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Determination of Water Quality Index (WQI) of Selected Rivers in Ezeagu Local Government Area of Enugu State, Nigeria

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Abstract: Assessment of water quality of Ajali, Karawa and Nnam rivers in Enugu State, Nigeria, was determined over a 10 year-span, in order to ascertain the level of deterioration of the water over time. Water samples were collected in 2013 and 2023 from the aforementioned rivers. For these 2years, the samples were collected in April and July to represent early rainy season and peak rainy season respectively. The physicochemical parameters such as pH, electrical conductivity, total hardness, total suspended solids, total dissolved solids, alkalinity, dissolved oxygen, biochemical oxygen demand, calcium, magnesium, sulphate, nitrate and chloride were determined using standard methods. The water quality indicator ranges were found to be as follows: pH: 4.10–9.23, electrical conductivity (µs/cm): 6.88-53.30, total hardness (mg/L): 4.00-220.00, total suspended solids (mg/L): 0.002-91.00, total dissolved solids (mg/L): 0.08-9.52, alkalinity (mg/L): 10.00-31.50, dissolved oxygen (mg/L): 0.25-36.80, biochemical oxygen demand (mg/L): 0.05-73.60, calcium(mg/L): 0.31-9.40, magnesium (mg/L): 0.003-0.68, sulphate (mg/L): 119.35-425.65, nitrate (mg/L): 0.07-36.80, chloride (mg/L): 3.60-30.00. The WQI values of the three rivers were as follows: 72.93, 78.93 and 66.17 in April 2013; 47.34,85.79 and 75.81 in July 2013, while 425.3, 194.1 and 242.0 in April 2023; 70.68, 50.61 and 62.95 in July 2023 for Ajali, Karawa and Nnam rivers respectively. Ajali and Karawa river water were only suitable for drinking in July 2013 and July 2023 respectively. All the April samples show high level of deterioration and as such is very poor and unfit for human consumption. Generally, there was an increasing trend in the pollution level of the rivers over the period. The need for appropriate treatment cannot be over-emphasized,

Keywords: Ajali, Karawa, Nnam, physicochemical properties, water quality index, rivers

I. Introduction

A river is a naturally occurring surface water with defined banks. It is essential for setting national development goals as well as those of the entire world because it touches on every aspect of the ecosystem and human endeavour while promoting national and human wealth, civilization and educational attainment. (UN-waters, 2016; Smith et al., 2019). In most cases, it provides drinkable water in areas where groundwater resources are insufficient or non-existent (Seiyaboh et al., 2017). Surprisingly, the indiscriminate discharge of sewage and industrial waste, along with a multitude of human activities that impact its physicochemical and microbiological quality, are polluting this vital natural resource for human progress. (Chauhan and Singh, 2010). One of the most basic human rights—access to clean water has been undermined by the global decline in river water quality. This problem continues to be a major focus of the UN water campaign, especially in the world's poorer nations (Ibrahim et al., 2015). The global degradation of freshwater quality is a threat to the world's economy and health (Barbosa et al., 2016; Nwabor et al., 2016; Otene and Nnadi, 2019; Zakir et al., 2020; Bhutiani et al., 2021), particularly in developing nations like Nigeria where policies and laws are rarely implemented (Iloba, 2021). Therefore, it is crucial to make sure that this limited resource is used appropriately, accepted, and upholds water quality requirements while maintaining its primary usage. Two reliable indices that offer helpful information on water quality are the comprehensive pollution index and the water quality index (WQI). The Water Quality Index (WQI) is a numerical value that lacks units and represents the overall quality of water by categorizing it based on its suitability for residential use.

(Tyagi et al. 2013). The objective of water quality index is to turn complex water quality data into information that is understandable and used by the public (Thakor *et al*, 2011). Many researchers have worked on water quality index of many rivers in and outside the country, but with limited knowledge on the extent of degradation over time. This study aims to assess the water quality of Ajali, Karawa and Nnam rivers in Enugu State, Nigeria, over a 10 year-span, in order to ascertain the level of deterioration.

II. Matrerials and Method

Study Area

Ajali, Karawa and Nnam Rivers are located in Ezeagu Local Government Area of Enugu State. It shares boundary with Udi Local Government Area, Oji Local Government Area and Uzo-Uwani Local Government Area.

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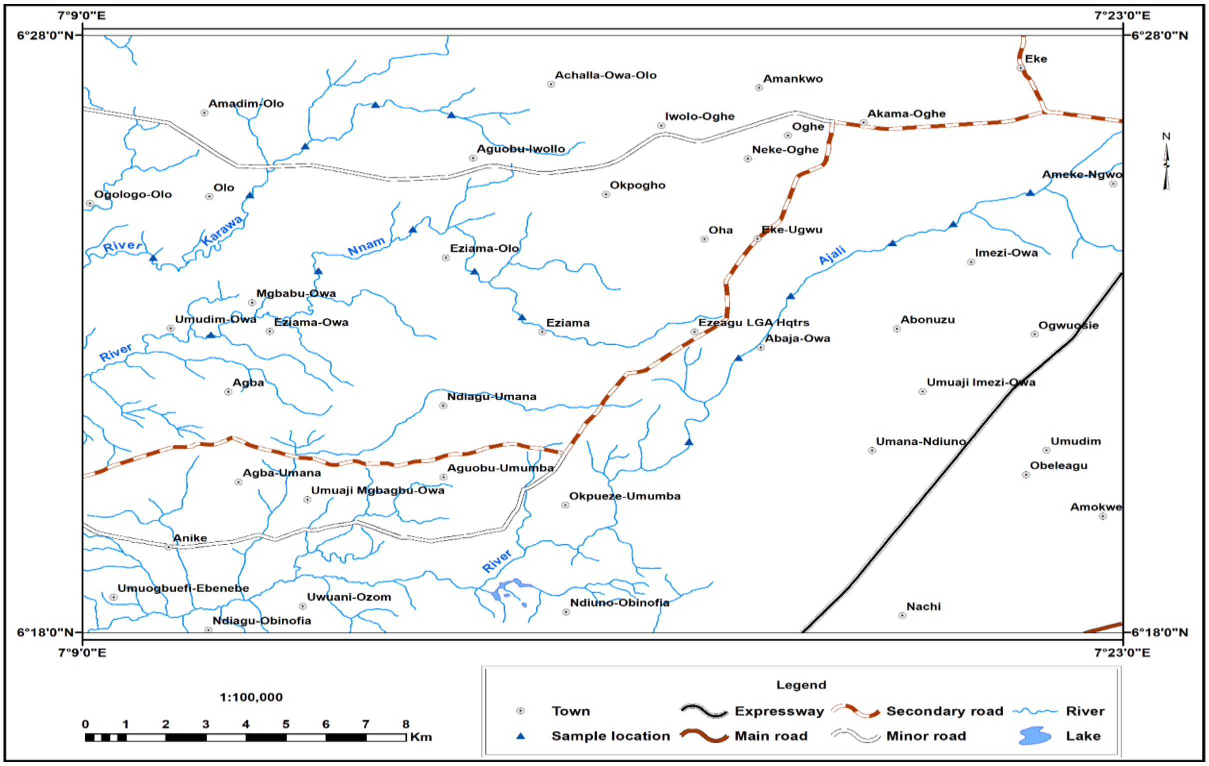

Fig 1: Map showing the sampled rivers in study area.

Sample collection:

Clean and sterilized air-tight plastic bottles were used to collect the samples. Equal volumes of the samples were collected from different points of the river to ensure good representation of the entire body of the water. For these 2 years (interval of 10 years), the samples were collected in April and July to represent early and peak of rainy season.

Sample Analysis

Total hardness as well as calcium and magnesium were measured using ethylenediaminetetraacetic acid (EDTA) titrimetric method (Smith 1999). pH was determined with pH meter (model 3510). Chloride (Cl^-) was determined by Mohr's Argentometric method using silver nitrate (Eaton et al. 2005). total dissolved solids (TDS) and electrical conductivity (EC) were done using Hanna multimeter with replaceable electrodes (Hanna HI 9811-5 multi-meter). Phosphate ($PO_4{}^{3-}$) was measured colorimetric ally using the ascorbic acid method (Murphy and Riley 1962; Edwards et al. 1965). Nitrate ($NO_3{}^-$) concentration was determined using cadmium reduction method (Eaton et al. 2005). All other parameters were analysed using standard methods (APHA 2012).

Water Quality Index method

The water quality index (WQI) was evaluated by using the weighted arithmetic water quality index method (Egun and Oboh 2021; Egun and Ogiesoba-Eguakun 2018; Oboh and Agbala 2017; Tyagi *et al.*, 2013). The reference standard used for the computation was the World Health Organisation standard for drinking water quality (WHO, 2017). The WQI was computed from Eq. (1):

$$WQI = \frac{\sum q_n - w_n}{\sum w_n} \qquad (1)$$

Where, qn = Quality rating of nth water quality parameter. Wn= Unit weight of nth water quality parameter

Quality rating (qn)

The quality rating (qn) is calculated using the expression given in Equation (2).

$$q_n = \left[\frac{(V_n - V_{id})}{(S_n - V_{id})}\right] \times 100 \qquad (2)$$

Where, Vn = Estimated value of nth water quality parameter at a given sample location.

Vid = Ideal value for nth parameter in pure water. (Vid = 0 for all parameters except pH (with a value of 7.0) and dissolved oxygen (with a value of 14.6 mg/L) Sn = Standard permissible value of nth water quality parameter.

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Unit weight

The unit weight (Wn) is calculated using the expression given in Equation (3).

$$W_n = \frac{k}{S_n} \qquad (3)$$

Where, Sn = Standard permissible value of n^{th} water quality parameter. k = Constant of proportionality and it is calculated by using the expression given in Equation (4).

$$k = \left[\frac{1}{\Sigma\frac{1}{S_n}}\right] \quad n = 1,2,3,\ldots.n \qquad (4).$$

WQI values are categorized into five classes based on the weighted arithmetic water quality index method (Tyagi *et al*. 2013) as follows: 0–25 (excellent water quality), 26–50 (good water quality), 51–75 (poor water quality), 76–100 (very poor water quality), and > 100 (water unsuitable for drinking).

III. Results and Discussions

A summary of the values of some physicochemical properties of the various rivers are presented in Tables 1, 2 & 3. The mean pH values range from 4.90 - 9.12, 4.15 - 9.23 and 4.10 – 8.92 for Ajali, Karawa and Nnam respectively. Showing a slight deviation from the stipulated limit by the World Health Organization (WHO, 2017). The higher pH values recorded in Ajali River can be attributed to washing of clothes in the river and processing of tapioca and cassava (Okoye *et al*. 2009; Ogbu *et al*. 2016). Iloba, *et al*., (2021), recorded a minimum pH value of 5.3. Otokune for and Obiukwu (2005) and Ekhaise and Anyasi (2005) reported an alkaline pH range of 8.3 to 8.5 in river water in Niger Delta, South-eastern Nigeria and 8.8 to 9.1 in Ikpoba River, Nigeria, respectively. The highest concentration of electrical conductivity (53.30 µS/cm) was obtained during the early rainfall from Ajali River. Karawa river recorded lowest value for electrical conductivity (6.88 µS/cm) in April 2013 and highest (13.4 µS/cm) in April 2023. This is lower than the values obtained by Alum and Okoye (2020) who reported electrical conductivity value in the range of 88.00 to 225.00 µS/cm for the same Karawa river. Parameters like electrical conductivity, total hardness and nitrate though within the permissible limit by WHO, show an increase in concentration in April and July 2023 when compared with values obtained in April and July 2013. In general, the mean values range for parameters like electrical conductivity (µs/cm), total hardness (mg/L), total suspended solids (mg/L), total dissolved solids (mg/L), alkalinity (mg/L), calcium(mg/L), magnesium (mg/L), sulphate (mg/L), nitrate (mg/L) and chloride (mg/L) were within the permissible limit (WHO, 2017). Higher values for TSS, TDS & Cl^- have been reported for river water from Ajali (Nwerem *et al*., 2023). Also, Alum and Okoye (2020) reported higher values for some parameters (EC, TDS, TH, magnesium, chloride, nitrate) for water sample from Ajali and Karawa river.

Table 1. Physicochemical parameters of Ajali river

Parameter	2013		2023		WHO
	April	July	April	July	
pH	8.77	4.90	8.485	9.12	6.5-8.5
Electrical Conductivity (µs/cm)	21.60	24.20	53.3	31.9	250
Total Hardness (mg/L)	40.0	36.00	65	140	300
TSS (mg/L)	80.0	91.00	0.006	15.91	250
TDS (mg/L)	20.0	43.00	26.6	0.08	500
Alkalinity (mg/L)	31.5	10.00	ND	ND	120
DO (mg/L)	0.25	11.00	36.8	8.2	5
BOD (mg/L)	0.05	1.10	73.6	0.1	5
Ca^{2+} (mg/L)	5.40	1.54	0.385	0.56	75
Mg^{2+} (mg/L)	ND	0.32	0.085	0.45	30
SO_4^{2-} (mg/L)	164.4	329.20	164.55	119.35	500
NO_3^- (mg/L)	1.106	1.46	3.402	31.20	50
Cl^- (mg/L)	3.60	21.00	4.998	4.99	250

ND = Not Detected

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Table 2. Physicochemical parameters of Karawa river

Parameter	2013		2023		WHO
	April	July	April	July	
pH	9.23	4.15	8.56	9.05	6.5-8.5
Electrical Conductivity (µs/cm)	6.88	11.81	13.4	12.08	250
Total Hardness (mg/L)	4.0	30.00	65	185	300
TSS (mg/L)	0.9	4.50	0.002	0.11	250
TDS (mg/L)	9.1	4.70	6.71	6.01	500
Alkalinity (mg/L)	21.5	10.00	ND	ND	120
DO (mg/L)	0.30	3.50	12.80	8.90	5
BOD (mg/L)	0.05	1.57	25.60	0.30	5
Ca^{2+} (mg/L)	5.31	ND	0.342	0.84	75
Mg^{2+} (mg/L)	ND	0.09	0.009	0.68	30
SO_4^{2+} (mg/L)	425.65	288.10	267.54	147.90	500
NO_3^- (mg/L)	1.07	10.41	4.108	31.7	50
Cl^- (mg/L)	12.00	30.00	14.995	ND	250

ND = Not Detected

Table 3 showing physicochemical parameters of Nnam river

Parameter	2013		2023		WHO
	April	July	April	July	
pH	8.26	4.10	8.08	8.92	6.5-8.5
Electrical Conductivity (µs/cm)	7.83	12.08	17.82	19.03	250
Total Hardness (mg/L)	40.0	32.00	50	220.00	300
TSS (mg/L)	0.90	1.50	0.002	0.009	250
TDS (mg/L)	9.10	6.50	8.91	9.52	500
Alkalinity (mg/L)	20.0	12.00	ND	ND	120
DO (mg/L)	0.25	6.20	18.40	8.60	5
BOD (mg/L)	0.05	1.38	36.800	0.30	5
Ca^{2+} (mg/L)	9.40	0.31	0.510	0.55	75
Mg^{2+} (mg/L)	ND	0.05	0.003	0.35	30
SO_4^{2+} (mg/L)	329.5	123.5	144.15	148.17	500
NO_3^- (mg/L)	0.07	9.67	3.48	36.8	50
Cl^- (mg/L)	7.2	17.00	4.998	9.99	250

ND = Not Detected

For a water source to be considered suitable for drinking and other domestic purposes, its WQI value must be less than 50. The WQI values obtained in this study are shown in Table 4. The elevated WQI values for April obtained in all the rivers indicate that the water quality at the various study locations in the first year is of very poor quality and deteriorated after 10years, therefore, is unsuitable for human consumption and possibly domestic use. For July samples, only Ajali river shows some level of deterioration after 10years. This could be as a result of agricultural activities around it. Generally, this water status report unambiguously revealed that this body of water is being affected by anthropogenic activities in and around the river.

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Table 4. WQI values for various samples

River	Year	Month	WQI	Water quality
Ajali	2013	April	72.93	Poor for drinking
		July	47.34	Good for drinking
	2023	April	425.33	Unsuitable for drinking
		July	70.68	Poor for drinking
Karawa	2013	April	78.93	Very poor for drinking
		July	85.79	Very poor for drinking
	2023	April	194.16	Unsuitable for drinking
		July	50.61	Poor for drinking
Nnam	2013	April	66.17	Poor for drinking
		July	75.81	Very poor for drinking
	2023	April	242.08	Unsuitable for drinking
		July	62.95	Poor for drinking

IV. Conclusion

The results presented in this study highlight the general quality of water from Ajali, Karawa and Nnam rivers in Ezeagu local government of Enugu state, Nigeria. The various significant physicochemical factors that have an impact on the overall quality of river water were identified. A comparison of the physicochemical water parameters with their respective permissible limits indicated that all but pH, DO and BOD were within the allowed permissible limits.

In the first year (2013), the water quality, as indicated by the WQI values (<50), showed that only water from Ajali in July was good for drinking. All the April samples very poor and deteriorated after 10 years as a result of pollution. The implication of the results of this study is that water from the aforementioned rivers are currently unsuitable for drinking. Remediation strategies need to be urgently put in place for continued use of this water source.

One way to achieve this is to stop untreated wastewater from entering the rivers.

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