alkalinity determinations of surface waters from Uyo, Ikot Ekpene and Eket , covering December,2024, January, 2025 and February, 2025 are presented in Table 3, with values ranging as follows: Dec, 2024 : Uyo (82.4 mg/L), Ikot Ekpene (67.74 mg/L), Eket (76.6 mg/L) ; January , 2025 : Uyo (92.16 mg/L), Ikot Ekpene (86.22 mg/L), Eket (80.79 mg/L); February, 2025 : Uyo (91.08 mg/L), Ikot Ekpene (67.74 mg/L), Eket (72.57 mg/L).

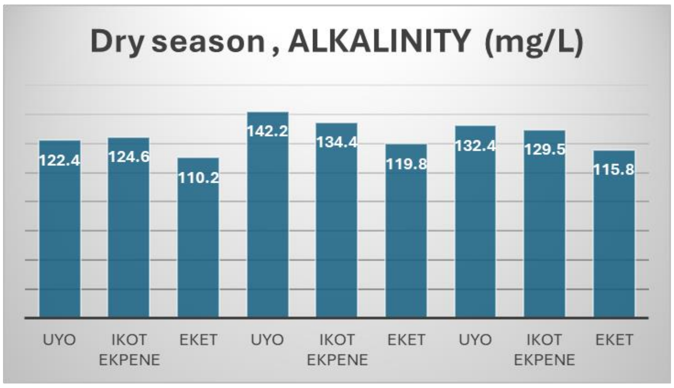

Figure 9: Results of Alkalinity at all study locations during dry season

The distribution of total alkalinity during the dry season is presented in Fig.9, with the lowest value of 110.2 mg/L in Eket and the highest value of 142 mg/L in Uyo , which were higher than 20 mg/L as the least alkalinity of surface waters for the protection of aquatic life (Etesin et al.2021).

3.2.4 Results of Total hardness of surface waters during dry season

The results of total hardness determinations of surface waters from Uyo, Ikot Ekpene and Eket , covering December,2024, January, 2025 and February, 2025 are presented in Table 3, with values ranging as follows : Dec, 2024 : Uyo (122.4 mg/L), Ikot Ekpene (124.6 mg/L), Eket (110.2 mg/L) ; January, 2025 : Uyo (142.2 mg/L), Ikot Ekpene (134.4mg/L), Eket (119.8 mg/L); February, 2025 : Uyo (132.4 mg/L), Ikot Ekpene (129.5 mg/L), Eket (115.8 mg/L).

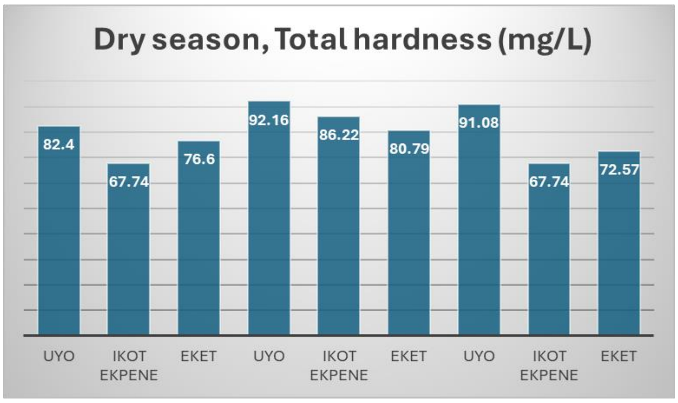

Figure 10: Results of total hardness at all study locations during dry season

The distribution of total hardness of surface waters at all study locations during dry season has the lowest total hardness of 67.74 mg/L in Ikot Ekpene and the highest total hardness of 92.16 mg/L in Uyo (Fig.10), which were within the water hardness classification of moderately hard (60 – 120 mg/L) according to United State Geological Survey (WHO, 2011 ; Cole and Fulton,2025).

3.2.5 Results of conductivity of surface waters during dry season

The results of conductivity determinations of surface waters from Uyo, Ikot Ekpene and Eket , covering December,2024, January, 2025 and February, 2025 are presented in Table 3, with values ranging as follows : Dec, 2024: Uyo (18.7 uS/cm), Ikot Ekpene (21.6 uS/cm) , Eket (18.2 uS/cm) ; January, 2025 : Uyo (23.87 uS/cm), Ikot Ekpene (19.76 uS/cm) , Eket (27.12 uS/cm); February, 2025 : Uyo (26.17 uS/cm), Ikot Ekpene (27.88 uS/cm) , Eket (22.96 uS/cm).

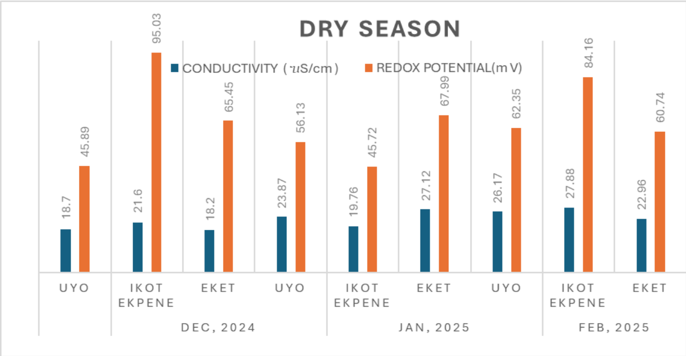

Figure 11: Conductivity and redox potentials in surface waters during dry season

The distribution of conductivity in surface waters (Fig.11) at the study locations during the dry season had the lowest value of 18.7 uS/cm in Uyo and the highest value of 27.12 uS/cm Eket, which were lower than the limit of 250 uS/cm (WHO, 2008; Etesin et. al. 2021).

3.2.6 Result of Redox potential of surface waters during dry season

The results of redox potential determinations of surface waters from Uyo, Ikot Ekpene and Eket , covering December,2024, January, 2025 and February, 2025 are presented in Table 3, with values ranging as follows : Dec, 2024 : Uyo (45.89 mV), Ikot Ekpene (95.03 mV). Eket (65.45 mV) ; Jan, 2025 : Uyo (56.13 mV), Ikot Ekpene (45.72 mV). Eket (67.99 mV); February,2025 : Uyo (62.35 mV), Ikot Ekpene (84.16 mV). Eket (60.74 mV).

The distribution of redox potentials in surface waters (Fig.11) at the study locations during the dry season had the lowest value of 45.72 m V and the highest value of 95.03 m V in Ikot Ekpene, which were far below the maximum limit of 800 m V for surface waters (Water Quality Standard , 2018). The values of the redox potential at all study locations indicated oxidized environment, with no depletion of dissolved oxygen (USEPA, 2009).

3.2.7 Results of Langelier saturation index (LSI) in surface waters

The results of LSI in surface waters during the rainy season are presented in Table 4 , with values as follows : May, 2024 : Uyo (- 3.232), Ikot Ekpene (- 4.062), Eket (-2.722); June, 2024 : Uyo (- 2.708), Ikot Ekpene (- 2.542), Eket (-2.547); July,2024 : Uyo (- 2.233), Ikot Ekpene (- 2.807), Eket (-2.286).

Table 4: Langelier Saturation Index of surface waters during rainy season

UYO		May, 2024			June, 2024			July, 2024	
		IKOT EKPENE	EKET	UYO	IKOT EKPENE	EKET	UYO	IKOT EKPENE	EKET
A	0.033	0.054	0.018	0.041	0.057	0.041	0.052	0.059	0.028
B	2.088	2.096	2.115	2.127	2.094	2.091	2.106	2.067	2.081
C	1.151	1.161	1.153	1.137	1.08	1.185	1.183	1.145	1.049
D	1.848	1.787	1.848	1.893	1.909	1.84	1.882	1.734	1.864
p Hs	8.422	8.502	8.432	8.438	8.464	8.407	8.393	8.547	8.496
p H	5.19	4.44	5.71	5.73	5.92	5.86	6.16	5.74	6.21
LSI (p H - p Hs)	-3.232	-4.062	-2.722	-2.708	-2.542	-2.547	-2.233	-2.807	-2.286

The results of LSI in surface waters during the dry season are presented in Table 5 , with values as follows : Dec, 2024; Uyo (- 1.212), Ikot Ekpene (-1.243) , Eket (-1.534); Jan, 2025: ; Uyo (- 1.775), Ikot Ekpene (-1.268) , Eket (-1.574); Feb,2025 : Uyo (- 2.707), Ikot Ekpene (-1.984) , Eket (-1.658).

Table 5: Langelier Saturation Index of surface waters during dry season

UYO		Dec, 2024			Jan, 2025			Feb, 2025	
		IKOT EKPENE	EKET	UYO	IKOT EKPENE	EKET	UYO	IKOT EKPENE	EKET
A	0.035	0.023	0.026	0.051	0.04	0.032	0.044	0.037	0.034
B	2.1	2.069	2.117	2.092	2.083	2.067	2.084	2.094	2.069
C	1.215	1.183	1.187	1.265	1.237	1.207	1.259	1.125	1.161
D	2.088	2.096	2.042	1.753	2.128	2.078	2.122	2.112	2.064
p Hs	8.132	8.113	8.214	8.425	8.058	8.114	8.047	8.194	8.178
p H	6.92	6.87	6.68	6.65	6.79	6.54	5.34	6.21	6.52
LSI (p H - p Hs)	-1.212	-1.243	-1.534	-1.775	-1.268	-1.574	-2.707	-1.984	-1.658

The results of LSI in surface waters during the rainy season in all locations range between – 2.233 to - 4.062, which were outside the optimum LSI range of -0.5 to + 0.5 (APHA, AWCF, APHA..2005)

The results of LSI in surface waters during the dry season are presented in Table 5 , with values which range between - 1.212 to - 2.707, which were outside the optimum LSI range of – 0.5 to + 0.5 (APHA, AWCF, APHA..2005).

In comparison to the optimum Langelier saturation index of – 0.5 to + 0.5 , in both seasons, the mean saturation index for the waters in all locations were out of the optimum range of the Langelier saturation index, indicating that all the waters in the study area are calcium carbonate dissolving and under -saturated with calcium carbonate, thereby have corrosive potential on metal substrates (Etesin et al., 2018). The results obtained in this study are comparable to a similar study on the potential corrosivity of borehole waters in Ikot Abasi, which indicated negative values for LSI (Etesin et al., 2012).

The seasonal and locational variations in the LSI of surface waters in Uyo, Ikot Ekpene and Eket in this study are not significant ($P \leq 0.05$).

4. Conclusion

In this study, the total alkalinity, total hardness and langelier saturation index of surface waters in Uyo , Ikot Ekpene and Eket were determined in both rainy and dry seasons.

As indicated in Fig 8 and Fig 9, all the variations in total alkalinity of surface waters amongst the locations studied (Uyo, Ikot Ekpene and Eket) during the rainy and dry seasons was not significant (P ≤ 0.05). However, it is significant to note that all the locations have higher than 20 mg/L total alkalinity, as the least alkalinity of surface waters for the protection of aquatic life and the surface waters not being negatively impacted by anthropogenic activities going on in these areas.

All the locations studied have total alkalinity that falls within the limit of moderate alkalinity (20 – 160 mg/L) , less than the maximum limit of 500 mg/L in surface waters, in both rainy and dry seasons. Alkalinity is important for fish and aquatic life because it protects or buffers against rapid pH changes. Living organisms, especially aquatic life, function best in a pH range of 6.0 to 9.0. Alkalinity is a measure of how much acid can be added to a liquid without causing a large change in pH. Higher alkalinity levels in surface waters will buffer acid rain and other acid wastes and prevents pH changes that are harmful to aquatic life.The p H of the surface waters in the studied locations in both seasons were less than 8.3, indicating that the dominant alkalinity of the surface waters in the study area is bicarbonate alkalinity, with trace of hydroxide and carbonate alkalinity. The total hardness determined in the surface waters of the studied locations during both rainy and dry seasons were within the WHO (2008) classification of hardness of water of moderately hard (60 – 120 mg/L) according to United State Geological Survey.

The Langelier saturation index of surface waters determined in the study locations in both the rainy and dry seasons were outside the optimum range of – 0.5 to + 0.5, indicating that all the surface waters studied in the study area are calcium carbonate dissolving and under -saturated with calcium carbonate, thereby have corrosive potential on metal substrates, also difficult in forming calcium carbonate scales.

Based on the outcome of the study on the seasonal variations of total alkalinity and Langelier saturation index in some parts of Akwa Ibom State (Uyo, Ikot Ekpene and Eket), the following recommendations seem appropriate: That the study be further extended to other parts of the Akwa Ibom State, mostly the coastal Local Government Areas that are subjected to intense oil and gas activities exploitation activities as to have an overview of the impact on surface water quality in these areas. For the fact that surface waters are prone to contaminations from anthropogenic activities, there should be regular monitoring of the status of surface waters in all the Local Government Areas of the State , with respect to total alkalinity, total hardness and Langelier saturation index , which are critical water parameters to aquatic life and corrosion of metal substrates.

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Conflicts Of Interest

The authors express no conflict of interest in this study.

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