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Utilising the National Sanitation Foundation Water Quality Index for Assessing the Water Quality Status of Eruvbi River in Benin City, Nigeria

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ABSTRACT: This study assessed the quality status of the Eruvbi River in Benin City, Nigeria using the National Sanitation Foundation Water Quality Index (NSFWQI). The physicochemical and microbiological parameters analysed were pH, temperature, turbidity, total dissolved solids (TDS), phosphate, nitrate, biochemical oxygen demand (BOD), dissolved oxygen (DO), and total coliforms. All parameters were analysed using standard methods. For each parameter, the temporal and spatial range were pH (5.3 - 6.2), temperature (22.0 - 28.0 ºC), turbidity (5.0 – 128.0 NTU), TDS (20.0 – 128.0 mg/L), phosphate (0.1 – 1.0 mg/L), nitrate (0.2 - 0.8 mg/L), BOD (3.4 - 6.2 mg/L), DO (5.0 - 11.2 mg/L), while the mean for total coliform count ranged from (416.9 - 295120.5 CFU/100 mL). The results were compared against national and international standards with the temperature, TDS, and nitrate values within set limits, while the non-conforming parameters were majorly total coliform, phosphate, turbidity, and pH. The overall NSFWQI results indicated moderate water quality, with WQI values ranging from 54.04 to 61.95 at all sampling locations. The middle stream had the lowest NSFWQI value caused by effluent discharge from a carbonated drink industry. The moderate water quality means that additional treatment is required before the water can be considered safe for drinking and domestic purposes. The NSFWQI protocol makes it easier to explain the water quality to the general public and decision-makers, and it can be a valuable tool for water management.

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Rivers and streams, categorised as surface water, are a veritable source of freshwater, traversing both rural and urban settlements. It plays an important role in the localised area by providing water for agricultural, domestic, industrial, and recreational activities. Surface water systems are prone to pollution from varied contaminants from numerous sources, and the pollution of surface water by dangerous substances poses serious environmental issues globally. Major contributors to surface water pollution include industrial effluent discharges, agricultural waste disposal, and extensive urbanisation (Singh *et al.*, 2022). The anthropogenic activities deposit pollutants in the surface water systems which are transported over long distances. The introduction of exogenous xenobiotics adversely affects the flora and fauna in aquatic ecosystems as they are extrinsic to the normal metabolism of living organisms. The monitoring of the quality status of surface waters is pertinent for the sustainability and maintenance of freshwater resources. More so, it provides vital information to the residents using the surface water (river or stream) as a source for drinking water and domestic use. Embarking on water monitoring regimes or programmes can be challenging and time-consuming since it involves gathering and analysing vast volumes

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of data. A number of tools and models have been developed to aid with this process. An extensively used method for analysing and combining data on surface water quality is the Water Quality Index (WQI) model (Oputu and Akharame, 2022). It makes it possible to compare the quality of the water over time and across locations. A water body's overall quality status can be evaluated using the WQI model, which can also be used to pinpoint regions that require improvement. The WQI model aggregates several water quality factors into a single numerical value using methods like weighted arithmetic and geometric means. The water quality can then be categorised in simple terms using the value obtained. Due to its ease of application and comprehension, as well as its ability to facilitate comparisons across various areas, the WQI model has gained popularity. Water quality criteria and various weightings can be used to tailor the WQI model to local conditions, as demonstrated by Uddin *et al.* (2021). Its adaptability to many domains' requirements renders it a versatile instrument.

Since its introduction to evaluate river water quality in the 1960s, the WQIs have been used more and more in the field of water management (Hamlat et al., 2017). Robert Horton invented the concept of the WQI in 1965. He proposed that the overall state of water resources could be evaluated by analysing ten parameters - sewage treatment, dissolved oxygen (DO), pH, coliforms, electrical conductivity (EC), carbon chloroform extract (CCE), alkalinity, chloride, temperature, and obvious pollution (Horton, 1965). Following Horton's original suggestion, Brown et al. (1970) achieved notable advancements in the creation of WQIs, modelling the National Sanitation Foundation Water Quality Index (NSFWQI). Nine essential and critical parameters were utilised in their WQI – pH, temperature, turbidity, DO, total dissolved solids (TDS), biochemical oxygen demand (BOD), phosphate, nitrate, and total coliforms (Brown et al., 1970). Rivers and lakes have been the subject of the bulk of WQIs applications; however, different models have been employed to evaluate a range of water sources (Uddin *et al.,* 2022). As evidence of their adaptability in evaluating various water sources, they have also been utilised to assess the quality of groundwater (Ramakrishnaiah *et al*., 2009; Akharame and Ajayi, 2022) and coastal water (Uddin *et al.*, 2022).

The exploitation of rivers by industries for the discharge of wastewater has significantly reduced the quality of the rivers; these industries exploit and subvert the natural process of river self-purification. The inability of the government to provide potable pipe-borne water for the majority of its people has led to the use of alternative sources such as rivers/streams and groundwater (Ekhosuehi *et al.,* 2018). The economic advantage of river water makes it the main source of water for the poor and low-income earners. Consequently, the objective of this paper was to utilise the NSFWQI protocol to assess the water quality status of the Eruvbi River in Benin City, Nigeria.

MATERIALS AND METHODS

Study Area: The Eruvbi River is located in Ovia North-East Local Government Area, Edo state, Nigeria with coordinates (6º27’8” N 5º36’37” E to 6º27’6” N 5º36’38” E). The study carried out sampling at three sampling stations on the Eruvbi River - the upstream (6º27’8” N 5º36’37” E), middle stream (6º27’7” N 5º36’38” E), and downstream (6º27’6” N 5º36’38” E). The landscape around the Eruvbi River is elevated, hilly, and highly gullied; contributing surface runoff to the river. Precipitation runoff, municipal wastewater, and construction debris are washed off from the land towards the river due to the elevation of the surrounding landscape. The River also stands as a boundary separating residential and forest used essentially for farming activities. Over the years, the water flow from the river source has reduced and there are dead trees along its bank, especially at the carbonated drink industrial facility discharge area.

Sample Collection and Preparation: The American Public Health Association's (2005) standard procedures for sampling were followed. To account for temporal variance in sampling, samples were taken over three months (November 2023, December 2023, and January 2024). The polytetrafluoroethylene (PTFE)-capped 500 mL bottles were used to collect water samples for physicochemical analysis, while the 33 cL bottles were used to collect samples for total coliform counts. Throughout the three-month sampling period, this procedure was repeated. Samples for BOD and DO were collected in 60 mL dark bottles, taking care to ensure that no air bubbles were collected with the samples. Following collection, 1 mL of Winkler's reagents A and B were injected into the DO samples; to stop light penetration, the DO and BOD samples were then wrapped in black nylons.

Analytical Procedures: Temperature (^{O}C), pH, turbidity (NTU), TDS (mg/L), DO (mg/L), BOD (mg/L), phosphate (mg/L), nitrate (mg/L), and total coliform (CFU/ 100 mL) were the physicochemical and microbiological parameters for which the quality status was assessed in this study. A HANNAH field pH metre and a mercury-in-glass thermometer were used to measure the temperature and pH *in-situ*. To measure the turbidity, nitrate, and phosphate levels, the HACH DR 2000 spectrophotometer was needed.

The HACH CO150 TDS/Conductivity/Salinity metre was utilised to measure TDS. Water samples' DO content was ascertained using the Winkler method's azide modification. In the lab, 2 mL of concentrated H_2SO_4 was added to the fixed samples to dissolve them. This solution was then transferred to a conical flask in an amount of 50 mL, and it was filtered using 0.2 N $Na_2S_2O_2$ as the titrant until a light yellow colour was seen. After adding three (3) drops of an indicator made of 1% aqueous starch solution to the sample, the sample's blue-black colour was eventually titrated until a colourless endpoint was attained. The DO content of the water samples was calculated using the following equation:

$$DO\left(\frac{mg}{L}\right) = (R) \times (0.04) \quad (1)$$

Where 0.04 = digital multiplier; R= readings on digital titrator

The BOD of the water samples was ascertained using the same azide modification of the Winkler method. After five (5) days, the samples were fixed by adding 1 mL of Winkler A and then 1 mL of Winkler B, which caused a precipitate to develop. After dissolving the precipitate in the solution with 2 mL of concentrated H_2SO_4, the sample was titrated according to the previously mentioned procedure. To calculate BOD, the following equation was used:

$$BOD = Day\ five\ (DO5) - Initial\ DO \quad (2)$$

Microbial Analysis (*total coliform):* The workbench and environment were sterilised using 70% ethanol. Water sample analysis was done using the heterotrophic plate count method within 24 hours of sample collection. One millilitre of the water samples was put into each of the media (nutrient agar and MacConkey agar) and plated.

After allowing the plates to harden, they were incubated at room temperature for a full day. Conventional biochemical methods were employed to identify and count the colonies. The sting test, differential test (media test, biochemical test, citrate test, and triple sugar iron agar test), and subculturing were used for additional confirmation. By using these tests, different bacterial colonies were distinguished from one another based on their distinct qualities or responses to particular chemicals, as well as their capacity to develop particular traits when exposed to KOH.

NSFWQI Analysis: To provide a standardised approach for determining and assessing the water quality of a specific water body, the Nation Sanitation Foundation created the NSFWQI in 1970. It is a publicly available indicator of overall water quality that disregards all forms of water use during evaluation and does not account for the usage capabilities of water. According to Hamlat *et al.* (2017), the NSFWQI uses the analysis of nine essential parameters, presented with their weight factor - BOD (0.10), DO (0.17), nitrate (0.10), total phosphate (0.10), temperature (0.10), turbidity (0.08), TDS (0.08), pH (0.12), and total coliform (0.15). The sum of the weight values is equal to 1.

The mathematical expression of the NSFWQI is given by the following equation 3:

$$NSFWQI = \sum_{i=1}^{n} WiQi \quad (3)$$

Where $n =$ the number of water quality parameters = 9; $Wi =$ Weight associated with the ith water quality parameters = 1; $Qi =$ Sub-index value for the ith water parameters (Matta *et al.*, 2020); Q-value or sub-index value in the NSFWQI analysis was evaluated using the rating curves for each parameter.

The water quality classification is presented in Table 1;

Table 1: The NSFWQI classification range

Definition	Colour code	NSFWQI value
Very bad	Red	0 - 25
Bad	Orange	26 - 50
Moderate	Yellow	51 - 70
Good	Green	71 - 90
Excellent	Blue	91 - 100

Source: Roozbahani and Boldaji (2013)

RESULT AND DISCUSSION

Physicochemical Parameters Profile of Eruvbi River: The results were compared against the World Health Organisation (WHO), United States Environmental Protection Agency (US EPA), National Environmental Standards and Regulations Enforcement Agency (NESREA), and Nigerian Standard for Drinking Water Quality (NSDWQ) standards. The stipulated standards by the national and international agencies for drinking and surface waters are presented in Table 2. *Temperature assessment:* In November, December, and January, there were only slight variations in the water temperature at the three riverside sampling sites, which ranged from 22.0 to 28.0 ºC (Figure 1a). Consistent temperatures were found across the river when data on water temperature from November's collection was analysed.

Table 2: Standards on drinking water quality

Parameter	Drinking/surface water	WHO, 2017	USEPA, 2014	NESREA, 2021	NSDWQ, 2015
Temperature (ºC)	Drinking water	25	-	-	Ambient
	Surface water	16 - 30	-	-	-
Turbidity (NTU)	Drinking water	≤5, ideally <1	1 maximum	5 maximum	5
	Surface water	5.0	5.0	10.0	-
pH	Drinking water	6.5 - 8.5	6.5 - 8.5	6.5 - 8.5	5.10 - 6.6
	Surface water	6.5 - 8.5	5.5 – 9.0	6.5 – 9.0	-
TDS (mg/L)	Drinking water	500	500	500	500
	Surface water	500	500	500	-
Phosphate (mg/L)	Drinking water	1.0	0.1	0.1	3.5
	Surface water	1.0	0.1	0.1	-
Nitrate (mg/L)	Drinking water	10	10	10	50
	Surface water	10.0	10.0	10.0	-
DO (mg/L)	Drinking water	6.5 – 8.0	≥5.0	≥5.0	6.0
	Surface water	≥5	≥5	≥5	-
BOD (mg/L)	Drinking water	5.0 maximum	5.0 maximum	5.0	5.0
	Surface water	5.0 – 7.0	<8.0	5.0	-
TC (CFU/ 100 mL)	Drinking water	<1 or 0	0	0	<10
	Surface water	<1.0	0	0	-

WHO: World Health Organisation, US EPA: United States Environmental Protection Agency, NESREA: National Environmental Standards and Regulations Enforcement Agency, NSDWQ: Nigerian Standard for Drinking Water Quality

This suggests a uniform thermal environment that could support aquatic habitat and the survivability of organisms. On the other hand, December had notable temperature swings, with the middle stream region seeing a minor increase. Seasonal variations, regional weather patterns, and human activity affecting the hydrological and thermal characteristics of the river could all be responsible for this. Temperatures returned to November levels in January, suggesting that the waterway's thermal equilibrium had once again been reached. The current study's conclusions verified that the surveyed region's water temperature was within the WHO's recommended limit for surface waters. The temperature values' consistency is in line with the environmental factors that support robust aquatic ecosystems and meet safety requirements for drinking water and surface water quality.

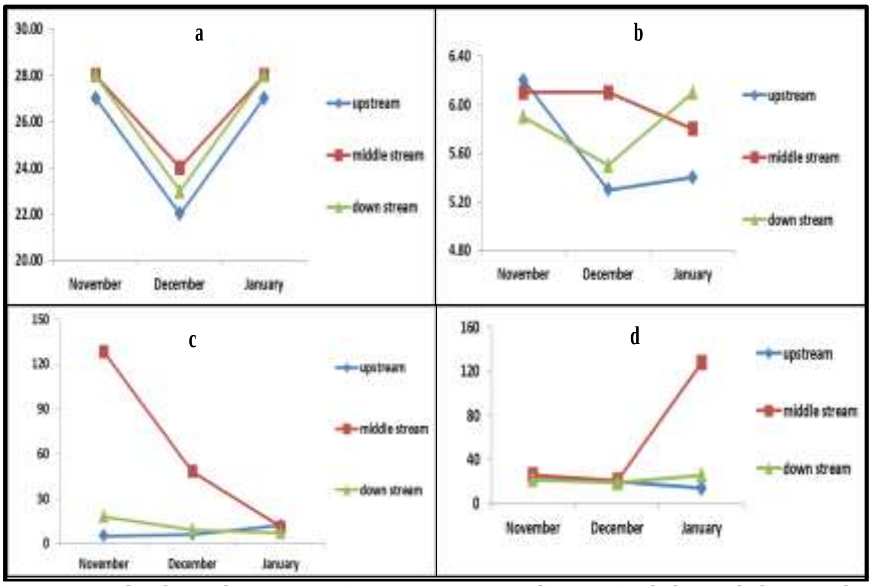

Fig 1: Temporal and spatial variation in (a) water temperature, (b) pH, (c) turbidity, and (d) TDS values

pH assessment: The study's findings showed that the waterway's pH varied significantly over time and space, with readings ranging from 5.3 to 6.2 in November, 5.3 to 6.1 in December, and 5.4 to 6.1 in January (Figure 1b). An increase in acidic conditions in that area is indicated by the downstream fall in pH values that was noted in November. Both the organic matter's natural decomposition and human activity's release of acidic effluents are plausible causes of this alteration. The December data indicates that the middle stream zone is constant while the upstream and downstream sections show a more marked decline in pH values. Seasonal variations in precipitation or temperature, as well as an increase in the amount of contaminants introduced into the river by humans, could cause this additional deterioration. The data from January shows a reversal of this tendency, with the downstream region's pH values rising relative to the middle and upstream streams. This change may be the result of things like altered river entry composition or increased water flow that dilutes acidic substances. Except for the NSDWQ standard, the pH range of 5.3 to 6.2 recorded at all sample locations throughout the study period is significantly lower than the drinking water requirements set by the US EPA, NESREA, and WHO. This acidic condition suggests that more research and management of the water quality in the study area are necessary since it may present a risk to both human health and the ecosystem.

Turbidity assessment: As presented in Figure 1c, the average monthly turbidity values were 5.0, 128.0, and 18.0 NTU for November, 6.0, 48.0, and 9.0 NTU for December, and 12.0, 11.0, and 7.0 NTU for January, at the upstream, middle stream, and downstream sampling locations, respectively. Of the various sampling locations, only the upstream site in November had a turbidity level that met the standards set by the WHO, NESREA, and NSDWQ for drinking water (5 NTU), as well as the NESREA standard for surface water (5 NTU). However, the upstream and downstream sites in December, as well as the downstream site in January, had turbidity levels that were within the NESREA standard for surface water (10 NTU). Turbidity serves as an important indicator of water quality, as high levels can impair aquatic ecosystems, hinder light penetration necessary for photosynthesis, and compromise drinking water treatment processes. Standard turbidity ranges established by regulatory agencies such as the WHO, USEPA, NESREA, and NSDWQ aim to ensure water quality meets specified criteria for designated uses.

Total dissolved solids assessment: The recorded TDS levels in Figure 1d ranged from 22.0 to 26.0 mg/L in November, 19.0 to 21.0 mg/L in December, and 14.0 to 128 mg/L in January, respectively. In January, the TDS level of 128 mg/L in the middle stream region was significantly higher than those recorded in the upstream and downstream regions. This sudden increase in middle stream TDS concentrations could be attributed to localized point source pollution, industrial discharges, or inputs of dissolved solids from land use activities in the surrounding area. These findings suggest that the middle stream region is particularly vulnerable to changes in TDS level. The range of TDS levels observed in this study (20 to 128 mg/L) suggests that the river water met the minimum requirements for TDS set by these guidelines, making it suitable for various uses. Excluding the elevated level recorded in January in the middle stream region, the recorded concentrations were similar to the TDS range of 26.96 to 30.11 mg/L obtained from Ogba River in Benin City by Anyanwu *et al.* (2013).

Phosphate assessment: The phosphate levels (Figure 2a) at the upstream, middle stream, and downstream sites varied significantly over time, as shown by the results of November (0.96, 0.47, and 0.56 mg/L, respectively), December (0.14, 0.12, and 0.11 mg/L, respectively), and January (0.38, 0.97, and 0.18 mg/L), respectively. In this study, all sampling locations were found to fall within the WHO standard for both drinking and surface water, with phosphate levels ranging from 0.11 to 0.97 mg/L. However, these values were above the lower limits recommended by other agencies, such as the US EPA and NESREA, highlighting the importance of considering multiple standards and guidelines when evaluating water quality. The elevated phosphate levels recorded in the upstream may result from detergents usage for washing activities taking place in the upstream; the middle stream levels may be from the effluent discharges from the carbonated drink facilities where phosphate-based cleansers such as trisodium phosphate (Na_3PO_4) is routinely used for cleaning and phosphoric acid is a component of some the beverage formulation (Akharame *et al.* 2017).

Nitrate assessment: The results of the study showed temporal and spatial variability in nitrate levels across the three sampling locations, with values ranging from 0.7 to 0.8 mg/L in November, 0.4 to 0.5 mg/L in December, and 0.2 to 0.8 mg/L in January, respectively. The results of this current study show that the nitrate concentrations measured across the sampling locations ranged from 0.2 to 0.8 mg/L (Figure 2b), falling within the standards set by the WHO, US EPA, NESREA, and NSDWQ for drinking and surface quality. This spatial distribution may be attributed to inputs from effluent discharges, agricultural sources, such as fertilizer application and livestock waste, as well as from natural sources such as atmospheric deposition and soil erosion. These sources of nitrate can have significant impacts on water quality and ecosystem health. The result is similar to those obtained in the studies by Ayobahan *et al*. (2015) and Anyanwu *et al*. (2013) in the Benin River and Ogba River in Benin City with ranges of 0.93 – 1.18 mg/L and 0.02 – 0.30 mg/L, respectively.

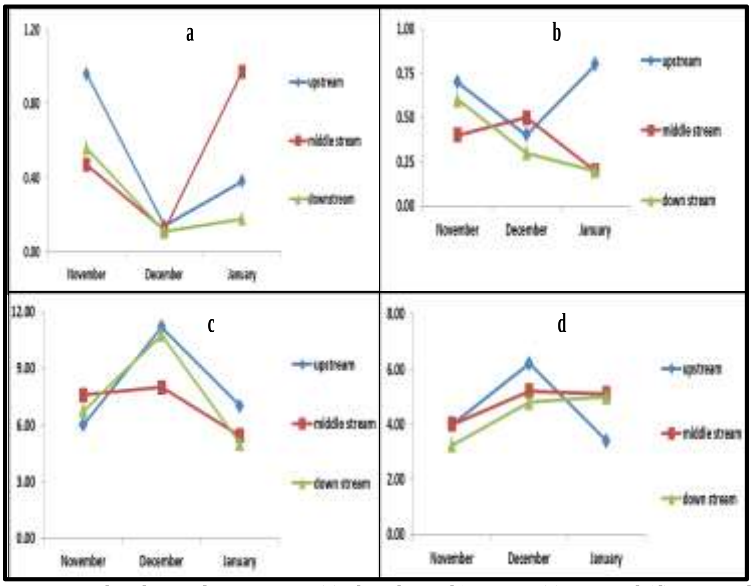

Fig 2: Temporal and spatial variation in (a) phosphate, (b) nitrate, (c) DO, and (d) BOD values

Dissolved oxygen assessment: The DO levels (Figure 2c) at the three locations (upstream, middle stream, and downstream) fluctuated over time and space, with the values in November being 6.0 mg/L, 7.6 mg/L, and 6.75 mg/L, respectively. In December, the values were 7.0 mg/L, 5.4 mg/L, and 5.0 mg/L, respectively. Finally, in January, the values were 11.2 mg/L, 8.0 mg/L, and 10.8 mg/L, respectively. In November, DO levels varied somewhat along the length of the waterway, with higher values observed in the middle stream region compared to the upstream and downstream regions.

However, the DO levels recorded for the middle stream region were lower compared to the upstream and downstream in the following months of December and January. The decline could be explained by reduced photosynthetic activity from lower sunlight levels and cooler temperatures that reduce oxygen solubility in water. More so, the organic load of the effluent from the carbonated drink facility could be responsible for the DO decrease. The WHO guidelines for DO in drinking water sources recommend a range of 6.5 – 8.0 mg/L to protect human health and prevent oxygen deficiency-related issues. The US EPA, NESREA, and NSDWQ standards recommend a minimum DO level of 6 mg/L. The recorded DO levels meet the requirement for surface water for the sustainability of aquatic life as lower DO levels can have negative impacts, including fish kills and algal blooms (Mishra *et al.*, 2022).

Biochemical oxygen demand assessment: The results (Figure 2d) of the BOD measurements for the upstream, middle stream, and downstream taken in November (4.0, 4.0, and 3.3 mg/L), December (6.2, 5.2, and 4.8 mg/L), and January (3.4, 5.1, and 5.0 mg/L) indicated differences in the amount of oxygen consumed by microorganisms to break down organic matter at the three sampling locations over the three months. The data showed that, in November, the BOD levels at all three sampling points met the drinking water standards established by the WHO, US EPA, NESREA, and NSDWQ. In December, the upstream and middle stream locations exceeded the drinking water standards, while all locations met the surface water standards set by the WHO and US EPA. Finally, in January, the middle stream location slightly exceeded the drinking water standards, while all locations met the surface water standards. The recorded BOD levels were slightly higher than the ranges of 2.78 – 3.58 mg/L reported by Ayobahan *et al*. (2014) for the surface water from the Benin River and 2.14 – 4.13 mg/L by Anyanwu *et al*. (2013) at the Ogba River in Benin City.

Total Coliform Assessment: The temporal and spatial variations in total coliform count at the three sampling locations are reflected in the results for November, December, and January (Figure 3). The range of the total coliform count in November was 500 to 29539 CFU/100 mL, while in December, it was 151 to 29000 CFU/100 mL, and in January, it was 600 to 30000 CFU/100 mL. These variations demonstrate the dynamic nature of the concentration of coliform bacteria in water. Total coliform bacteria are used as indicators of the presence of faecal contamination, since they are commonly found in the intestines of warm-blooded animals, including humans. Five different bacteria were identified, namely *Vibrio parahaemolyticus, Bacillus mycoides, Enterobacter aerogenes, Serratia marcescens*, and *Alcaligenes faecalis*. However, the absence of *E. coli* indicates that the Eruvbi River is not contaminated with faecal matter. This is an important finding for ensuring the safety of the river for human use. Although no faecal contamination was detected in the Eruvbi River, the presence of any bacteria in water bodies requires a treatment process before the water can be considered fit for human consumption. According to the WHO, the level of total coliform bacteria in drinking water and surface water should be $<$ 1 or zero CFU/100 mL to ensure public health and safety. NSDWQ set a maximum standard of $\leq$ 10 CFU/100 mL. The WHO guidelines are generally considered more stringent and are the internationally accepted standard. The data collected from the Eruvbi River shows that the river does not meet the standards set by WHO or NSDWQ. The identification of the physiological and biochemical characteristics of coliform isolates found in the water samples is represented in Table 3.

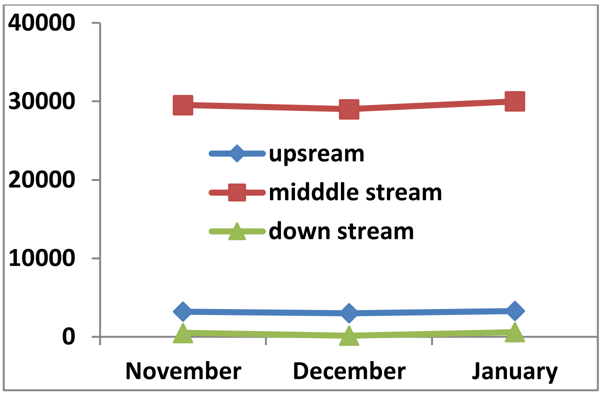

Fig 3: Temporal and spatial variation in TC counts

Table 3: Physiological and biochemical characterisation of the coliforms

Morphological					
Elevation	Raised	Flat	Flat	Raised	Raised
Margin	Smooth	Coarse	Undulate	Ntire	Entire
Color	Cream	Milk White	Cream	Cream	Cream
Shape	Concave	Concave	Irregular	Circular	Circular
Size	Small	Large	Large	Medium	Medium
Gr. diff. agar	MCC	BCA	EMB	EMB	PCA
Color	Pink	Straw	Pink	Opaque	Cream
Staining					
Gram stain	-	+	-	-	-
cell type	Coccobacilli	Rod	Rod	Rod	Rod
Arrangement	Pairs	Disperse	Disperse	Disperse	Disperse
Color	Pink	Purple	Pink	Pink	Pink
Spore staining	-	+	-	-	-
Biochemical					
KOH String Test	+	-	+	+	+
Catalase	+	+	+	+	+
Indole	+	-	-	-	-
Citrate	+	-	+	+	+
Oxidase	+	-	-	-	+
Motility	+	+	+	+	+
Urease	-	-	-	-	-
Glucose	+	+	+	+	-
Sucrose	(+/-)	-	+	+	-
Lactose	-	-	+	+	-
Mannitol	+	-	-	+	-
Gas formation	-	-	-	-	-
H_2S formation	-	-	-	-	-
TSI (Slant/Butt) reaction	**K/A**	**K/A**	**A/A(K*)G***	**K/A (*A/A)**	**K/K**
Esculin Hydrolysis	+	+	+	-	-
Identity	*Virbrio parahemolyticus*	*Bacillus mycoides*	*Enterobacter aerogenes*	*Serratia marcescens*	*Alcaligenes faecalis*

NSFWQI Assessment: The final NSFWQI scores for the three locations (upstream, middle stream, and downstream) were 61.95, 54.04, and 60.38, respectively. This indicates that the overall water quality is moderate, and there are some variations in the scores along the waterway. The upstream location had the highest NSFWQI score, suggesting the best overall water quality, followed by the downstream location and then the middle stream location. The reduction in water quality at the middle stream; as suggested by the NSFWQI score of 54.04 is largely attributed to the deposition of effluent discharge from the carbonated drink facility. While the water quality scores are considered moderate, additional purification may be required depending on the specific end-use of the water, such as drinking, agricultural, or industrial applications. The level of purification may vary based on the intended use and local regulations. Overall, the major sources of pollution in the study area are the carbonated drink industrial facility situated in the locale, agricultural activities, and the various religious practices or sacrifices at the upstream region of the river. The sacrificial items range from organic biodegradables like animals, animal blood, food, sugar cubes, and so on; candles, biscuit wrappings, bottles, and cans of alcoholic/non-alcoholic drinks are among the non-biodegradables found near the river. The carbonated drink industrial facility utilizes the river to dispose of industrial effluent contributing to pollution of the river at the middle stream. In a similar study by Aminirad *et al.* (2021), moderate water quality was observed upstream of the Haraz River after four seasons of sampling with an NSFWQI range value of 57.0 – 62.0. The study explained that rivers naturally purify themselves at the upstream point and become increasingly polluted traversing downstream. Prabagar *et al.* (2023) found that the upstream section of the Moragoda Canal had moderate water quality, while the middle stream and downstream sections were poor. The pattern is similar to the result obtained in this study with the upstream having a higher WQI score, signifying better water quality. However, the middle stream which is inundated with effluent discharge from the carbonated drink facility had a lower WQI score than the downstream. This identifies the carbonated drink facility as a point source of pollution in the Eruvbi River system.

Conclusion: This study evaluated the water quality status of the Eruvbi River in Benin City, Nigeria using the NSFWQI protocol. The WQI results show moderate water quality at all the sampling locations with total coliform, phosphate, turbidity, and pH being the major non-conforming parameters. The WQI score indicates that additional treatment is required before the water can be considered safe for drinking and domestic purposes. The NSFWQI makes it easy to explain the water quality to the general public and decision-makers, and it can be a valuable tool for water management. To improve the water quality of the Eruvbi River, it is recommended to reduce pollution inputs, enhance wastewater treatment from the industrial facility, implement watershed management strategies, establish an effective monitoring and enforcement system, and increase public awareness about the importance of protecting the river. These measures will help to preserve the health and safety of the river and its surrounding communities.

Competing Interests: The authors declare that they are no competing interests

Availability of Data and Materials: All data generated or analysed during this study are included in this published article

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