Assessing Ecosystem Health: A Comparative Study Using Water Quality Index Analysis Across Ten Lotic System in the Cross River System

Abstracts

This review synthesizes findings from 10 scientific publications utilizing the weighted arithmetic Water Quality Index (WQI) to assess the status of diverse water bodies(Ikpa River, Lower Enyong Creek, Nwaniba River, Imo River, Etim Ekpo River, Lower Qua Iboe River, Ibeno Estuary, Cross River, Ikot Ebak River and Oboroenyin River) all within the Cross River System. The Analysis reveals that 6 out of 10 sampled water bodies are moderately polluted, while the remaining 4 exhibit slight pollution levels. These findings underscore significant concerns regarding water quality degradation, predominantly attributed to industrial effluents, agricultural runoff and urban contaminants. The WQI proves effective in consolidating multiple water quality parameters into a comprehensive index, facilitating a holistic assessment of pollution levels and guiding management strategies. Moving forward, concerted efforts are imperative to enhance monitoring efforts, implement stringent regulatory measures, and adopt sustainable practices to safeguard freshwater resources globally. This review underscores the urgency of integrated approaches to mitigate pollution and ensure resilience of aquatic ecosystems and public health.

Keywords: River Health, Water Quality Index, Lotic System, Slightly Polluted, Moderately Polluted

1.0 Introduction

Rivers are essential parts of our landscapes as silvery lines winding through the land, creating along their path a variety of landscapes that enlighten our spirit. Several facts lie beyond this idealized perception. The first fact is that rivers host a huge variety of organisms that live within, make use of, or transform them in a complex relationship with their physical template. Another fact is that humans have lived along rivers throughout history, using them for drinking, to harvest fish and other foods, for transportation, irrigation, or energy production (Sabater & Elosegi, 2013).

Globally, water is one of the most abundant and essential commodities of man and occupies about 97% of the earth surface. About 70% of this volume of earth's water is contained in oceans, 21% in polar ice and glaciers. (Eja, 2002). It is one of the most abundant natural resources and has a variety of uses ranging from domestics, agricultural, industrial, navigational, and energy uses [36-39]. Water has been highly degraded both in quantity and quality due to industrialization and anthropogenic activities. Rivers harbour freshwater species, unfortunately, it has long been used and abused for the disposal of wastes.

Although the rivers have the capacity of self-purification, this capacity is altered because of anthropogenic activities in the river, leading to the destruction of this important ecosystem. Humans strongly influence almost every major aquatic ecosystem and their activities have dramatically increased the fluxes of growth limiting nutrient from surrounding land to receiving water bodies. The flux of these nutrients has profound negative effect upon the quality of surface water worldwide (Smith, 2003). Surface water is most exposed to pollution due to their accessibility for disposal of waste waters (Samarghandi *etal*., 2007).

The quality and functioning of any aquatic ecosystem and its stability to support life forms, depend to a great extent; on the physicochemical characteristics of its water (George *et al*., 2017). The monitoring of the physicochemical properties of a water body is necessary for both long-term and short-term evaluation of its quality. Expanding human population, industrialization, intensive agricultural practices and discharges of waste into rivers and streams have been some of the major causes of pollution in water bodies throughout the world. Akwa-Ibom state hasn't been an exception to the devolutionary trend in the water quality of its water bodies.

In natural water bodies, water quality is very important because the quality of the water influence the whole aquatic community as well as each stage of the life cycle of the organisms and as such plays a major role in structuring that community (Ogar *et al*., 2013; Anyadiegwu and Uwaezuoke, 2015). Water quality is important for the protection of aquatic ecosystems. Availability of safe and reliable source of water is an essential prerequisite for sustainable development (Adakole and Annune,2008). High levels of contaminants such as phosphorus, dissolved metals and sediment can have an adverse effect on the productivity of aquatic organisms (Boyd, 1982). The higher the water quality, the more applications it can be used for with minimal treatment (USEPA, 2006; USGS, 2012).

The water quality from the rivers has a considerable importance for the reason that these water resources are generally used for multiple matters such as: drinking domestic and residential water supplies, agriculture (irrigation), hydroelectric power plants, transportation and infrastructure, tourism, recreation, and other human or economic ways to use water (George, *et. al* 2020). For a given river the water quality is the result of several interrelated parameters with a local and temporal variation which are influenced by the water flow rate during the year (Mandal *et al*, 2012). In the context of sustainable water management, many hydrological studies have been published around the world, which highlights the ecological role of water from the rivers.

Physicochemical properties play an essential role in the maintenance of healthy aquatic ecosystem. These physicochemical parameters of water and the dependence of all life process of these factors make it desirable to take water as an environment. Maintenance of good water quality is essential for the survival of the aquatic habitats. Hamey *et al*. (2013) stated that physicochemical characteristics of the aquatic environment directly influence the life inhabiting it. In this vein, water quality assessment is of immense importance to practices involving the use of water bodies such as: in the management of fisheries, water supply, pollution control, irrigation, reservoir and impoundment (Adakole *et al*., 2008).

Water quality data are used to characterize waters, identify trends over time, identify emerging problems, determine whether pollution control programs are working, help direct pollution control efforts to where they are most needed and respond to emergencies such as flood and spills (USEPA, 2006). The most common standards used to assess water quality relate to health of ecosystem, safety to human contact and drinking water. In the setting of standards, agencies make political and technical scientific decisions about how the water will be used (USEPA, 2006). Most of the studies related to the assessment of the water resources quality use several water quality indices among the most important are water quality index (WQI), water pollution index (WPI), and river habitat survey (RHS) (Milanovic, *et. al*. 2011).

In Nigeria, results of studies have shown a rapid and progressive deterioration of surface water quality as a result of physico-chemical and biological pollution, climate changes, etc. (Oluseyi *et al*., 2011). Udousoro and Umoren (2014) asserted that as water quality issues become more serious and widespread, the need for water quality monitoring as an important component of health promotion strategy in the developing countries cannot be overemphasized. In Akwa Ibom State, environmental degradation due to human activities is among the severest in Nigeria. This present study is therefore, to assess the quality of some of the rivers and streams in the state using the weighted arithmetic water quality index (WQI) method, which is one of the most reliable indices and the most convenient way to express the water quality at the same time.

2.0Description of Study Areas

The rivers/streams/creeks assessed in this study were; Lower Qua Iboe River, Lower Enyong Creek, Imo River, Ikpa River, Ibeno Estuary, Nwaniba River, Oborenyin River, Cross River, Ikot Ebak River and Etim Ekpo River.

2.1. 1Ikpa River

Ikpa River is situated in Akwa Ibom State (Latitude 05°11′ N and 05°16′N and Longitude E07°55′E and 08°07′E) within the rainforest zone of Southeastern Nigeria. It is a small perennial rainforest River located west of the lower reaches of the Cross River System. It drains a catchment area of 516.5km2, 76.5km2 (14.8%) of which is liable to annual flooding. The total length of the main channel (between its source in Ikono and discharge point into the Cross River Creek close to Nwaniba in Uruan L.G.A) is 53.5km. The Cross River finally empties into the Atlantic Ocean. The river drains several parts of Akwa Ibom State including Ikono, Ibiono Ibom, Itu, Uyo and Uruan Local Government Areas of Akwa Ibom State (*Etteokong, et. al*, 2019**).**

2.1.2 Lower Enyong Creek

The Lower Enyong Creek lies between latitudes 5°11′to 5°28′ N and longitudes 7°51′to 8° 001E. Geologically, the area under study is underlain by a wide range of diverse geological formations ranging from Asu River Formations - the Abakiliki Anticlinorium to the recent alluvium in the south (Udosen, *et. al*., 2016).

2.1.3 Nwaniba River

Nwaniba River is located in Uruan Local Government Area of Akwa Ibom State, Nigeria. Nwaniba River lies between latitude 5°2'51"N and longitude 8°2'41"E. The annual rainfall received is about 2500 mm with a mean annual temperature of 32°C and a relative humidity of 75%. The banks of the river are mostly covered with grass and other tropical marginal vegetations (Esenowo *et. al*., 2017).

2.1.4 Imo River

The Imo River which is one of the essential rivers in Niger Delta region. It is situated on the South-East coast of Nigeria. The river originates from the Imo State (hill region) and flows through Imo, Abia and Rivers State before emptying into the Atlantic Ocean. The river is located between Latitude 4°30'32"N and Longitude 7°32'3"E.

It is a tidal River with extensive mangrove swamps, intertidal mud flats and influenced by semidiurnal tidal regime. Industrial activities are also predominant (e.g.,NNPC Power Station) add with illegal petroleum refineries and bunkering activities. The river is a source of drinking water and livelihood of the people of the area. The major occupation is fishing, lumbering and farming activities (George and Efiom, 2018; Efiom and George, 2018).

2.1.5 Etim Ekpo River

Etim Ekpo River is located in Akwa Ibom State, South-South Nigeria and lies between Latitude 50 01’’7’ N and Longitude 70 61’’7’ E (Figure 1). The river has its origin from Inyang-udo Nwanquo, flows in East-west direction to Ukanafun River. The human activities here include intensified agricultural practice, sand mining, fishing and other domestic activities such as laundry and bathing. The river received wastes from point and non-point sources through surface runoff. The region has a clear distinguished between wet season (April and October) and dry season (November and March) (Jonah and George, 2019; George *et.al*., 2020a).

2.1.6 Lower Qua Iboe River

Lower Qua-Iboe River is a tributary of the Great Qua-Iboe River located in the Eastern part of AkwaIbom State, Nigeria. The Lower Qua-Iboe River flows from Ekpene Ukpa in Etinan through Ibawa in Oruk Anam Local Government Area. The river is 26km from Uyo, the state capital. The river is located in the Central Akwa Ibom with length of about 46km, bounded with Nsit Ibom Local Government Area (East), Mkpat Enin Local Government Area (West), Onna Local Government Area (South), Uyo and Abak Local Government Area in the North. The river is a tidal river. It flows North-South direction at low tide and South-North direction at high tide. The study area lies between latitude 4^o 42’ and 4^o 46’ North and longitude 7o 44’ and 7o 45’ East (Okarafor *et. al*., 2014).

2.1.7 IbenoEstuary

The area is located within the equatorial belt of West Africa, which comprises the region lying between latitudes 040 41’ North of the equator and between longitudes 07o41’ on the Atlantic Coast of Africa. George*et al.* (2017) described the described the climate of this region of study to be of two main seasons; rainy or wet and dry seasons, spanning between March to October and November to February respectively. The rainy seasons are often characterized by intermittent high solar radiation that is mostly diffused due to cloud cover, which often leads to precipitations upon saturation. Rain therefore falls sparingly even during the dry season months, however there is usually a clearly dry spell between the months of January to March in some parts of this region. The harmattan wind, which is usually cold, dry and hazy, is usually experienced around the months of November to December (Akankali *et. al*, 2017;George and Efiom, 2017; George, *et. al*., 2017; George, *et. al*., 2020b).

2.1.8 Cross River

The Cross River basin lies approximately between longitudes 7^o 30^o and latitudes 4^o and 8^o, covering an estimated area of 54000km^2 of which 14000km^2 lies in the Cameroon and 39000km^2 lies in Nigeria. The river rises from the Cameroon mountains and flows south-westwards into the Atlantic Ocean.

2.1.9 Ikot Ebak River

Ikot Ebak River is located in Afaha Ikot Ebak community in Essien Udim Local Government area, Akwa Ibom State. It lies between 7° 32' North of latitude and 5° 44' East of longitude (Fig 1). The river flows from Ekpenyong/Mkpatak Rivers and empty into the Etim Ekpo water channels. The area is marked by two seasons; rainy, which starts from April and dry seasons which starts from November. Temperature is always high with slight variations between 27°C and 29°C, while relative humidity ranges from 60 - 90%. The river is subjected to various anthropogenic activities such as bathing and waste disposal (Unanam and Akpan, 2007).

2.1.10 Oboroenyin River

Oboroenyin River is located in Ikot Abasi local government area, Akwa Ibom State. The area is marked by two seasons; rainy, which starts from April-October and dry seasons which starts from November-March.The river is subjected to various anthropogenic activities such as indiscriminate waste disposal, open defecation, bathing, sand mining (Anietie, *et. al*., 2017).

2.2 Calculating Water Quality Using the Weighted Arithmetic Water Quality Index

In this work, water quality parameters from physicochemical analysis carried out by different researchers were employed and available parameters were harnessed. The WQI was calculated by using the standards of water quality recommended by WHO and FEPA of Nigeria. The Weighted ArithmeticMethod, developed by Shah and Joshi (2017) was used in calculating Water Quality Index throughout this work.

2.3 Determination of Weightage

The unit weight was calculated by a value inversely proportional to the recommended standard valueof the corresponding parameter using the equation Wn = k/Sn

Where:

Wn = Unit weight for the nth parameter

Sn = Standard permissible value for the nth parameter

K = Proportionality constant, given by $1/\sum(1/Sn)$

The researcher has to decide upon a water quality standard to refer to. Here, the WHO water quality standard for river water was used.

2.4Determination of Sub-Indices

Sub-Index Qn = 100 [Vn – Vio] / [Sn – Sio]

Where:

Qn = Quality rating for the nth water quality parameter

Vn = Estimated value of the nth parameter at a given water sampling station

Sn = Standard permissible limit

Vio = Ideal value of nth parameter in pure water [which is 0 for every other parameter except pH and Dissolved Oxygen which are 7 and 14mg/l, respectively).

2.5Water Quality Index:

Weighted arithmetic index method was used to compute the water quality index as expressed in equation one according to Shah and Joshi (2017).

$$\mathrm{WQI} = \sum_{i=1}^{n} q_i\, w_i$$

Where;

n = the number of parameters,

Wi = the relative weight of the ith parameter

qi = 0–100 water quality rating of the ith parameter.

2.6 Categorization of Water Quality

Table 1: Index value intervals and the corresponding quality category (Shah and Joshi, 2017)

Value intervals (%)	Water quality status
0-25	Excellent
26-50	Slightly polluted(good)
51–75	Moderately polluted (poor)
76–100	Polluted
>100	Excessively polluted

WQI scores below 25 represent stations of “Excellent” quality that generally meet state water quality standards. WQI scores between 26 and 50 indicate stations of “Good or Slightly polluted” quality. WQI scores between 51 and 75 indicate stations of “Poor or Moderately polluted” quality, which are generally of concern to state and relevant authorities. At WQI scores between 76 and 100, outright pollution and impairment is said to have occurred. Such water body is of pressing concern to state and relevant authorities. WQI scores of above 100 are typically of the highest concern. The water is declared unfit for consumption, or use of any reasonable kind, ranging from drinking, recreation or irrigation.

3.0 Results

3.1 Water Quality Status of Reviewed Lotic Systems

Table 2 to Table 11 presents results of water quality parameters computed by different authors in the different study Areas and analyzed using Water Quality Index (WQI) to categorized and assess the status of each of these rivers.

Table 2: Water Quality Index for Lower Qua Iboe River

WATER QUALITY INDEX FOR LOWER QUA IBOE RIVER

NO.	PARAMETER	LOWER RANGE	UPPER RANGE	MEAN	PERMISSIBLE LIMITS	1/S	∑1/S	K	wi	Ideal value	Q	Q%	Wn * Qn
1	Temperature	22.8	23.2	23	30	0.033333	5.958838	0.167818	0.005594	0	0.76666667	76.66667	0.428868
2	pH	6.12	7.45	6.785	8.5	0.117647	5.958838	0.167818	0.019743	7	0.143333	14.3333	0.282987
3	DO (mg/L)	2.8	4.1	3.45	7	0.142857	5.958838	0.167818	0.023974	14	1.5071429	150.7143	3.613224
4	Turbidity (FTU)	11.37	14.04	12.705	5	0.2	5.958838	0.167818	0.033564	0	2.541	254.1	8.528509
5	Conductivity (us/cm)	11.24	12.15	11.695	1000	0.001	5.958838	0.167818	0.000168	0	0.011695	1.1695	0.000196
6	Nitrates	0.022	0.035	0.0285	50	0.02	5.958838	0.167818	0.003356	0	0.00057	0.057	0.000191
7	Nitrites	0.018	0.16	0.089	0.2	5	5.958838	0.167818	0.83909	0	0.445	44.5	37.3395
8	Phosphate	9.2	16.4	12.8	5	0.2	5.958838	0.167818	0.033564	0	2.56	256	8.59228
9	Total Hardness	10	15	12.5	150	0.006667	5.958838	0.167818	0.001119	0	0.08333333	8.333333	0.009323
10	TDS	5.62	6.09	5.855	500	0.002	5.958838	0.167818	0.000336	0	0.01171	1.171	0.000393
11	TSS	652	800	726	500	0.002	5.958838	0.167818	0.000336	0	1.452	145.2	0.048734
12	BOD	0.32	2.8	1.56	7.5	0.133333	5.958838	0.167818	0.022376	0	0.208	20.8	0.465415
13	COD	0	0.45	0.225	10	0.1	5.958838	0.167818	0.016782	0	0.0225	2.25	0.037759
					SUM=	5.958838			1				59.34738
					K=	0.167818							

IDEA VALUE	Vn	Vio	Sn	Vn – Vio	Sn – Vio	Vn-Vio/Sn-Vio
PH	6.785	7	8.5	-0.215	1.5	-0.1433333
DO	3.45	14	7	-10.55	-7	1.50714286

NOTES:

- **Physicochemical data for this water body was provided by Okorafor K. A, et. al., 2014.**
- For this water body, the mean of two ranges of values across the same station provided the estimated or monitored value of the parameters.
- The WATER QUALITY INDEX for LOWER QUA IBOE RIVER is **59.34738.** Its QUALITY STATUS is **MODERATELY POLLUTED.**

Table 3: Water Quality Index for Lower Enyong Creek

WATER QUALITY INDEX FOR ENYONG CREEK

NO.	PARAMETER	STATION A	STATION B	MEAN	PERMISSIBLE LIMITS	1/S	∑1/S	K	wi	Ideal value	Q	Q%	Wn * Qn
1	Temperature	28.3	29.4	28.85	30	0.033333	0.480171	2.082592	0.06942	0	0.961667	96.16667	6.675864
2	pH	6.09	6.39	6.24	8.5	0.117647	0.480171	2.082592	0.245011	7	0.50667	50.667	12.41396
3	DO (mg/L)	3.25	3.24	3.245	7	0.142857	0.480171	2.082592	0.297513	14	1.53643	153.643	45.71081
4	Salinity	0.33	0.26	0.295	250	0.004	0.480171	2.082592	0.00833	0	0.00118	0.118	0.000983
5	Conductivity (us/cm)	28.5	28.6	28.55	1000	0.001	0.480171	2.082592	0.002083	0	0.02855	2.855	0.005946
6	Sulphate	5.88	6.4	6.14	250	0.004	0.480171	2.082592	0.00833	0	0.02456	2.456	0.020459
7	Nitrates	1.96	2.02	1.99	50	0.02	0.480171	2.082592	0.041652	0	0.0398	3.98	0.165774
8	Total Hardness	5.77	7.77	6.77	150	0.006667	0.480171	2.082592	0.013884	0	0.045133	4.513333	0.062663
9	TDS	10.5	5.87	8.185	500	0.002	0.480171	2.082592	0.004165	0	0.01637	1.637	0.006818
10	TSS	0.017	0.0002	0.0086	500	0.002	0.480171	2.082592	0.004165	0	1.72E-05	0.00172	7.16E-06
11	BOD	0.3	1.4	0.85	7.5	0.133333	0.480171	2.082592	0.277679	0	0.113333	11.33333	3.147028
12	Calcium	0.19	0.35	0.27	75	0.013333	0.480171	2.082592	0.027768	0	0.0036	0.36	0.009996
					SUM=	0.480171			1				68.22031
					K=	2.082592							

IDEAL VALUE CALCULATION	Vn	Vio	Sn	Vn - Vio	Sn - Vio	(Vn - Vio)/(Sn - Vio)
PH	6.24	7	8.5	-0.76	1.5	-0.50667
DO	3.245	14	7	-10.755	-7	1.536429

NOTES:

- **Physicochemical data for this water body was provided by Udosen, et. al., 2016.**
- For this water body, the mean of measured values across two stations provided the estimated or monitored value of the parameters.
- STATION A = ITO STATION B = OBIO USERE
- The WATER QUALITY INDEX for ENYONG CREEK is **68.22031.** Its QUALITY STATUS is **MODERATELY POLLUTED.**

Table 4: Water Quality Index for Imo River

WATER QUALITY INDEX FOR IMO RIVER													
NO.	**PARAMETER**	**DRY MEAN SEASON**	**WET MEAN SEASON**	**MEAN**	**PERMISSIBLE LIMITS**	**1/S**	**∑1/S**	**K**	**wi**	**Ideal value**	**Q**	**Q%**	**Wn * Qn**
1	Temperature	26.45	27.68	27.065	30	0.033333	0.658171	1.519362	0.050645	0	0.902167	90.21667	4.56906
2	pH	6.25	7.27	6.76	8.5	0.117647	0.658171	1.519362	0.178749	7	0.16	16	2.859976
3	DO (mg/L)	6.11	5.88	5.995	7	0.142857	0.658171	1.519362	0.217052	14	1.507143	150.7143	32.7128
4	Conductivity (us/cm)	47.47	49.21	48.34	1000	0.001	0.658171	1.519362	0.001519	0	0.04834	4.834	0.007345
5	Sulphate	7.97	8.28	8.125	250	0.004	0.658171	1.519362	0.006077	0	0.0325	3.25	0.019752
6	Nitrates	3.64	2.07	2.855	50	0.02	0.658171	1.519362	0.030387	0	0.0571	5.71	0.173511
7	Phosphate	0.41	0.27	0.34	5	0.2	0.658171	1.519362	0.303872	0	0.068	6.8	2.066333
8	Chloride	13.04	13.58	13.31	250	0.004	0.658171	1.519362	0.006077	0	0.05324	5.324	0.032356
9	TDS	26.79	25.94	26.365	500	0.002	0.658171	1.519362	0.003039	0	0.05273	5.273	0.016023
10	BOD	1.63	1.55	1.59	7.5	0.133333	0.658171	1.519362	0.202582	0	0.212	21.2	4.294731
					SUM=	0.658171			1				46.75189
					K=	1.519362							

IDEAL VALUE CALCULATION	**Vn**	**Vio**	**Sn**	**Vn - Vio**	**Sn - Vio**	**(Vn - Vio)/(Sn - Vio)**
PH	6.76	7	8.5	-0.24	1.5	-0.16
DO	5.995	14	7	-8.005	-7	1.143571

NOTES:

- **Physicochemical data for this water body was provided by George, U. U & Efiom, E 2018**
- For this water body, the mean of measured values across dry and wet means seasons provided the estimated or monitored value of the parameters.
- The WATER QUALITY INDEX for IMO RIVER is **46.75189.** Its QUALITY STATUS is **SLIGHTLY POLLUTED**

Table 5: Water Quality Index for Ikpa River

WATER QUALITY INDEX FOR IKPA RIVER													
NO.	**PARAMETER**	**UPSTREAM**	**DOWNSTREAM**	**MEAN**	**PERMISSIBLE LIMITS**	**1/S**	**∑1/S**	**K**	**wi**	**Ideal value**	**Q**	**Q%**	**Wn × Qn**
1	Temperature	24.85	26.15	25.5	30	0.033333333	0.756170868	1.322452427	0.044081748	0	0.85	85	3.746948543
2	pH	6.129	5.588	5.8585	8.5	0.117647059	0.756170868	1.322452427	0.155582638	7	0.761	76.1	11.83983879
3	DO (mg/L)	8.042	6.654	7.348	7	0.142857143	0.756170868	1.322452427	0.188921775	14	0.950285714	95.02857143	17.95296642
4	Salinity	0.008	0.028	0.018	250	0.004	0.756170868	1.322452427	0.00528981	0	0.000072	0.0072	3.80866E-05
5	Conductivity (us/cm)	11.32	19.18	15.25	1000	0.001	0.756170868	1.322452427	0.001322452	0	0.01525	1.525	0.00201674
6	Nitrates	0.719	0.81	0.7645	50	0.02	0.756170868	1.322452427	0.026449049	0	0.01529	1.529	0.040440595
7	Phosphate	0.005	0.004	0.0045	5	0.2	0.756170868	1.322452427	0.264490485	0	0.0009	0.09	0.023804144
8	Sulphate	0.692	0.698	0.695	250	0.004	0.756170868	1.322452427	0.00528981	0	0.00278	0.278	0.001470567
9	BOD	1.941	1.991	1.966	7.5	0.133333333	0.756170868	1.322452427	0.17632699	0	0.262133333	26.21333333	4.622118171
10	COD	2.493	3.277	2.885	10	0.1	0.756170868	1.322452427	0.132245243	0	0.2885	28.85	3.815275252
					SUM=	0.756170868			1				42.0449173
					K=	1.322452427							

IDEAL VALUE CALCULATION	**Vn**	**Vio**	**Sn**	**Vn - Vio**	**Sn - Vio**	**(Vn - Vio)/(Sn - Vio)**
PH	5.8585	7	8.5	-1.1415	1.5	-0.761
DO	7.348	14	7	-6.652	-7	0.950285714

NOTES:

- **Physicochemical data for this water body was provided by Etteokong S.E et. al, 2019.**
- For this water body, the mean of measured values across two stations provided the estimated or monitored value of the parameters.
- The WATER QUALITY INDEX for IKPA RIVER is **42.044917.** Its QUALITY STATUS is **SLIGHTLY POLLUTED**

Table 6: Water Quality Index for Ibeno Estuary

WATER QUALITY INDEX FOR IBENO ESTUARY

NO.	PARAMETER	MEAN	PERMISSIBLE LIMITS	1/S	∑1/S	K	Wi	Ideal value	Q	Q%	Wn × Qn
1	Temperature	28.576	30	0.033333333	0.500837535	1.996655462	0.066555182	0	0.952533333	95.25333333	6.339602943
2	pH	7.568	8.5	0.117647059	0.500837535	1.996655462	0.234900643	7	0.378666667	37.86666667	8.894904334
3	DO (mg/L)	7.41	7	0.142857143	0.500837535	1.996655462	0.285236495	14	0.941428571	94.14285714	26.85297856
4	Salinity	66.372	250	0.004	0.500837535	1.996655462	0.007986622	0	0.265488	26.5488	0.212035226
5	Conductivity (us/cm)	2869	1000	0.001	0.500837535	1.996655462	0.001996655	0	2.869	286.9	0.572840452
6	Turbidity	1.5136	5	0.2	0.500837535	1.996655462	0.399331092	0	0.30272	30.272	12.08855083
7	TDS	1491.72	500	0.002	0.500837535	1.996655462	0.003993311	0	2.98344	298.344	1.191380354
			SUM=	0.500837535			1				56.1522927
			K=	1.996655462							

IDEAL VALUE CALCULATION	Vn	Vio	Sn	Vn - Vio	Sn - Vio	(Vn - Vio)/(Sn - Vio)
PH	7.568	7	8.5	0.568	1.5	0.378666667
DO	7.41	14	7	-6.59	-7	0.941428571

NOTES:

- **Physicochemical data for this water body was provided by Akankali et. al, 2017.**
- For this water body, the mean of 25 sample locations provided the estimated or monitored value of the parameters.
- The WATER QUALITY INDEX for IBENO ESTUARY is **56.1522927.** Its QUALITY STATUS is **MODERATELY POLLUTED**

Table 7: Water Quality Index for Nwaniba River

WATER QUALITY INDEX FOR NWANIBA RIVER

NO.	PARAMETER	MEAN	PERMISSIBLE LIMITS	1/S	∑1/S	K	Wi	Ideal value	Q	Q%	Wn × Qn
1	Temperature	28.02	30	0.033333333	0.434170868	2.303240666	0.076774689	0	0.934	93.4	7.17075594
2	pH	6.61	8.5	0.117647059	0.434170868	2.303240666	0.27096949	7	0.26	26	7.045206743
3	DO (mg/L)	4	7	0.142857143	0.434170868	2.303240666	0.329034381	14	1.428571429	142.8571429	47.00491155
4	Salinity	0.02	250	0.004	0.434170868	2.303240666	0.009212963	0	0.00008	0.008	7.37037E-05
5	Conductivity (us/cm)	25.27	1000	0.001	0.434170868	2.303240666	0.002303241	0	0.02527	2.527	0.005820289
6	BOD	0.66	7.5	0.133333333	0.434170868	2.303240666	0.307098755	0	0.088	8.8	2.702469048
7	TDS	12.67	500	0.002	0.434170868	2.303240666	0.004606481	0	0.02534	2.534	0.011672824
			SUM=	0.434170868			1				63.9409101
			K=	2.303240666							

IDEAL VALUE CALCULATION	Vn	Vio	Sn	Vn - Vio	Sn - Vio	(Vn - Vio)/(Sn - Vio)
PH	6.61	7	8.5	-0.39	1.5	-0.26
DO	4	14	7	-10	-7	1.428571429

NOTES:

- **Physicochemical data for this water body was provided by Esenowo et. al, 2017.**
- For this water body, the mean from a range of values provided the estimated or monitored value of the parameters.
- The WATER QUALITY INDEX for NWANIBA RIVER is **63.9409101.** Its QUALITY STATUS is **MODERATELY POLLUTED**

Table 8: Water Quality Index for Oboroenyin River

WATER QUALITY INDEX FOR OBOROENYIN RIVER

NO.	PARAMETER	MEAN	PERMISSIBLE LIMITS	1/S	∑1/S	K	wi	Ideal value	Q	Q%	Wn × Qn
1	Temperature	25.8	30	0.033333333	0.660837535	1.513231236	0.050441041	0	0.86	86	4.337929544
2	pH	6.36	8.5	0.117647059	0.660837535	1.513231236	0.178027204	7	0.426666667	42.66666667	7.595827381
3	DO (mg/L)	5.95	7	0.142857143	0.660837535	1.513231236	0.216175891	14	1.15	115	24.86022745
4	Conductivity (us/cm)	45.22	1000	0.001	0.660837535	1.513231236	0.001513231	0	0.04522	4.522	0.006842832
5	Nitrates	0.23	50	0.02	0.660837535	1.513231236	0.030264625	0	0.0046	0.46	0.013921727
6	Phosphate	0.3	5	0.2	0.660837535	1.513231236	0.302646247	0	0.06	6	1.815877483
7	Sulphate	2.5	150	0.006666667	0.660837535	1.513231236	0.010088208	0	0.016666667	1.666666667	0.01681368
8	TDS	12.15	500	0.002	0.660837535	1.513231236	0.003026462	0	0.0243	2.43	0.007354304
9	Chloride	5.93	250	0.004	0.660837535	1.513231236	0.006052925	0	0.02372	2.372	0.014357538
10	BOD	0.5	7.5	0.133333333	0.660837535	1.513231236	0.201764165	0	0.066666667	6.666666667	1.345094432
			SUM=	0.660837535			1				40.01424637
			K=	1.513231236							

IDEAL VALUE CALCULATION	Vn	Vio	Sn	Vn - Vio	Sn - Vio	(Vn - Vio)/(Sn - Vio)
PH	6.36	7	8.5	-0.64	1.5	-0.426666667
DO	5.95	14	7	-8.05	-7	1.15

NOTES:

- **Physicochemical data for this water body was provided by Anietie et. al, 2017.**
- For this water body, the mean from a range of values provided the estimated or monitored value of the parameters.
- The WATER QUALITY INDEX for OBOROENYIN RIVERis **40.01424637.** Its QUALITY STATUS is **SLIGHTLY POLLUTED**

Table 9: Water Quality Index for Cross River

WATER QUALITY INDEX FOR CROSS RIVER

NO.	PARAMETER	MEAN	PERMISSIBLE LIMITS	1/S	∑1/S	K	wi	Ideal value	Q	Q%	Wn × Qn
1	Temperature	26.4	30	0.033333333	0.656837535	1.52244649	0.050748216	0	0.88	88	4.465843039
2	pH	7.43	8.5	0.117647059	0.656837535	1.52244649	0.179111352	7	0.286666667	28.66666667	5.134525419
3	DO (mg/L)	9.25	7	0.142857143	0.656837535	1.52244649	0.217492356	14	0.678571429	67.85714286	14.75840986
4	Conductivity (us/cm)	23.66	1000	0.001	0.656837535	1.52244649	0.001522446	0	0.02366	2.366	0.003602108
5	Nitrates	0.22	50	0.02	0.656837535	1.52244649	0.03044893	0	0.0044	0.44	0.013397529
6	Phosphate	0.56	5	0.2	0.656837535	1.52244649	0.304489298	0	0.112	11.2	3.410280139
7	Sulphate	2744	150	0.006666667	0.656837535	1.52244649	0.010149643	0	18.29333333	1829.333333	18.56708076
8	Salinity	25.2	500	0.002	0.656837535	1.52244649	0.003044893	0	0.0504	5.04	0.015346261
9	BOD	3.16	7.5	0.133333333	0.656837535	1.52244649	0.202992865	0	0.421333333	42.13333333	8.552766062
			SUM=	0.656837535			1				54.92125117
			K=	1.52244649							

IDEAL VALUE CALCULATION	Vn	Vio	Sn	Vn - Vio	Sn - Vio	(Vn - Vio)/(Sn - Vio)
PH	7.43	7	8.5	0.43	1.5	0.286666667
DO	9.25	14	7	-4.75	-7	0.678571429

NOTES:

- **Physicochemical data for this water body was provided by Ukenye EA & Taiwo IA, 2019.**
- For this water body, the mean values for the upstream and downstream provided the estimated or monitored value of the parameters.
- The WATER QUALITY INDEX for CROSS RIVERis **54.92125117.** Its QUALITY STATUS is **SLIGHTLY POLLUTED**
- The samples were collected in Oron LGA.

Table 10: Water Quality Index for Ikot Ebak River

WATER QUALITY INDEX FOR IKOT EBAK River

NO.	PARAMETER	MEAN	PERMISSIBLE LIMITS	1/S	∑1/S	K	wi	Ideal value	Q	Q%	Wn × Qn
1	pH	6.8	8.5	0.117647059	0.627504202	1.593614827	0.187484097	7	0.133333333	13.33333333	2.499787964
2	DO (mg/L)	6.98	7	0.142857143	0.627504202	1.593614827	0.227659261	14	1.002857143	100.2857143	22.83097161
3	Conductivity (us/cm)	4.9	1000	0.001	0.627504202	1.593614827	0.001593615	0	0.0049	0.49	0.000780871
4	Nitrates	0.31	50	0.02	0.627504202	1.593614827	0.031872297	0	0.0062	0.62	0.019760824
5	Phosphate	0.022	5	0.2	0.627504202	1.593614827	0.318722965	0	0.0044	0.44	0.140238105
6	Total Hardness	0.64	150	0.006666667	0.627504202	1.593614827	0.010624099	0	0.004266667	0.426666667	0.004532949
7	Salinity	0.41	250	0.004	0.627504202	1.593614827	0.006374459	0	0.00164	0.164	0.001045411
8	BOD	2.65	7.5	0.133333333	0.627504202	1.593614827	0.212481977	0	0.353333333	35.33333333	7.50769652
9	TDS	46	500	0.002	0.627504202	1.593614827	0.00318723	0	0.092	9.2	0.029322513
10	TSS	16	500	0.002	0.627504202	1.593614827	0.00318723	0	0.032	3.2	0.010199135
			SUM=	0.627504202			1				33.03413676
			K=	1.593614827							

IDEAL VALUE CALCULATION	Vn	Vio	Sn	Vn - Vio	Sn - Vio	(Vn - Vio)/(Sn - Vio)
PH	6.8	7	8.5	-0.2	1.5	-0.133333333
DO	6.98	14	7	-7.02	-7	1.002857143

NOTES:

- **Physicochemical data for this water body was provided by Unanam A.E & Akpan A. W., 2007**
- For this water body, the mean values from a range of values provided the estimated or monitored value of the parameters.
- The WATER QUALITY INDEX for IKOT EBAK Riveris **33.03413676.** Its QUALITY STATUS is **SLIGHTLY POLLUTED**
- The samples were collected in Essien Udim LGA.

Table 11: Water Quality Index for Etim Ekpo River

NO.	PARAMETER	STATION A	STATION B	MEAN	PERMISSIBLE LIMITS	1/S	∑1/S	K	wi	Ideal value	Q	Q%	Wn * Qn
						WATER QUALITY INDEX FOR ETIM EKPO RIVER							
1	Temperature	26.68	26.81	26.745	30	0.033333333	0.460837535	2.169962132	0.072332071	0	0.8915	89.15	6.448404136
2	pH	6.7	6.6	6.65	8.5	0.117647059	0.460837535	2.169962132	0.255289663	7	0.233333333	23.33333333	5.956758794
3	DO (mg/L)	3.16	6.31	4.735	7	0.142857143	0.460837535	2.169962132	0.30999459	14	1.323571429	132.3571429	41.02999827
4	Conductivity (us/cm)	57.42	43.14	50.28	1000	0.001	0.460837535	2.169962132	0.002169962	0	0.05028	5.028	0.01091057
5	Phosphate	5.35	3.15	4.25	250	0.004	0.460837535	2.169962132	0.008679849	0	0.017	1.7	0.014755742
6	Nitrates	6.86	3.35	5.105	50	0.02	0.460837535	2.169962132	0.043399243	0	0.1021	10.21	0.443106267
7	Total Hardness	50.5	55.31	52.905	150	0.006666667	0.460837535	2.169962132	0.014466414	0	0.3527	35.27	0.510230429
8	TDS	38.1	33.18	35.64	500	0.002	0.460837535	2.169962132	0.004339924	0	0.07128	7.128	0.03093498
9	BOD	2.25	1.13	1.69	7.5	0.133333333	0.460837535	2.169962132	0.289328284	0	0.225333333	22.53333333	6.519530672
					SUM=	0.460837535			1				60.96462986
					K=	2.169962132							

IDEAL VALUE CALCULATION	Vn	Vio	Sn	Vn - Vio	Sn - Vio	(Vn - Vio)/(Sn - Vio)
PH	6.65	7	8.5	-0.35	1.5	-0.233333333
DO	4.735	14	7	-9.265	-7	1.323571429

NOTES:

- **Physicochemical data for this water body was provided by Jonah U. E & George U. U, 2019.**
- For this water body, the mean of two stations provided the estimated or monitored value of the parameters.
- The WATER QUALITY INDEX for ETIM EKPO RIVER is 60.9642986**.** Its QUALITY STATUS is MODERATE**LY POLLUTED**
- STATION A = URUK ATA IKOT EKPOR STATION B = UTU ETIM EKPO

3.2 Summary of Assessed Rivers / Streams and their Water Quality Index Classes

From Table 12 above, it follows that none of the assessed water bodies were in excellent condition. 6 of them namely; Lower Qua Iboe River, Lower Enyong Creek, Ibeno Estuary, Nwaniba River, Cross River and Etim Ekpo River representing 60% of the assessed rivers were moderately polluted, indicating rather poor water qualities and high pollution index. Four (4) of the assessed rivers, namely, Imo River, Ikpa River, Oboroenyin River and Ikot Ebak Riverrepresenting 40% of the assessed rivers were slightly polluted, or in fairly good condition. Ikot Ebak River at Essien Udim represented the water body in best quality index, at 33.0341.

Table 12: Summary of Assessed Rivers and Their Water Quality Index Classes

S/N	RIVER/STREAM/CREEK	WATER QUALITY INDEX	WATER QUALITY STAUS
1.	Lower Qua Iboe River	59.3474	Moderately polluted
2.	Lower Enyong Creek	68.2203	Moderately polluted
3.	Imo River	46.7519	Slightly polluted
4.	Ikpa River	42.0449	Slightly polluted
5.	Ibeno Estuary	56.1522	Moderately polluted
6.	Nwaniba River	63.9409	Moderately polluted
7.	Oborenyin River	40.0142	Slightly polluted
8.	Cross River	54.9212	Moderately polluted
9.	Ikot Ebak River	33.0341	Slightly polluted
10.	Etim Ekpo River	60.9646	Moderately polluted

4.0 Discussion

The review of 10 scientific publications focusing on water quality assessment through the weighted arithmetic Water Quality Index (WQI) provide valuable insights into the current status of various water bodies. The findings reveal that out of the ten (10) water bodies studied, 6 were categorized as moderately polluted while four (4) were classified as slightly polluted based on their respective WQI scores. The findings of this review provide crucial insights into the extent and severity of pollution in these ecosystems which directly impacts aquatic life, biodiversity and overall ecosystem health. Pollution in lotic systems can affects the quality of drinking water and may pose risks to human health through the consumption of contaminated water or aquatic food sources (George and Atakpa, 2015a, b).

Understanding the pollution levels helps in assessing the resilience of these ecosystems and identifying vulnerable species or habitat that require conservation efforts (George, *et. al.*, 2017).At moderate pollution levels, water is nearly unfit for use in general human activities and the environment does not foster optimal growth and health of aquatic life. Aquatic organisms with low tolerance for polluted waters either start to die off or seek new habitats, while those with more tolerance thrive. The factors contributing to the moderate pollution levels observed in the majority of the water bodies could vary widely. Common contributors often include industrial effluents, agricultural runoff containing pesticides and fertilizers, domestic sewage and urban run-off containing contaminants such as heavy metals and microplastics (George, *et. al.*, 2017; George, *et. al.*, 2020 a). These pollutants can degrade water quality, impacting aquatic ecosystems and posing risks to human health.

Overall, the effects of moderately polluted water underscore the importance of addressing pollution sources, implementing effective environmental regulations, and promoting sustainable practices to safeguard both aquatic ecosystems and human well-being. Findings from the review will inform policymakers and stakeholders about the urgent need for measures to mitigate pollution, such as implementing stricter regulations, promoting sustainable practices and investing in water treatment infrastructure.

At slightly polluted levels, water quality is considered good and perhaps suitable for a number of activities, including drinking – if thorough purification processes may be carried out.Healthy lotic systems support various economic activities such as fishing, agriculture, tourism and domestic purposes. Assessing pollution levels helps in understanding the potential socio-economic impacts of degraded water quality on local communities and economies.

The use of weighted arithmetic Water Quality Index (WQI) in these studies underscores its effectiveness as a tool for synthesizing complex water quality data into a single numerical value. By incorporating multiple parameters such as pH, dissolved oxygen, biochemical oxygen demand, total suspended solids and nutrients concentrations, the WQI provides a comprehensive assessment of the overall water quality status. This holistic approach aids in identifying pollution trends, assessing the effectiveness of remedial actions, and guiding water resource management decisions.

The findings of this review emphasize the critical need for enhanced water quality monitoring and management strategies. Effective regulatory measures and pollution control initiatives are essential to mitigate further degradation of water bodies identified as moderately polluted. Additionally, targeted efforts are necessary to prevent slight pollution from escalating into more severe levels, ensuring sustainable water resource use and environmental conservation.The primary threats to the environment as highlighted in this study include reduction in surface and groundwater quality as a result of industrial and agricultural activities as well indiscriminate disposal of waste. These problems touch on all three constituent parts of sustainable development namely environmental, economic and socio-political sustainability (UNEP, 1996; UNICEF/WHO, 2008; UN, 2009).

4.2 Conclusion and Recommendation

The review of these 10 scientific publications using weighted arithmetic water quality index highlights significant challenges in maintaining water quality across various ecosystems. The predominance of moderately polluted water bodies underscores the urgency of adopting integrated water resource management approaches to safeguard freshwater resources for present and future generations. The observations in this review point to a trend of increasing water quality deterioration in the Cross River System. More and more studies spring up each year to measure and assess specific chemical and biological aspects of rivers and streams towards achieving broader and actionable knowledge about their conditions, and their possibilities for salvaging and restoration.Many communities within the Cross River System, indeed in the entire southern part of Nigeria, depend heavily on rivers and streams for their means of income, livelihood, food, tradition, and recreation. In the light of these, there is pressing need to invest in the assessment of the quality of these water bodies. Pollution of river and stream water can lead to a number of major issues for communities that depend on water for survival. Its impact on the state can also be measured where aquatic life is destroyed, or the hydrosphere is severely polluted as to exude odor and unsightliness, thereby closing the door to income generation from export and tourism.Based on the observations, routine checks on water quality of lotic ecosystems are strongly recommended.

4.3 Recommendations

Moving Forward, future research should focus on expanding the geographical scope of WQI assessment to include diverse hydrological setting and varying degrees of anthropogenic pressures. Long term monitoring studies can provide insights into temporal trends and seasonal variability in water quality, contributing to more robust management practices and policy formulation.

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5.0 References

1. Adakole J. A., Annune, P. A. (2008). Benthic macroinvertebrates as indicators of Environmental quality of an urban stream, Zaria. *Nigerian Journal of Aquatic Science*; 18(2):85- 92.
2. Akankali, J. A., Ambrose, S. D. and Nweke, C. O. (2017) Use of in-situwater quality parameters for pollution status assessment of Ibeno dark brown water marine environment, Niger delta, Nigeria. *International Journal of Development and Sustainability*; 6(11):1510-1525.
3. Anietie, M. E, Anie, E. B. and Michael, U. E. (2017). Physicochemical Parameters and Trace Metals Contents of Water of Oboroenyin River in Ikot Abasi, Niger Delta – Nigeria. *AASCIT Journal of Environment*, 2(5):56-60.
4. Anyadiegwu, C. I. C. and Uwaezuoke N. (2015). Benthic studies and Environmental Assessment in the Oil producing Area of the Niger Delta. *American Journal of Environmental Protection*; 3(1):21-37.
5. Boyd, C. E. (1982). Water quality management for pond fish culture. Elsevier Science Publishers B.V. p. 318.
6. Efiom E. andGeorge, U. (2018). Source Evaluation and Trace Metal Contamination in Benthic Sediments from Imo River, South-East, Nigeria Using Multivariate Statistical Techniques. *World Rural Observation*, 10(2): 66 – 72.
7. Eja, M. E. (2002). Water Pollution and Sanitation for Developing Countries. Calabar: Seasprint (Nig.) Company. 152Pp.
8. Esenowo. I. K., Ugwumba, A. A. and Akpan, A. U. (2017) Evaluating the Physico-chemical Characteristics and Plankton Diversity of Nwaniba River, South-South Nigeria. *Asian Journal of Environment & Ecology*; 5(3):1-8.
9. Etteokon S. E., Akpan, A. W. and Ayotunde, E. O. (2019) Spatial trend in the physico-chemical characteristics of Ikpa River, Akwa Ibom State, Nigeria. *International Journal of Environment and Ecology Research*; 3(3):1-6.
10. George, U.U. and Efiom, Edak (2018). Physical and Chemical Variations in Water Quality of Imo River Owing to Human Perturbations in the System. *Research*er, 10(6): 47 – 54.
11. George, U.and Effiom, E. (2017). Impacts of Coastal Activities on Benthic Sediments from Qua Iboe River Estuary, South-South, Nigeria using Multivariate Statistical Techniques. *International Journal of Applied Research*, 3(7): 39-50.
12. George, U. U. and Atakpa, E. O. (2015b). Seasonal Variation in Physico-Chemical Characteristics of Cross River Estuary, South Eastern Nigeria. *Nature and Science*, 13(12):86-93.
13. George, U. U., Akpan, E. R. and Akpan, M. M. (2020a). Assessing the Impacts of Coastal Activities on the Water Quality of Qua Iboe River Estuary, South-South, Nigeria. New York Science Journal; 13(3):1-15.
14. George, U. U., Atakpa, E. O. (2015a). Impacts of Human Perturbations on the Physico-chemistry and Biological Parameters on the Water Quality of Cross River Estuary, South Eastern Nigeria. *Report and Opinion*, 7(11): 49-55.
15. George**, U. U**., Jonah, U. E., Nkpondion, N. N. and Akpan, M. M. (2020b). Assessment of Water Quality and Benthic Macroinvertebrates Assemblage of Etim Ekpo River, Niger Delta, Nigeria. *World Rural Observation*;12(1):16 – 24.
16. George, U**.,** Inyang-Etoh, A. and Ikot, N. (2017).Biotic Index Assessment of Human Perturbations in Qua Iboe River Estuary using Macro-Benthic Invertebrate as Indicator Organisms.*International Journal of Applied Research*, 3(7): 51-59.
17. Hamey, N. V., Dhamani, A. A. and Andrew, R. J. (2013) Physicochemical Status of Three Water Bodies Near Bhadrawati Town, Distt. Chandrapur, India. Bionano Front. Eco. Revol. Colombo, Srilanka, 18-21.
18. Jonah, U. E., George, U. U**.** and Avoaja, D. A. (2019). Impacts of Anthropogenic Perturbation on Water Quality Characteristics of Ikpe Ikot Nkon River, Southern Nigeria. *New York Science Journal*; 12(9):70-77.
19. Mandal, S. H., Das, A. and Nanda, A. K. (2012). Study of Some Physico-chemical Water Quality Parameters of Karola River, West Bengal: An attempt to estimate pollution status. *Inter. J. Environ. Protect*; 2(8):16-22.
20. Milanovic, A. Milijasevic, D. and Brankov, J. (2011). Assessment of Polluting Effects and Surface Water Quality Using Water Pollution Index: A case Study of Hydro-System Danube-Tisa-Danube Serbia. Carpathian Journal of Earth and Environmental Science; 6(2):269-277.

21. Ogar, E., Eneji, I. S., Etim, E. E. (2013). Seasonal Variation of Phyisco-chemical Properties of Selected Rivers in North Central States of Nigeria. *International Journal of Modern Analytical and Separation Science*; 2(1):31-38.
22. Okorafor K. A., James, E. S. and Udoh, A. D. (2014). Assessment of Macro-invertebrates and Physico-chemical Parameters of the Lower Qua Iboe River, Akwa Ibom State, Nigeria. ARPN Journal of Science and Technology; 4(11):666-677.
23. Oluseyi, T., Olayinka, K. and Adeleke, I (2011). "Assessment of ground water pollution in the residential areas of Ewekoro and Shagamu due to cement production". *African Journal of Environmental Science and Technology*; 5(10):786-794.
24. Sabater, S. and Elosegi, A. (2013). *River Conservation: Challenges and Opportunities*. Fundacion BBVA, Plaza de San Nicolas.
25. Samarghandi, M., Nouri J., Mesdaghinia, A. R., Mahvi A. H., Nasseri, S. and Vaezi, F. (2007). Efficiency removal of phenol, lead and cadmium by means of UV/TiO2/H2O2 processes. Int. J. Environ. Sci. Tech., 4(1):19-25.
26. Shah, K. A. and Joshi, G. S. (2017). Evaluation of Water Quality Index for River Sabarmati Gujarat. India Appl. Water Sci., 7:1349-1358.
27. Smith, E. P., Zahran, A., Mahmoud, M. and Keying, Y. E (2003). Evaluation of water quality using acceptance sampling by variables. Environmetrics 2003; 14: 373–386.
28. Udosen, C., Esshiett, A. A., Etok, A. S. (2016). The Physicochemical Hydrology of a Humid Tropical River System in South Eastern, Nigeria. *International Journal of Research in Geography*; 2(2):22-35.
29. Udousoro, I. and Umoren, I. (2014): Assessment of Surface and Ground Water Quality of Uruan in Akwa Ibom State of Nigeria. *Journal of Natural Sciences Research*; 4(6):11-27.
30. UN WWAP. (2009). United Nations World Water Assessment Programme. *The World Water Development Report 3: Water in a Changing World*. UNESCO: Paris, France.
31. Unanam A. E and Akpan A. W. (2007) Analysis of Physicochemical parameters of some fresh water bodies in Essien-Udim L.G.A. of Akwa-Ibom State. 21st Annual Conference of the Fisheries Society of Nigeria (FISON), Calabar, Nigeria, pp 310-312.
32. UNICEF WHO (2008). UNICEF and World Health Organization Joint Monitoring Programme for Water Supply and Sanitation. *Progress on Drinking Water and Sanitation: Special Focus on Sanitation.* UNICEF, New York and WHO, Geneva, 2008.
33. United Nations Environment Programme (UNEP)(1996). Groundwater: a threatened resource. UNEP Environment Library No. 15, UNEP, Nairobi, Kenya.
34. United State Environmental Protection Agency (USEPA) (2006). Water Quality Standards Review and Revision. Washington, DC. 1192Pp.
35. United State Geological Survey (USGS) (2012). Water Quality, Water Science for School. USA. 526Pp.
36. Bidyabati , Sanasam, and Satyendra Nath. 2023. "Monitoring and Assessment of Water Quality of Iril River, Manipur, India". International Journal of Environment and Climate Change 13 (11):221-30. https://doi.org/10.9734/ijecc/2023/v13i113161.
37. Mukut, Sanjida, Md. Mostafizur Rahaman, Md. Rashedul Azim, Md. Moazzam Hossain, and Mohammad Helal Uddin. 2023. "Water Quality Assessment of Karnaphuli River of Bangladesh Using CCME-WQI Method". Asian Journal of Environment & Ecology 20 (1):6-15. https://doi.org/10.9734/ajee/2023/v20i1429.
38. Edet A, Ukpong A, Nganje T. Hydrochemical studies of Cross River Basin (southeastern Nigeria) river systems using cross plots, statistics and water quality index. Environmental Earth Sciences. 2013 Dec;70:3043-56.
39. Edet AE, Offiong OE. Evaluation of water quality pollution indices for heavy metal contamination monitoring. A study case from Akpabuyo-Odukpani area, Lower Cross River Basin (southeastern Nigeria). GeoJournal. 2002 Aug;57:295-304.