Physicochemical Characterisation and Water Quality Status of the Lower Orashi River, Niger Delta, Nigeria

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Abstract

A study on levels of physicochemical characterisation and water quality status of the Orashi river was conducted to assess the magnitude of deterioration in the water quality. To achieve this, eight essential physicochemical parameters namely dissolved oxygen (DO), pH, electrical conductivity (EC), temperature, turbidity and salinity, were examined on-site all through the bi-weekly sampling for 3 months (Oct-Dec 2021), with the aid of a handheld digital multi-meter checker (Extech model Do 700). The biochemical oxygen demand was later determined in the laboratory using standard analytical method. Data obtained from this study were statistically analysed using a one-way analysis of variance. The result of the study revealed mean dissolved oxygen (DO) showed spatial and monthly variation ($p<0.05$), electrical conductivity (EC) was found to exhibit monthly variation and total dissolved solids (TDS) followed the same trend as EC. All the parameters were within the permissible limit for both national and international regulatory agencies except for turbidity. Therefore, this river water is good for domestic and agricultural use, although it requires close monitoring to avoid activities that will contaminate the water quality in future.

Keywords: Aquatic, Ecosystem, Spatial variation and Seasonal changes

Introduction

Water is an essential and integral part of human nutrition, which is directly or indirectly present as a content of food with several other uses in day-to-day activities (Adesakin et al., 2020). Being vital for human health, the (UN, 2016) has proclaimed access to safe and clean water as a human right, and therefore, water should be provided when needed. However, the recent expansion in urbanisation, industrialisation, and unabated rise in the human population globally, have brought about anthropogenic activities with the capacity to change the physicochemical properties of most surface water, thereby making the availability, distribution, and quality of water to be difficult for public use (Benventti et al., 2015, Okey-Wokeh and Wokeh, 2022). Due to these changes in water characteristics, the surety of water security and public health in developing countries that depends on river water is not guaranteed (Assigede et al., 2021). So, to ensure there is available and sustainable water as was outlined in the seventeen sustainable development goals (Number 6), there is a need to assess and monitor river water quality as an essential strategy for water quality management (Sener et al., 2017, Kroll et al., 2019, Bedim-Godoy et al., 2021).

Surface waters like rivers are major sources of water used for human consumption, irrigation, fishing and aquaculture, power generation, recreation and disposal of industrial effluents in Nigeria and some other developing countries of the world (Pareek et al., 2018; Okey-Wokeh et al., 2020; Okwodu et al., 2022). Despite the significant importance of surface water, there have been increasing reports of environmental impacts occasioned by anthropogenic pressure due to the nonchalant attitudes of waste managers, agricultural practitioners, and the industrial organisations (Chebet et al., 2020). Some of these anthropogenic activities like discharges of industrial effluents, solid wastes, fertilizers runoff from agricultural farms, and sewage discharges from households, can pollute the surface water with toxic chemicals as well as overload the aquatic ecosystem with nutrients (Yang et al., 2020). This will result in the deterioration of water quality due to eutrophication and algal bloom, thereby causing the loss of coral reef, aquatic flora and the death of aquatic fauna because of dissolved oxygen depletion (Bedim-Godoy et al., 2021). One of the surface water that has severely suffered the inimical impacts of human environmental mismanagement is the river ecosystem (Arafat et al., 2021).

Over the years, water pollution has become endemic in most rivers within the Niger delta axis of Nigeria due to oil exploration and exploitation by the multi-national companies in the area (Emuedo et al., 2014, Okey-Wokeh and Wokeh, 2022). Apart from the poor sustainability plan by these multi-national companies operating in the region, which has negatively impacted the air and water quality in the area, currently, the Niger delta region is battling the siege of illegal oil bunkering and pipeline vandalism, which has caused oil spillages in the rivers, wetlands and other aquatic ecosystems with consequential impacts on water quality, aquatic life and the benthic community (Odoemelam et al., 2019, Bodo et al., 2020). As a result of these activities in the region, there is hardly any aquatic ecosystem within the Niger delta that has not been impacted, of which the Orashi river is not an exception (Ezeilo and Oba, 2016, Edori and Edori, 2021).

The Orashi river is a non-tidal freshwater aquatic ecosystem of significant importance in the lower Niger basin that flows through major communities of Ogba, Egbema and Ndoni in Rivers State, and a few other communities in Imo State (Okwodu et al., 2022). This river serves an array of purposes such as drinking, irrigation for agrarian communities, fishing points and other domestic uses. According to Kalagbor et al (2021), rivers and streams are known to have played a vital role in the growth, development and sustainability of many communities within and around the water course. The Orashi river is located at the heart of the Enginni, Ogba, and Egbema communities that are known for decays of oil exploration, and agricultural and lumbering activities and are prone to sedimentation due to flood (Ezeilo and Oba, 2016, Seiyaboh et al., 2016). This river has become an aquatic ecosystem of research interest because of its significant importance to some communities that depend on it as a source of livelihood, which is an essential strategy for water quality management.

Therefore, the study on levels of physicochemical properties and water quality status of the lower Orashi river is aimed to assess and provide basic information on the water quality of this aquatic ecosystem. Data obtained from this study will add to the pool of information provided in the past, and will help water management authorities to proffer solution on how to improve the Orashi river water quality, and possibly suggest the best ways of protecting the River against inimical anthropogenic activities.

Materials and Method

Study Area

The study was conducted on the Orashi river, a non-tidal freshwater ecosystem of significant importance in the lower Niger basin, which originates from Oguta in Imo State and flows through communities in Enginni, Ogba, Ndoni and Egbema, then empties into Sombreiro river around Abonnema in Kalabari through central Abua, all in Rivers State, Nigeria (Fig 1). Most communities around this watercourse are known for their beehive of activities ranging from Oil exploration, sand dredging, fishing and crop farming. Amongst these communities are: Okarki (STN_1), Okparaki (STN_2), Ikodi (STN_3) and Kunusha (STN_4). This area lies between latitude 4º 59 N and longitude 6º 28 E, and the average monthly temperature range between 23 to 30.50º C.

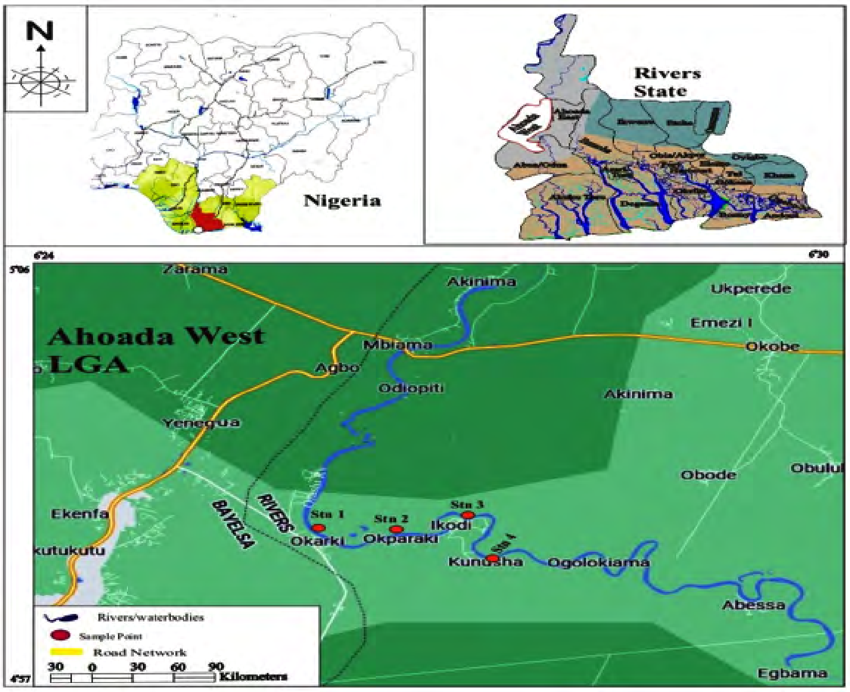

Fig. 1 Map of the study area showing the sampling locations

Sample Collection

Samples of Orashi river water were collected at four different points marked as STN_1, STN_2, STN_3 and STN_4 (Fig. 1), and each location was 500 metres away from the other. The sample collection was done bi-weekly for three months (Oct-Dec 2021), and each of the water samples collected with the vial containers were kept airtight, preserved and later analysed in-situ except for biochemical oxygen demand (BOD).

Method of Analysis

Eight (8) essential physicochemical parameters were analysed on-site to check the water quality, and the parameters include: dissolved oxygen, electrical conductivity, total dissolved solids, water pH, temperature, turbidity, salinity and biochemical oxygen demand. With the use of a handheld digital multi-meter checker (Extech model Do 700), turbidity, temperature, total dissolved solids, pH, electrical conductivity and salinity were determined. Dissolved oxygen was measured with the aid of Milwaukee DO metre (MW 600), while the samples for BOD were analysed in the laboratory using standard analytical procedure (APHA 1998).

Statistical Analysis

Data obtained from this study were subjected to analysis using one-way analysis of variance (ANOVA) at a confidence limit of 95% to determine spatial and monthly variation.

Results

The results of the spatial and monthly variations of physiochemical properties of the Orashi river water such as dissolved oxygen (DO), electrical conductivity (EC), total dissolved solids (TDS), water pH, temperature, turbidity, biochemical oxygen demand (BOD), and salinity were recorded at STN_1, STN_2, STN_3 and STN_4 as shown in (Fig 1) for 3 months (October-December 2021) and the results are presented in Tables 1 & 2. The mean dissolved oxygen (4.93 ± 0.35 mg/L) in water samples at the station (STN1) showed a statistical difference ($p < 0.05$) with the mean DO concentration of (5.47 ± 0.35 mg/L) that were observed in STN4, whereas values of STN_1, STN_2 (5.17 ± 0.29 mg/L) and STN_3 (5.17±0.15 mg/L) showed no statistical variation from each other. In terms of monthly variation, the mean DO value recorded in

October (5.40 ± 0.30 mg/L) when compared with the values observed in November (5.18 ± 0.28 mg/L) and December (5.00 ± 0.13 mg/L), was significantly higher. The mean values of electrical conductivity (EC) analysed across the four sample stations showed station (STN_2) recorded the highest value (26.50 ±0.54 µS/cm), followed by STN_1 (25.17 ±2.70 µS/cm), and the lowest value (22.90±6.67 µS/cm) was observed in STN_3. The concentration of EC showed no spatial variation while the monthly variation revealed November recorded the highest mean concentration, which showed no significant difference from the values observed in December (24.59±4.08 µS/cm) but varied from the mean EC observed in October (20.27 ± 4.82 µS/cm) as shown in Table (2). Similarly, the highest TDS value was observed in the water sample obtained from STN_2 (15.88 ± 1.30 mg/L) compared to STN_1 (14.94±3.84 mg/L), STN_4 (14.50±4.72 mg/L), and STN_3 (13.32 ± 5.35 mg/L) as shown in Table (1). The values of TDS showed no spatial variation across the stations, but in terms of monthly variation, the values recorded in October showed a significant difference ($p < 0.05$) from other months.

The results of pH presented in Tables 1 & 2 showed station (STN_4) recorded the highest mean value (8.68 ± 0.60 mg/L), while STN_1 (8.21±0.26 mg/L) had the lowest mean concentration. The pH values were mainly alkaline across the stations, with no spatial or monthly variations. In terms of mean temperature, STN_4 (28.63±0.06ºC) had the highest value compared to the values observed in the other stations, with no monthly variation. Although, the mean values of temperature observed in stations STN_1 and STN_2 were significantly different ($p < 0.05$) from the values recorded in STN_3 and STN_4. The highest mean turbidity value was recorded in STN_4 (30.95 ±14.25 NTU), followed by STN_1 (26.74 ±14.40 NTU), while STN_3 recorded the lowest value (8.39±2.09 NTU) as shown in Table (1). There was spatial variation ($p< 0.05$) across the stations, and no monthly variation ($p > 0.05$). The maximum mean salinity was recorded in the water sample obtained from

TABLE 1
Spatial variation in physiochemical parameters of Orashi river

Parameter	STN_1	STN_2	STN_3	STN_4	P-value	WHO
DO (mg/l)	4.93 ± 0.15^a	5.17 ± 0.29^{ab}	5.17± 0.15^{ab}	5.47 ± 0.35^b	0.158	5-7
EC (µS/cm)	25.17 ± 2.70^a	26.50 ± 0.54^a	22.90±6.67^a	23.77± 5.31^a	0.767	1000
TDS (mg/l)	14.94 ± 3.84^a	15.88± 1.30^a	13.32± 5.35^a	14.50± 4.72^a	0.896	500
PH (mg/L)	8.21 ± 0.26^a	8.30 ± 0.14^a	8.35 ± 0.40^a	8.68 ± 0.60^a	0.043	6.5-8.5
Temperature (ºC)	27.60 ± 0.10^a	27.57± 0.06^a	28.30± 0.17^b	28.63± 0.06^c	0.000	< 40
Turbidity(NTU)	26.74±14.40^{ab}	14.33±3.25^{ab}	8.39 ± 2.09^a	30.95±14.25^b	0.088	5
Salinity (mg/l)	0.02 ± 0.00^b	0.01 ± 0.01^a	0.01 ± 0.00^a	0.17 ± 0.58^a	0.009	1000
BOD (mg/l)	0.57 ± 0.45^a	0.73 ± 0.60^a	0.73 ± 0.25	0.83 ± 055	0.915	2-5

TABLE 2
Monthly Variation in Physicochemical Parameters

Parameter	Oct	Nov	Dec	P- value
DO(mg/l)	5.40 ± 0.32^b	5.18 ± 0.28^{ab}	5.00 ± 0.13^a	0.111
EC(µs/cm)	20.27 ± 4.82^a	26.30 ± 0.04^b	24.59 ± 4.08^b	0.013
TDS(mg/l)	10.13 ± 2.81^a	16.98 ± 0.27^b	16.89 ± 0.48^b	0.000
pH(mg/l)	8.94 ± 0.62^a	8.79 ± 0.52^a	8.92 ± 0.54^a	0.922
Temp(ºC)	27.99 ± 0.52^a	28.10 ± 0.59^a	28.00 ± 0.49^a	0.941
Turbidity(NTU)	20.65 ± 12.10^a	19.92 ± 11.33^a	19.74 ± 18.44^a	0.996
Salinity(mg/l)	0.02 ± 0.01^a	0.13 ± 0.01^a	0.04 ± 0.00^a	0.748
BOD(mg/l)	1.10 ± 0.14^b	0.50 ± 0.50^a	0.60 ± 0.24^a	0.054

STN_1 (0.02 ±0.00 mg/L), followed by STN_4 (0.17 ± 0.58 mg/L), while STN_2 and STN_3 had the lowest values as presented in Table (1). The concentration of salinity obtained from station STN_4 showed spatial variation ($p < 0.05$) from others and there was no monthly variation ($p > 0.05$) across the stations as shown in Table (2). The lowest mean biochemical oxygen demand was observed in the water sample obtained from STN_1 (0.57 ± 0.45 mg/L), while the highest mean BOD was observed in STN_4 (0.83 ± 0.55 mg/L), and the values showed no spatial variation ($p > 0.05$).

Discussion

The eight physicochemical parameters of water samples obtained from the four stations in the Orashi river were discussed according to the World Health Organisation guidelines for drinking water quality. The importance of dissolved oxygen (DO), in river is seen in its effects on the aerobic and metabolic processes of living organisms in an aquatic environment (Okey-Wokeh et al., 2020). Dissolved oxygen is one physicochemical property of water that reveals the basic information on the nutrients load level, pollution, and microbial activities in the water (Adesakin et al., 2020). The results obtained from this study in terms of DO revealed the concentrations across the stations were within the 5-7 mg/L permissible limit for drinking water established by the World Health Organisation (WHO 2017). This depicts that the water quality was good for domestic and agricultural uses. However, the DO concentrations were higher in October, being the peak of the wet season in southern Nigeria when the temperature was low, and this favoured dissolved oxygen solubility. The findings observed in this study was similar to the results previously reported by (Okwodu et al., 2022) in Orashi river, but varied with report of low dissolved oxygen in Ntawaogba stream, attributed to the degradable organic matter presence in the water, which demand more oxygen by the microorganisms(Kalagbor et al., 2021).

Electrical conductivity is the capability of water to conduct electric current, which is governed by the presence of ions in the water and is used to assess the purity and freshness of water (Murugesan et al., 2006). The concentration of electrical conductivity observed in this study was below 1000 µS/cm provided by the World Health Organisation as the permissible limit for drinking water. Edori and Edori (2021) reported similar EC concentrations in the Orashi river attributed to the low salt inflow into the river ecosystem. The electrical conductivity values generally obtained from the water samples across the stations were far below 250 µS/cm recommended for domestic water supply (Adesakin et al., 2020, Kalagbor et al., 2021), and this could be due to low salt and mineralization of the river water. The total dissolve solids mean concentrations followed a similar trend with electrical conductivity in both spatial and monthly variations. The TDS concentrations observed in this study were below 500 mg/L threshold for drinking water (WHO 2017), which indicates good water quality suitable for both agricultural and domestic uses (Arafat et al., 2021) .The values of TDS shown in Tables 1 and 2, is suitable for both agricultural and other domestic uses (Arafat et al.,2021). This finding was consistent with the previous reports documented from the Orashi river by (Edori and Edori, 2021, OKwodu et al., 2022). The TDS values observed from the sampling stations revealed the river water was void of bitter taste and salt, and can be used for irrigation without the occurrence of soil salinization and decrease in macro porosity (Kidu et al., 2015).

pH is known as the hydrogen ion concentration, which is a vital physicochemical parameter used to determine the acidic and alkaline nature of a water body and its impacts on chemical and biological reactions in the water (Okey-Wokeh et al., 2021). The water pH recorded across the four sample stations was alkaline and the values were within 6.5-8.5 mg/L stipulated for fresh and drinking water (WHO 2017). The mean concentrations observed in this study were in contrast with 5.6 mg/L reported in previous study of the

Orashi river (Edori and Edori, 2021), but was consistent with the values from the findings of (Okwodu et al., 2022) in the Orashi river. The pH concentration in water influences the use of water for different activities and water with a pH range 6.5-8.0 mg/L is considered good for aquaculture and irrigation purposes (Arafat et al., 2021). Therefore, the Orashi river is suitable for consumption and other agricultural uses. The mean temperature obtained across the sample stations was within the standard (< 40°C) provided by the World Health Organisation for drinking water. This finding was in agreement with the values previously reported from different aquatic ecosystems in the Niger delta (Kalagbor et al., 2021, Okey-Wokeh et al., 2021, Okwodu et al., 2022). The temperature values observed in this study confirmed the assertion that river system maintains characteristic higher temperature values in both dry and wet seasons for the Niger delta waters, situated at the equatorial latitude where the temperature is consistently high all round (Chindah et al., 2011). Water temperature is a significant physicochemical parameter that plays a role in the metabolic activities of organisms, and it changes daily and seasonally due to different activities that can contribute to the changes in surface water such as river water. The temperature values recorded in this study was good for the solubility of dissolved oxygen and moderate pH values observed generally.

Turbidity measures the degree of cloudiness and disorderliness in a water body, and this could be attributed to suspended fine insoluble particles and colloidal impurities such as clay, silt, and algae (Okey-Wokeh et al., 2020). The mean values of turbidity recorded across the sample stations exceeded the 5.0 NTU threshold (WHO 2017), attributed to runoffs and re-suspension of particles. Similarly, Kalagbor et al (2021) reported of related values in the past caused by water runoff. River water with elevated turbidity values can harbour microbial activities, block light penetration and influence oxygen depletion in aquatic ecosystems (Edori and Aniekan 2021). The mean salinity concentrations of water samples obtained across the stations from Orashi river were significantly low compared to the 1000 mg/L permissible limit for freshwater. This indicated the Orashi river was purely a freshwater ecosystem. This finding was consistent with the values recently reported from the Orashi river water (Okwodu et al., 2022). Higher salt content in the freshwater ecosystem will affect the osmotic balance of the aquatic flora and fauna (Edori and Aniekan 2021).

Biochemical oxygen demand determines the amount of oxygen required by microbes like bacteria to break down the decomposable organic matter present in the water into simpler substances (Kidu et al., 2015). The mean concentrations of biochemical oxygen demand recorded across the four sample stations were below 2-5 mg/L earmarked by the World Health Organisation (WHO 2017) as the permissible limit for drinking water and aquatic organisms. Similar results were reported previously in some aquatic ecosystems in the Niger delta (Okey-Wokeh et al., 2020, Okwodu et al., 2022). The BOD concentrations observed from the four sample stations suggest the water was suitable for drinking and aquaculture use. It was a clear indication that the Orashi river had low organic matter content, and this may have contributed to the elevated dissolved oxygen concentrations observed in this study.

Conclusion

Generally, the results of the physicochemical parameters in this study were found to be within national and international standards for drinking water, which depict Orashi river water quality to be good and suitable for domestic, aquaculture, and other agricultural use. To maintain this river water quality within the threshold suitable for human consumption, routine monitoring of the aquatic environment is of great essence and this can be achieved by regulating human activities that are capable of deteriorating the water quality of Orashi river by all stakeholders.

Ethical Statement

The authors declared that this study was carried out according to the institutional guidelines of University of Port Harcourt, Nigeria and there was no conflict of interest among the authors.

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