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Application of Water Quality Index (WQI) and Principal Component Analysis (PCA) in Assessment of Water Quality Status of River Gongola at Yamaltu Deba, Gombe State, Nigeria

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Abstract
Water quality is a term used to express the suitability of water to sustain various uses. There are still however activities that release large amounts of pollutants into the environment. The Majority of people however are unaware of the effects of residing in an environment where these chemicals are present. Therefore the objective of this study was to assess the surface water quality of River Gongola at Yamaltu-Deba, Gombe state, Nigeria using Water Quality Index (WQI) and Principal Component Analysis (PCA) where water samples were collected from four study location for the period of 18 months and the physical and chemical parameters were checked using standard laboratory procedures. Of all the parameters analysed, turbidity and total dissolved solids (TSS) were the highest, above standard limit. Other parameters were within range. WQI results showed that stations 1. 3 and 4 were categorized as very poor water quality (76-100) and station 2 as unsuitable for drinking (above 100). The major parameters that contributed to such bad water quality were turbidity, TSS, and DO. DO rating became higher in the WQI calculation because of the high turbidity and TSS in the water body. PCA analysis showed that most parameters correlated positively with each other and parameters such as EC, TDS, TH, Turbidity, TSS and BOD contributed most to the contamination of the water and thus these parameters can be attributed to both anthropogenic (especially agricultural activities) and natural sources. This study indicated that the water at this location is not of good quality and therefore regular monitoring and public education on the dangers of human activities that renders water unfit for use by human and biota is recommended.

Keywords: Surface water, Water quality, River Gongola, WQI

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Introduction

Poor water quality poses significant risks to human health and environmental sustainability, particularly in areas with inadequate sanitation and waste management infrastructure. The study area is likely vulnerable to waterborne diseases and environmental degradation due to potential pollution sources. Surface water quality refers to the chemical, physical, and biological characteristics of water bodies found on the Earth's surface, such as rivers, streams, lakes, ponds, and reservoirs (Chapman *et al*., 2013; Neighbourhood Water Quality Fall, 2000; Syeed *et al*., 2023). According to Meybeck *et al*. (1996) "Water quality is a term used to express the suitability of water to sustain various uses or processes". Any other uses to which the water is put to most have certain requirements for the physical, chemical and biological characteristics of water. The quality of surface water is influenced by natural processes including hydrological cycles, geological weathering, climate, and biological activity, which control the spatial and temporal variability of water chemistry. Surface water bodies such as rivers, lakes, streams, reservoirs, and dams play consequential role in water resource provisioning. These surface water sources support a range of socio-economic activities including agriculture, domestic water supply, aquaculture, recreation, hydroelectric power generation, and industrial use (Kareem *et al.,* 2021; kumar *et al*., 2022). Human activities have increasingly impacted surface water quality, often leading to deterioration. Urbanization, agricultural runoff containing fertilizers and pesticides, effluents from industries, and poorly managed sewage systems often find their way into surface water bodies, leading to significant degradation of water quality by introducing pollutants that degrade water quality and threaten aquatic ecosystems and human health (Chapman *et al*., 2013; WHO, 2017).

Physical and chemical characteristics are crucial in evaluating the overall condition of river water quality with respect to pollution, aquatic biodiversity, and river basin management (Davies and Ekperusi, 2021; Kikuda *et al*., 2022). The physical and chemical properties of water are greatly influenced by biotic and abiotic factors, as noted by Unanam and Akpan (2006) and Kadye *et al*. (2008). These factors also have a significant impact on the distribution and richness of fish and biota, as well as how water is used. Public interest in safeguarding fresh water has prompted an increase in research into their quality requirements in the area of physicochemical parameters, such as temperature, pH, dissolved oxygen, salinity, conductivity and so forth (Imevbore, 1990). One technique for evaluating the quality of water, particularly for surface water bodies like rivers and ground water, is the water quality index. It provides a quick way to assess and compare the water quality of many water systems by combining multiple environmental parameters into a single unit-less result (Wu *et al.,* 2018).

One of the many fresh water bodies that empty into the River Benue at Numan is the River Gongola at Yamaltu Deba. The water from this river is used for purposes of irrigation, fishing (even at commercial level), domestic uses such as washing, bathing, cooking, drinking etc. Therefore the quality and safety of the water from this river is consequential because inhabitants of this area depend on this water for their day to day uses. Also aquatic life forms and crops irrigated by this water have the tendency to absorb and accumulate contaminants thereby resulting in detrimental effects to the final consumer. Consequently, the objective of this paper is to assess the water quality of the river at this location using water quality index to ascertain its suitability for use and safety for biota.

Materials and Methods

Collection and analysis of water samples

Water samples were collected from four sampling locations in 1 liter container at a depth of 10cm for physical and chemical parameters analysis. The samples were collected between 9am and 12noon monthly for a period of 18 months (Dec. 2021-May 2023). Temperature, pH, Electrical Conductivity (EC) and TDS (Total Dissolved Solids) were determined with a portable Hanna HI9828/30 pH meter in situ. Other parameters were analysed following APHA (1998) standard procedures.

Water Quality Index (WQI)

A Water Quality Index (WQI) is a tool that characterizes the overall water quality by combining intricate and technical data on water quality into a single meaningful unitless numerical value (Lukhabi *et al*., 2023). It involves four processes which are: (1) parameter selection, (2) transformation of the raw data into common scale, (3) providing weights and (4) aggregation of sub-index values (Chidiac *et al*., 2023). The Weighted Arithmetic Water Quality Index (WAWQI), which provides information regarding the quality evaluation of a body of water, was adopted in this study to calculate the water quality as described by Shweta *et* *al*. (2013). This WQI method was chosen for the study because it is one of the WQI techniques that have been adopted the most in the past ten years (Lukhabi *et al.,* 2023). The most often measured water quality parameters such as pH, BOD, COD, DO, P-PO_4^{-3}, N-NO_3^- and N-NO_2^-) as used in this study. For the calculation of water quality index in this study, twelve (12) important parameters were chosen, namely; Temperature, pH, EC, TDS, Nitrate, Phosphate, Turbidity, TH, Alkalinity, BOD, DO and TSS. The WQI method is calculated according to the following formula:

$$\textbf{WAWQI} = \frac{\sum W n Q n}{\sum W n}$$

Where: WQI has a value between 0 and 100 which indicates the quality of the water;

Qn represents a relative value of the water quality, specific to each parameter;

n represents the number of parameters taken into consideration;

Wn is a factor which measures the importance of a parameter in the calculation of the WQI index (relative weight).

Qn is calculated by applying formula below:

$$Qn = \frac{Vn - Vo}{Sn - Vo} \times 100$$

Where:

Vn represents the value experimentally determined of the n^{th} analyzed parameter;

Vo represents the ideal value of ith parameter in pure water

Note: Ideal value in most cases Vo= 0 except in certain parameters like pH and dissolved oxygen. Calculation of quality rating for pH is 7 while dissolved oxygen is14.6mg/l

Sn represents the standard, legally accepted value for the n^{th} parameters

Wn factor is calculated by using formula:

Wn= K /Sn

Where K is a constant =1, which can result from applying the formula K= 1

∑(1/ Sn)

The water ecological status can be ascertained using the value obtained from the Weighted Arithmetic WQI method, as shown in the classification in Table 1 below.

Table 1: **Water Quality Rating as per WAWQI Method**

WQI Value	Water Quality
0-25	Excellent
26-50	Good
51-75	Poor
76-100	Very Poor
> 100	Unsuitable for drinking

Source: **(**Shweta *et al*., 2013)

Results

Table 2 shows the minimum, maximum, mean, standard deviation and the National and International standard of the physical and chemical parameters measured during the study period in River Gongola for all the four stations. Most of the parameters measured were within standard limit except for turbidity and Total suspended solids (TSS) in all the locations. The highest values of Turbidity (10.69NTU) and TSS (95.25mg/l) were recorded in station 2.

Most of the physical and chemical parameters measured were reported to be higher in station 2 and lower in station 3. The concentration pattern for levels of turbidity and TSS were station 2 > station 1> station 3 > station 4.

Figure 1 below presents the results of the WQI values for all the stations and Tables 1 to 4 in the Appendix presents the steps used in calculating the WQI of all the four stations respectively. The WAWQI method was used for the calculations.

Table 2: Summary of Physical and Chemical Characteristics in River Gongola between December 2021 and May 2023

Parameter	Units	Station 1	Station 2	Station 3	Station 4)	P-Value	WHO	NSDWQ
Temperature	°C	29.80±2.33 (25.50-33.95)	29.56±2.10 (24.60-32.83)	29.90±2.09 (25.60-33.72)	29.98±2.28 (25.50-33.57)	p>0.05	30	Ambient
pH		7.21±0.31 (6.40-7.86)	7.22±0.30 (6.48-7.95)	7.19±0.21 (6.94-7.87)	7.30±0.30 (6.73-7.83)	p>0.05	8.5	6.5-8.5
EC	Mg/l	97.26±38.36 (46.96-218.60)	136.40±85.60 (48.04-354.66)	84.75±30.70 (50.19-174.92)	93.84±52.31 (51.87-286.98)	P<0.05	250	1000
TDS	Mg/l	65.12±31.79 (23.92-109.01)	80.18±47.98 (24.32-173.28)	47.13±18.40 (25.60-89.47)	49.88±25.95 (26.00-141-90)	P<0.05	500	500
Nitrate	Mg/l	37.51±14.64 (17.38-56.96)	39.01±11.07 (20.19-58.34)	37.12±13.03 (20.29-59.98)	37.57±13.90 (19.43-61.50)	p>0.05	50	50
Phosphate	Mg/l	2.46±1.56 (0.73-5.30)	1.78±0.88 (0.95-3.96)	1.46±1.11 (0.19-3.29)	2.41±1.56 (0.80-5.87)	p>0.05	5	-
Turbidity	NTU	9.47±4.10 (4.34-18.15)	10.69±4.02 (5.41-16.46)	8.83±3.19 (7.07-17.11)	8.68±3.72 (5.28-17.40)	P<0.05	5	5
TH	Mg($CaCo_3$)/l	71.19±21.90 (49.00-143.12)	113.47±67.24 (51.45-216.40)	59.82±20.19 (30.76-116.77)	62.51±22.02 (38.25-125.11)	P<0.05	200	150
Alkalinity	Mg/l	92.07±27.44 (58.04-139.04)	81.56±23.17 (59.02-131.80)	86.93±23.70 (60.00-130.49)	98.66±41.57 (55.63-200.76)	p>0.05	200	-
BOD_5	Mg/l	6.18±0.95 (4.88-7.99)	6.52±1.33 (4.01-8.03)	6.06±1.05 (3.09-7.81)	5.96±0.75 (5.21-7.71)	p>0.05	10	-
DO	Mg/l	3.00±0.59 (2.00-3.83)	2.95±0.72 (2.01-4.60)	3.06±1.08 (1.12-5.21)	3.15±0.65 (1.97-4.16)	p>0.05	6	-
TSS	Mg/l	82.68±18.55 (35.58-101.06)	95.25±48.78 (52.72-273.50)	69.55±20.21 (40.46-98.22)	66.55±33.33 (29.64-141.80)	P>0.05	30	-

Results of the Water Quality Indices showed that station 2 with the highest WQI value (Figure 1) is categorized as unsuitable for drinking (Above 100) followed by stations 1, 3 and 4 (figure 1) and are categorized as very poor water quality (76-100). The WQI values of the stations were; 98.10, 109.21, 94.40 and 93.38 for stations 1- 4 respectively. According to the WAWQI method, 0-25 is excellent quality, 26-50 is good water quality, 51-75 is poor water quality, 76-100 is very poor water quality and Above 100 is classified as unsuitable for drinking. The water quality report showing the quality rating of each parameter for all the stations can be seen in Tables 1 - 4 in the appendix. In station 1, the parameter with the highest quality rating was turbidity (42.71), followed by DO (25.34), then TSS (10.36). BOD and phosphate had a quality rating of 6.97 and 4.78. The quality rating for turbidity and DO in station 2 were 28.21 and 25.45 while TSS, phosphate and BOD had 11.93, 8.03 and 7.35 respectively. For station 3, the highest quality rating was in turbidity (39.82), followed by DO (25.21) and in station 4, turbidity and DO gave the quality rating of (39.14) and (25.01) respectively. TSS, BOD and phosphate gave 8.34, 6.72 and 5.41 as rating respectively. All other parameter not mentioned had below 5 as rating.

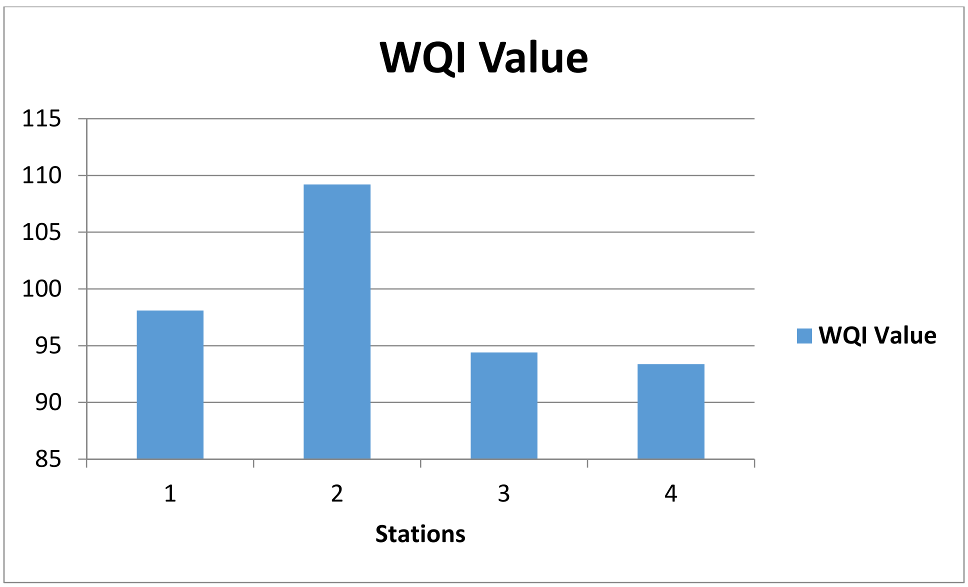

Figure 1: Water Quality Index values for the four study stations of River Gongola

Principal Component Analysis (PCA) for Physical and Chemical Characteristics in Water

The PCA results gained 3 Principal Components (PC) out of which the first 2 PC's were used because their eigen value is > 1 suggesting a two factor solution. Other smaller eigen values < 1 were not used to obtain a probable number of contributing source factors. This indicates that the first and second principal components (PC1 and PC 2) are the right choices. The first principal component (PC1) with 80.60% of variance comprises EC, TDS, Nitrate, Phosphate, Turbidity, TH, BOD and TSS with strong positive loadings (Table 7).

PC 1 was also seen to be negatively correlated with Temperature, pH, alkalinity and DO. The second principal component (PC2) accounts for 12.775% of variance and has high strong positive loadings for pH. It can be observed that the cumulative variance contribution of the first two PC's was 93.371% which explains why the total variance was 93.371%.

The results showed that the most important variables for the first PC were EC, TDS, Nitrate, Phosphate, Turbidity, TH, DO, BOD and TSS. The Biplot of the PCA is shown in figure 4.30. The plot showed that EC,TDS, TH, Turbidity, TSS, BOD and phosphate placed to the right in the loading plot are close together and therefore positively correlated, indicating a common Source. Temperature, alkalinity and DO correlated negatively in PC1 while pH correlated but negatively and positively in both PC's.

As seen in the Biplot (Fig. 1), parameters such as EC, TDS, TH, Turbidity, TSS and BOD were the key parameters that affected the water in station 2. Alkalinity, DO and Temperature were more in station 4 and Phosphate was more in station 1. Nitrate and pH contributed to both stations 2 and 4.

Table 3: Varimax normalized factor loading of physical and chemical characteristics in River Gongola

Parameters	PC 1	PC 2
Temp.	-0.997	0.038
pH	-0.377	**0.922**
EC	**0.940**	0.335
TDS	**0.947**	0.169
Nitrate	**0.908**	0.403
Phosphate	**0.736**	-0.080
Turbidity	**0.993**	0.072
TH	**0.973**	0.218
Alkalinity	-0.826	0.482
BOD	**0.999**	-0.019
DO	-0.916	0.293
TSS	0.968	0.006
Eigen values	9.672	1.533
% variance	80.596	12.775
Cummulative %	80.596	93.371

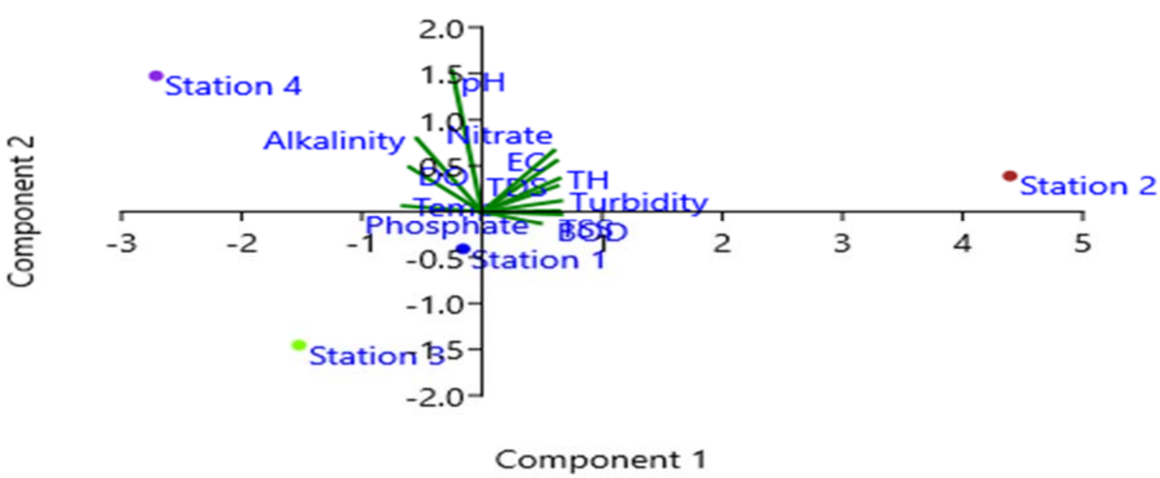

Figure 1: Biplots for PC1 and PC 2 for physical and chemical characteristics in water

Note: Green lines positively correlated are seen very close to each other.

Discussion

Most of the physical and chemical parameters checked for in the water samples are within the standard except for turbidity and Total Suspended solids (TSS). Turbidity is the ability of water to retain light and it is brought on by tiny particles found in water bodies (Dirisu and Olomukoro, 2015). The mean turbidity values recorded in this study were high for all stations. They were higher than the 5 NTU limit stipulated by WHO/NSDWQ. The elevated levels noted may be ascribed to surplus surface runoffs resulting from rainfall and additional human activities. Aquatic live cannot thrive in turbid water; the higher the turbidity measurement, the more suspended solids there are in water, giving the water a hazier appearance (Eze *et al*., 2021). There was a strong negative correlation observed between Turbidity and DO. Dissolved Oxygen depletion in the water may happen if organic particles are the main cause of the turbidity (Seema, 2015). The inverse relationship between turbidity and dissolved oxygen in this study may be explained by Eze *et al*. (2021) suggesting that higher turbidity raises temperature, which in turn lowers the levels of Dissolved Oxygen in water. The higher values of turbidity recorded in this study is in line with the findings of Atobatele and Ugwumba (2008) and Eze *et al*. (2021). However, this disagrees with the reports of Abdulhammed *et al*. (2010), Olomukoro and Dirisu (2012), Umar *et al*. (2018) and Muhammad *et al*. (2020). Increased turbidity may result in fewer photosynthetic organisms available to feed a wide variety of invertebrates, which could lead to a general decline in the number of invertebrates and subsequent decline in the fish population in the river.

Total Suspended Solids, which are the percentage of total solids held by a filter when water is filtered, are markers of erosion that occurred nearby or upstream, according to Andem *et al*. (2012) and Seema (2015). The mean values of TSS for the four stations were above the WHO value of 30mg/l. The high TSS found in this study could be caused by the dumping of solid wastes at the river bank, runoff from farm lands, and household domestic sewage. Heavy metals can also contribute to high TSS in water. Leachates from landfills, home discharges, and other human activities are the sources of elevated concentrations of heavy metals in water (Rapheal *et al.,* 2021, Chukwujindu *et al*., 2023) Elevated TSS may decrease the amount of light that reaches the water, which could result in less photosynthesis and have an impact on the aquatic ecosystem. Station 2 had the highest TSS value followed by station 1. The reason could be as a result of the influx of waste water from Gombe metropolis that joins the river at station 2. High TSS owing to geologic factors may also be caused by soil erosion and other natural causes. The results of this study are in line with the findings of Ojekunle *et al*. (2014), Abdulwasiu (2016), Awomeso *et al*. (2019) and Eze *et al*. (2021).

Water Quality Index (WQI)

The results of the water quality index as seen in tables 4.3- 4.6 showed that stations 1, 3 and 4 had WQI values between the ranges of 76-100. This is categorized as grade D according to the Weighted Arithmetic Water Quality index rating. This implies that the water from these stations is of very poor water quality. Station 2 had WQI value >100 which classify it as group E, implying it is unsuitable for drinking purposes. From these results, it can be deduced that the water of River Gongola is of very poor quality and thus unsuitable for drinking. It can be seen from the WQI calculation tables (Tables 4.3-4.6) that the parameters that contributed to this poor water quality were DO, TSS and turbidity which may be attributed to anthropogenic activities along the river. The physical and chemical characteristics results reported turbidity and TSS to be above the standard limits, this in turn affected the levels of oxygen in the water. Phosphate also added moderately to it. These parameters in turn reduced the levels of DO in the water thus affecting the water quality. Therefore the water of River Gongola at these locations needs to be properly treated before it can be used for domestic purposes. The values presented in this study were higher than the values of Kalagbor *et al*. (2019) and Hnar, (2022); however it is in line with the reports of Amadi *et al*. (2010), Ekhator *et al*. (2015), Uzochukwu *et al*. (2019) and Kalagbor *et al*. (2020).

According to Grimm and Yarnold (2000), loadings > 0.71 are principally regarded as excellent and loadings < 0.32 were regarded as very poor. The PCA results for water shows that the parameters with the strong positive loadings in PC1 (EC, TDS, Nitrate, Phosphate, TSS, BOD and Turbidity) contributed most to the contamination of the water and thus these parameters can be attributed to both anthropogenic (especially agricultural activities) and natural sources.

Conclusion

The physical and chemical characteristics investigated in the water of River Gongola showed that the River water is not of good quality. This may be as a result of natural and anthropogenic process along the river course. This water when consumed will result in detrimental effect on the consumer. Treatment of the water before consumption is highly recommended and a long term effective monitoring plan should be put in place by the government to help safeguard the water resources. Public enlightenment and education is also needed to curb indiscriminate waste disposal in water bodies.

Additional data

Additional data/information on the research are available with the corresponding author upon request.

References

Abdulwasiu, S.O. (2016). Physicochemical analysis of water from Asa River, Ilorin, Nigeria. *Imperial Journal of Interdisciplinary Research,* 2(3): 122-129.

Amadi, A.N., Olasehinde, P.I., Okosun, E. A. and Yisa J. (2010). Assessment of the water quality index of Otamiri and Oramiriukwa Rivers. *Physics International*, 1(2): 102-109.

Andem, A., Udofia, U., Okoroafor, K.A., Okete, J.A. and Ugwumba, A.A. (2012). A study on some physical and chemical characteristics of ona River, Apata, lbadan, Southwest, Oyo State, Nigeria. *European Journal of Zoological Research,* 1(2): 37–46.

AOAC. (1990). *Official Method of Analysis*. Arlington, USA: Association of Analytical Chemists

APHA. (1998). Standards methods for examination of water and wastewater. American Public Health Association. Washington DC., 20th edition

Atobatele, O. E and Ugwumba, O. A. (2008). Seasonal variation in the physicochemistry of a small tropical reservoir (Aiba Reservoir, Iwo, Osun, Nigeria). *African Journal of Biotechnology,* 7(12): 1962-1971

Awomeso, J. A., Ogundairo, E.S., Taiwo, A.M., Gbadebo, A.M. and Oyetunde, O.A. (2019). Assessment of water quality of Ogun river in southwestern Nigeria. *Ife Journal of Science,* 21(2): 375-388.

Chapman, P. J., Kay, P., Mitchell, G. N. and Colin, P. (2013). Surface watervquality. In: Holden, J, (ed.) water resources: an integrated approach. Routledge, 79-122 ISBN 0415602823.

Chidiac, S., El Najjar, P., Ouaini, N., El Rayess, Y. and El Azzim, D. (2023). A comprehensive review of water quality indices (WQIs): history, models, attempts and perspectives. *Review of Environmental Science and Biotechnology*, 22: 349–395.

Chukwujindu, M. A., Iwegbue, T. K., Faran, P. O., Iniaghe, J. O., Godswill, O. T. Godwin, E. N. and Bice, S. M. (2023). Water quality of Bomadi Creek in the Niger Delta of Nigeria: assessment of some physicochemical properties, metal concentrations, and water quality index. *Applied Water Science,* 13(36): 1-15.

Davies, C. L. and Ekperusi, A. O. (2021). Evaluation of heavy metal concentrations in water, sediments and fishes of New Calabar River in Southern Nigeria; *Limnofish,* 7(3): 207-218.

Dirisu, A. R. and Olomukoro, J. O. (2015). Investigation of water quality of two rivers in Agbede-wetlands in southern Nigeria. *GLOBAL NEST Journal*, 17(3): 451-462.

Ekhator, O., Izegaegde J. I. and Osadebamwen O. S. (2015). Assessment of Water Quality Index (WQI) for Osse River in Edo State, Southern Nigeria. *Nigerian Annals of Natural Sciences*, 15(1): 031 -041.

Eze, C. C., Ahmad, A. D., Anaebonam E., Frank-Ogu N., Nweze K. E. and Onyemeka R. M. (2021). Assessment of surface water quality of Onuiyieke River in Imo state, Nigeria. *GSC, Biological and Pharmaceutical Sciences.* 16(3): 71-84.

Grimm, L.G. and Yarnold, P.R. (2000). *Reading and understanding multivariate statistics*. First edition. Washington, DC: American Psychological Association.

Hnar, A. K. A. (2022). Water quality index application to evaluate the ground water quality in Kalar City- Kurdistan Region-Iraq. *Earth and Environmental Science* 1120: 012002 doi:10.1088/1755-1315/1120/1/01200, 1-11.

Imevbore, A. (1990). Some preliminary observation on the ratios and fecundity of the fish in the River Niger, In: S.A Visser (ed) *Kainji Lake Studies* 1: 87-88.

Kalagbor, A.I., Godslove, E. U. and Bale, D. (2020). Water quality assessment of Ahoada River and its suitability for use. *Research Journal of Environmental and Earth Sciences,* 12(3): 48-52.

Kalagbor, I.A., Johnny, V. I. and Ogbolokot, I. (2019). Application of National Sanitation Foundation and Weighted Arithmetic Water quality indices for the assessment of Kaani and Kpean Rivers in Nigeria*. American Journal of Water Resources*, 7(1): 11-15.

Kareem, S.L.; Jaber, W.S.; Al-Maliki, L.A.; Al-Husseiny, R.A.; Al-Mamoori, S.K.; Alansari, N. (2021) Water quality assessment and phosphorus effect using water quality indices: Euphrates River-Iraq as a case study. *Groundw. Sustain. Dev*., 14: 100630.

Kayde, W.T., Moyo N.A.G., Magadza, C.H.D. and Katwu, S. (2008). Stream fish assemblages in relation to environmental factors on a Montane Plateau (Nyika Plateau, Malawi). *Environmental Biology of Fishes,* 83: 17-428.

Kikuda, R.; Gomes, R.P.; Gama, A.R.; Silva, J.A.D.P.; Dos Santos, A.P.; Alves, K.R.; Arruda, P.N.; Scalize, P.S.; Vieira, J.D.G.; Carneiro, L.C.; (2022). Evaluation of Water Quality of Buritis Lake. *Water*, 14: 1414.

Kumar, S; Islam, ARMT; Hasanuzzaman, M; Salam. R; Islam, MS; Khan, R; Rahman MS; Pal, SC, Ali, MM; Idris, AM, Gustave, W; Elbeltagi, A. (2022) Potentially toxic elemental contamination in Wainivesi River, Fiji impacted by gold-mining activities using chemometric tools and SOM analysis. *Environ. Sci. pollut Res. Int*, 29(28): 42742-42767. Doi: 10.1007/s11356-022-18734-w

Lukhabi, D. K., Paul, K. M., Noble, K. A., Tchaka, P. and Kennedy, O. O. (2023). Adapted water quality indices: Limitations and potential for water quality monitoring in Africa. *Water*, 15: 1736 1-30.

Meybeck, M. K., Makela, A. E. and Malkki, E. (1996). *Water quality Monitoring- A practical guide to the design and implementation of freshwater quality studies and monitoring Programmes.* Published on behalf of United Nations Environment Programme and the World Health Organization UNEP/WHO

Muhammad, F., Sa'idu, A. and Jehu, A. (2020). Study of seasonal variation of physicochemical parameters of River Kaduna, Kaduna State Nigeria. *International Journal of Advances in Scientific Research and Engineering,* 6(1): 1-6.

Neighbourhood Water Quality Fall (2000) *Project Oceanography*. 13-25.

Ojekunle, Z. O., Ufoegbune, G. C., Oyebamiji, F. F, Sangowusi, R. O., Taiwo, A. M. and Ojekunle V. O. (2014). Assessment of the effect of commercial activities on the surface water quality of Ogun River, Nigeria. *Merit Research Journal of Environmental Science and Toxicology*, 2(9): 196-204.

Olomukoro, J. O. and Dirisu, A. (2012). Macroinvertebrate community of a post lindane treated stream flowing through derived savannah in southern Nigeria. *Tropical Freshwater Biology*, 21(1): 67-82.

Seema, T. (2015). Water quality parameters; A review. *International Journal of Engineering Science Invention Research and Development,* 1(4): 319-324.

Shweta, T., Bhavtosh, S., Prashant, S. and Rajendra, D. (2013). "Water quality assessment in terms of water quality index". *American Journal of Water Resources*, 1(3): 34-38.

Syeed, M. M; Shakhawat H.; Karim, R.; Uddin M.F.; Hasa, M.and Khan R.H. (2023)surface water quality profiling using the water quality index, pollution index and statistical methods: a critical review, *environ. Sustain. Indicators* 18: 100247https://doi.org/10.1016/j.indic.2023.100247

Umar, D. M., Dantata, A. G., Mbaya, L. A., Mbimbe, E. Y., Umar, A. M. and Wasa, A. A. (2018). A study of physico-chemical characteristics and Macro invertebrate communities of three contrasting streams in Dadin kowa, Gombe State Nigeria. *Bima Journal of Science and Technology,* 2(2): 239-248.

Unanam, A. E. and Akpan A. W. (2006). Analysis of physicochemical characteristics of some fresh water bodies in Essien Udim Local Government area of AkwaIbom State Nigeria in: *Proceeding of the 21st annual conference of the fisheries Society of Nigeria* (FISON), Calabar 13th-17th November, 2006

Uzochukwu, C. U., Amaka, L. O. and Onyechi, H. O. (2019). Assessment of the water quality of Oji River Using Water Quality Index (WQI). *Journal of Environment and Earth Science*, 9(1): 72-77.

Wu, Z., Wang, X., Chen, Y., Cai, Y., Deng, J. 2018. Assessing river water quality using water quality index in Lake Taihu Basin, China. *Science of the Total Environment*, 612: 914-922