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Constituents Budget of Njaba River at Okwudor

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Abstract

*The constituent budget of Njaba River at Okwudor was undertaken to understand the loading rate of constituents over a period of time (2011-2019). Water samples were obtained at equal distances of 2 km along the stretch of the River. The samples were obtained with the aid of sterilized 1.5 plastic bottle; the sample bottles were corked under water immediately after collection so as to prevent oxidation of the constituents. The water samples obtained from Okwudor was used to probe some physiochemical parameters and constituent budget of Njaba River over a period of eight years (2011 – 2019). The result indicates the pH of the River with values of 6.40 in 2011 and 6.44 in 2019. The TDS value for 2011 was 14.70 mg/l while for 2019 was 7.00 mg/l and the Total hardness of the water for 2011 was 11.80 mg/l and 2019 as 41.46 mg/l.The constituent budget indicates continuous loading of constituents (Ca^{2+},Mg^{2+}, Na^+, K^+,**SO^{2-}_4**,NO^-_3,Cl^-, and PO^{-3}_4) into the Njabariver. However, there was a decline in **HCO^-_3**.The constituent budgetindicates that Chlorine has the highest loading rate (2.97) while bicarbonate has the lowest loading rate (-0.63). The constituent budget also shows that Mg^{2+}has the highest percentage increase (3111%) while **HCO^-_3**has the lowest (-20.41%).Over a period of eight years (2011-2019), it was revealed the pH of the River remains slightly acidic though there was slight improvement in 2019. This SAR values of the water still remains excellent for irrigational purposes.The trend of cations for 2011 was Na>Ca>K>Mg, while that of anions was HCO_3>SO_4>Cl. The trend of cations for 2019 was Mg>K>Na>Ca, while for anions was Cl> HCO_3>SO_4.The Pollution Index of the water remain less from the critical value of 1 with values of 0.71 for 2011 and 0.72 for 2019. The pH can be raised using sodium bicarbonate (Soda ash) due to the contamination and pollution. Thus, the contamination and pollution trends in the Njaba River needs appropriate monitoring procedures for pollution control and mitigation for sustainable development of the resource.*

Keywords*: Constituents Budget, Biocarbonate, Chlorine, Okwudor and Njaba*

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I. Introduction

Rivers are one of the basic water resources which ensure the remarkable economic value. According to Das & Acharya (2003) it is a delicate part of the environment which is an essential requirement for human and industrial development). River water quality is the combination of numerous interconnected compounds, which are exposed to local and temporal variations and also affected by the volume of water flow (Mandal et al., 2010).The composition of water is always been influenced by natural (Geologic) and unnatural (Pollution) factors (Karbassi&Pazoki, 2015). The change in physical and chemical characteristics of river water causes great damage to the riverine biota (Sinha, 2002).

The Njaba River originated from Isu (Figure1) and flows through Ogwudo, Awomanma and empties into the Oguta Lake which is the largest fresh Lake in Southeastern Nigeria. Apart from the Njaba river serving as the major source for aggregates (sediments) and domestic water supply, the river and its watershed constitute a focal point for transport, fishing, sports and tourism (Ahiarakwem&Onyekuru, 2011). The exploitation of aggregates at the banks of Njaba River has lasted for over 40 years and it is being estimated that about 200 – 400 metric tons of laterite, gravel and sand have been exploited from the banks of the river and used for various construction purposes.

Aside sand excavation, other human activities such as washing and farming take place along the banks of the river hence chemicals from detergents and those used in agricultural lands surrounding the river flow into it during rain fall. Aside providing fishing ground, Njaba River also provides water for domestic purposes to the local population. The pressure on it increases during dry season and festive periods.

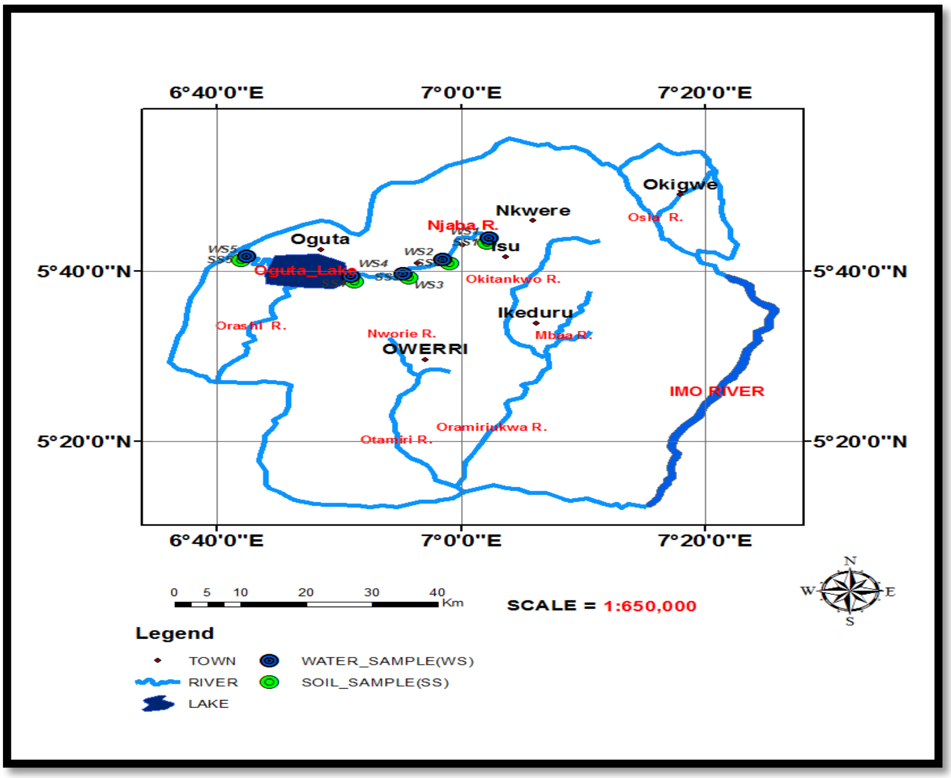

Figure 1: Location Map of the Study Area

Geology of the Area

The study area is underlain by the Benin Formation (a major stratigraphic unit in the Niger Delta Basin (Figure 2). The Benin Formation is made up of continental sands with lenses of clay/shale and some isolated units of gravel, conglomerate and sandstones (Ananaba et al., 1993). The Formation is Pliocene to Miocene in age and overlies the Agbada Formation which consists of sands and shale units.

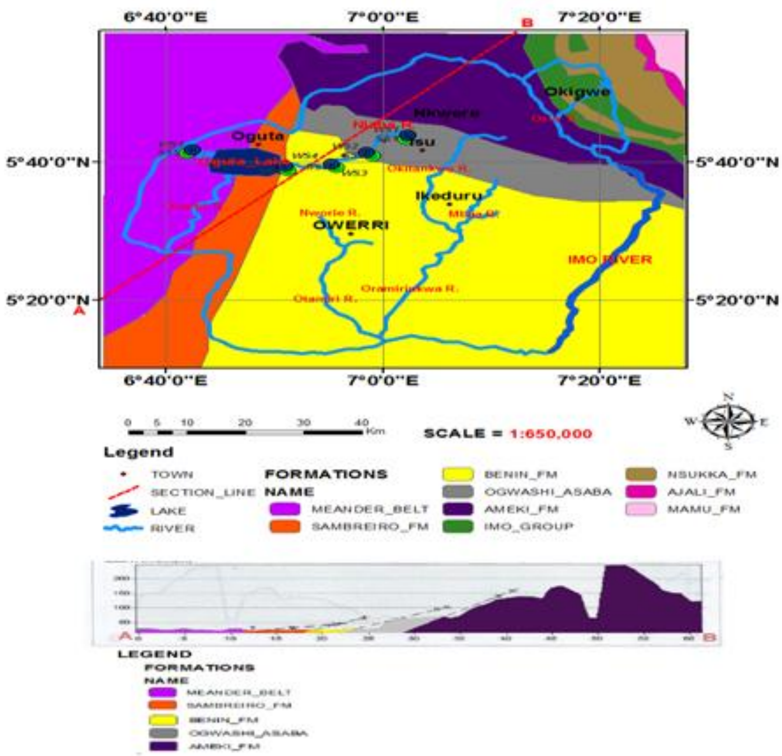

Figure 2: Geologic Map and Cross-section of the Study Area

II. Methodology

Water sampleswereobtainedat equal distances of 2 km along the stretch of the River. The samples were obtained with the aid of sterilized 1.5 plastic bottle; the sample bottles were corked under water immediately after collection so as to prevent oxidation of the constituents. The sample bottles were sent to the laboratory for analysis of major cations and anions using Atomic Absorption Spectrophotometer (AAS).

The water samples obtained from Okwudor was used to probe the constituent budget of Njaba River.

The concentrations of the major constituent cations and anions in milligram/liter (mg/l) were converted to milliequivalent/liter (meq/l) using the equation (i) developed by Todd (1980)

Concentrations (meq/l) = $\frac{\text{Concentrations (mg/l)}}{\text{Equivalent mass}}$ ………………………..(i)

The concentrations in meq/l were used to prepare Piper trilinear, Schoeler, Durov and Stiff diagrams as well as calculation of Sodium Adsorption Ratio (SAR). The SAR was determined using the equation (ii) (Wilcox, 1955).

SAR= Na^+

$\frac{\sqrt{(Ca2+ + Mg2+)}}{2}$ …………………………(ii)

The total hardness as ($CaCO_3$) of the Otamiri River water was determined using the equation (iii) developed by Todd (1980).

Total hardness as $CaCO_3$ mg/l = 2.5 [Ca^{2+}] + 4.1 [Mg^{2+}] ……………………………(iii)

The parameters considered for the determination of the pollution index (PI) of the Otamiri River water samples were pH, Total Hardness, Total dissolved solids (TDS), Sulphate and Chloride. The PI was calculated using the equation (iv) developed by Horton (1965).

PI= $\frac{\sqrt{(maxCi/Lj)2 + (meanCi/Lj)2}}{2}$ ………….(iv)

Where;

Ci = concentration of chemical parameters

Lj = World Health Organization (2011) permissible limit.

The Constituent Budget of the river was determined using the method described by Clark et al. (1972). A single conceptual model structure for a single constituent (v) is expressed as:

$Cu - Co = \Delta Cic/\Delta t$ (v)

Where Cu = Constituent input into the system per unit time

Co = Constituent output from the system per unit time

$\Delta Cic = Cu - Co$ (Change in concentrations of constituent storage within the system).

Δt = Time Interval ($t2 - t1$)

In this study, equation (vi) was simplified as follows:

$Cu - Co$ = Change in mean constituent concentrations (Conc2011 – Conc.2019)/8 (vi)

The change in mean constituent concentrations ($Cu - Co$) is equivalent to the constituent loading rate.

The values gotten from the calculations were used to compare the values of Ahiarakwem&Onyekuru (2011) which is within the length of eight (8) years.

III. Results And Discussion

pH, TDS and Total Hardness

Generally the pH of the River is slightly acidic with values of 6.40in 2011 and 6.44 in 2019 (Table 1 and Figure 3). However, there is an improvement of the pH value from 2011-2019. The TDS value for 2011 was 14.70 mg/l while for 2019 was 7.00 mg/l (Table 1 and Figure 4). This indicates that the water remains fresh. While the Total hardness of the water for 2011 was 11.80mg/l and 2019 as 41.46 mg/l (Table 1 and Figure 5).

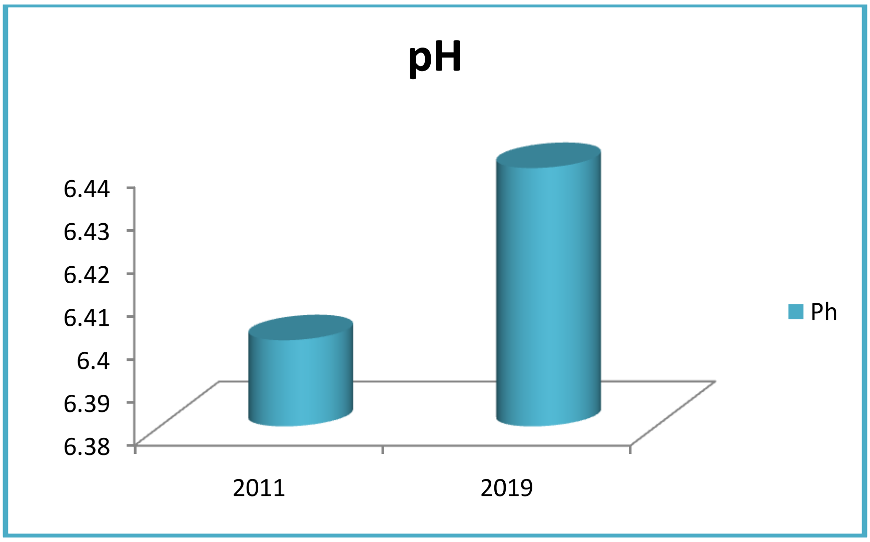

Figure 3: pH values for 2011 and 2019

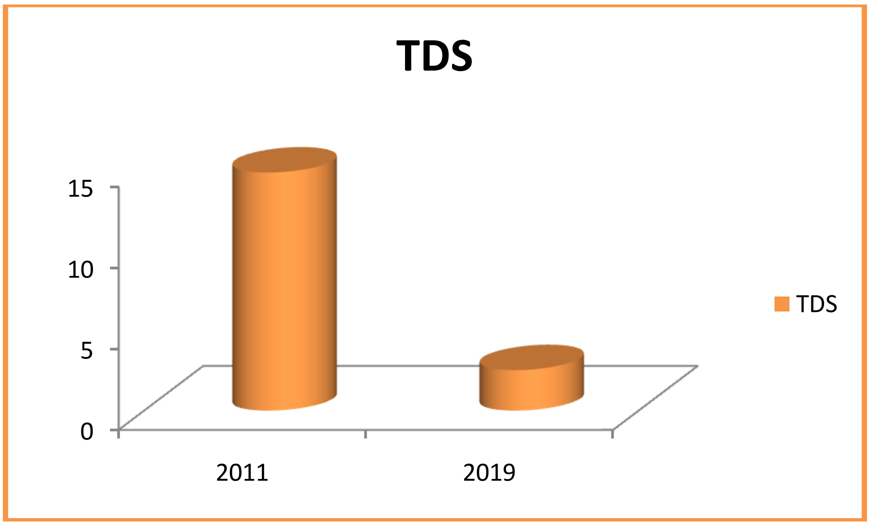

Figure 4: TDS concentrations for 2011 and 2019

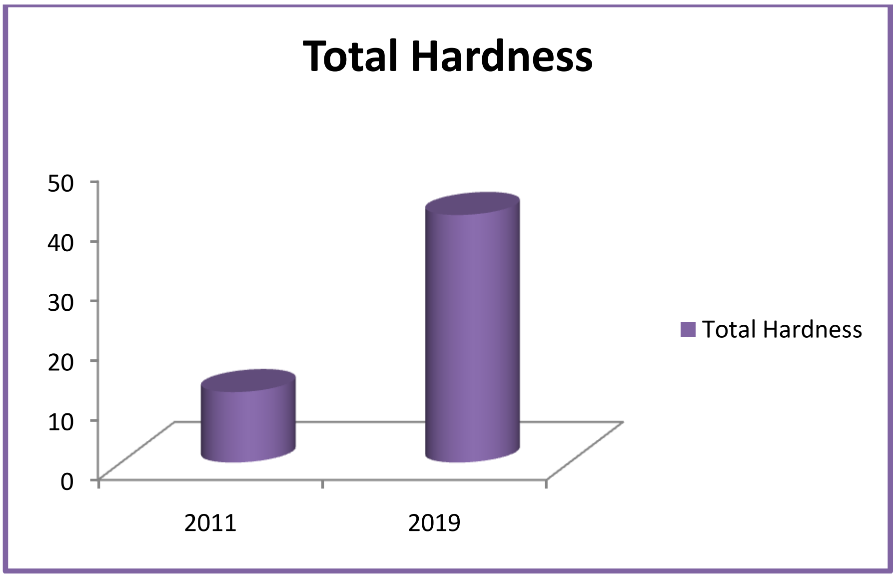

Figure 5: Total Hardness values for 2011 and 2019

Constituents Budget

The constituent budget at Okwudorfor 2011 and 2019 indicates that Chlorine has the highest loading rate (2.97) while bicarbonate has the lowest loading rate (-0.63 and -0.029) (Table 4). The constituent budget also shows that the percentage increase from 2011 to 2019 of calcium, magnesium sodium and potassium are 2.27, 3111, 1.56 and 837% respectively. The percentage increase for silica, nitrate, chlorine and phosphateare 54, 536, 1485 and 10% respectively (Figure 6). The percentage decrease at Okwudor was bicarbonate (-20.41%) (Figure 7). Since majority is increasing while a single constituent was decreasing, these trend shows loading as erratic. This is as a result of chemical reactions and activities such as waste disposal and other anthropogenic activities within and around the watershed.

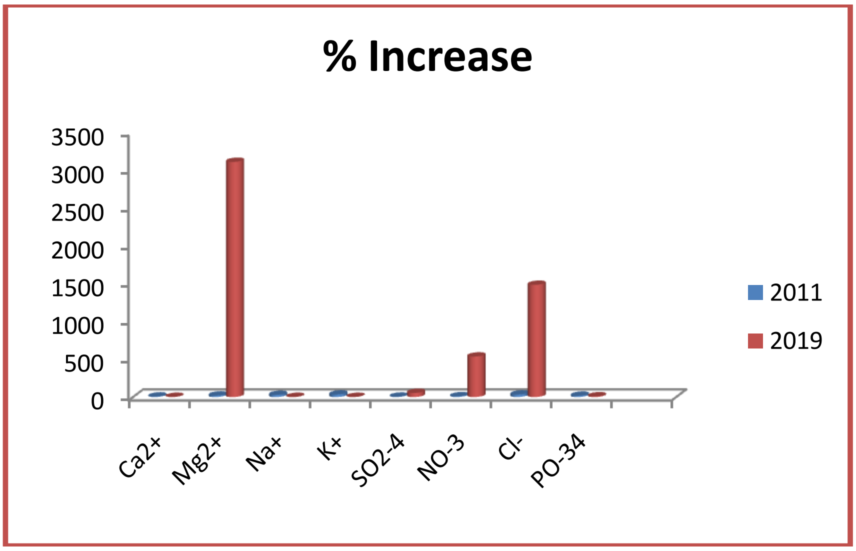

Figure 6: The percentage increase of constituents

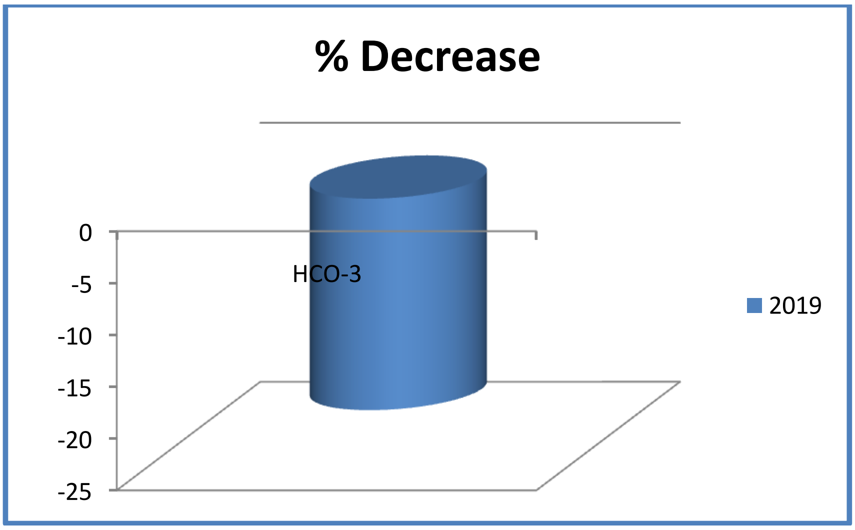

Figure 7: The percentage Decrease of constituents

Geochemical Models

Piper trilinear diagram shows a difference in relationship of chemistry of the river water in 2011 and 2019 (Figure 8). This is due to the increase of constituents. Both plotted within the potable water zone of the diamond portion of the Piper diagram. The Durov diagram depicts the same as Piper diagram with pH and TDS values (Figure 9). The Stiff diagram for 2011 and 2019 shows a difference in shape with variations in size as a result of increased concentration levels. While the Schoeller diagram indicates the constituent values of 2019 to be higher than 2011 values (Figure 10). The trend of cations for 2011 was Na>Ca>K>Mg, while for anions was HCO_3>SO_4>Cl (Figure 12 and 13). The trend of cations for 2019 was Mg>K>Na>Ca, while for anions was Cl> HCO_3>SO_4(Figure 12 and 13).

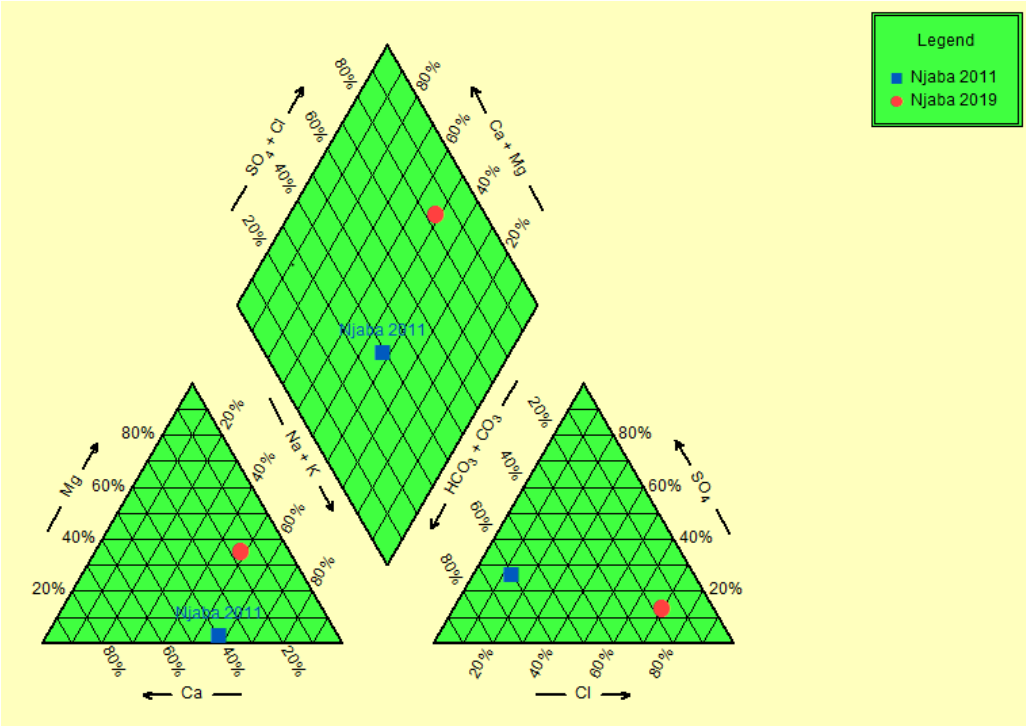

Figure 8: Piper Diagram for 2011 and 2019

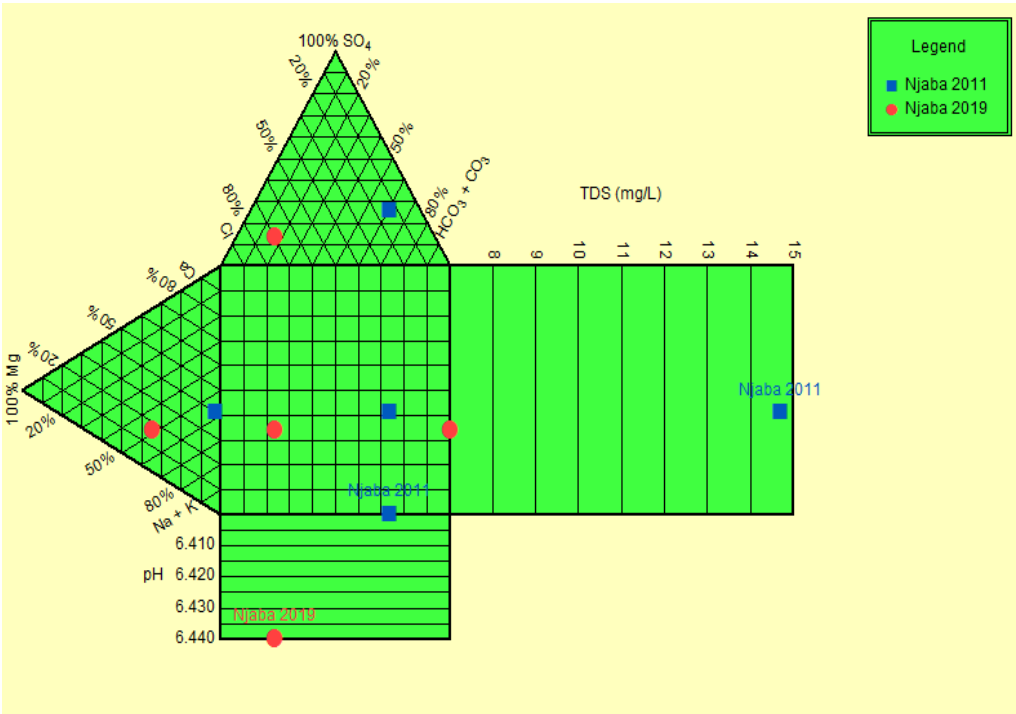

Figure 9: Durov Diagram for 2011 and 2019

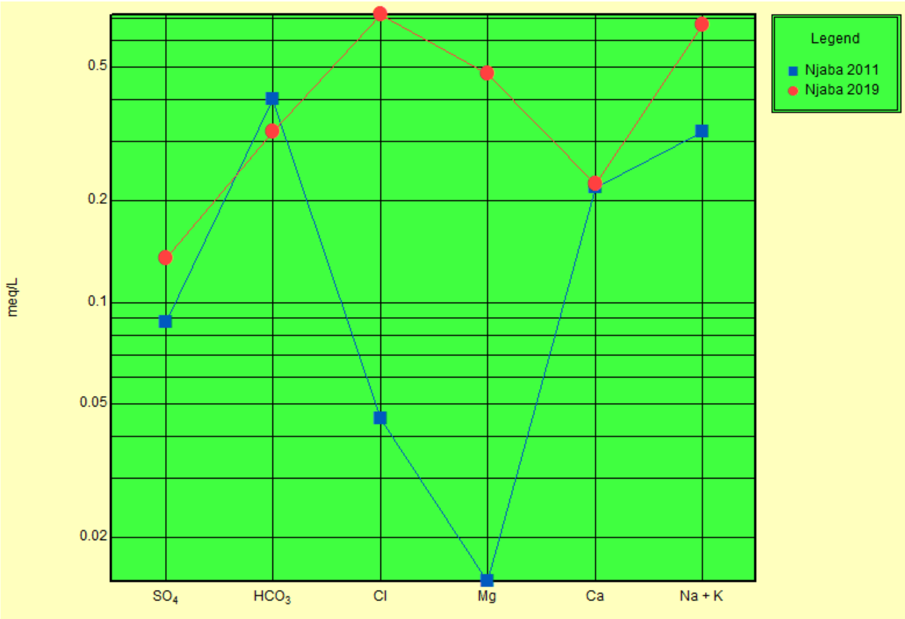

Figure 10: Schoeller Diagram for 2011 and 2019

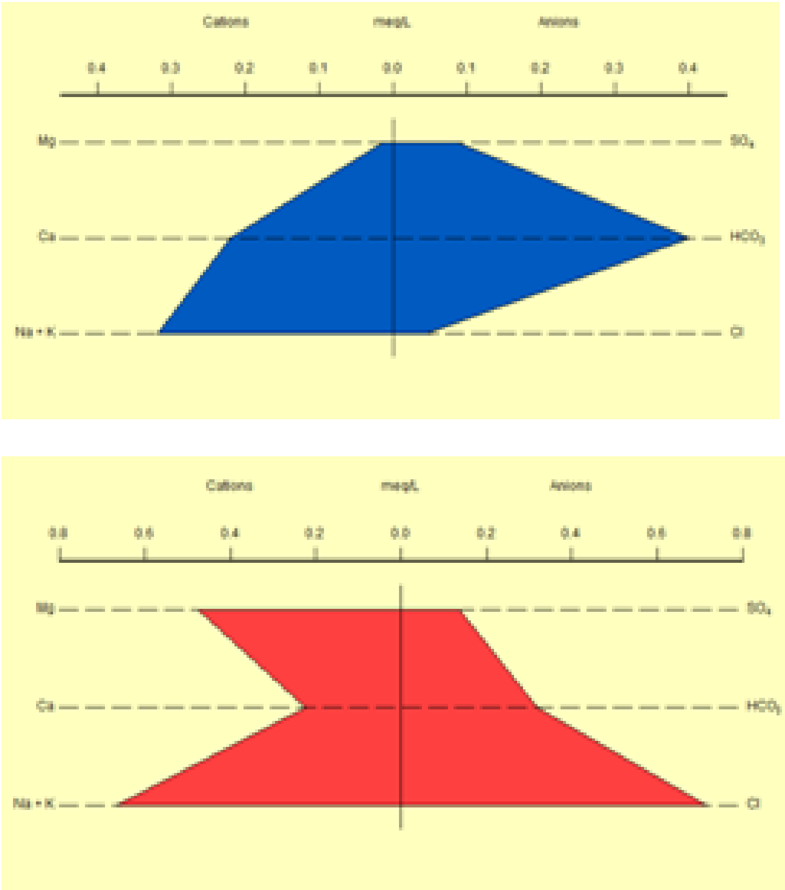

Figure 11: Stiff Diagrams for 2011 (Blue) and 2019 (Red)

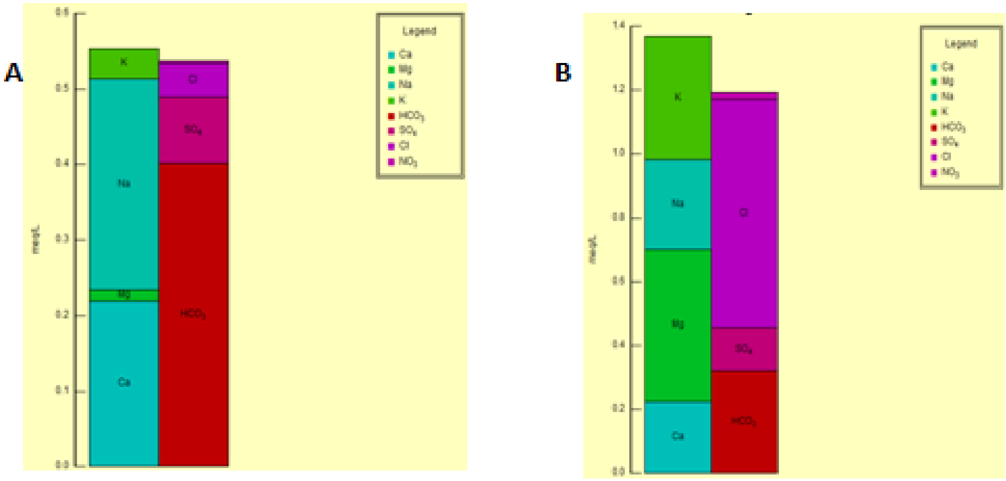

Figure 12: Ionic Balance for 2011(A) and 2019 (B)

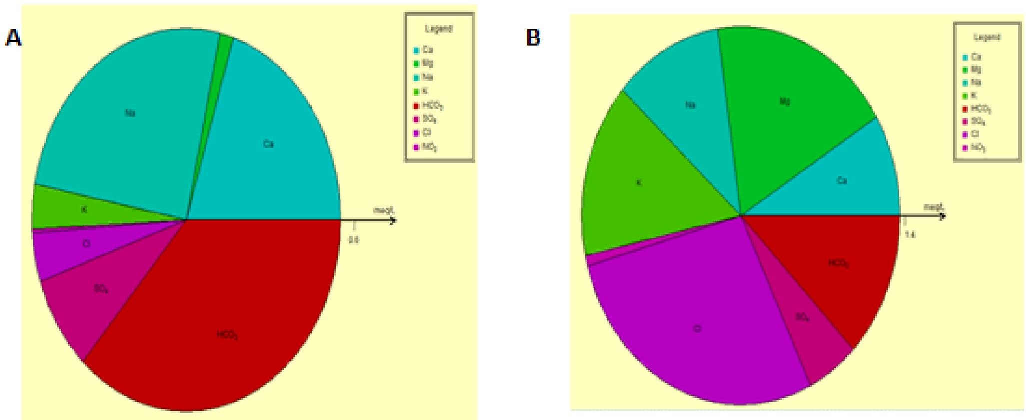

Figure 13: Pie Charts for 2011(A) and 2019 (B)

Table 1: Physiochemical Characteristics of NjabaRiver atOkwudor from 2011-2019

PARAMETER	2011		2019		WHO
	Range	Mean	Range	Mean	
pH	6.1-6.50	6.40	6.43-6.45	6.44	6.50-9.00
Total Dissolved Solid, mg/l	15-24	14.70	6.50-7.50	7.00	1500
Total Hardness as $CaCO_3$ mg/l	10.00-12.40	11.80	40.46-42.48	41.46	<150
Ca^{2+}mg/l	2.40-4.70	4.4	4.49-4.55	4.50	200
Mg^{2+} mg/l	0.17-0.24	0.18	5.68-5.88	5.78	150
Na^{+} mg/l	5.50-6.60	6.40	5.46-6.55	6.50	500
K^{+} mg/l	1.00-1.40	1.60	15.00-15.50	15.00	50
HCO^{-}_3 mg/l	18.50-25.0	24.50	19.00-20.00	19.50	500
SO^{2-}_4 mg/l	3.20-4.30	4.20	4.50.4.52	6.50	400
NO^{-}_3 mg/l	0.16-0.24	0.22	1.40-1.45	1.40	40-70
Cl^{-} mg/l	1.20-1.80	1.60	24.97-25.95	25.36	500
PO^{-3}_4 mg/l	0.17-0.23	0.20	0.70-0.75	0.70	10

Table 2: The Mean Concentrations of Constituents of Njaba River in Milliequivalent/Liter (meq/l)

Parameters	Equivalent mass	2011		2019		2011	2019
		Mean (mg/l)	Mean (meq/l)	Mean (mg/l)	Mean (meq/l)	%, epm	%, epm
Ca^{2+}	20	4.40	0.220	4.50	0.225	40.20	16.47
Mg^{2+}	12.2	0.18	0.015	5.78	0.474	2.70	34.69
Na^{+}	23	6.40	0.278	6.50	0.283	51.00	20.72
K^{+}	39.1	1.30	0.033	15.00	0.384	6.00	28.11
TOTAL CATIONS (meq/l)			**0.546**		**1.366**	**100**	**100**
HCO_3^-	61	24.50	0.402	19.50	0.319	74.60	32.45
SO_4^{2-}	48	4.20	0.088	4.50	0.093	16.30	9.460
NO_3	62	0.22	0.004	1.40	0.223	0.70	22.69
Cl^-	35.5	1.60	0.045	12.00	0.348	8.40	35.40
TOTAL ANIONS (meq/l)			**0.539**		**0.983**	**100**	**100**

Table 3: Pollution Index of Njaba River at Okwudor

Parameters	L_{ij} (WHO, 2006)	Mean Concentration (C_{ij})		(C_{ij}/L_{ij})	
		2011	2019	2011	2019
pH	6.50	6.40	6.44	0.984	0.98
TDS mg/l	1500	14.70	7.00	0.0098	0.0050
Total Hardness mg/l	<150	11.80	41.46	0.079	0.276
SO_4^- mg/l	400	4.20	4.50	0.010	0.011
Cl^- mg/l	500	1.60	25.36	0.0032	0.051
				0.217	0.264
PI				**0.71**	**0.72**

Table 4: Constituent Budget of Njaba River at Okwudor

Parameters	2011 (A)	2019 (B)	Time Interval (Δt)	B-A (ΔC_{ic})	$\Delta C_{ic}/\Delta t$	Percentage Increase	Percentage Decrease
Ca^{2+}mg/l	4.4	4.50	8	0.10	0.013	2.27	
Mg^{2+} mg/l	0.18	5.78	8	5.60	0.70	3111	
Na^+ mg/l	6.40	6.50	8	0.10	0.013	1.56	
K^+ mg/l	1.60	15.00	8	13.40	1.68	837	
HCO^-_3 mg/l	24.50	19.50	8	-5.0	-0.63		-20.41
SO^{2-}_4 mg/l	4.20	6.50	8	2.30	0.29	54.76	
NO^-_3 mg/l	0.22	1.40	8	1.18	0.15	536	
Cl^- mg/l	1.60	25.36	8	23.73	2.97	1485	
PO^{-3}_4 mg/l	0.20	0.70	8	0.50	0.063	10	

Sodium Adsorption Ratio (SAR)

The computed SAR values for 2011 and 2019 were 1.54 and 0.48 respectively. According to Wilcox (1955) water with SAR value of 1 to 10 is classified as excellent for irrigation purposes while those with SAR values above 26 are considered poor (Table 5). This means that the water remains excellent for irrigation purposes.

Table 5: Classification of Water Based on Sodium Absorption Ratio (SAR) (After Wilcox, 1955)

SAR	WATER CLASS
0-10	Excellent
10-18	Good
18-26	Fair
>26	Poor

Pollution index (PI)

The mean Pollution Indices (PI) of Njaba river at Okwudor during the periods of 2011 and 2019 were0.71 and 0.72respectively (Table 3). It has been shown that the critical value of Pollution Index is 1; hence, pollution index of more than 1 indicates very high degree of pollution (Horton, 1965). The PI values still remain less from the critical value of 1.

IV. Conclusion

Over a period of eight years (2011-2019), it was revealed the pH of the River is slightly acidic and an improvement from 2011-2019. The constituent budget indicates continuous loading of constituents Ca^{2+}, Mg^{2+}, Na^{+}, K^{+}, SO^{2-}_{4}, NO^{-}_{3}, Cl^{-} and PO^{-3}_{4}into the Njaba river at Okwudorwith a decrease in HCO^{-}_{3}. The increasing load of constituents into the river were as a result of chemical reactions and activities within the Njaba watershed. This SAR value of the water remains excellent for irrigational purposes.The Pollution Index of the water remains less from the critical value of 1.The trend of cations for 2011 was Na>Ca>K>Mg, while that of anions was HCO_3>SO_4>Cl. The trend of cations for 2019 was Mg>K>Na>Ca, while for anions was Cl> HCO_3>SO_4.

The pH can be raised using sodium bicarbonate (Soda ash). However, the bicarbonate needs to be monitored to avoid imbalance of constituents or bicarbonate lining.

Thus, Njaba River needs appropriate monitoring procedures for pollution control and mitigation for sustainable development of the resource.

Acknowledgements

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