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# SUSTAINABLE WATER QUALITY MONITORING IN RIVERINE AREA OF ONDO STATE

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**Abstract**
The availability of good quality water is one of the key target of sustainable development goals. Public water supply is not available in the riverine area of Ondo State, there is need for regular quality monitoring of drinking water sources to safe guard human health. The present study was carried out to evaluate the quality of water available to people in the riverine communities of Ondo State, Nigeria. Water samples were collected from four major towns, proximal to the Atlantic Ocean (namely, Mahin, Ugbo, Ugbonla and Igbokoda) and were analyzed for physicochemical parameters (TDS, pH, Conductivity, Alkalinity, Chlorides Phosphates, and Sulphates) using standard methods. Heavy metals (Pb, Cr, Mn, Zn and Ni) in the water samples were determined using Atomic Absorption Spectrophotometer. The results showed average concentration of Pb, Cr, Mn, Zn and Ni to be 0.576±0.04 $mgL^{-1}$, 6.81 ±0.76 $mgL^{-1}$, 43.3 ±2.3 $mgL^{-1}$, 0.056±0.01 $mgL^{-1}$, and16.4 ±2.4 $mgL^{-1}$ respectively. The water quality index (WQI) calculated across seasons showed the range of 217.26 to 289.02 in the dry season and 297.27 to 414.82 in the rainy season. The results implied that the water is not of good quality for human consumption. Government should assist the people living in the area to create a water treatment unit.
**Keywords:** metal, pollutants, quality, water, sustainable development

## Introduction

Globally, water quality is a critical issue that is of great concern. In some regions, people suffer from lack of safe quality water, which is essential for popular needs. The population increase and developmental activities triggered water pollution and quality challenges (Musliu *et al.*, 2018). In riverine areas, numerous human activities such as construction of recreation facilities, inappropriate waste disposal and coastal erosion disrupt marine ecosystem. Marine water quality alteration affects fish and mammals through the trophic level. The disturbances originated from the primary producer as a result of exposure to toxicants such as chemicals and metals originating from human settlements and Cities (Islam *et al*, 2016, Egun and Oboh, 2022).

Water resources availability depends on evaporation rates, rainfall, temperature, vegetation type and water run off (Kılıç, 2020). All these create stress on biodiversity and general ecosystem structure. The none availability of pipe-borne water, low economic capacity and high cost of bottled water makes access to potable water in most riverine communities very difficult. Generally, high water bill prevents poor people in urban settings to lack access to good quality water. Water quality indices are formulated to show gradual reduction in chemical and biological pollutant in a given water body after treatment (Kumar, et al., 2024). Parameters most commonly used for water quality indices are, DO, pH, BOD, electrical conductivity, $NO_3$, nitrites, temperature, and, feacal and total coliform (Barbulescu *et al.*, 2021). The purpose of water quality monitoring in riverine waters is multiple. It can be viewed from a policy perspective which consist of pollutant identification and concentrations measurements in comparison with threshold value. It can also be viewed from scientific perspective, where biogeochemical properties of a system is evaluated and variations at different time scale is used to validates model predictions. The hypothesis about to be tested is there is significant difference in water quality parameters across seasons caused by human activities in riverine area of Ondo State of Nigeria while the null hypothesis is there is no significant difference in water quality parameters in riverine area of Ondo State across seasons. The present study used water quality index (WQI) to evaluate overall water quality status of selected locations in riverine communities of Ondo State

**Methods and Materials**

**Study Area:** The study areas are four Ilaje communities (Ugbonla, Mahin, Ugbo, and Igbokoda) with a population of 289,838 (NPC, 2006) and projected to be 445, 200 in the year 2022. The area of coverage of 1,357 square kilometers.

**Sampling:** Water samples were collected into high density polyethylene plastics which were earlier soaked in 5% nitric acid overnight, rinsed with de-ionized water and then with the source water. The water samples for heavy metals were acidified with 2 mL of concentrated nitric acid, capped and stored at 4 $^0$C (APHA, 1995).

**Justification for sample size and frequency:** lack of access to the water around human activities limits the sample size but each of the samples are collected in triplicates. The sample size is 20, but in reality they are 60 samples. The collection of samples across seasons is to allow for changes that is likely to occur due to weather changes.

**Analysis:** The physicochemical parameters (pH, temperature, total dissolve solids (TDS) and electrical conductivity (E C) were determined on site with multi-parameter kit (Hanna model Hi 9828). The parameters measured in the laboratory are dissolved oxygen (DO), alkalinity, nitrate ($NO_3^-$), phosphate ($PO_4^{3-}$), chloride ($Cl^-$), ammonium ion ($NH_4^+$) and sulphate ($SO_4^{2-}$) using colourimetric methods (APHA, 1995). Concentration of metals (Mn, Cr, Pb, and Zn) were analyzed using atomic absorption spectrophotometer (AAS) (900H, Perkin Elmer, Akron, OH).,

**Calculation**

Water Quality Index (WQI) for the water was calculated below (Liu *et al.*, 2017).

$WQI = (\Sigma wiQi)/(\Sigma wi)$

Where Wi is the unit weight of the parameter and Qi is the quality rating scale of the ith parameter.

$Wi= k/Si$

Si = maximum allowable recommended standard for (WHO, 2017) the ith parameters

$k = 1/(\Sigma si))$

**Results and Discussion**

The temperature of water sample collected during dry season ranged from 28.2 to 31.7°C with a mean value of 29.5±0.18 °C while during the wet season the range was 27.10 to 31.7 °C with a mean value of 29.7±1.4°C (Table 1). The pH ranged from 5.48 to 7.50 across the two seasons which implies that some of the water samples were acidic with values below the minimum of 6.5 recommended by the WHO. Total dissolved solid (TDS) ranged between 55.3 $mgL^{-1}$ to 1040 $mgL^{-1}$ with a mean value of 286±16 $mgL^{-1}$ in the dry season, while twenty-three percent (23%) of the water sample exceed the recommended limit set by WHO. This could be due to the presence of higher level of inorganic compounds in the samples. However, it was observed that none of the TDS values recorded in the water samples during the wet season is greater than WHO limit. This may be as a result of constant washing away of dirt and regular flow of water during wet season (Zakaria *et al.,* 2021). This result is similar to values reported in previous studies in water of Ogun and Lagos (Ayedun *et al.*, 2015).

**Table 1: Range of physicochemical parameters in the dry and wet season (N = 20)**

| | Dry Season | | | Wet Season | | | |
|---|---|---|---|---|---|---|---|
| Parameters | Minimum | Maximum | Mean ± SD | Minimum | Maximum | Mean ± SD | WHO 2017 limit |
| Temperature ( °C) | 28.2 | 31.7 | 29.5±0.2 | 27.10 | 31.7 | 29.7±1.4 | 25 |
| pH | 5.48 | 7.50 | 6.58±0.09 | 5.40 | 7.20 | 6.46±0.51 | 6.5-8.5 |
| TDS ( $mgL^{-1}$) | 55.3 | 1040 | 286±16 | 10.0 | 200 | 66.2±6.6 | 500 |
| Conductivity($\mu Scm^{-1}$) | 110 | 2070 | 578±14 | 20.4 | 380 | 127±12 | 250 |
| Alkalinity ( $mgL^{-1}$) | 28.0 | 350 | 87.9±6.2 | 20.0 | 80.0 | 48.5±1.3 | 120 |
| DO ($mgL^{-1}$) | 5.40 | 8.60 | 6.69±0.16 | 6.30 | 8.03 | 7.05±0.46 | 5 |
| Chloride ( $mgL^{-1}$) | 155 | 477 | 238±6 | 52.6 | 541 | 293±15 | 250 |
| $NO_3^-$ ($mgL^{-1}$) | 4.32 | 8.38 | 6.9±0.2 | 4.80 | 14.3 | 9.76±2.65 | 50 |
| $PO_3^{2-}$ ($mgL^{-1}$) | 5.33 | 9.04 | 7.15±0.19 | 12.7 | 25.0 | 19.6±3.6 | NA |
| $SO_4^{2-}$ ($mgL^{-1}$) | 5.23 | 10.2 | 7.11±0.20 | 3.70 | 18.3 | 9.35±4.06 | 100 |
| $NH_4^+$ ($mgL^{-1}$) | 0.87 | 1.92 | 1.29±0.07 | 1.06 | 2.60 | 1.76±0.42 | 0.5 |

Key: NA-Not Available

Electrical conductivity recorded from all the water samples ranged from 110 to 2070 µS/cm with a mean value of 578±14 µS/cm in the dry season. Sixty-eight percent (68%) of the samples exceeded WHO recommended limit. The values recorded during wet season is within the WHO recommended limit. Similar result was reported in Surma river, Bangladesh (Howlader *et al.*, 2021).

Total alkalinity varied from 28.0 $mgL^{-1}$ to 350.0 $mgL^{-1}$ ($CaCO_3$) with a mean value of 87.9±6.2 $mgL^{-1}$) in dry season while in the wet season, it ranged from 20.0 to 80.0 $mgL^{-1}$ ($CaCO_3$) with a mean value of 48.5±1.3 $mgL^{-1}$). These values fall within the WHO limit and agree with Al Mamum *et al.*, (2019) in the Piyain river.

The dissolved oxygen (DO) measured during dry season ranged from 5.40 to 8.60 $mgL^{-1}$ with a mean value of 6.69±0.16 $mgL^{-1}$ this study, 75% of the water samples exceeded the WHO limit of 5 $mgL^{-1}$. However, during the wet season, the DO values ranged from 6.30 to

8.03 $mgL^{-1}$ with a mean value of 7.05±0.46 $mgL^{-1}$. This showed that the water is well aerated and can support the existence of aquatic organisms more than in the dry season. Similar results were obtained from Sagbama Creek, Nigeria and Awash river basin in Ethiopia (Seiyaboh *et al.,* 2017; Tadesse and Lakew, 2024). Chloride concentration ranged from 155 to 477 $mgL^{-1}$ with a mean value of 238±6.7 $mgL^{-1}$ in the dry season while in the wet season, chloride concentration in the water ranged from 52.6 $mgL^{-1}$ to 541 $mgL^{-1}$ with a mean value of 293±15 $mgL^{-1}$. Sixty-eight percent (68%) of the water samples exceeded the WHO limit for drinking water. The Chloride concentration in this study was higher than values reported by Razeel *et al.*, (2020) in the Dalgan basin, Iran.

The mean values of nitrate, phosphate, sulphate and ammonium are 6.9±0.2 $mgL^{-1}$, 7.15±0.19 $mgL^{-1}$, 7.11±0.20 $mgL^{-1}$ and 1.29±0.07 $mgL^{-1}$ respectively in the dry season while in the wet season, the average values are 9.7±2.65 $mgL^{-1}$, 19.6±3.6 $mgL^{-1}$, 9.35±4.06 $mgL^{-1}$ and 1.76±0.42 $mgL^{-1}$ respectively. These values fall within the WHO recommended limit in drinking water. The increase of phosphate and nitrate in the sampling points is due to run-off of fertilizer into the study water. Etim *et al.,* (2012), reported similar results in the water of Niger Delta, Nigeria.

Duncan Multiple Range Test (DMRT) showed no significant difference in the mean value of temperature and ammonium ion concentration from all locations during the dry season (Table 2). The pH recorded from water sample was significantly ($P \leq 0.05$) higher in Mahin compared to other locations. Similarly, TDS and EC were significantly higher in Mahin. This may be due to the presence of dissolved ions in the water. Significantly high ($P \leq 0.05$) value of alkalinity and chloride were recorded in Ugbo with a mean value of 213±78 $mgL^{-1}$ and 359±59 $mgL^{-1}$, respectively. A similar result was reported in Atonsu-Kumasi, Ghana (Opoku *et* al., 2020). Nitrate concentration was significantly higher in Ugbonla. This could be due to discharge of urine, faeces and other animal wastes into the water body.

The results obtained during the wet season sampling showed that temperature was significantly higher ($P \leq 0.05$) in all sampling point (Table 2). pH was significantly ($P \leq 0.05$) high in Ugbonla. Alkalinity was significantly high in Mahin during the wet season, Chloride was significantly ($P \leq 0.05$) high in Ugbonla during the wet season with the value 532±5 $mgL^{-1}$ This was higher than 359±59 $mgL^{-1}$ obtained from Ugbo during the dry season. Continuous flow of water during raining season may be responsible for this trend. There was no significant variation in phosphate values recorded in the water bodies from Ugbo and Ugbonla but the two locations were significantly($P \leq 0,05$) higher in phosphate than the other locations.

**Table2: Distribution of physicochemical parameters using Duncan Multiple Range Test (N = 20)**

| | Dry Season | | | | | Wet Season | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Location | Temp | pH | TDS | EC | Alkalinity | Temp | pH | TDS | EC | Alkalinity |
| A | 29.9±0.2$^{a}$ | 7.11±0.22$^{b}$ | 737±292$^{c}$ | 1466±575$^{b}$ | 53.3±8.8$^{a}$ | 30.6±0.2$^{c}$ | 7.04±0.03$^{c}$ | 10.1±0.1$^{a}$ | 20.5±0.1$^{a}$ | 70.0±5.8$^{c}$ |
| B | 30.1±0.9$^{a}$ | 6.87±0.13$^{ab}$ | 311±105$^{ab}$ | 621±207$^{ab}$ | 213±78$^{b}$ | 30.9±0.5$^{c}$ | 6.43±0.17$^{ab}$ | 13.2±1.8$^{a}$ | 26.1±3.3$^{a}$ | 33.3±8.8$^{a}$ |
| C | 30.2±0.4$^{a}$ | 6.74±0.18$^{b}$ | 573±197$^{bc}$ | 1177±409$^{b}$ | 99.3±36.7$^{a}$ | 31.1±0.4$^{c}$ | 7.15±0.06$^{c}$ | 10.9±0.3$^{a}$ | 21.6±0.6$^{a}$ | 50.0±5.8$^{ab}$ |
| D | 29.7±0.2$^{a}$ | 6.62±0.26$^{ab}$ | 405±24$^{abc}$ | 832±70$^{ab}$ | 60.0±11.5$^{a}$ | 30.6±0.3$^{c}$ | 5.85±0.08$^{a}$ | 28.1±1.7$^{b}$ | 55.8±3.8$^{b}$ | 33.3±3.3$^{a}$ |

Key: A-Mahin; B- Ugbo; C- Ugbonla; D-Igbokoda

Data with different alphabets down the column are significantly different ($P < 0.05$)

**Table2 Cont'd**

| | Dry Season | | | | | | Wet Season | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Location | DO | $Cl^-$ | $NO_3^-$ | $PO_3^{2-}$ | $SO_4^{2-}$ | $NH_4^+$ | DO | $Cl^-$ | $NO_3^-$ | $PO_3^{2-}$ | $SO_4^{2-}$ | $NH_4^+$ |
| A | 6.10±0.40$^{a}$ | 283±18$^{bc}$ | 6.83±0.28$^{ab}$ | 7.40±0.30$^{ab}$ | 6.69±0.09$^{ab}$ | 1.57±0.19$^{a}$ | 6.97±0.12$^{ab}$ | 329±13$^{d}$ | 10.1±0.1$^{b}$ | 17.2±1.9$^{ab}$ | 6.70±1.45$^{a}$ | 1.86±0.22$^{a}$ |
| B | 6.20±0.49$^{a}$ | 359±59$^{c}$ | 6.36±0.36$^{ab}$ | 6.47±0.57$^{ab}$ | 6.67±0.33$^{ab}$ | 1.52±0.21$^{a}$ | 6.57±0.088$^{a}$ | 463±8$^{e}$ | 11.2±0.6$^{b}$ | 23.2±0.9$^{c}$ | 6.07±0.85$^{a}$ | 2.27±0.07$^{ab}$ |
| C | 6.57±0.37$^{ab}$ | 201±21$^{ab}$ | 8.19±0.09$^{c}$ | 7.75±0.87$^{ab}$ | 5.49±0.15$^{a}$ | 1.17±0.17$^{a}$ | 7.30±0.12$^{b}$ | 532±5$^{f}$ | 10.7±1.3$^{b}$ | 23.4±0.6$^{c}$ | 7.17±0.18$^{a}$ | 1.63±0.18$^{b}$ |
| D | 6.63±0.29$^{ab}$ | 164±3$^{a}$ | 6.34±0.341$^{ab}$ | 7.28±0.19$^{ab}$ | 8.033±1.09$^{b}$ | 1.47±0.27$^{a}$ | 7.54±0.47$^{b}$ | 97.1±41.8$^{a}$ | 12.6±1.0$^{b}$ | 20.8±0.3$^{bc}$ | 15.9±1.2$^{c}$ | 1.87±0.37$^{ab}$ |

Key: A-Mahin; B- Ugbo; C- Ugbonla; D-Igbokoda

Data with different alphabets down the column are significantly different ($P < 0.05$)

TDS and EC were significantly higher during the dry season than the rainy season which may be due to slower flow of water during the period. However, chloride was significantly higher during the wet season than the dry season which could be due to leaching of rocks containing salts into the water body. The implication of unabated high TDS, EC and chlorides on water ecosystem management is that, it can lead to declines in biodiversity of the ecosystem. The water may not be economically useful for irrigation, fisheries and tourisms leading to revenue loss.

Manganese (Mn), Chromium(Cr), and Zinc (Zn) concentration are within WHO limit. The Pb concentration recorded was greater than the permissible limit of $0.01 mgL^{-1}$ set by WHO (2011) which suggests a potential health risk associated with drinking this water (Eremasi *et* al., 2015), The values obtained exceeded results for Elechi and Ikoli rivers (Otene and Alfred-Ockiya, 2019). During the dry season, manganese (Mn) concentration was significantly($P \leq 0.05$) high in Ugbonla water (Table 3). Cr was significantly high in Ugbonla and Igbokoda. The presence of Mn, Ni and Cr in water may be attributed to dumping of wastes into the water body. Pb concentration was significantly ($P \leq 0.05$) high in Mahin. In the dry season, Ugbonla water was contaminated with Mn while Igbokoda with Cr. However, during the wet season, significantly high Mn concentration was recorded in Igbokoda water (Table 3) compared to Ugbonla recorded in the dry season. This occurs due to transport of wastes by erosion during the raining season. Pb was high in Mahin. Zn concentration was significantly ($P \leq 0.05$) high in Ugbo. In the wet season, Igbokoda water was contaminated with Mn, Ugbonla with Cr, Mahin with Pb, and Ugbo with Zn.

**Table 3: Duncan Multiple Range Test for heavy metals in all the water samples during dry and wet seasons (N=20)**

| | Dry Season | | | | Wet Season | | | |
|---|---|---|---|---|---|---|---|---|
| | Mn | Cr | Pb | Zn | Mn | Cr | Pb | Zn |
| A | 0.011±0.005a | 0.403±0.047c | 0.063±0.032b | 0.075±0.059a | 0.047±0.0118a | 0.564±0.161b | 0.075±0.022b | 0.813±0.067b |
| B | 1.187±0.338b | 0.065±0.004a | 0.003±0.001a | 0.560±0.053b | 0.280±0.024a | 0.825±0.015b | 0.036±0.019ab | 1.110±0.047c |
| C | 1.903±0.561c | 0.692±0.062e | 0.036±0.014a | 0.721±0.014c | 0.119±0.0181a | 1.805±0.057c | 0.032±0.007ab | 0.362±0.069a |
| D | 0.025±0.006a | 0.793±0.025e | 0.003±0.001a | 0.063±0.015a | 1.314±0.0503b | 0.136±0.045a | 0.032±0.0123ab | 0.587±0.017b |

Values with different alphabet down the column are significantly different ($P < 0.05$)

Variation of metals across seasons is not significantly differs but individual differences can only be observed across locations which is a function of wastes introduced through human activities. Presence of metals in water makes cost of water treatment for human consumption to be high thereby exposing the consumers of such water to be exposed to carcinogenic diseases.

The water quality index (WQI) was calculated and plotted against locations across the seasons. (Figure 1). The order of WQI values in the dry season is Mahin > Ugbo > Igbokoda > Ugbonla while in the wet season, it is Ugbo > Mahin > Igbokoda >Ugbonla with all the values greater than 100. This is similar to the reported WQI results obtained for Bomadi river, Delta State of Nigeria. WQI values of 0 to 25 were categorized as excellent, 26 to 50 as good, 51 to 75 as poor, 76 to 100 as very poor. Water from all locations has WQI above 100 which indicates non-suitability for drinking. In a similar study carried out in Bomadi river in Niger delta, all locations showed their WQI to be greater than 100 (Iwegbue *et al.*, 2022). When WQI is greater than 100 the water is considered as unsuitable (Tyagi *et* al., 2013).

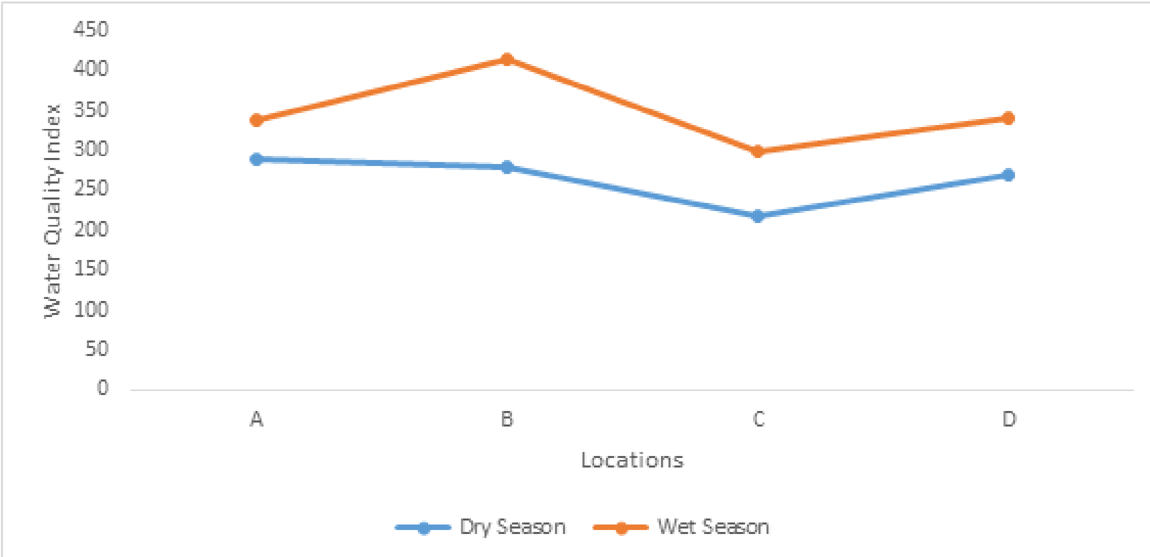


**Figure 1: A plot of water quality index against location**

Key: A-Mahin; B- Ugbo; C- Ugbonla; D-Igbokoda

## Conclusion

This study assessed the quality of water available to people in Mahin, Ugbo, Ugbonla and Igbokoda, a riverine communities of Ondo State. The results showed that the water is more polluted during dry season than the wet season with respect to physicochemical parameters while the results of water quality index indicated that the water from all location is not suitable for drinking. Dumping of wastes into the water bodies should be prevented by strict monitoring and control while government should assist in providing sustainable water treatment facilities for the communities. Government should enforce existing laws that prohibit water pollution.

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