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Physico-Chemical and Some Trace Metal Analysis of Ogba River, Benin City, Nigeria

Emeka D. Anyanwu

Department of Animal and Environmental Biology, Delta State University, Abraka, Nigeria.

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Abstract

The physico-chemical parameters and some trace metal contents of Ogba River in Benin City, Nigeria were investigated from January to August 2008. Four stations were studied from upstream to downstream using standard methods. A total of twenty-six physico-chemical characteristics and trace metal contents were examined; Air and water temperatures, depth, transparency, turbidity, flow velocity, pH, total alkalinity, conductivity and dissolved solids. Other includes dissolved oxygen, oxygen saturation, biochemical oxygen demand, chloride, phosphate, nitrate, sulphate, potassium, calcium, magnesium, iron, lead, copper, zinc and manganese Thirteen (13) parameters exhibited clear seasonal variations. However, there were significant differences ($p < 0.05$) in the values of depth, flow velocity, BOD5, sulphate, phosphate, nitrate and sodium among the stations. The Benin City wastewater had negatively impacted at station 2 of the river, although the recorded values were still within acceptable limits.
Keywords: Physico-chemical parameters, trace metal, anthropogenic activities, water quality, acceptable limits, Nigeria.

1. Introduction

The quality of any water body is governed by its physicochemical and heavy metal factors. The monitoring of physicochemical characteristics of a water body is vital for both long term and short evaluation of its quality (Wood, 1995). Lakes, rivers and streams have important multi – usage components, such as sources of drinking water, irrigation, fishery and energy production (Iscen *et al*., 2008). Water is a scarce and fading resource, and its management can have an impact on the flow and the biological quality of rivers and streams (Prat and Munné, 2000). Expanding human population, industrialization, intensive agricultural practices and discharges of massive amount of wastewater into the rivers and streams have resulted in deterioration of water quality (Herschy, 1999). The impact of these anthropogenic activities has been so extensive that the water bodies have lost their self-purification capacity to a large extent (Sood *et al*., 2008). Freshwater ecosystems have been used for the investigation of factors controlling the distribution and abundance of aquatic organisms. The physical and chemical characteristics of water bodies affect the species composition, abundance, productivity and physiological conditions of aquatic organisms (Bagenal, 1978).

In Nigeria, studies on the physicochemical quality of water bodies have been reported extensively (Mustapha and Omotosho, 2005; Omoigberale and Ogbeibu, 2007; Yusuf and Osibanjo, 2007; Asonye *et al*., 2007; Davies and Otene, 2009). However, less attention has been given to smaller rivers like Ogba River, which are scattered all over the country and contain a significant proportion of the nation’s aquatic biodiversity. Ogba River plays important roles in the lives of the surrounding inhabitants. Fishing, farming, bathing, washing/laundry, car/motorbike washing, refuse disposal, municipal wastewater and human waste disposal and religious activities are constantly going on within and around this river. The objective of the present study was therefore to evaluate the physico-chemical parameters and some trace metal contents of Ogba River, Benin City, Nigeria.

2. Materials and Methods

2.1. Study area and sampling stations

Ogba river is a forth order (4^o) river, located at the Southwest region of the outskirt of Benin City in Edo State, Nigeria between Latitude 6.20^oN and Longitude 5.34^oE (Fig. 1). The river is about 42 km long and takes its source at Ekewan and flows in a South East direction through Ogba village and empties to Osiomo River, into Benin River, which in turn empties into the Atlantic Ocean. This study was carried out in the upper part of the river stretching from Ogbe Ibuya area to Ogba community. Four sampling stations were chosen for the study; Station 1 located at Ogbe Ibuya area was open to a number of

* Corresponding author: ekadon@yahoo.com

aquatic macrophytes within the water and around the edges blocking the northern part completely. No human activity was observed during the study. Station 2, also located at Ogbe Ibuya area, 0.66km downstream of station 1.

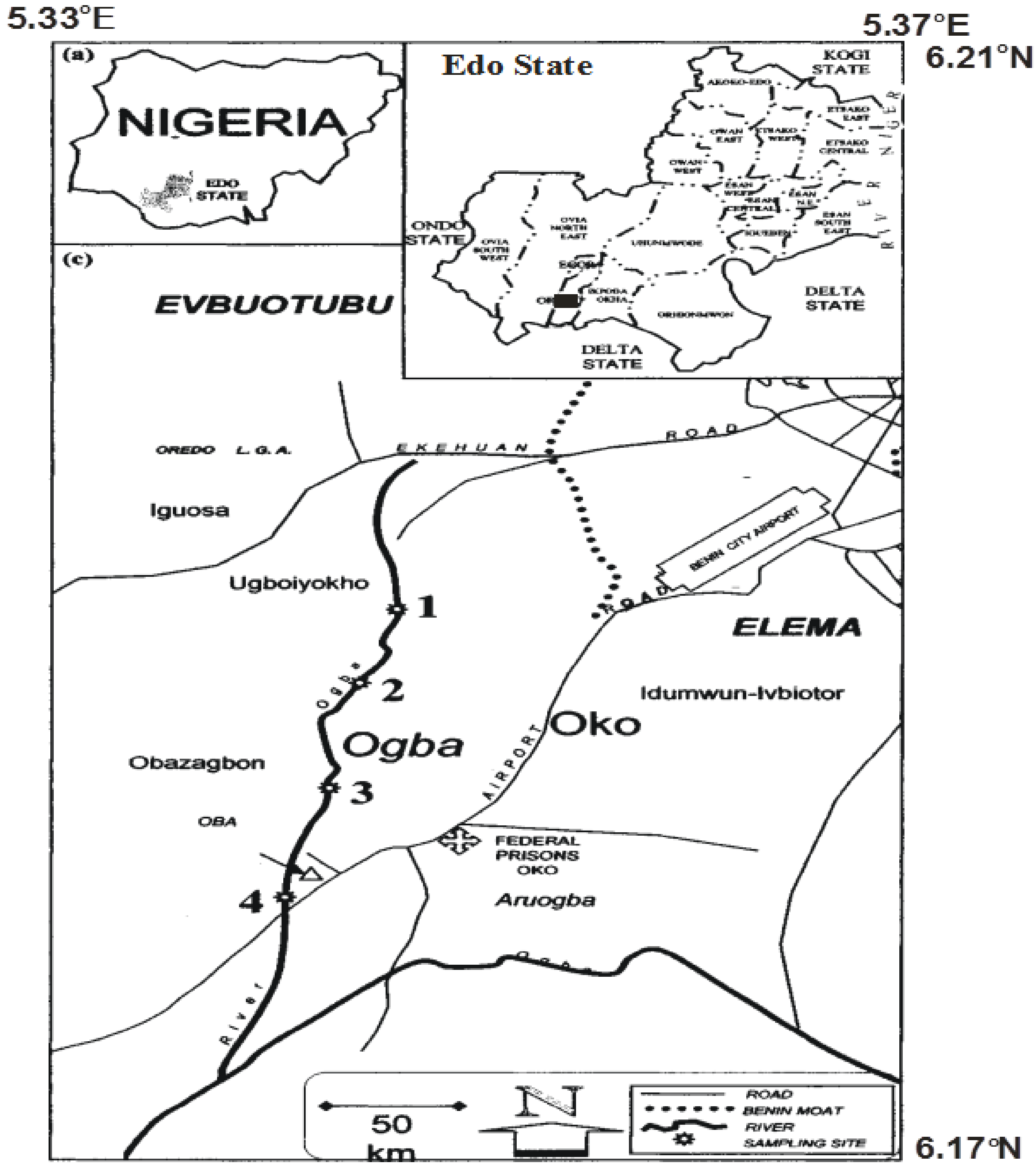

Figure 1: Map of Benin City showing location of sampling stations 1 – 4 in the Ogba River.

2.2. Samples collection and analyses

Benin City wastewater from GRA area discharges into the river at this point. Station 3, located behind Oko Open Prison, 0.6km downstream of station 2; the human activities include bathing, washing and farming by the inmates of the prison. Station 4 located within Ogba community by the bridge, 2km downstream of station 3 where human activities include: bathing, washing of clothes, cars and motor bikes as well as idol worshiping and water baptism.

Samples were collected once a month between January and August 2008. Water samples were collected with a 2 liter plastic hydrobios water sampler and transferred to clean 2 litre polyethylene containers. All samples were transported in ice chests and analyzed for pH and conductivity within 12 hours of collection. Other physicochemical parameters were analyzed later using refrigerated samples. They were analyzed according to standard methods (APHA, 1998) for physicochemical parameters. The determination of heavy metal was carried out in two stages. The samples were digested in concentrated Nitric Acid and analyzed by Atomic Absorption Spectrometer (Varian Techtron Spectra B). The data obtained were subjected to analysis for means, standard error and significance between the means at 95% probability level. These were carried out using Microsoft Excel (2003) package.

3. Results

The physicochemical parameters and trace metal contents of the studied river are presented in Tables 1 and 2, respectively. The air temperature ranged between 15°C and 31.5°C while the surface water temperature ranged between 20.0oC and 27.5oC. The pattern of fluctuation for both air and water temperatures was similar in all the stations. Water depth ranged from 21.0cm to 113cm and station 2 was significantly different ($p<0.001$) while transparency and turbidity ranged from 12.5cm to 100.0cm and 0.11NTU to 53.08 NTU respectively. The mean flow velocity was lowest in station 1 (1.41 m/s) while stations 2 (4.90 m/s), 3 (4.73 m/s) and 4 (4.63 m/s) had high mean values which decreased spatially. Temporally, there was a distinct seasonal pattern in the variation of both transparency and turbidity. While transparency values were highest in the dry season months, the reverse is the case for turbidity.

The pH values revealed that the water was moderately acidic to moderately alkaline with a range of 5.4 to 8.1 while the total alkalinity values ranged between 6.1mgl^{-1} and 183mgl^{-1}. The conductivity values ranged from 23.3µScm^{-1} to 116.5µScm^{-1} while total dissolved solids which followed the same spatial variation trend, ranged between 14.48mgl^{-1} and 66.4mgl^{-1}. There was a clear seasonal variation in both conductivity and total dissolved solids; values increased from dry season to rainy season. The dissolved oxygen content ranged from 4.8mgl^{-1} to 6.9mgl^{-1}; concentrations generally increased with the rains while oxygen saturation values confirmed that water was well saturated. The oxygen saturation in all the stations throughout the study period was above 50%. The values of BOD5 ranged between 1.7mgl^{-1} and 4.8mgl^{-1} with station 2 being significantly different ($p<0.05$). The temporal variation of DO and oxygen saturation was similar while that of BOD5 was irregular. The chloride concentration ranged between 19.5mgl^{-1} and 106mgl^{-1} in an irregular temporal variation. Nitrate values ranging from 0.001mgl^{-1} to 0.3mgl^{-1} were observed throughout the period of study. Peak values were recorded in the rainy season months and the lower values in the dry season months while sulphate and phosphate values observed ranged from 0.60mgl^{-1} to 6.39mgl^{-1} and from 0.10mgl^{-1} to 1.44mgl^{-1}, respectively. There was no clear seasonal pattern observed in sulphate and phosphate fluctuations. There was a significant difference in the values recorded in all the stations ($p<0.05$) for nitrate, sulphate and phosphate. The cations such as sodium and potassium values ranged from 1.15mgl^{-1} to 2.80mgl^{-1} and 0.18mgl^{-1} to 0.91mgl^{-1} respectively. There was a significant difference in the values of sodium in all the stations ($p<0.05$). On the other hand, the concentrations of calcium in all the stations were relatively close (between 9.60 and 12.83 mgl^{-1}) while magnesium values ranged between 1.57mgl^{-1} and 5.83mgl^{-1}. In both cases, no significant differences were observed in the stations.

The values of the heavy metals were generally low. Iron values ranged from 1.00mgl^{-1} to 4.23mgl^{-1} with higher value recorded in the rainy season months. Lead ranged from 0.012mgl^{-1} to 0.20mgl^{-1}, most of the high lead values were recorded during the dry season months. The highest copper value was 0.505mgl^{-1} while the lowest value was 0.256mgl^{-1}. The trend showed that in all the stations, the values of copper increased with increase in rains and dropped with slight decrease in rains in August 2008. The highest zinc concentration was 0.15mgl^{-1} while the lowest was 0.09mgl^{-1}. The value of manganese ranged from 0.22mgl^{-1} to 0.53mgl^{-1}. Zinc and manganese did not show any clear trend in their temporal variations. There were no significant differences observed among the heavy metals.

4. Discussion

Atmospheric temperatures recorded in the study were lower in January and February, 2008 with a relatively higher value in March before decreasing in April in all the stations; increasing and stabilizing with minimal fluctuations from May to August, 2008. Low atmospheric temperature recorded in the months of January and February 2008 were probably due to the North East trade wind that blows across the Sahara, often referred to as the Harmattan while that of April could be attributable to early rains. This condition is typical of tropical weathers (Awachie, 1980). The surface water temperature followed the same trend that was observed in the air temperature.

Station 3 recorded the highest depth in March while station 2 recorded the lowest in June 2008. The variations in depth are usually associated with the rainfall pattern of the drainage basin. Lower depths recorded during the rainy season especially in stations 2 to 4 could be attributed to heavy siltation associated with increase in rainfall exacerbated by the increased floodwater entering the river system from Benin City wastewater drain in station 2 and moving down to station 4 (Mligo, 2007).

Transparency values recorded indicated that stations 1, 3 and 4 were clear zones with high transparency values. In this study, transparency showed a seasonal pattern, lower transparency values were recorded in the rainy season months while higher transparency values were recorded in the dry season months. This is primarily due to the fact that in the rainy season, rivers receive run-offs from nearby terrestrial environment thereby increasing the suspended solids load. This trend is consistent with reports from most Nigerian inland waters (Imoobe and Oboh, 2003).

In this study, turbidity showed seasonal and spatial patterns; relatively higher turbidity values were observed during the rainy season period due to increased suspended solids loads laden run-offs while the mean value increased from station 1 to 4; this could be attributable to the level of human activity in the river system, which is highest in station 4.

Table 1: Mean and standard error of physicochemical parameters of Ogba River, Benin City, Nigeria during the eight (8) months study period

LEVEL RECORDED/DETECTED						Maximum Permissible Levels	
Parameter	Station 1 $\overline{X}$ ± S.E.	Station 2 $\overline{X}$ ± S.E.	Station 3 $\overline{X}$ ± S.E.	Station 4 $\overline{X}$ ± S.E.	P - Value	FEPA**	SON***
Air Temperature (°C)	22.85±1.35 15.0–25.5)	23.89±1.38 (18.0–30.5)	24.79±1.38 (18.9–31.5)	26.09±1.06 (20.5–31.5)	$p > 0.05$	-	-
Water Temperature (°C)	24.72±0.97 (20.0–27.5)	24.44±094 (20.2–25.6)	24.83±0.92 (20.5–26.9)	24.79±0.82 (20.6–26.7)	$p > 0.05$	< 40	Ambient
Depth (cm)	85.83±4.13 (71.0–104.0)	41.5±5.58 (21.0–62.0)	70.1±10.23 (40.0–113.0)	76.91±5.26 (52.0–98.0)	$p < 0.001$*	-	-
Transparency (cm)	63.38±8.31 (22.0–94.0)	33.63±5.20 (16.0–57.0)	50.24±12.05 (12.5–100.0)	51.43±7.09 (22.0–82.3)	$p > 0.05$	-	-
Velocity (m/s)	1.41±1.79 (10.8–25.6)	4.90±3.89 (28.2–65.6)	4.73±1.95 (37.7–53.0)	4.63±1.61 (37.7–51.4)	$p < 0.001$*	-	-
pH	6.78 ±0.10 (5.4–7.5)	6.23±0.05 (5.7–6.9)	6.83 ± 0.15) (5.9–8.1)	6.45± 0.09 (5.7–7.2)	$p > 0.05$	6.0 – 9.0	6.5 – 8.5
Conductivity (µS/cm)	50.6±11.22 (23.3–116.5)	45.73±4.06 (33.4–69.7)	47.6±3.67 (31.0–74.7)	40.8±6.18 (29.3–78.2)	$p > 0.05$	-	1000
Turbidity (NTU)	7.30±2.58 (0.11–17.18)	8.51±3.81 (0.63–28.2)	9.19±4.11 (0.22–32.8)	11.07±6.11 (1.7–53.08)	$p > 0.05$	10	15
Total Dis. Solids (Mgl^{-1})	30.11±6.33 (14.5–66.4)	27.66±2.43 (20.1–41.8)	28.95±3.42 (19.2–44.9)	26.96±3.74 (18.1–47.0)	$p > 0.05$	2000	500
Dissolved Oxygen (Mgl^{-1})	5.59±0.25 (4.9–6.9)	5.53±0.15 (4.8–6.0)	5.95±0.13 (5.4–6.5)	5.78±0.16 (4.9–6.3)	$p > 0.05$	5	-
Oxygen Saturation (%)	73.3±3.86 (58.1–86.5)	67.3±1.96 (60.6–74.8)	73.0±1.75 (68.5–81.7)	71.3±2.91 (56.9–80.8)	$p > 0.05$	-	-
BOD_5 (Mgl^{-1})	2.16±0.15 (1.7–3.0)	4.13±0.15 (3.5–4.8)	4.04±0.23 (2.9–4.8)	2.56±0.24 (1.7–3.9)	$p < 0.001$*	10	-
Alkalinity (Mgl^{-1})	35.08±9.83 (12.2–100.7)	50.33±19.43 (18.3–183.0)	38.13±7.38 (15.3–82.4)	33.17±10.79 (6.1–97.6)	$p > 0.05$	-	-
Chloride (Mgl^{-1})	34.80±3.19 (19.5–49.7)	35.72±3.68 (21.5–53.3)	41.78±9.60 (21.8–106.5)	34.98±5.39 (21.3–71.0)	$p > 0.05$	2000	250
Sulphate (Mgl^{-1})	2.83±0.30 (1.98–4.11)	6.06±0.10 (5.49–6.39)	0.90±0.03 (0.76–1.00)	0.66±0.02 (0.60–0.72)	$p < 0.001$*	200 – 400	100
Phosphate (Mgl^{-1})	1.08±0.01 (1.00–1.11)	1.24±0.03 (1.12–1.44)	0.23±0.12 (0.10–1.10)	0.86±0.17 (0.10–1.18)	$p < 0.001$*	5	-
Nitrate (Mgl^{-1})	0.02±0.01 (0.001–0.05)	0.13±0.05 (0.004–0.3)	0.04±0.01 (0.02–0.08)	0.03±0.01 (0.011–0.06)	$p < 0.01$*	20	50
Calcium (Mgl^{-1})	12.28±0.72 (9.62–16.03)	12.39±0.94 (9.60–16.05)	11.79±0.48 (9.60–12.83)	12.92±1.16 (9.26–19.24)	$p > 0.05$	-	-
Magnesium (Mgl^{-1})	2.23±0.25 (1.76–3.89)	2.58±0.26 (1.94–3.60)	2.05±0.23 (1.57–3.75)	3.08±0.51 (1.85–5.83)	$p > 0.05$	30 – 150	0.20
Potassium (Mgl^{-1})	0.44±0.06 (0.27–0.72)	0.46±0.08 (0.18–0.91)	0.43±0.69 (0.20–0.72)	0.43±0.05 (0.27–0.68)	$p > 0.05$	75 – 200	-
Sodium (Mgl^{-1})	1.27±0.02 (1.15–1.35)	1.88±0.15 (1.38–2.80)	1.64±0.06 (1.29–1.82)	1.40±0.04 (1.23–1.56)	$p < 0.001$*	-	200

* Significantly different means ($p < 0.05$). Range in parenthesis

** Nigerian Water Quality Standard for Inland Surface Water. Federal Environmental Protection Agency (FEPA), 2003.

***Nigerian Standard for Drinking Water Quality. Standards Organisation of Nigeria (SON), 2007

Table 2: Mean and standard error of some trace metal contents of Ogba River, Benin City, Nigeria during the eight (8) months study period

LEVEL RECORDED/DETECTED						Maximum Permissible Levels	
Parameter	**Station 1** $\bar{X}$ **± S.E.**	**Station 2** $\bar{X}$ **± S.E.**	**Station 3** $\bar{X}$ **± S.E.**	**Station 4** $\bar{X}$ **± S.E.**	***P* - Value**	**FEPA****	**SON*****
Copper (Mgl^{-1})	0.41±0.03 (0.27–0.50)	0.39±0.03 (0.26–0.50)	0.40±0.02 (0.30–0.46)	0.40±0.03 (0.26–0.49)	$p > 0.05$	0.05 – 1.5	1
Zinc (Mgl^{-1})	0.12±0.004 (0.11–0.14)	0.11±0.003 (0.09–0.12)	0.12±0.008 (0.09–0.15)	0.11±0.003 (0.10–0.12)	$p > 0.05$	5 – 15	3
Iron (Mgl^{-1})	2.09±0.36 (1.00–3.95)	2.61±0.39 (1.23–4.23)	2.00±0.36 (1.03–3.82)	2.02±0.19 (1.06–2.87)	$p > 0.05$	20	0.3
Lead (Mgl^{-1})	0.09±0.02 (0.012–0.20)	0.06±0.08 (0.02–0.09)	0.10±0.02 (0.07–0.18)	0.07±0.01 (0.03–0.13)	$p > 0.05$	0.01 – 1.0	0.01
Manganese (Mgl^{-1})	0.36±0.02 (0.27–0.43)	0.36±0.02 (0.30–0.45)	0.39±0.02 (0.33–0.53)	0.34±0.02 (0.22–0.45)	$p > 0.05$	0.05 – 0.5	0.2

* Significantly different means ($p < 0.05$). Range in parenthesis

** Nigerian Water Quality Standard for Inland Surface Water. Federal Environmental Protection Agency (FEPA), 2003.

***Nigerian Standard for Drinking Water Quality. Standards Organisation of Nigeria (SON), 2007

The flow velocity of water in station 1 was generally low, though the flow velocity increased generally during the rainy season in all the stations. The highest flow velocity was recorded in station 2; this could be as a result of Benin City wastewater entering the river at that point. The pH recorded in this study indicates that the water was moderately acidic to moderately alkaline. The range observed in this study is close to those recorded elsewhere in most Nigerian inland water bodies (Onwudinjo, 1990; Ogbeibu, 1991; Odum, 1992). There was no clear predictable seasonal pattern in the pH values recorded in this study, though in some stations a number of high pH values (>7) were recorded during the rainy season. The highest total alkalinity value was recorded in January 2008 at station 2, the entry point of the Benin City wastewater. Akin-Oriola (2003) reported values as high as 346.8 and 175.8 mgl^{-1} respectively in Ogunpa and Ona Rivers in Ibadan while Radojevics and Bashkin (1999) reported that untreated domestic wastewaters are normally alkaline with alkalinities between 50 and 2000mgl^{-1}. This can also explain at least partly the high pH values recoded in some stations during the rainy seasons.

Conductivity showed that the water is fresh in all the station but an indication of negligible impact of human activities in the area. The study revealed that the monthly values were generally lower in months of January to March than in the months of April to August 2008 in all the stations except in station 1 in January 2008, which had the highest value that could not be explained.

Total dissolved solids in this study revealed a similar trend with conductivity. Egborge (1994) observed higher values in rainy season months than in the dry season - a phenomenon common in most Nigerian inland waters. However, low dissolved oxygen was recorded during March at station 2, could be attributed to the extent of flora composition, organic pollution and population density of fauna. Concentrations below 5mgl^{-1} may adversely affect the functioning and survival of biological communities and below 2mgl^{-1} may lead to the death of most fishes (Chapman, 1996). Dissolved oxygen can also be expressed in terms of percentage saturation. The highest value of oxygen saturation (86.5%) was record in August 2008 while the lowest value (58.1%) was recorded in January 2008, both in station 1. The lowest values of BOD_5 recorded throughout the sampling period was 1.7mgl^{-1} at stations 1 and 4, both in January 2008 while the highest value recorded was 4.8mgl^{-1} in January 2008 at station 2 and in February 2008 at station 3. This could be attributed to entrance of high organic materials from the Benin City wastewater and prison farms, respectively.

The chloride values showed that the river was completely freshwater type in all the study stations. The values were relatively similar to the values of Osse River, Owo River and Ologe lagoon (Omoigberale and Ogbeibu, 2007; Yusuf and Osibanjo, 2007). The nitrate – nitrogen concentration obtained was relatively low (0.001 to 0.3mgl^{-1}), and similar to those reported for some Nigerian inland waters (Omoigberale and Ogbeibu 2007). The irregular higher values obtained during the study especially in station 2 can be attributed to the increased nutrients coming in through the Benin City wastewater drain. These high values of nitrate observed in station 2 corresponded with the findings of Obhahie *et al.* (2007) whose station 4 is station 2 in this study. The other potential factor is the disposal of human wastes in the immediate watershed, which is washed into the river in small volumes via run-offs.

The reason for the decreased phosphate value, compared to other aquatic systems, may involve heterotrophic uptake by micro-organisms, sediment adsorption and removal by the currents. Omoigberale and Ogbeibu (2007) reported higher values of 0.28mgl^{-1} to 3.52mgl^{-1} for Osse River. In contrast to what is obtainable in most Nigerian inland waters, peak value was observed in April 2008 as against rainy season months when allochthonous phosphorus containing materials are introduced by surface run-offs. An important source of phosphate in Ogba River is likely to be from soaps and detergents used in washing of cars and motorcycles, bathing and other laundry activities, which commonly take place in the river as well from the Benin City wastewater. High sulphate values were observed in station 2 throughout the period of study. Obhahie *et al.* (2007) recorded lower monthly mean values of between 0.06 and 0.13mgl^{-1} which was similar to that recorded in station 2.

Sodium values were low compared to those of some freshwater bodies in Nigeria (Ogbeibu and Edutie, 2002; Omoigberale and Ogbeibu, 2007 and Ebadin, 2006). Many surface waters, including those receiving waste waters, have concentrations well below 50mgl^{-1}. There was no marked seasonal pattern of lower values in dry season and higher values in rainy season as observed by Egborge (1978), but high values were generally recorded for station 2. The level of potassium recorded in this study ranged from 0.18mgl^{-1} to 0.91mgl^{-1} with no clear pattern of seasonality. The highest value was recorded in August 2008 in station 2. Some recent studies reported higher values (Ogbeibu and Edutie, 2002; Ebadin, 2006; Omoigberale and Ogbeibu, 2007). Calcium values are relatively high compared to 1.11mgl^{-1} to 9.62mgl^{-1} for Osse River (Omoigberale and Ogbeibu, 2007) but higher values have also been recorded in some Nigerian waters. Ogbeibu and Edutie (2002) recorded a range of 4.80mgl^{-1} to 25.0mgl^{-1} in Ikpoba River and Ebadin (2006) reported values of 0.40mgl^{-1} to 19.24mgl^{-1} for Utor River. The level of magnesium recorded in this study are comparable to some Nigerian water bodies (Okogwu and Ugwumba, 2006; Omoigberale and Ogbeibu, 2007). No seasonality was observed. The results of the present study show that the major cations in Ogba River are in the order of Ca > Mg > Na > K. This order is consistent with the common trend observed in Nigerian inland freshwaters in which calcium and magnesium are the most important cations (Imevbore, 1970; Egborge, 1971).

The results showed that water had low concentrations of heavy metals. The concentrations of the heavy metals in the Ogba River were below the Nigerian standard for drinking water quality.

In conclusion, the physico-chemical parameters and some heavy metal content of Ogba River as observed from this study are within the acceptable limits of Federal Environmental Protection Agency (FEPA) guidelines and Nigerian standard for drinking water quality. The impact of the Benin City wastewater was observed at the point of entry (station 2) in relation to depth, velocity, Biochemical Oxygen Demand (BOD), sulphate, phosphate, nitrate and sodium which were statistically different from the other stations but are still within the limits.

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