BIOLOGIJA
2024. Vol. 70. No. 4. P. 198–210

ISSN 1392-0146 eISSN 2029-0578
DOI: https://doi.org/10.6001/biologija.2024.70.4.4

# Spatial and seasonal variations in physico-chemical parameters and the water quality index at the Okhuaihe River in Ikpe Community, Edo State, Nigeria

**Omorede Odigie**[*],

**Isaiah Elimhingbovo**

*Department of Biological Sciences,*
*Faculty of Science,*
*Benson Idahosa University,*
*P.M.B. 1100, Benin City*

The scarcity of clean water in rural Nigerian communities leads to dependence on streams and rivers which are often polluted by domestic and industrial activities distorting the quality of water. Freshwater ecosystems, which are important for global biodiversity, are constantly burdened with threats from environmental changes as well as human misuse. This study was aimed at investigating the spatial and temporal variations of physico-chemical parameters and the water quality index (WQI) of the Okhuaihe River in Ikpe, Edo state, Nigeria, used for different domestic activities. The study assessed parameters like air and water temperature, pH, electrical conductivity, flow rate, total dissolved solids, phosphate, chloride, iron, zinc, and manganese at four stations over a six-month period. Samples such as air and water temperature and pH were collected and measured in situ, while others were collected using polyethylene bottles and a 250 ml amber bottle for biochemical oxygen demand ($BOD_5$). Results indicated that while some physico-chemical parameters like the width, the flow rate, and phosphate showed considerable differences, most did not differ significantly. Temporally, there were significant seasonal variations in air temperature, electrical conductivity, total dissolved solids, chloride, iron, zinc, and manganese. The WQI calculations showed that the water quality at all stations was within safe limits for human consumption and supported aquatic life. Despite some fluctuations due to seasonal changes and anthropogenic activities, the overall quality remained suitable for domestic use. This underscores the importance of constant monitoring and management of water resources to allay pollution and ensure sustainable water supply in rural communities.

**Keywords:** physico-chemical parameters, water quality index (WQI), pollution, freshwater ecosystems, anthropogenic activities

---

[*] Corresponding author. Email: oodigie@biu.edu.ng

## INTRODUCTION

The scarcity of suitable potable water, especially in the rural communities of Nigeria, has resulted in (human) communities reliant on streams and rivers as their main sources of drinking water. According to Farah et al. (2002), water bodies such as rivers are vital fresh water sources, which are susceptible to pollution by any various form of activities of domestic and industrial use and have an impact on their physical and chemical parameters affecting the overall quality of the water body. Water bodies are endlessly used as dumping grounds for untreated waste from homes and industries, thus leaving it very unfit for usage when needed. Having a good and clean source of water is a major problem in the underdeveloped countries. Though water is important to life, it is one of the most ill-managed resources in the world (Fakayode, 2005). Numerous studies in Nigeria recognised anthropogenic activities as an easy source of water pollution (Akintola, Nyamah, 1978; Ayoade, 1988; Ayoade, Oyebande, 1983; Obasi, Balogun, 2001; Ovrawah, Hymore, 2001).

Freshwater ecosystems are being increasingly studied worldwide because of their role in conserving and sustaining several globally important species (Arimoro et al., 2015; Edegbene et al., 2015). Without treatment, much of the world's fresh water (including surface and groundwater) is unfit for human consumption. Fresh water may readily become contaminated as a result of human activity or natural processes such as erosion. Fresh water is a finite, renewable, and fluctuating natural resource that can only be supplied via the water cycle, which involves water evaporating from seas, lakes, forests, land, rivers, and reservoirs, forming clouds, and then returning inland as precipitation. However, if more fresh water is consumed than is naturally replenished, this can then lead to a reduction in the availability of fresh water (or water scarcity) from surface and subsurface sources, as well as to major environmental harm. The supply of fresh water is also reduced as a result of water contamination and consequent eutrophication.

Freshwater habitats are essential for maintaining global biodiversity because they offer critical services to the environment. Studies show that freshwater environments are exposed due to the effects of environmental change (Pinceel et al., 2018; Reid et al., 2019), which contribute to permanent changes in the regime through which biodiversity and ecological services can be lost (Hossain et al., 2018; Jarić et al., 2019). Due to the rising exploitation by humans, the physical, chemical, and biological aspects of aquatic ecosystems have undergone significant changes. Freshwater ecosystems have changed significantly throughout time, which has impacted their properties (Carpenter et al., 2011).

While it takes some time for the freshwater environment to recover, it is crucial to maintain it because it is a source of biodiversity, economy, and water supply. It is crucial to look for ways to preserve freshwater environment while also ensuring that people have access to basic requirements (Matthews, 2016).

Conducting a check and balance of the water and of its physical and chemical parameters is vital to the sustenance of life for all that survive on it and those that do not. The study of the physico-chemical properties of water is a vital tool in analysing the waterbody (Djukic et al., 1994), biological productivity in the water body, and the trophic status (Mustapha, 2003), as well as the composition, distribution, and abundance of biotic organisms (Mustapha, Omotosho, 2006).

The Okhuaihe River serves as a major source of water supply to the Ikpe community and its environs. The people of the Ikpe community use the river for laundry, bathing, cooking and other anthropogenic activities which are capable of altering the physico-chemical parameters of this river. However, there has not been any research work carried out on the physico-chemical parameters and water quality index of the Okhuaihe River, Ikpe community in Edo state, Nigeria, a river loaded with economic and social reputation to the communities in the area.

The aim of this study is to investigate spatial and temporal variation of physico-chemical parameters as well as the water quality index of the Okhuaihe River at the Ikpe community, Benin City, Edo state, Nigeria.

## MATERIALS AND METHODS

***Description of the study area.*** The study was carried out at four stations along the the Okhuaihe River in Ikpe village, Edo State, Nigeria, in the Ikpoba-Okha local government area. The portion of the river investigated extends 30 km from Benin City, over the Benin-Abraka express road, with an average elevation of –8.48 m below sea level to 1.87 m above sea level. The Okhuaihe River is one of the primary rivers that flow into the Ossiomo River, which empties into the Atlantic Ocean. It is situated in the tropical rainforest of Southern Nigeria. The Ijaws and Urhobos make up the majority of the population of over 500 people of the Okhuaihe community. Farming, fishing, local gin making, palm wine production, and timber and lumber production are among their main activities (Fig. 1).

The climate is characterised by tropical wet and dry seasons primarily determined by rainfall. The wet season has high flow rate, high turbidity due to influx, decreased transparency, and increased depth, especially after heavy rainfall; in the dry season, the temperature ranges between 22°C and 31°C. The wet season characteristically lasts from April to October, and the dry season from November to March (Olomukoro, 1996).

Vegetation surrounding the river is characterised by *Colocasia esculenta* (wild cocoyam plants), *Raphia farinifera* (raffia palms), *Musa paradisiaca* (plantain), *Musa sapientum* (banana), *Cynodon dactylon* (Bahama grasses), *Cocos nucifera* (coconut trees), *Elaeis guineensis* (palm trees), *Mimosa pudica* (shameplant), *Sida acuta* (stubborn grass). Floating and submerged

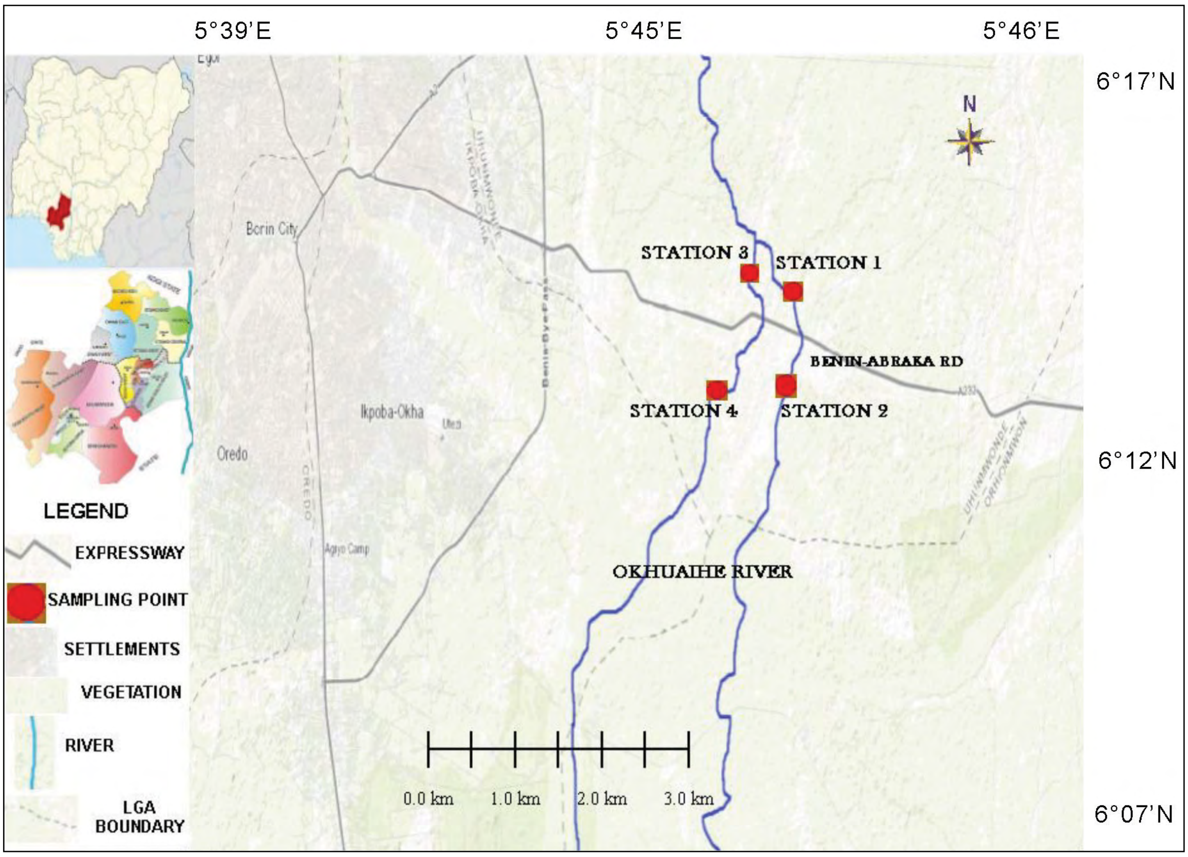

**Fig. 1.** Map of the study area

macrophyte vegetation such as *Eichhornia crassipes* (water hyacinth) was also observed in the river.

Based on a number of anthropogenic activities along the river length that are likely to have an impact on the ecology of the water, four sampling stations were chosen along the river course.

***Station 1*** is located down the left side of the bridge at about 500 m above the Orhionmwon bridge, at latitude 6° 12' 25.19" N and longitude 5° 45' 17.12" E. It has an average depth of 0.8 m; the water is transparent with sticky muddy substratum; fish fingerlings could be seen swimming. The marginal vegetation includes *Elaeis guineensis* (palm tree), *Raphia farinifera* (Raffia palms), *Cynodon dactylon* (Bahama grasses), *Musa paradisiaca* (plantain), *Sida acuta* (stubborn grass), *Mimosa pudica* (shameplant), *Tracheophyta* (fern), *Eichhornia crassipes* (water hyacinth), and *Colocasia esculenta* (wild cocoyam plants). Anthropogenic activities carried out in the station include swimming, local gin (ogogoro) production, cooking, doing laundry, fishing, broom making, timber work, palm wine production, and spiritual activity.

***Station 2*** is located down the right side of the bridge opposite station 1, at 500 m above the Orhionmwon bridge, at latitude 6° 12' 24.18" N and longitude 5° 45' 15.99" E. It has an average depth of 0.6 m; the station is transparent, with a moderate flow rate and presence of algae. It is surrounded with vegetation forming canopy: *Elaeis guineensis* (palm tree) make up the fringe vegetation; other vegetation include *Tracheophyta* (fern), *Mimosa pudica* (shameplant), *Raphia farinifera* (raffia palms), *Mimosa pudica* (shameplant), *Musa paradisiaca* (plantain), *Eichhornia crassipes* (water hyacinth), *Colocasia esculenta* (wild cocoyam plants), and the like. Typical human activities include timber production, washing, cooking, bathing, and spiritual practices.

***Station 3*** is located 200 m to station 4 at latitude 6° 12' 28.76" N and longitude 5° 45' 8.55" E. The water is transparent and has high flow velocity compared to other stations; the depth of this station is 0.4 m. The vegetation at this station includes *Musa paradisiaca* (plantain), *Raphia farinifera* (raffia palms), *Cocos nucifera* (coconut trees), and *Colocasia esculenta* (wild cocoyam plants), also submerged and floating macrophytes. A shrine can be seen in the middle of the water. Activities such as timber and lumber production, cooking, fishing, and spiritual activities are carried out.

***Station 4*** has a water depth of 0.3 m and a width of 2 m. It is located 100 m to station 1 at latitude 6° 12' 29.93" N and longitude 5° 45' 3.84" E. It has a high pollution rate because of the refuge dump on the shore very close to the water, which makes the water not transparent. Anthropogenic activities observed include broom making, timber production, and spiritual activities. The marginal vegetation is made up of *Musa paradisiaca* (plantain), *Mimosa pudica* (shameplant), *Elaeis guineensis* (palm tree), *Raphia farinifera* (raffia palms), *Colocasia esculenta* (wild cocoyam plants), and macrophyte vegetation.

***Sample collection.*** Sampling was carried out between 08:00 and 12:00 each sampling day and collected monthly for a period of six months (August 2021 to January 2022). In-situ measurements such as air and water temperature, pH, and depth were taken in the field. Air and water temperature were measured with a mercury-in-glass thermometer which was left in the open for some minutes and the average value taken for air temperature. For water temperature, the thermometer was immersed in the water for about 3–5 minutes and the average reading was taken. this was done in all the four stations every month. Depth was measured with a graduated metre rule immersed in the water, and the depth at which the metre rule touched the ground was taken.

For chemical analysis, the methods used were according to Ogbeibu (2001) where water samples from the river were collected with polyethylene bottles, pre-washed, rinsed, and dried in the laboratory. Collection was done by totally immersing the bottle several centimetres beneath the water surface and closing it after filling while still immersed in the water and before taking it out. Water samples for ascertaining dissolved oxygen were collected using 250 ml reagent bottles with glass stoppers. These were filled and stoppered below the water surface to eliminate all air bubbles. The dissolved oxygen was immediately fixed by adding 1.5 ml each of Winkler's solutions A (manganous sulphate) and B (potassium iodide) to the sample to form a brown precipitate. For biochemical oxygen demand ($BOD_5$), a 250 ml amber bottle was used to collect water sample; the bottle was stoppered cautiously to eliminate air bubbles and mixed by inverting the bottle a few times before taking to the laboratory for analysis.

### Calculating the Water Quality Index (WQI)

The water quality index is calculated by converting complex water quality data into information that the public can understand and use. WQI is an effective tool used to classify the suitability of water resource. Over time, WQI has progressed as an efficient tool to summarise huge amounts of water quality data into simple terms (excellent, good, poor) for reporting to management and the public in a steady manner (Ashwani, Anish, 2009; Ramakrishniah et al., 2009). Therefore, it is a very actual method which can offer a simple indication of water quality and is based on some germane parameters. The parameters adopted in this study include chloride, colour, nitrate, turbidity, conductivity, chromium, total dissolved solid, zinc, hardness, sulphate, magnesium, iron, cadmium, lead, etc.

In this study, WQI was calculated by using the Weighted Arithmetic Index method as described by Cude (2001). In this model, numerous water quality components are multiplied by a weighting factor and are then summed up using a simple arithmetic mean.

In determining the quality of water in this study, the quality rating scale (*Qi*) for each parameter was initially calculated by the following equation:

$$Qi = \{[(V\ actual - V\ ideal) / (V\ standard - V\ ideal)] * 100\}$$

Qi = quality rating of the nth parameter for a total of n water quality parameters

V actual = actual value of the water quality parameter obtained from laboratory analysis

V ideal = ideal value of that water quality parameter can be obtained from the standard tables.

V ideal for pH = 7 and for other parameters it is equalling to zero, but for DO, V ideal = 14.6 mg/L

V standard = Recommended Federal Ministry of Environment permissible limit standard of the water quality parameter.

After calculating the quality rating scale (Qi), the relative (unit) weight (Wi) was estimated by a value inversely proportional to the recommended standard (Si) for the corresponding parameter using the following expression:

$$Wi = K/Si,$$
$$K = 1/\Sigma\ (1/Si)$$

where Wi = relative (unit) weight for nth parameter, Si = standard permissible value for the nth parameter, K = proportionality constant.

Finally, the entire WQI was calculated by combining the quality rating with the unit weight linearly, by the following equation:

$$WQI = \Sigma\ WiQi\ /\ \Sigma\ Wi$$

where, Qi = quality rating, Wi = relative weight.

In general, the WQI is defined for a clear and intended use of water. In this study, the WQI was regarded for human consumption amongst other uses, and the extreme permissible WQI for the drinking water was taken as 100 score.

## RESULTS

The summary of the physical and chemical parameters of the water samples collected at the study stations of the Okhuaihe River in Ikpe community, Edo State, is presented for spatial comparisons (Table 1). All parameters except the flow rate, width, and phosphate were

Table 1. **Spatial variation of physical and chemical parameters for water samples of the Okhuaihe River**

| **Parameters** | **STATION 1**<br>$\bar{X}$ **± SD**<br>**(Min–Max)** | **STATION 2**<br>$\bar{X}$ **± SD**<br>**(Min–Max)** | **STATION 3**<br>$\bar{X}$ **± SD**<br>**(Min–Max)** | **STATION 4**<br>$\bar{X}$ **± SD**<br>**(Min–Max)** | ***p*-value** | **FME limits** | **WHO limits** |
|---|---|---|---|---|---|---|---|
| Air temperature (°C) | 28.33 ± 1.86<br>(25.00–30.00) | 28.33 ± 1.97<br>(26.00–30.00) | 27.67 ± 2.07<br>(24.00–30.00) | 28.33 ± 2.50<br>(25.00–31.00) | $p > 0.05$ | – | – |
| Water temperature (°C) | 25.50 ± 0.55<br>(25.00–26.00) | 24.83 ± 0.98<br>(24.00–26.00) | 25.83 ± 0.75<br>(25.00–27.00) | 26.67 ± 1.75<br>(25.00–30.00) | $p > 0.05$ | 35.00 | – |
| Depth (cm) | 0.48 ± 0.35<br>(0.15–1.00) | 0.36 ± 0.17<br>(0.13–0.60) | 0.36 ± 0.25<br>(0.11–0.81) | 0.28 ± 0.09<br>(0.14–0.40) | $p > 0.05$ | – | – |
| pH | 6.08 ± 0.14<br>(5.90–6.30) | 5.90 ± 0.23<br>(5.58–6.30) | 5.70 ± 0.34<br>(5.30–6.30) | 5.92 ± 0.25<br>(5.70–6.30) | $p > 0.05$ | 6.50 | 8.50 |
| Electrical conductivity (µS/cm) | 95.17 ± 42.46<br>(52.50–161.30) | 92.52 ± 44.71<br>(40.70–155.50) | 109.00 ± 219.80<br>(39.30–219.80) | 106.67 ± 52.86<br>(40.80–181.60) | $p > 0.05$ | – | 100 |
| Flow rate (m/s) | 0.09 ± 0.09$^{A}$<br>(0.00–0.20) | 1.51 ± 1.63$^{B}$<br>(0.01–3.00) | 1.01 ± 1.08$^{AB}$<br>(0.00–2.00) | 0.01 ± 0.00$^{A}$<br>(0.00–0.01) | $p < 0.05$ | – | – |
| Total dissolved solids (mg/L) | 46.78 ± 21.17<br>(24.20–80.60) | 45.67 ± 21.64<br>(21.40–77.50) | 54.25 ± 30.08<br>(19.50–108.40) | 52.97 ± 26.16<br>(20.50–90.70) | $p > 0.05$ | 1000 | 30 |
| Transparency (m) | 0.95 ± 0.22<br>(0.70–1.20) | 0.67 ± 0.23<br>(0.40–1.00) | 0.82 ± 0.74<br>(0.20–2.00) | 0.50 ± 0.50<br>(0.20–1.50) | $p > 0.05$ | – | – |
| Width (m) | 16.58 ± 2.33$^{C}$<br>(14.00–20.00) | 11.50 ± 1.84$^{B}$<br>(10.00–15.00) | 10.58 ± 1.36$^{B}$<br>(9.00–13.00) | 3.17 ± 1.33$^{A}$<br>(2.00–5.00) | $p < 0.01$ | – | – |
| Dissolved oxygen (mg/L) | 1.15 ± 0.70<br>(0.20–2.00) | 1.00 ± 0.66<br>(0.60–2.30) | 1.75 ± 1.52<br>(0.50–4.60) | 1.97 ± 2.42<br>(0.50–6.80) | $p > 0.05$ | 7.50 | 5.00 |
| Biochemical oxygen demand (mg/L) | 3.60 ± 1.65<br>(0.05–5.40) | 3.37 ± 1.18<br>(1.10–4.30) | 3.55 ± 0065<br>(2.80–4.60) | 3.82 ± 0.54<br>(3.20–4.60) | $p > 0.05$ | 20.00 | – |
| Sulphate (mg/L) | 13.17 ± 15.26<br>(3.00–43.00) | 4.67 ± 2.73<br>(3.00–10.00) | 6.00 ± 7.51<br>(2.00–21.00) | 7.67 ± 4.84<br>(3.00–17.00) | $p > 0.05$ | 500.00 | 500.00 |
| Nitrate (mg/L) | 0.86 ± 0.69<br>(0.25–2.12) | 0.85 ± 0.54<br>(0.25–1.61) | 0.72 ± 0.43<br>(0.21–1.47) | 1.16 ± 1.58<br>(0.22–4.36) | $p > 0.05$ | 10.00 | 50.00 |
| Ammonium–N (mg/L) | 0.26 ± 0.23<br>(0.12–0.72) | 0.19 ± 0.09<br>(0.09–0.31) | 0.15 ± 0.11<br>(0.01–0.31) | 0.49 ± 0.76<br>(0.09–2.04) | $p > 0.05$ | < 1.00 | – |
| Phosphate (mg/L) | 0.12 ± 0.04$^{A}$<br>(0.04–0.14) | 0.08 ± 0.06$^{A}$<br>(0.02–0.18) | 0.09 ± 0.07$^{A}$<br>(0.02–0.20) | 0.23 ± 0.14$^{B}$<br>(0.03–0.40) | $p < 0.05$ | 5.00 | – |
| Chloride (mg/L) | 10.59 ± 3.87<br>(7.06–14.12) | 10.59 ± 3.87<br>(7.06–14.12) | 11.77 ± 3.65<br>(7.06–14.12) | 10.59 ± 3.87<br>(7.06–14.12) | $p > 0.05$ | 5.00 | 400.00 |

Table 1. **(Continued)**

| Parameters | STATION 1<br>$\bar{X}$ ± SD<br>(Min–Max) | STATION 2<br>$\bar{X}$ ± SD<br>(Min–Max) | STATION 3<br>$\bar{X}$ ± SD<br>(Min–Max) | STATION 4<br>$\bar{X}$ ± SD<br>(Min–Max) | *p*-value | FME limits | WHO limits |
|---|---|---|---|---|---|---|---|
| Turbidity (NTU) | 42.33 ± 61.26<br>(5.00–165.00) | 9.50 ± 5.99<br>(0.00–18.00) | 12.50 ± 6.98<br>(5.00–25.00) | 17.33 ± 6.15<br>(10.00–25.00) | $p > 0.05$ | 15.00 | – |
| Iron (mg/L) | 0.59 ± 0.36<br>(0.37–1.32) | 0.53 ± 0.11<br>(0.43–0.75) | 0.52 ± 0.17<br>(0.39–0.87) | 0.89 ± 0.64<br>(0.41–2.14) | $p > 0.05$ | 1.00 | – |
| Zinc (mg/L) | 0.42 ± 0.19<br>(0.25–0.74) | 0.34 ± 0.04<br>(0.28–0.38) | 0.39 ± 0.14<br>(0.24–0.65) | 0.43 ± 0.22<br>(0.25–0.84) | $p > 0.05$ | 1.00 | – |
| Copper (mg/L) | 0.33 ± 0.03<br>(0.29–0.38) | 0.32 ± 0.03<br>(0.29–0.36) | 0.33 ± 0.04<br>(0.28–0.37) | 0.32 ± 0.06<br>(0.21–0.38) | $p > 0.05$ | 0.10 | – |
| Manganese (mg/L) | 0.05 ± 0.01<br>(0.04–0.06) | 0.04 ± 0.01<br>(0.03–0.05) | 0.04 ± 0.01<br>(0.03–0.06) | 0.05 ± 0.01<br>(0.04–0.07) | $p > 0.05$ | 0.05 | – |
| Chromium (mg/L) | 0.07 ± 0.02<br>(0.05–0.09) | 0.06 ± 0.02<br>(0.04–0.10) | 0.06 ± 0.02<br>(0.04–0.09) | 0.07 ± 0.01<br>(0.05–0.10) | $p > 0.05$ | 0.05 | – |

Note: $p < 0.01$ – highly significant difference; $p > 0.05$ – no significant difference; similar superscripts row-wise – no significant difference using Duncan Multiple Range Tests (DMRT), where X = mean, SD = standard deviation, Min. = minimum value, and Max. = maximum value.

not significantly different ($p > 0.05$) among all the stations. The flow rate at stations 2 and 3 were significantly higher ($p < 0.05$) than at others. The width at station 4 was significantly lower ($p < 0.01$) than at others, while phosphate at station 4 was significantly higher ($p < 0.05$) than at other stations.

For the temporal comparison (Table 2), all parameters except air temperature, electrical conductivity, total dissolved solids, chloride, iron, zinc, and manganese were not significantly different ($p > 0.05$) among all the stations. Air temperature of the dry season was significantly higher ($p < 0.01$) than of the rainy season;

Table 2. **Seasonal variation of physical and chemical parameters of water samples of the Okhuaihe River**

| Parameter | Rainy season | | | Dry season | | | *p*-value |
|---|---|---|---|---|---|---|---|
| | Min | Max | $\bar{X}$ ± SD | Min | Max | $\bar{X}$ ± SD | |
| Air temperature (°C) | 24.00 | 30.00 | 26.83 ± 1.75 | 27.00 | 31.00 | 29.50 ± 1.17 | $p < 0.01$ |
| Water temperature (°C) | 24.00 | 27.00 | 25.83 ± 0.83 | 24.00 | 30.00 | 25.58 ± 1.56 | $p > 0.05$ |
| Depth (m) | 0.11 | 1.00 | 0.41 ± 0.28 | 0.15 | 0.81 | 0.33 ± 0.17 | $p > 0.05$ |
| pH | 5.30 | 6.30 | 5.93 ± 0.33 | 5.58 | 6.16 | 5.88 ± 0.20 | $p > 0.05$ |
| Electrical conductivity (μS/cm) | 68.50 | 219.80 | 128.73 ± 46.48 | 39.30 | 122.50 | 72.95 ± 31.04 | $p < 0.01$ |
| Flow rate (m/s) | 0.01 | 3.00 | 0.87 ± 1.24 | 0.00 | 3.00 | 0.44 ± 0.99 | $p > 0.05$ |
| Total dissolved solids (mg/l) | 33.60 | 108.40 | 63.86 ± 23.24 | 19.50 | 57.80 | 35.98 ± 14.33 | $p < 0.01$ |
| Transparency (m) | 0.20 | 1.50 | 0.68 ± 0.42 | 0.20 | 2.00 | 0.79 ± 0.54 | $p > 0.05$ |
| Width (m) | 2.00 | 20.00 | 11.46 ± 5.72 | 2.00 | 15.00 | 9.46 ± 4.56 | $p > 0.05$ |

Table 2. **(Continued)**

| **Parameter** | **Rainy season** | | | **Dry season** | | | ***p*-value** |
|---|---|---|---|---|---|---|---|
| | **Min** | **Max** | **$\bar{X}$ ± SD** | **Min** | **Max** | **$\bar{X}$ ± SD** | |
| Dissolved oxygen (mg/L) | 0.50 | 1.90 | 1.03 ± 0.55 | 0.20 | 6.80 | 1.90 ± 1.94 | $p > 0.05$ |
| Biochemical oxygen demand (mg/L) | 3.10 | 4.60 | 3.83 ± 0.43 | 0.50 | 5.40 | 3.34 ± 1.39 | $p > 0.05$ |
| Sulphate (mg/L) | 2.00 | 43.00 | 8.08 ± 11.58 | 3.00 | 21.00 | 7.67 ± 5.85 | $p > 0.05$ |
| Phosphate (mg/L) | 0.02 | 0.40 | 0.16 ± 0.12 | 0.02 | 0.26 | 0.10 ± 0.07 | $p > 0.05$ |
| Nitrate (mg/L) | 0.21 | 1.61 | 0.69 ± 0.42 | 0.385 | 4.36 | 1.11 ± 1.16 | $p > 0.05$ |
| Ammonium-N (mg/L) | 0.12 | 0.72 | 0.27 ± 0.15 | 0.009 | 2.04 | 0.27 ± 0.56 | $p > 0.05$ |
| Chloride (mg/L) | 7.06 | 14.12 | 12.36 ± 3.19 | 7.06 | 14.12 | 9.41 ± 3.48 | $p < 0.05$ |
| Turbidity (NTU) | 7.00 | 165.00 | 27.67 ± 43.89 | 0.00 | 32.00 | 13.17 ± 9.33 | $p > 0.05$ |
| Iron (mg/L) | 0.43 | 2.14 | 0.80 ± 0.49 | 0.37 | 0.56 | 0.46 ± 0.07 | $p < 0.05$ |
| Zinc (mg/L) | 0.32 | 0.84 | 0.50 ± 0.17 | 0.24 | 0.35 | 0.29 ± 0.03 | $p < 0.01$ |
| Copper (mg/L) | 0.9 | 0.38 | 0.34 ± 0.03 | 0.21 | 0.36 | 0.32 ± 0.04 | $p > 0.05$ |
| Manganese (mg/L) | 0.03 | 0.07 | 0.05 ± 0.01 | 0.03 | 0.05 | 0.04 ± 0.00 | $p < 0.01$ |
| Chromium (mg/L) | 0.04 | 0.10 | 0.07 ± 0.02 | 0.04 | 0.07 | 0.06 ± 0.01 | $p > 0.05$ |

Note: $p < 0.01$ – highly significant difference; $p > 0.05$ – no significant difference; similar superscripts row-wise – no significant difference using Duncan multiple range tests (DMRT), where X = mean, SD = standard deviation, Min. = minimum value, and Max. = maximum value.

electrical conductivity, total dissolved solids, zinc and manganese of rainy season were significantly higher ($p < 0.01$) than the dry season; chloride and iron of the rainy season were significantly higher ($p < 0.05$) than of the dry season (Figs 2, 3).

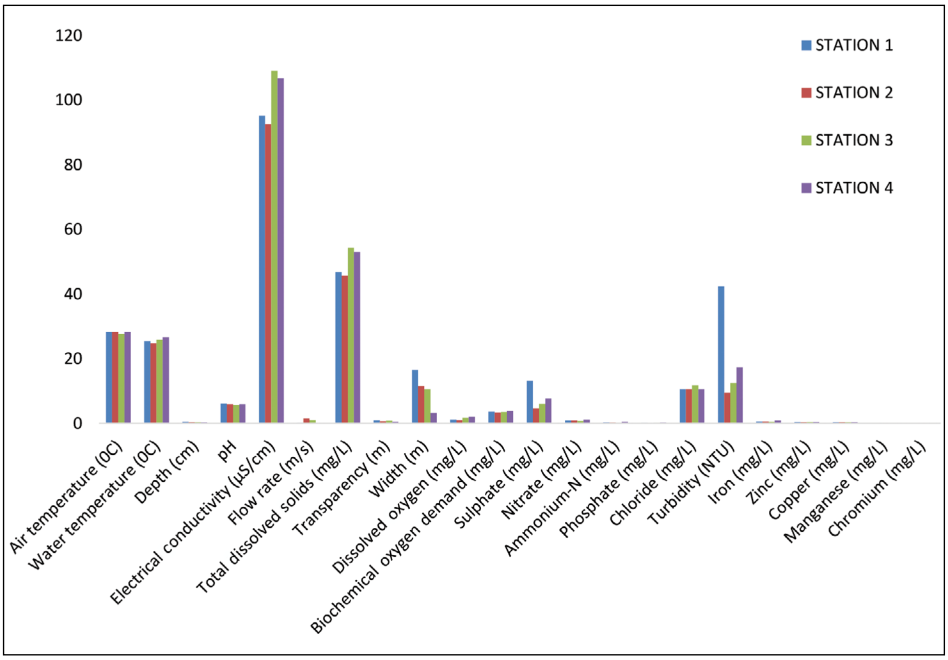

**Fig. 2.** Spatial variation in physical and chemical parameters

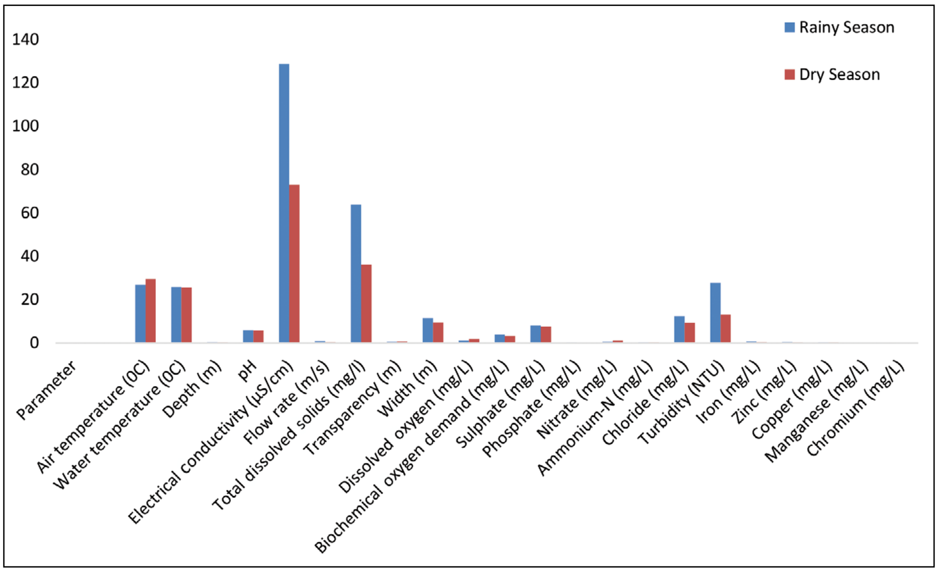

**Fig. 3.** Seasonal variation in physical and chemical parameters

## Water quality index (WQI)

The computation of water quality at the study stations is shown in Table 1. The values recorded are 12.50, 10.25, 11.94, and 11.92 for stations 1, 2, 3, and 4, respectively (Table 3). The results of the water quality at stations 1 to 4 indicate that the sampling stations are safe for human consumption, support aquatic life and other domestic activities (<50).

<50 = Excellent,
50–100 = Good
100–200 = Poor
200–300 = Very poor (bad) water
>300 = Unsuitable (unfit) for drinking (Ramakrishniah et al., 2009) (Fig. 4).

Table 3. **Water quality at the study stations**

| Station | Water quality index (WQI) |
|---|---|
| Station 1 | 12.50 |
| Station 2 | 10.25 |
| Station 3 | 11.94 |
| Station 4 | 11.92 |

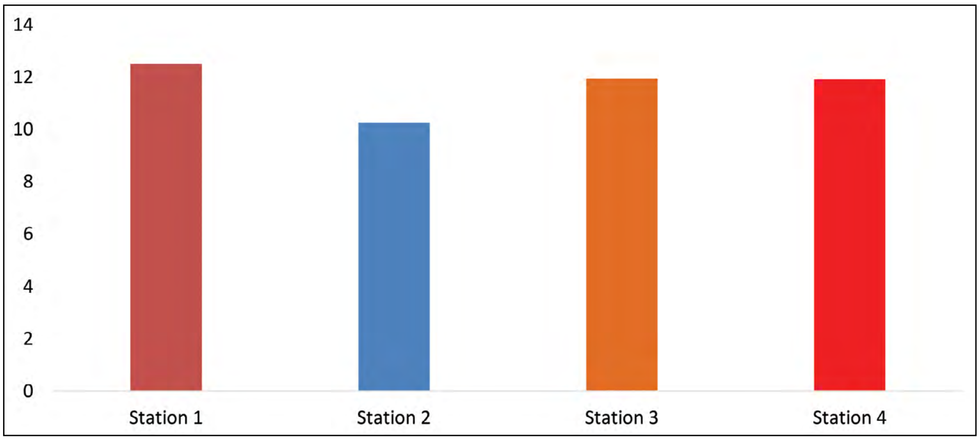

**Fig. 4.** Spatial variations of the WQI in the Okhuaihe River, Ikpe, Edo State

## DISCUSSION

Consistent assessment of the physico-chemical parameters of water has become a vital tool in the protection of the ecosystem against frightening anthropogenic events. The air temperature (24–31°C) varied similarly with that of the water temperature (24–30°C) in every sampling month across each station. The values of air temperature and water temperature were higher during the dry season than those recorded during the rainy season (Awachie, 1981; Ikhuoriah, Oronsaye, 2016); this is because abundance of sunshine during the dry season, and the warm winds (harmattan) that blow from the Sahara Desert to the north result in low humidity.

The pH value range (5.30–6.30) recorded was somewhat acidic when related to the recognised range of 6.50 to 8.50 (FME, 2001; WHO, 2011) for tropical water bodies. This may be due to the anthropogenic activities such as local brewing (production of ogogoro) and lumbering activities that were observed during the sampling period. This is similar to the study carried out by Ogbeibu and Ogiesoba-Eguakun (2019), where the pH range recorded was 4.03–6.72 on the Okhuaihe River.

The mean values of electrical conductivity ranged from 92.52–109.00 μS/cm. Conductivity in water is determined by the presence and degree of sodium concentration, magnesium ions, and calcium ions. These ions help stabilise the effect of carbonate and bicarbonate ions, hence maintaining the pH level (Raymont, 1983).

The mean flow velocity ranged from 0.01–1.51 m/s across the sampling stations. The lowest flow velocity recorded was at station 4 and the highest flow velocity recorded was at station 2; this may be due to the vegetation encroaching into the river pathways and the level of suspended solids at station 4. Also, there was an increase in flow velocity in the rainy season compared to the dry season due to surface runoff leading to an increase in water level. A study carried out by Olomukoro and Egborge (2004) on the Warri River and that by Ikhuoriah and Oronsaye (2016) on the Ossiomo River were in agreement with this finding.

The mean values of the total dissolved solids ranged between 45.67–54.25 mg/l. Values decreased from the rainy season to the dry season; this could be due to the fact that there are more run-offs during the rainy season, and this is peculiar to most inland waters of Nigeria. This finding is similar to that recorded by Udofia et al. (2014) on the Akpa Yafe River.

The width of the river varied across all sampling stations, with station 4 being the narrowest and station 1 the widest. During the rainy season, the mean value of the width of the river was high compared to that of the dry season. This could be the result of the high temperature recorded during the dry season, leading to rapid evaporation of the water body.

The mean values of phosphate ranged from 0.08–0.23 mg/l; these low values were due to the usage by micro-organisms, removal by water movement, and absorption by the waterbed (sediment) (Anyanwu, 2012). An important source of phosphate in the Okhuaihe River is likely to come from soaps and detergents used in washing of motorcycles, bathing, and other laundry activities, which commonly take place in the river.

Chloride values range from 10.59–11.77 mg/l. High values of chloride were recorded in the months of the rainy season and lower values were recorded in the dry season, resulting in a significant difference ($p < 0.05$) observed across seasons. The values of chloride are quite low compared to the WHO limit, which is 200 mg/l; this may be due to the fact that there are no industries discharging effluents high in chloride around the study area. This is similar to the study carried out by Edori et al. (2021), who recorded chloride values of 11.50–18.65 mg/l.

The values of iron ranged from 0.37–2.14 mg/l. The mean value of iron was higher during the rainy season than the dry season, and this is because some rocks and soil contain minerals that are very rich in iron, so when it rains, the water on land seeps through iron-rich rocks and soil into the river, hence the presence of dissolved iron in the river. This is in agreement with the findings of Ikhuoriah and Oronsaye (2016) on the Ossiomo River.

The values of zinc ranged from 0.24 to 0.84 mg/l across the sampling stations. Zinc is naturally present in water; the presence of algae is one of the factors that contribute to the level of zinc in the river. Ogbeibu and Ogiesoba-Eguakun (2019) study on the Okhuaihe River had similar findings.

Manganese ranged from 0.03 to 0.07 mg/l across the sampling stations. Manganese is naturally present in surface water and ground water, but anthropogenic activities such as applying the manganese as fertiliser could increase its level in surface water. The mean value of manganese in the rainy season was slightly higher than that of the dry season; this could be a result of surface runoff into the water body. Omoregie (2017) observed the same in the study on the Osse River.

The water quality index (WQI) at the sampling stations showed distinctively that the water body of the Okhuaihe River is suitable for human consumption, it supports aquatic life and can be used for other domestic activities. Similarly, Ishaku et al. (2012) reported WQI values of 15 to 43 in Jada in North-Eastern Nigeria, Asuquo and Etim (2012) reported 33.01 to 40.32 in Uyo Metropolis, Oko et al. (2014) reported 26 to 38 in Wukari town, and Etim et al. (2013) reported WQI values of 38.52 to 48.67 for some chosen and 55.05 to 84.94 for stream water across the Niger Delta region in Nigeria.

## CONCLUSIONS

This study of the Okhuaihe River in Ikpe, Edo state, Nigeria shows that the water supports aquatic life and is generally safe for human consumption. While investigating the different physico-chemical parameters, there were significant seasonal variations, especially in parameters including air and water temperature, total dissolved solids, and electrical conductivity. Regardless of the impact of activities such as washing, cooking, and local gin production, the physico-chemical parameters such as conductivity, pH, and dissolved solids generally fall within acceptable limits. Although anthropogenic activities impact the measured parameters, the overall WQI values at all stations were within tolerable limits. This demonstrates the river's resilience and the need for constant monitoring and sustainable practices.

Received 6 March 2024
Accepted 11 November 2024

## References

1. Akintola FO, Nyamah NC. Land-use and surface water pollution in Ibadan. In Efe SI. et al: seasonal variations of Physico-Chemical Characteristics in Water Resources. Quality in Western Niger Delta Region, Nigeria. J Appl Sci Envir Manag. 1978;9(1):191–5.
2. Anyanwu ED. Physicochemical and some trace metal analysis of Ogba River, Benin City, Nigeria. Jord J Bio Sci. 2012;5(1):47–54.
3. Arimoro FO, Odume ON, Uhunoma SI, Edegbene AO. Anthropogenic impact on water chemistry and benthic macroinvertebrate associated changes in a southern Nigeria stream. Envir Monit Ass. 2015;187(2):1–14.
4. Ashwani K, Anish D. Water quality index for assessment of water quality of River Ravi at Madhopur (India). Glob J Envir Sci. 2009;8(1):49–57.
5. Asuquo JE, Etim EE. Physicochemical and bacteriological studies of selected borehole water in Uyo Metropolis in Akwa Ibom State. Intl J Mod Chem. 2012;2(1):7–14.
6. Awachie JBE. Running Water Ecology in Africa. In: Lock MA and Williams DD, editors. Perspectives in running water ecology. New York and London: Plenum Press; 1981. 389 pp.
7. Ayoade JO. Tropical hydrology and water resources. Macmillan; 1988.
8. Ayoade JO, Oyebande BC. Water Resources, in: Oguntoyinbo JS. and Areola, editors.

A Geography of Nigeria Development. 2nd ed. Ibadan: Heinemann; 1983.

9. Carpenter SR, Stanley EH, Vander Zanden MJ. State of the world's freshwater ecosystems: physical, chemical, and biological changes. Annual review of Environment and Resources. 2011;36:75–99.
10. Djukic N, Maletin S, Pujin V, Ivanc A, Milajonovic B. Ecological assessment of water quality of Tisze by physico-chemical and biological parameters. Tisca Szeged. 1994;28(1):37–40.
11. Edegbene AO, Arimoro FO, Odoh O, Ogidiaka E. Effect of anthropogenicity on the composition and diversity of aquatic insects of a municipal river in North Central Nigeria. Biol Res Tod's World. 2015;1:69–80.
12. Edori ES, Iyama WA. Awari JO. Some physicochemical parameters in the surface water of Mini Whuo Stream in Port Harcourt, Rivers State, Nigeria. GSC Adv Res Rev. 2021;9(3):39–47.
13. Egun NK, Ogiesoba-Eguakun CU. Physicochemical and water quality index analysis of the Okhuaihe River, Edo State, Nigeria. Afri J Aqua Sci. 2018;43(4):345–51.
14. Etim E, Odoh R, Itodo A, Umoh S. Water Quality Index for the assessment of water quality from different sources in the Niger Delta region of Nigeria. Front. Sci. 2013;3:89–95.
15. Fakayode SO. Impact assessment of industrial effluent on water quality of the receiving ALaro River in Ibadan, Nigeria. Ajeam-Ragee. 2005;10:1–13.
16. Farah N, Zia MA, Rehman K, Sheikh M. Quality characteristics and treatment of drinking water of Faisalabad city. Intl J Agr Biol. 2002;3:347–9.
17. Federal Ministry of Environment. Guidelines and Standards for Water Quality in Nigerian Publication Federal Ministry of Environment. 2001.
18. Hossain MA, Lahoz Monfort JJ, Burgman MA, Böhm M, Kujala H, Bland LM. Assessing the vulnerability of freshwater crayfish to climate change. Div Distr. 2018;24(12):1830–43.
19. Ikhuoriah SO, Oronsaye CG. Assessment of Physicochemical Characteristics and some Heavy Metals of Ossiomo River, Ologbo – A Tributary of Benin River, Southern Nigeria. J. Appl. Sci. Environ. Manage. 2016;20(2):472–81.
20. Ishaku JM, Ahmed AS, Abubakar MA. Assessment of Groundwater Quality using Water Quality Index and GIS in Jada, North-Eastern Nigeria. Int Res J Geo Min. 2012;2(3):54–61.
21. Jarić I, Lennox RJ, Kalinkat G, Cvijanović G, Radinger J. Susceptibility of European freshwater fish to climate change: Species profiling based on life history and environmental characteristics. Glob Chan Biol. 2019;25(2):448–58.
22. Matthews N. People and fresh water ecosystems: pressures, responses and resilience. Aqua Proc. 2016;6:99–105.
23. Mustapha MK. A pre-impoundment study of the limno-chemical conditions of Oyun lake in Ilorin, Kwara State, Nigeria. Afr J Appl Zool Environ Boil. 2003;5:44–8.
24. Mustapha MK, Omotosho JS. Hydrobiological studies of Moro Lake, Ilorin, Nigeria. Nig J Pure & Appl Sci. 2006;21:1948–54.
25. Obasi RA, Balogun O. Water quality and Environmental impact assessment of water resources in Nigeria. African Journal of Environmental Studies. 2001;2(2):228–31.
26. Oboh IP, Agbala CS. Water quality assessment of the Siluko River, southern Nigeria. Afri J Aqua Sci. 2017;42(3):279–86.
27. Ogbeibu AE. Distribution, density and diversity of dipterans in a temporary pond in Okomo forest reserve, southern Nigeria. J Aquat Sci. 2001;16:43–52.
28. Ogbeibu AE, Ogiesoba-Eguakun CU. Evaluation of water quality parameters of the Okhuaihe River, Edo State, Nigeria. Trop Freshwat Biol. 2019;28(2):91–111.

29. Oko OJ, Aremu MO, Odoh R, Yebpella G, Shenge GA. Assessment of Water Quality Index of Borehole and Well Water in Wukari Town, Taraba State, Nigeria. J Environ Earth Sci. 2014;4(5):1–9.
30. Olomukoro JO, Egborge ABM. Hydrobiological studies on Warri River, Nigeria. Part II: Seasonal Trend in the Physico-chemical Limnology. Trop Freshwat Biol. 2004;12:9–23.
31. Olomukoro JO. Macrobenthic Fauna of Warri River. Ph.D. Thesis, University of Benin, Benin City, Nigeria. 1996.
32. Omoregie IP. Heavy metals, nutrients, total hydrocarbons and zooplankton community structure of Osse River, Edo State, Nigeria. Jord J Biol Sci. 2017;10(2):109–16.
33. Ovrawah L, Hymore FK. Quality of water from hand-dug wells in the Warri environs of Niger delta region. Afri J Environ Stud. 2001;2(2):169–73.
34. Pinceel T, Buschke F, Weckx M, Brendonck L, Vanschoenwinkel B. Climate change jeopardizes the persistence of freshwater zooplankton by reducing both habitat suitability and demographic resilience. BMC ecol. 2018;18(1):1–9.
35. Ramakrishniah CR, Sadashivaiah C, Ranganna G. Assessment of water quality index for the groundwater in Tumkur Taluk. E-J Chem. 2009;6(2):523–30.
36. Raymont JEG. Plankton and Productivity in the Oceans: Zooplankton. London: Pergamon Press; 1983.
37. Reid AJ, Carlson AK, Creed IF, Eliason EJ, Gell PA, Johnson PT, Kidd KA, MacCormack TJ, Olden JD, Ormerod SJ, Smol JP. Emerging threats and persistent conservation challenges for freshwater biodiversity. Biol Rev. 2019;94(3):849–73.
38. Udofia SI, Owoh PW, Attah VI, Thomas AD. Assessment of plant species composition in Ayan Nsit Sacred Forest of Akwa Ibom State, Nigeria. Nig J Agr, Food Envir. 2014;10(2):34–7.
39. World Health Organization (WHO). Guidelines for drinking water quality. 4th ed. 2011.

---

**Omorede Odigie, Isaiah Elimhingbovo**

## OKHUAIHE UPĖS ERDVINĖ IR SEZONINĖ FIZIKINIŲ-CHEMINIŲ PARAMETRŲ BEI VANDENS KOKYBĖS INDEKSO KAITA IKPĖS BENDRUOMENĖJE (EDO VALSTIJA, NIGERIJA)

### *Santrauka*

Švaraus vandens trūkumas kaimiškose Nigerijos bendruomenėse verčia gyventojus naudotis upėmis ir upeliais, kurie dažnai būna užteršti dėl buitinės ir pramoninės veiklos, bloginančios vandens kokybę. Gėlavandenių ekosistemų, svarbių pasaulio biologinei įvairovei, būklė nuolat blogėja dėl aplinkos pokyčių ir netinkamo žmonių elgesio. Šio tyrimo tikslas buvo ištirti erdvinę ir sezoninę fizikinių-cheminių parametrų bei vandens kokybės indekso (WQI) kaitą Okhuaihe upėje Edo valstijoje (Nigerijoje), kurios vanduo naudojamas įvairioms buitinėms reikmėms. Buvo analizuojama oro ir vandens temperatūra, pH, elektros laidumas, tėkmės greitis, bendras ištirpusių kietųjų dalelių kiekis, fosfatas, chloridas, geležis, cinkas ir manganas šešis mėnesius keturiose stotyse. Oro ir vandens temperatūros bei pH buvo matuojami vietoje, o kiti mėginiai, skirti biologiniam deguonies poreikiui ($BOD_5$) išmatuoti, buvo surinkti į polietileno butelius. Rezultatai rodo, kad reikšmingai skyrėsi kai kurie fizikiniai-cheminiai parametrai, tokie kaip upės plotis, tėkmės greitis ir fosfatas, tačiau dauguma parametrų skirtumais nepasižymėjo. Laiko požiūriu buvo reikšmingi sezoniniai oro temperatūros, elektrinio laidumo, bendro ištirpusių kietųjų dalelių, chlorido, geležies, cinko ir mangano kiekio pokyčiai. Remiantis WQI skaičiavimais, vandens kokybė visose stotyse atitiko saugaus vartojimo normas ir palaikė gyvybę vandenyje. Nepaisant kai kurių svyravimų, susijusių su sezoniniais pokyčiais ir antropogenine veikla, bendra vandens kokybė išliko tinkama buitinėms reikmėms. Šie rezultatai pabrėžia nuolatinio vandens išteklių stebėjimo ir valdymo svarbą, siekiant sumažinti taršą ir užtikrinti tvarų vandens tiekimą kaimo bendruomenėms.

**Raktažodžiai:** fizikiniai-cheminiai parametrai, vandens kokybės indeksas (WQI), tarša, gėlo vandens ekosistemos, antropogeninė veikla