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# Quantification of contaminants level in Otuoke River: Assessment of physicochemical properties, and Water Quality Index for domestic portability

**Opololaoluwa Oladimarum Ogunlowo**

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**Author Affiliation:**
Department of Civil Engineering, Faculty of Engineering, Federal University Otuoke, Otuoke, Bayelsa state, Nigeria, Ogbia (562103)

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## ABSTRACT

The present study revealed the qualification of some monitored pollutants in Otuoke River. The investigation of the physicochemical parameters and water quality index confirmed the portability of the surface water for domestic use. Water samples were collected from four different locations along the course of the river within the Otuoke community, within a month and 2 weeks. The water quality index was monitored in terms of pH, electric conductivity (EC (mS/cm)), biochemical oxygen demand (BOD (mg/L)), dissolved oxygen (DO (mg/L), Total dissolved solids (TDS/ (mg/L), Total Suspended Solid (TSS/ (mg/L) and HCO3 (mm/l) and results from the laboratory were compared with WHO and FEPA Standard. Statistical analysis of variance was done using Python 3.6. The pH values were found to range from 6.5-6.7 conductivity from 52.3-57.8μS/cm, Total dissolved oxygen from 49.7-78.0 mg/L, dissolved oxygen from 2.45-3.3mg/L, total suspendered solid from 69.0-82.8, biochemical oxygen demand from 3.1-4.4mg/L and HCO3- from 6.5-6.7mg/L. The results of this study showed that the concentrations of most monitored samples exceeded the WHO and FEPA guideline values. The WQI indicated poor water quality in the river with values ranging above 100. This study concluded that the Otuoke River is contaminated and the water quality is not suitable for domestic portability. It is therefore important to take appropriate steps to reduce the level of contaminants and bring the water quality to acceptable standards.

**Keywords:** Qualification, Monitored, Water quality index, Otuoke River, Domestic

## 1. INTRODUCTION

There are minimum requirements for water standards used for domestic purposes as prescribed by Public Health institutes and the World Health Organization (WHO) for good hygiene. Rivers remain one of the abundant natural freshwater resources from where quality water is obtained for different purposes. This freshwater resource serves multiple functions most of which are critical to human settlement and survival of humans (Nwankwola and Ngah, 2014; Nwankwola et al., 2018; Abadom and Nwankwoala, 2018). Rivers however are contaminated by the contacts in the course of their flow, both chemical and biological contaminants. These contaminants constitute pollution and the pollution of riverine systems is a major issue for attaining the required water quality (Viswanathan et al., 2015).

Moreover, "anthropogenic" activities and natural processes have the potential to introduce substances that degrade river water quality, such as pesticides, heavy metals, polycyclic aromatic hydrocarbons, and polychlorinated biphenyls (Atibu et al., 2013; Ali et al., 2016; Otene and Alfred-Ockiya, 2019). These contaminants resist the self-purification capacity of rivers (Ijaola et al., 2013). The pollution which is either organic or inorganic contaminates the river through the discharge of contaminated effluents, terrestrial runoff, agricultural activities, dredging, industrial waste, and atmospheric deposition. Heavy metals are one of the most common inorganic pollutants which have negatively affected aquatic ecosystems (Ali et al., 2016; Nazeer et al., 2014). Heavy metals, in contrast to organic contaminants in water, cannot break down biologically Hegazy et al., (2009), which can have a major negative impact on human health by destroying biodiversity and the food chain (Li and Zhang, 2010).

Due to the toxicity, abundance, and durability of heavy metals in the environment, as well as their subsequent accumulation in aquatic ecosystems, heavy metal contamination in aquatic environments has drawn a great deal of concern. According to, Deniseger et al., (1990) and other authors, heavy metal residues in contaminated ecosystems may build up in microbes, aquatic flora, and animals, which may then enter the human food chain and cause health issues. According to Sin et al., (2001), heavy metals are dispersed between the aqueous phase and bed sediments when they are transported by natural or man-made sources into a river system. Because of adsorption, hydrolysis, and co-precipitation only a small portion of free metal ions stay dissolved in water, and a large quantity of them get deposited in the sediment (Gaur et al., 2005).

The report of the Department for International Development (DFID) of 1998 revealed that every year, about millions of the world's poorest people, die from preventable diseases which stem from inadequate potable water and sanitation. Hundreds of millions suffer from regular bouts of diarrhea or parasitic worm infections that ruin their life, which is a major challenge in Africa. Tyagi et al., (2013), state that, water quality can be described as the measurement of the condition of water relative to the requirements of humans, animals, and plants. The Water Quality Index (WQI), a succinct numerical depiction of the overall quality of water, is a convenient and straightforward method of expressing an assessment of the quality of the water.

According to the reason for its popularity is its ease of calculation and interpretation. The WQI is essentially a result of the concentrations of the Water Quality Parameters taken into consideration; The main water quality parameters that are measured in natural water are; temperature, dissolved oxygen, pH, electrical conductivity/salinity, and turbidity (Moscuzza et al., 2007). Otuoke is in Ogbia local government area of Bayelsa State in Nigeria. The majority of its inhabitants are farmers and fishermen. Rivers like the Otuoke River have many outlets where the community-dwelling can access the river to get water for domestic and industrial usage. Since Otuoke River is not exceptional from this pollution, it is very important to study the contaminants in Otuoke River and determine its water quality with its suitability for domestic use.

## 2. METHODOLOGY

**Study Area**

The study Community, Otuoke is within the lower section of the upper floodplain deposits of the sub-aerial Niger Delta Geographically, it is situated between longitudes 60 15'E and 60 23'E and latitudes 40 46'N and 50 51'N. The region is bordered to the north by Yenagoa, the capital of Bayelsa State; to the south, by the local government districts of Brass and Nembe; and to the west, by the local government districts of Southern Ijaw and Ahoada-west, respectively, of Rivers State and Bayelsa State (Figures 1 & 2). The area can be accessed from the north by the Mbiama-Yenagoa road and on the south by the Nembe and Brass Rivers. Most of the area is motor-able; hence there is a network of roads that links the different parts of the area. The area lies in the coastal Niger Delta sedimentary basin (Nwankwoala et al., 2018; Ogunlowo and Sopakirite, 2022). The community, which has a population of over 18040, is a humid tropical wetland area with an average annual rainfall of roughly 2539 mm and an average temperature of 26.2ºC. (Ogunlowo and Sopakirite, 2022).

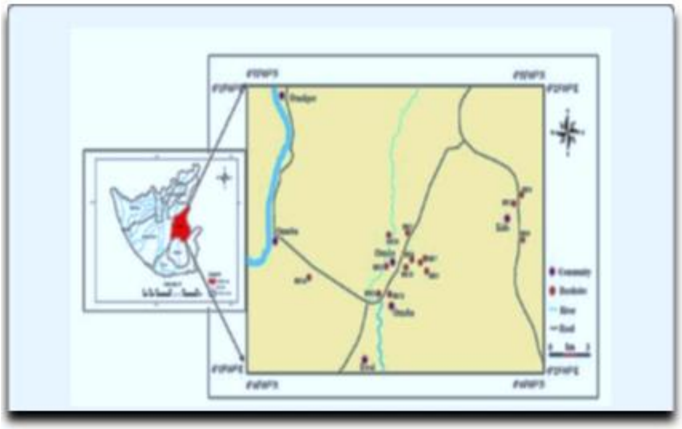

**Figure 1** Map of Bayelsa Projecting sampling points along Otuoke River with Otuoke Community. Source: Nwankwoala et al., (2018)


**Figure 2** Map of Bayelsa Showing the Study Area Source: Ogunlowo and Sopakirite, (2022)

**Samplings**

Water samples that were analyzed were taken from Otuoke River at different points along the river randomly from the center of the river within the vicinity of the village. A total of six samples were taken from each location for a month and 2 weeks in (February and March). 75 cl pre-clean plastic containers were used to collect water samples at some centimeters below the water surface, between the hours of 8-9 am each collection day. A sample was collected weekly at each aforementioned point. The sample containers were first immersed in 5% v/v nitric acid for an entire night, followed by rinsing with deionized water and river water. After adding 2 milliliters of concentrated nitric acid to the water samples, they were sealed and kept at 4 °C (Chukwujindu et al., 2022).

**Laboratory analysis of water samples**

The physiochemical parameters were determined as previously described (American Public Health Association (APHA), 2005). The obtained samples were subjected to physico-chemical analyses in laboratory. Likewise, the physical parameters like: pH, electric conductivity (EC (mS/cm)), biochemical oxygen demand (BOD (mg/L)), dissolved oxygen (DO (mg/L), Total dissolved solids (TDS/(mg/L), Total Suspended Solid (TSS/(mg/L) and HCO3-(mm/l) are known to be indicators of organic pollution in water were measured.

**Analysis of Variances (ANOVA)**

To determine the differences among the mean of contaminants tested and the variation with each sample collected, relative to the amount of variation between the samples, the analysis of variances was done employing Python 3.6 for all physicochemical parameters tested in terms of the mean ± standard deviation (M±SD). Confident level of determination (P=0.05).

**Water quality data and model development/Application of Water Quality Index**

Eight common water quality parameters are pH, electric conductivity (EC (mS/cm)), biochemical oxygen demand (BOD (mg/L)), dissolved oxygen (DO (mg/L), Total dissolved solids (TDS/ (mg/L), Total Suspended Solids (TSS/ (mg/L) and HCO3- (mm/l). were measured, and data were collected for this analysis and model development of water quality for Otuoke River. The water quality index has been used by many researchers and can be mathematically expressed as $WQI = \sum w_i Q_i$ which is developed using the weighted arithmetic index methods, further expressed as $W_i = \frac{w_i}{\sum w_i}$ and $Q_i = 100\left[\frac{V_i}{S_i}\right]$, where $w_i$= Unit weightage, $Q_i$= Sub index of $i^{th}$ parameters, $V_i$ monitored values of $i^{th}$ parameters, $S_i$ = Recommended Standard for $i^{th}$ parameters.

# 3. RESULTS AND DISCUSSION

**Analysis of Variances for Monitored Parameters at Otuoke River**

Comparing the variances analysis of monitored parameters at Otuoke River at locations A and B and locations C and D using Python 3.6 version as shown in Figures 3 and 4, it was observed that in Figure 3 the P values range from (0.05-0.80) for all parameters monitored, it then indicate that the P value ≥ 0.05 significant level. In Figure 4 the value of P falls within and out of significant level, for Turbidity and TDS P values range between (0.001 and 0.025) respectively, meaning that P ≤ 0.05 while other monitored parameters are within the range of (0.125-1.0) which are above significant level (P ≥ 0.05). It can then be inferred that if P values are lower than the significant level, the null hypothesis is true and the assertion that the Otuoke River is contaminated with pollutants from anthropogenic activities is true. For those values with low P-values less than 0.05, the null hypothesis is rejected, and can be deduced that the contaminant data are either insufficient to confirm the contaminated level or at that point of sampling the contamination level is less of those other contaminants sampled

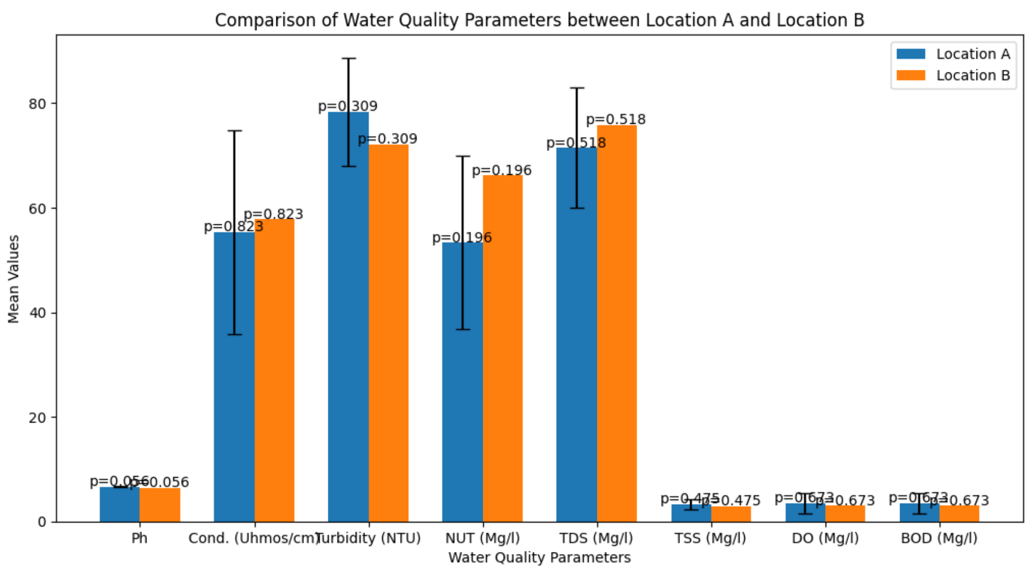


**Figure 3** Analysis of Variances for Physicochemical Parameters at P-Values of 0.05 using Python 3.6 (Location A and B)

**Table 1** Water quality status (WQS) based on the WQI.

| WQI | WQS | Intended Usage | | |
|---|---|---|---|---|
| | | Drinking | Irrigation | Industrial |
| 0–25 | Excellent | Suitable | Suitable | Suitable |
| 25–50 | Good (Slightly polluted) | Suitable | Suitable | Suitable |
| 50–75 | Poor (Moderately polluted) | Not Suitable | Suitable | Suitable |
| 75–100 | Very poor (polluted) | Not Suitable | Suitable | Not Suitable |
| Above 100 | Unsuitable (Excessively polluted) | Proper treatment is required | Proper treatment is required | Proper treatment is required |

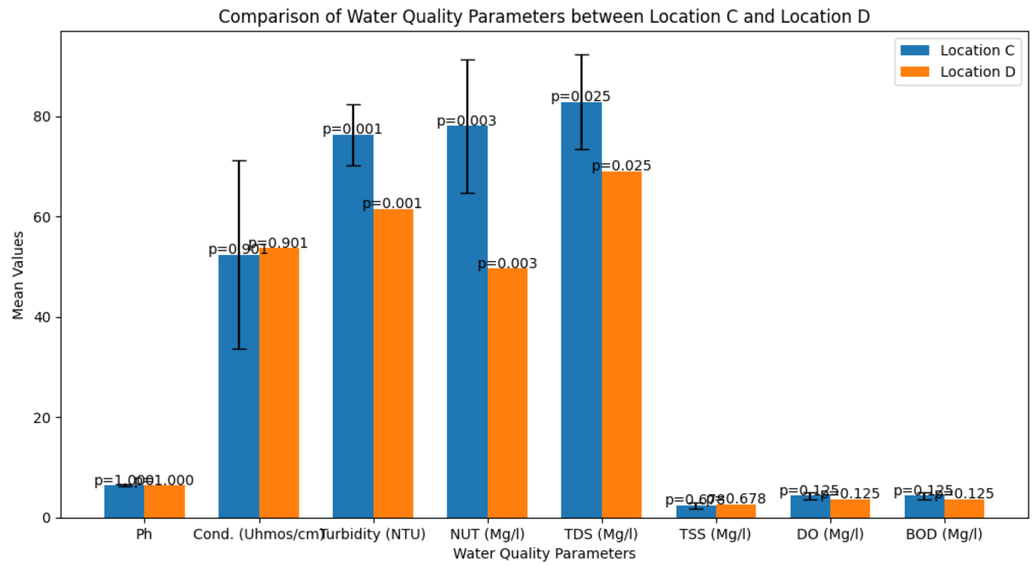


**Figure 4** Analysis of Variances for Physicochemical Parameters at P-Values of 0.05 using Python 3.6 (Location C and D)

**Temporospatial Variation on Water Quality**

The water quality status (WQS) was generated using (the WQI) rating as indicated in Table 1, the water quality index was obtained using the mathematical expression

WQI = $\sum w_i Q_i$……………………….1 where

$W_i = \frac{w_i}{\sum w_i}$ ……………………………. 2

$Q_i = 100\left[\frac{V_i}{S_i}\right]$ …………………… 3

To determine WQI, $w_i \, \alpha \, \frac{1}{s_i}$ ……. Implying that $w_i = \frac{K}{s_i}$ and $K = \frac{1}{\sum \frac{1}{s_i}}$

Where $W_i$ = relative weight, $w_i$= Unit weightage, $Q_i$= Sub index of $i^{th}$ parameters, $V_i$ monitored values of $i^{th}$ parameters, $S_i$ = Recommended Standard for $i^{th}$ parameters and $K$ proportional constant. Which is developed using the weighted arithmetic index methods, furthermore, table 1 was used in the classification of water suitability in Otuoke River.

Tables 2-6 were generated from WQI mathematical expressions using concentrations of eight monitored sampled parameters at the various sampled locations as shown in the tables. The temporospatial variation of monitored parameters was studied using the mean values to understand the change in Patten for each considered parameter as shown in (Table 2 & Figure 5). It was observed that the pH mean values of all locations sampled were within 6.5-6.7 which is acidic and deviates from 7.5 as stated by WHO and FEPA guidelines, since it is acidic, it is likely contaminated with chemicals or heavy metals resulting from domestic waste. Low pH enables elements and compounds within heavy metals to move and are available for uptake by plants and animals and this can result in a condition that is unfit for aquatic life particularly, sensitive species (Ijaola et al., 2013; Jessica et al., 2020).

The pH outside the range of (6.5-8.0) reduces the diversity in the stream because it stresses the physiological systems of most organisms and can reduce reproduction rate, this is following the Department of Environmental Protection approved SOP for Lakes and Rivers. The values of monitored mean for conductivity were within the range of (52.3-57.8) Uhmos/cm as compared to the WHO limit of 1200 and FEPA of 300, the result clearly shows that locations, where water samples were collected within the rivers, were not considerably ionized and has a lower level of ionic concentration activity due to small dissolved solids. Additionally, conductivity can be used as an indirect indicator of other water quality parameters, such as the presence of pollutants such as heavy metals; with the above findings, it means the river water has low heavy-meter content (Muhammad et al., 2021).

For monitored turbidity, there is not much difference between the different locations sampled along the river since the mean values range from (61.5-78.3) NUT, according to turbidity is said to be the measurement of relative clarity of liquid, excess turbidity leads to health concern and indications of pathogens because when it high it promote pathogen growth in water leading to waterborne disease outbreak in a community, from the result, the amount of turbidity is much greater than the specified stander by WHO and FEPA hence the condition of Otuoke rivers using turbidity as an indicator of water quality may be said to be unfit for usage. The presence of dissolved organic or inorganic minerals within sampled water is an indication of a high amount of TDS and TSS, the sampled water in the various locations has TDS to range within (49.7-78.0) mg/L while TSS ranges between (69.0-82.8) mg/L. from the result, the TDS is seen to be within the range of the limit described by WHO and FEPA while TSS is far from the stated recommendations limit by WHO.

Although elevated TDS concentrations in groundwater are normally not hazardous to humans, they can have an adverse effect on those with heart and kidney conditions. High solids content water can have laxative or constipation-causing effects. To conclude, the values of DO and BOD are found with the mean range of (2.45 - 3.3) mg/L and (3.1-4.4) mg/L respectively, resulting in the fact that at lower BOD, less oxygen is removed from the water and DO is stabilized and pollution rate is reduced. Bicarbonate HCO3- dominates between pH 6.3 and 10.3. Water above pH 7.5 is usually associated with high bicarbonates. From our results, it is seen that the pH has an average of 6.5-6.7 which also implies that the bicarbonate content is minimal showing that the water is may not harmful to health which is in contrast to turbidity and TDS and TSS.

**Table 2** Mean values of monitored parameters and indices of water quality index

| Parameters | Locations/ (Mean Values) | | | | Standards | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | A | B | C | D | WHO | FEPA | $S_i$ | $\frac{1}{S_i}$ | $w_i$ | $W_i$ |
| pH | 6.7 | 6.5 | 6.5 | 6.5 | 7.5 | 7.5 | 7.5 | 0.133333 | 0.142275 | 0.142275 |
| EC. Uhmos/cm) | 55.3 | 57.8 | 52.3 | 53.7 | 1200 | 300 | 300 | 0.003333 | 0.003556 | 0.003556 |
| Turbidity (NUT) | 78.3 | 72.2 | 76.3 | 61.5 | 5.0 | 5 | 5.0 | 0.2 | 0.213412 | 0.213412 |
| TDS (Mg/l) | 53.3 | 66.2 | 78.0 | 49.7 | 500 | - | 500 | 0.002 | 0.002134 | 0.002134 |
| TSS (Mg/l) | 71.5 | 75.8 | 82.8 | 69.0 | 5.5 | 30 | 5.5 | 0.181818 | 0.194011 | 0.194011 |
| DO (Mg/l) | 3.3 | 2.9 | 2.45 | 2.6 | 5 | 5 | 5 | 0.2 | 0.213412 | 0.213412 |
| BOD (Mg/l) | 3.5 | 3.1 | 4.4 | 3.7 | 6 | 10 | 6 | 0.166667 | 0.177843 | 0.177843 |
| HCO3 (mm/l) | 0.23 | 0.23 | 0.23 | 0.23 | 50 | 20 | 20 | 0.05 | 0.053353 | 0.053353 |
| Total | | | | | | | | 0.937152 | 1 | 1 |

Location A, B, C, and D, are sampling locations of monitored parameters at President Good luck Ebele Jonathan's house waterside, Otuoke Beach Side, Market Water side and Highness Road along the main Bridge respectively. $S_i$, recommended standards for ith parameters, $w_i$ Unit weight and $W_i$ , unit weightage/ Relative weight which are indices of water quality index.

**Water Quality Index Analysis of Otuoke River**

From the Previous discussion four locations were sampled along the Otuoke River to understand the temporospatial changes in water quality in Otuoke River, the few data generated were used to calculate the mean values of each monitored parameter within each considered location. The WQI was calculated using the weighted arithmetic methods. The calculated values were then illustrated in Tables 3 and 4, also in (Figure 6). The WQI for Location A was found to be 623.7374, location B was around 610.7394, location C was 9196.961 and the last location sampled gave a WQI of 540.436. Comparing the values of WQI gotten for all monitored locations it can be deduced that all are above 100, and from Table, it can be implied that the water quality status of Otuoke River within the period of sampling was excessively polluted and unsuitable for it to meet the required domestic need of the community unless properly treated. The upshot in location C was due to a lot of anthropogenic activities going on at that location. The reduction in location D may be due to low human activities and because it is located downstream of the river and pollution may be reduced down the river.

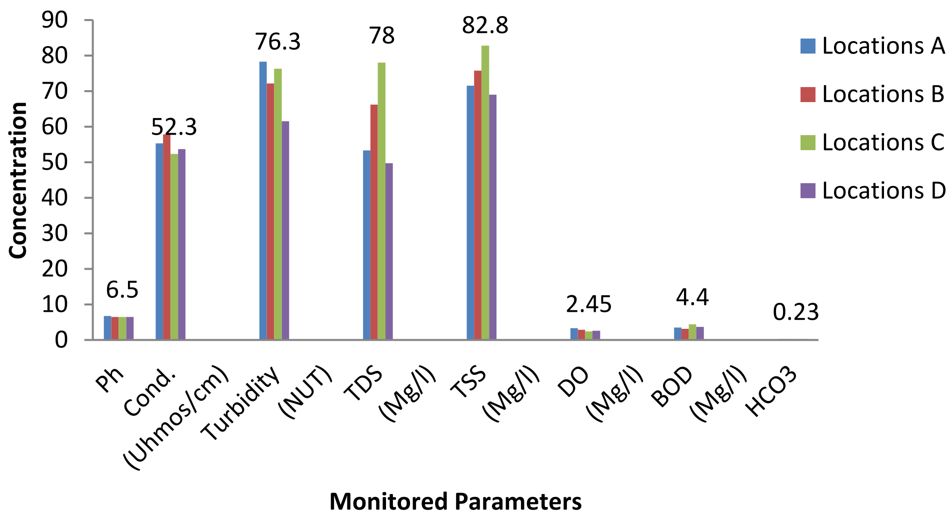


**Figure 5** The calculated water parameters from four locations

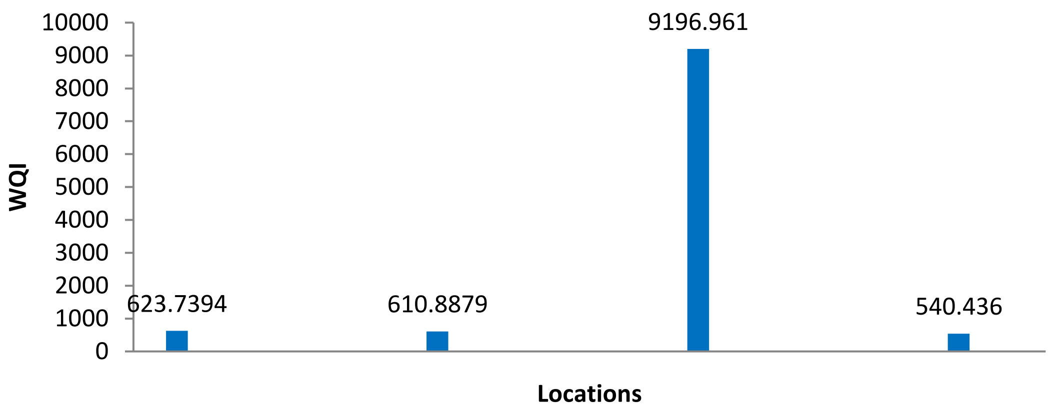


**Figure 6** Calculated Values for WQI at Locations A, B, C, and D.

Note: Locations of monitored parameters are at President Good Luck Ebele Jonathan's house waterside, Otuoke Beach Side, Market Waterside, and Highness Road along the main Bridge respectively

**Table 3** Water quality index for Mean values of monitored parameters at locations A and B

| Parameters | Location (A) | | | | | Location (B) | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | A | $S_i$ | $W_i$ | $Q_i$ | $\sum w_i Q_i$ | B | $S_i$ | $W_i$ | $Q_i$ | $\sum w_i Q_i$ |
| Ph | 6.7 | 7.5 | 0.142275 | 89.33333 | 12.7099 | 6.5 | 7.5 | 0.142275 | 86.66667 | 12.3305 |
| Cond. (Uhmos/cm) | 55.3 | 300 | 0.003557 | 18.43333 | 0.065567 | 57.8 | 300 | 0.003557 | 19.26667 | 0.068532 |
| Turbidity (NUT) | 78.3 | 5 | 0.213413 | 1566 | 334.2048 | 72.5 | 5 | 0.213413 | 1450 | 309.4489 |
| TDS (Mg/l) | 53.3 | 500 | 0.002134 | 10.66 | 0.022748 | 66.2 | 500 | 0.002134 | 13.24 | 0.028254 |
| TSS (Mg/l) | 71.5 | 5.5 | 0.194012 | 1300 | 252.2156 | 75.8 | 5.5 | 0.194012 | 1378.182 | 267.3838 |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| DO (Mg/l) | 3.3 | 5 | 0.213413 | 66 | 14.08526 | 2.9 | 5 | 0.213413 | 58 | 12.37795 |
| BOD (Mg/l) | 3.5 | 6 | 0.177844 | 58.33333 | 10.37423 | 3.1 | 6 | 0.177844 | 51.66667 | 9.188607 |
| HCO3 (mm/l) | 0.23 | 20 | 0.053353 | 1.15 | 0.061356 | 0.23 | 20 | 0.053353 | 1.15 | 0.061356 |
| Total | - | | | | 623.7394 | - | | | | 610.8879 |
| - | | | WQI (A) | 623.7394 | - | - | - | WQI (B) | 610.8879 | - |

Si is the recommended standard for $i^{th}$ parameters, and $W_i$, unit weightage, QI is sub-index of for $i^{th}$ parameters, and $WQI$ is water quality index

**Table 4** Water quality index for Mean values of monitored parameters at locations C and D

| Parameters | Locations | | | | | Locations | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | C | $S_i$ | $W_i$ | $Q_i$ | $\sum w_i Q_i$ | D | $S_i$ | $W_i$ | $Q_i$ | $\sum w_i Q_i$ |
| pH | 6.5 | 7.5 | 0.142275 | 86.66667 | 12.3305 | 6.5 | 7.5 | 0.142275 | 86.66667 | 12.3305 |
| Cond. (Uhmos/cm) | 52.3 | 300 | 0.003557 | 17.43333 | 0.06201 | 53.7 | 300 | 0.003557 | 17.9 | 0.06367 |
| Turbidity (NUT) | 76.3 | 5 | 0.213413 | 1526 | 325.6682 | 61.5 | 5 | 0.213413 | 1230 | 262.498 |
| TDS (Mg/l) | 78 | 500 | 0.002134 | 15.6 | 0.03329 | 49.7 | 500 | 0.002134 | 9.94 | 0.021212 |
| TSS (Mg/l) | 82.8 | 5.5 | 0.194012 | 45540 | 8835.306 | 69 | 5.5 | 0.194012 | 1254.545 | 243.3969 |
| DO (Mg/l) | 2.45 | 5 | 0.213413 | 49 | 10.45724 | 2.6 | 5 | 0.213413 | 52 | 11.09748 |
| BOD (Mg/l) | 4.4 | 6 | 0.177844 | 73.33333 | 13.04189 | 3.7 | 6 | 0.177844 | 61.66667 | 10.96705 |
| HCO3 (mm/l) | 0.23 | 20 | 0.053353 | 1.15 | 0.061356 | 0.23 | 20 | 0.053353 | 1.15 | 0.061356 |
| Total | - | | | | 9196.961 | - | | | | 540.4361 |
| - | | | WQI (C) | 9196.961 | | | | WQI (C) | 540.4361 | - |

Si is recommended standards for $i^{th}$ parameters, and $W_i$, unit weightage, QI is sub index of for $i^{th}$ parameters, and $WQI$ is water quality index

## 4. CONCLUSION

The Present findings reveal the state of Otuoke River and the quantification of contaminants gave a disturbingly high level of some monitored physicochemical parameters that posed a significant threat to domestic portability because most are not in conformity with WHO and FEPA standards. The analysis of variances also affirmed the pollution rate of the river, since the null hypothesis is true and the assertion that the Otuoke River is contaminated with pollutants from anthropogenic activities is true. The assessment of water quality status (WQS) using the water quality index (WQI) shows high pollutant rates which render the river unsuitable because the WQI at various locations was above 100. The study then emphasizes the urgent need for effective measures to mitigate pollution sources, implement proper wastewater treatment, and monitor water quality to ensure ecological integrity and public health safety.

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**Informed consent**

Not applicable.

**Ethical approval**

Not applicable.

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**Conflict of Interest**

The author declares that there are no conflicts of interests.

**Data and materials availability**

All data associated with this study are present in the paper.

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