POLLUTION IN WATER AND FISH OF TROPICAL MAJIDUN CREEK, LAGOS NIGERIA

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Abstract: Pollution of water bodies by natural and anthropogenic activities is on the increase and rendering water unsafe for aquatic biota and man. This study assessed the tropical pollution of Majidun Creek, Lagos, Nigeria. Fifteen sampling points were selected along the River course based on pollution hotspots or dump sites for water collection. Surface water samples were monthly collected between May, 2016 and April, 2017 and their physico-chemical parameters were analysed following standard procedures. Metal concentration in water and fish species per sampling point was determined using Atomic Absorption Spectrophotometer. Physico-chemical parameters and metal concentrations data were subjected to descriptive statistics using SPSS. The physico-chemical parameters showed contrasting results in the sampling points. Temperature (°C) varied between 27.90±0.53 and 28.70±0.47, pH ranged between 6.03±0.53 and 6.78±0.08, Conductivity (μScm^{-1}) varied between 3470.31±1255.05 and 4415.42±1446.50, dissolved oxygen (mgL^{-1}) ranged between 3.25±0.78 and 6.95±2.98, Salinity (‰) varied between 9.69±2.63 and 15.48±2.91, while total petroleum hydrocarbon (mgL^{-1}) varied between 157.74±93.51 and 165.60±101.27. All these parameters except temperature and pH values were significantly different ($p < 0.05$) and within acceptable level for aquatic biota survival. The metal composition (mgL^{-1}) of Majidun water showed Fe, Zn, Pb and Mn less than 1.0 and Cr range of 6.68±0.61 and 7.42±0.11, but higher than WHO standard, the condition which might be due to ecological variation, bioremediation and pollution. It was concluded that there were significant variations in quantification of physico-chemical parameters and metal constituents in water and fish of Majidun creek, Nigeria.

Keywords: Biota, Ecology, Fish, Majidun River, Metals

Introduction

Water is essential for all living organisms as it is used in all environments for various activities. Nowadays, water bodies are becoming polluted as a result of various human activities which include littering, pouring chemicals, down drains of agricultural and industrial discharges (Lawson *et al.,* 2013; Awoyemi *et al.,* 2014). There is a clear link between population growth, urbanization, industrial development and human activities that are likely to generate pollution and water depreciation which has negatively affected water quality management in cities especially waste-water management (Badr *et al.,* 2013).

Freshwater is a limited resource and its demand will continue to increase due to population growth, increased irrigation requirement and industrialization (Banadda *et al*., 2011, Nhapi *et al.,* 2012). Creeks and Lagoons are common hydrological features of Southwest Nigeria and form part of the numerous ecological niches associated with the Nigerian coastal environment (Chukwu and Nwankwo, 2004). Over the years, tidal creek ecosystems, particularly in the industrialised areas of Lagos metropolis, are enduring stress-induced changes as a result of steadily yet increasing human activities and associated effects (Onyema and Nwankwo, 2006).

Heavy metals are dangerous elements of the earth crusts as they tend to bioaccumulate by increasing in concentration level in biological organisms over time (Dural *et al.,* 2007). Therefore, heavy metals can be bio-accumulated, bio-absorbed, biomagnified via the food chain and finally assimilated by human resulting in health risks (Agah *et al*., 2009). Fish accumulate toxic chemicals such as heavy metals directly from water in their tissues which has been identified as an indirect measure of the abundance and availability of metals in the aquatic environment (Ali and Abdel-Satar, 2005; Alinnor and Obiji, 2010; Oladunjoye *et al.,* 2021).

As a consequence, fish are often used as pollution indicators in aquatic ecosystem, because they occupy high trophic levels and retain heavy metals from their environment depending on concentration exposure and duration, as well as salinity, temperature, water hardness and metabolism of the animals. However, this study assessed the physico-chemical parameters and metals concentration in water of Majidun Creek in relation to their accumulation in fish species.

Materials and Methods

Study area

This study was carried out in Majidun River, Ikorodu, Lagos State, Nigeria. The choice of the study was based on the high socio-economic activities of the River (Esenowo and Ugwumba, 2010; Lawson *et al.,* 2013; Awoyemi *et al.,* 2014). It is a multipurpose resource river used for artisanal fishing, commercial transportation, logging, recreational activities, sand mining and domestic uses. Majidun Creek is relatively a small, narrow and shallow water body with average depth of 3m that lies within longitudes 3°27'25.1"E and 3°28'28.1"E and stretch between latitudes 6°38'25.5"N and 6°36'45.7"N (Figure 1).

Majidun River has its major source from River Oworu (freshwater) in Ogun State and flows into Lagos lagoon at Ipakoda where it receives tidal waters from the Lagoon (Figure 1). It experiences seasonal flooding which introduces a lot of detritus, domestic and industrial wastes. It receives human-induced wastes as faeces, discharge of domestic wastes, agricultural runoff, oil spill from heavy motor traffic and transportation by boat across the River. The sampling locations were chosen to reflect different activities in the river (Upstream, midstream and downstream) which might affect the quality situation in the river. It's also the River pollution hotspots as well as inflow and outflow of the River (confluence).

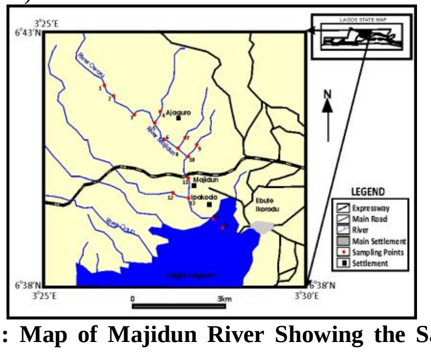

Figure 1: Map of Majidun River Showing the Sampling Points (1-15)

Sampling Procedures

Sampling points on Majidun River were selected based on location of effluent discharges (domestics and industrial), inflow and outflow region of the river (confluence), proximity of residential sites located on the river and accessibility towards the river. Pollution critical parts as hotspots were surveyed and identified in order to assess their contributions and impacts as suggested (Banadda *et al.*, 2011; Nhapi *et al.*, 2011; Awoyemi *et al.*, 2014). Each sampling point was mapped using high sensitivity Global Positioning System (GPS) Model IEC 60529 IPX7 (GARMIN eTrex®H) with compact size of 4.1 × 2.0 × 1.2 inches (11.2 × 5.1 × 3.0 centimetres) on a boat ride to ensure that samples were always taken from the same points on the River throughout the sampling period.

Fifteen (15) sampling points were chosen from the beginning of Majidun River till point of empty into the Lagos lagoon. Out of the fifteen stations, Point 4, 7, 9 and 12 were inflow Rivers into Majidun River, while Point 5, 8, 10 and 13 are confluence with Majidun River and Point 14 and 15 are Lagos Lagoon (Figure 1 and Table 1). Locations of each sampling points with their corresponding coordinates and their distance between each points on the River (measured in Kilometres) using the GPS is represented in Table 1.

Table1: List of Sampling Points on Majidun River and its Coordinates

Point	Geographic Coordinates, GPS (Latitude / Longitude)	Distance from reference point (Km) (4 s.f)	Elevation (m)	Status
1	06 ° 38 ' 25.5 " N/03 ° 27 ' 25.1 " E	0	7	Starting Point
2	06 ° 38 ' 23.6 " N/03 ° 27 ' 24.4 " E	0.07145	9	Downstream
3	06 ° 38 ' 21.1 " N/03 ° 27 ' 25.6 " E	0.1366	5	Downstream
4	06 ° 38 ' 05.9 " N/03 ° 27 ' 25.1 " E	0.6054	5	Inflow
5	06 ° 37 ' 55.1 " N/03 ° 27 ' 25.8 " E	0.6428	6	Confluence
6	06 ° 37 ' 44.9 " N/03 ° 27 ' 25.9 " E	0.9578	7	Downstream
7	06 ° 37 ' 42.7 " N/03 ° 27 ' 54.8 " E	1.370	4	Inflow
8	06 ° 37 ' 41.5 " N/03 ° 27 ' 55.2 " E	1.405	4	Confluence
9	06 ° 37 ' 41.5 " N/03 ° 28 ' 63.8 " E	2.526	5	Inflow
10	06 ° 37 ' 61.4 " N/03 ° 28 ' 55.7 " E	2.092	6	Confluence
11	06 ° 37 ' 35.2 " N/03 ° 28 ' 53.0 " E	2.333	9	Downstream
12	06 ° 37 ' 04.8 " N/03 ° 28 ' 55.8 " E	3.004	3	Inflow
13	06 ° 36 ' 25.9 " N/03 ° 28 ' 55.2 " E	3.892	6	Confluence
14	06 ° 36 ' 05.1 " N/03 ° 28 ' 58.1 " E	4.496	6	Point of Entry (Lagos Lagoon)
15	06 ° 36 ' 45.7 " N/03 ° 28 ' 45.9 " E	3.224	4	Lagos Lagoon

Water samples for physico-chemical analysis were monthly collected (from May, 2016 to April, 2017) covering both wet and dry seasons. The grab sampling methods described by Nhapi *et al.* (2011 and 2012) and Thomas (2014) were used. Surface water samples were collected and stored with 600ml plastic sampling bottles. The bottles were rinsed with 1M hydrochloric acid (HCl) and distilled water and left to stand overnight. The bottles were also rinsed thrice with sample water before final collection. The bottle was covered when dipping into the river, opened at about 15cm depth and then screwed with its cap while still submerged.

The samples were placed in a cooler-box with block ice for transportation to the laboratory and stored in a refrigerator at 4^{o}C. The samples were analysed according to standard recommended APHA (2005) procedures for water and waste-water examination. Moreso, other data such as total amount of rainfall, sunshine and relative humidity in Majidun river community/area throughout the sampling period were obtained from Nigerian Meterological Agency (NIMET) Oshodi, Lagos State.

Determination of Physico-chemical Parameters

Physico-chemical parameters of Majidun River were examined monthly at each sampling points. Some water physico-chemical parameters measured *in-situ* such as the river depth (cm) using calibrated meter rule, pH using portable digital pH metre (Model pH-009), temperature (^{o}C) using mecury in the glass thermometer, conductivity (µScm^{-1}) using portable electronic Lamotte tracer pocket tester (Model 1766), total dissolved solids (mgL^{-1}) using Lamotte tracer pocket tester (Model 1766), salinity (‰) using salinity bridge metre (Model EES 13 - 135) and dissolved oxygen (mgL^{-1}) using portable digital dissolved oxygen probes (Model HI9146).

Other parameters were measured *ex-situ* which include total suspended solids (mgl^{-1}), biochemical oxygen demand (mgL^{-1}), chemical oxygen demand (mgL^{-1}), total hardness (mgL^{-1}), chloride (mgL^{-1}), sulphate (mgL^{-1}), phosphate (mgL^{-1}), total nitrogen (mgL^{-1}), ammonium-nitrogen (mgL^{-1}), nitrate-nitrogen (mgL^{-1}), total organic carbon (mgL^{-1}) and total organic matter (mgL^{-1}) using APHA (2005) standard recommended procedures.

Determination of Metal Composition in Water

100 ml of the water sample was transferred into Pyrex beaker containing 10ml of concentrated nitric acid (HNO_3) and boiled slowly till evaporated to 20 ml on hot plate. The beaker was allowed to cool, while another 5ml of concentrated nitric acid (HNO_3) was added and heated until digestion was completed. The sample was then evaporated again to dryness and the beaker was cooled, then followed by the addition of 5ml of hydrochloric acid (HCl) solution (1:1 v/v). The solution was warmed, 5ml of 5M sodium hydroxide (NaOH) was added and then, filtered. The filtrate was transferred to 100 ml volumetric flasks and diluted with distilled water.

Lead (Pb), zinc (Zn), copper (Cu), iron (Fe), manganese (Mn), cadmium (Cd) and chromium (Cr) in the water sample was determined using computer controlled Atomic Absorption Spectrophotometer (VGB 210 Bulk Scientific). Its settings and operational conditions were done in accordance with the manufacturers' specifications and instructions. All the measurements were carried out in triplicate as standard procedure by USEPA (2007) method as described by Agah *et al.* (2009). Concentration of each metals at each sampling point was measured and recorded in mgL^{-1}

In Fish

At each sampling point, *Oreochromis niloticus* fish species was used as a biomarker to assess the bio-concentration of metals in the biota. The choice of the fish species was because of its ubuiqutos nature in the River, its ecological and economical importance (Oladunjoye *et al.,* 2015). Each *O. niloticus* caught at each sampling point was labelled appropriately *in-situ*, while the abdominal flesh and inner bone of each point fish species were removed, weighed and dried in an oven set at 105^0C for 24 hours. The dried sample organs were ground and stored in desiccators until digestion.

2g of each oven dried samples were taken into 300ml dry digestion tube. 10ml of nitric acid (HNO_3) was added into each organ sample in a glass tube well labeled which was then placed on heating block/digestion block and heated for 20 minutes at 150°C. The temperature was raised to 230°C, so that cold spots in the heating block were noted and the tubes were rotated for the HNO_3 to be given off uniformly. This continued until when all tubes have reached the dense white fume stage. Meanwhile, this stage was not reached until all the HNO_3 has been given off and digestion continued for 20 minutes until colourless solution was observed. The tubes were removed from the digestion block and allowed to cool for 30 minutes. Then, 10ml of distilled water was added and poured into 50 ml volumetric flask while gently mixed thoroughly. This method was in accordance with USEPA (2007) as described by Agah *et al.* (2009).

Following the digestion, all samples were analyzed for the metals concentrations using Atomic Absorption Spectrophotometer (VGB 210 Bulk Scientific). The AAS was calibrated with standard solutions settings and operational conditions were carried out in accordance with the manufacturers' specifications and instructions. Each metal has its own hollow cathode lamp, the cathode lamp of each metal was inserted into the AAS and the rubber tube connected was then dipped into each organ solution prepared. The value of the concentration of the metals on AAS are read and recorded while the actual concentration of each metal was calculated as suggested by Mansour and Sidky, (2002)

Actual concentration of metal in sample = (mg/g) R× dilution factor

Where;

(mg/g) R - AAS Reading of digest

Dilution Factor - Volume of digest used ∕ Weight of sample digested

Statistical Analysis

Data were subjected to descriptive statistics using SPSS version 20.0. The water physico-chemical parameters, organic matter, organic contents and metal composition in water and fish species were analyzed using One-way Analysis of Variance (ANOVA) expressed in mean and standard error of mean (SEM) (Esenowo and Ugwumba, 2010; Banadda *et al.*, 2011; Lawson *et al.*, 2013; Oladunjoye *et al.*, 2020).

The ANOVA was used to compare the differences between the means and were separated using Duncan Multiple Range Test (DMRT) of variance to determine variations due to sampling error. Mean values were separated using Student-Newman-Keuls (SNK), while P value was set at 0.05. Bioaccumulation factor (BAF) was calculated as the ratio of the concentration of metals in the fish ($Conc._{Fish}$) to the concentration of metals in the water ($Conc._{Water}$). BAF = $Conc._{Fish}$ / $Conc._{Water}$

Results and Discussion

Physical Parameters of the Water

Physical parameters of Majidun River at fifteen sampling points are presented in Table 2. No significant difference ($p > 0.05$) in the levels of water, air temperature and conductivity between the sampling points. Highest water and air temperature were recorded at Point 5, while the least was at Point 15. The river recorded highest and least conductivity at Point 10 and 15 respectively. The least water and air temperature recorded at Point 15 might be due to the volume and constant tidal wave of the lagoon water which give rise to uniform low temperature and increases surrounding atmospheric moisture that further reduces air temperature.

Table 2: Physical Parameters of Majidun River throughout the Sampling Points

	Water Temp. (°C)	Air Temp. (°C)	Conductivity (µScm^{-1})	TSS (mgl^{-1})	Depth (cm)	Elevation (m)
Point 1	28.23±0.36^a	29.38±0.59^a	3554.33±1349.54^a	512.58±88.90^a	427.59±35.36^a	5.67±0.38^b
Point 2	28.52±0.41^a	29.34±0.59^a	3497.23±1276.21^a	506.38±81.95^a	289.77±31.15^b	6.83±0.41^a
Point 3	28.50±0.38^a	29.32±0.59^a	3771.78±1387.01^a	512.34±86.77^a	182.00±24.96^c	5.50±0.34^b
Point 4	28.43±0.35^a	29.34±0.59^a	3543.92±1328.96^a	515.58±86.08^a	201.68±15.86^c	4.50±0.23^c
Point 5	28.70±0.47^a	29.56±0.59^a	3842.08±1208.82^a	479.50±82.99^a	197.72±44.68^c	5.54±0.22^b
Point 6	28.04±0.55^a	28.97±0.54^a	3488.27±1414.36^a	514.36±87.65^a	277.49±87.13^b	6.55±0.16^a
Point 7	27.94±0.48^a	29.28±0.57^a	3537.58±1265.52^a	499.26±83.46^a	131.98±24.22^c	5.83±0.47^b
Point 8	28.40±0.46^a	29.28±0.57^a	3617.75±1288.71^a	492.54±84.27^a	175.87±24.43^c	4.67±0.14^c
Point 9	28.62±0.44^a	29.24±0.57^a	3653.17±1328.48^a	483.39±81.62^a	243.58±45.02^b	5.50±0.15^b
Point 10	28.54±0.52^a	29.25±0.57^a	3470.31±1255.05^a	488.44±85.77^a	237.70±15.61^b	6.00±0.17^a
Point 11	28.41±0.50^a	29.23±0.58^a	3996.03±1435.54^a	470.73±90.42^a	274.53±45.28^b	6.17±0.51^a
Point 12	28.37±0.49^a	29.23±0.58^a	3727.92±1288.43^a	465.24±87.37^a	403.20±11.07^a	5.00±0.43^b
Point 13	28.60±0.51^a	29.14±0.59^a	4017.08±1348.56^a	410.45±92.32^a	170.24±16.12^c	5.50±0.29^b
Point 14	28.24±0.51^a	29.09±0.59^a	3911.08±1305.64^a	220.49±48.47^b	276.88±63.32^b	5.83±0.21^b
Point 15	27.90±0.53^a	29.09±0.59^a	4415.42±1446.50^a	202.53±46.78^b	497.85±99.87^a	4.83±0.32^c
FEPA, 2001	24 – 28	35	10,000			
WHO, 2011			≤ 10,000			

^{abcd}Mean (±Standard error of mean) in the same columns having similar superscripts were not significantly different at P > 0.05
Key: TSS – Total Suspended Solids

Water temperature varied between 27.90±0.53ºC (Point 15) and 28.70±0.47ºC (Point 5) was above Lawson *et al.* (2013) and below higher water temperature reported by Lawson (2011) in mangrove swamps of the neighbouring Lagos lagoon. Air temperature in Majidun River that varied between 28.97±0.54ºC (Point 6) and 29.56±0.59ºC (Point 5) was in conformity with the findings of Emmanuel and Onyema (2007). Although, the water temperature was high, but within acceptable level for survival, metabolism and physiology of aquatic organisms in tropical regions (Bolawa and Gbenle, 2012; Awoyemi *et al.*, 2014). The slight temperature difference at each point might be attributed to constant wave action of the water body, movement by transportation, fishing and load carriage.

Highest conductivity at Point 15 might be due to the salt content of the lagoon which was higher than concentration observed by Ushurine (2013) findings and conductivity in aquatic environment is a function of organic detritus, weed growth and biomass degradation in the benthic layer which provides information on the level of mineralization of the aquatic habitat (Agorye *et al.,* 2014; Udofia *et al.*, 2014). Air temperature, water temperature (except Points 7 and 15) and conductivity values fell within the standard limits of FEPA (2001) and WHO (2011).

Chemical Parameters of the Water

Chemical compositions of Majidun River at the different points are shown in Table 3. No significant difference ($p > 0.05$) in pH, BOD, COD, DO (except at Point 12), TH, TDS, salinity and chloride recorded among each point was observed. Meanwhile, Points 4, 6, 8 and 14 recorded significant higher ($p < 0.05$) SO_4 and BOD, COD and TDS at different sampling points which were above FEPA (2001) and WHO (2011) standard limits, while pH, TH, DO and SO_4 were lower than the standard.

Table 3: Chemical Parameters of Majidun River throughout the Sampling Points

	pH	BOD (mgl^{-1})	COD (mgl^{-1})	DO (mgl^{-1})	TH (mgl^{-1})	TDS (mgl^{-1})	Salinity (ppt)	Cl^- (mgl^{-1})	SO_4 (mgl^{-1})
Point 1	6.37±0.42^a	27.22±4.81^a	304.47±70.53^a	3.70±0.80^b	560.75±93.98^a	1248.49±540.15^a	10.93±2.67^a	43.25±5.95^a	20.15±4.33^b
Point 2	6.26±0.42^a	26.69±6.92^a	306.88±63.81^a	4.32±0.89^b	545.75±96.24^a	1271.51±513.09^a	10.75±2.72^a	48.72±7.69^a	20.56±5.58^b
Point 3	6.31±0.43^a	27.87±7.78^a	295.03±60.55^a	4.18±0.86^b	569.83±100.45^a	1363.53±572.25^a	10.88±2.70^a	46.55±7.18^a	19.37±3.36^b
Point 4	6.31±0.43^a	34.65±7.36^a	296.22±57.62^a	3.61±0.81^b	538.42±97.45^a	1094.42±520.65^a	10.38±2.76^a	49.35±7.85^a	26.01±5.81^a
Point 5	6.03±0.53^a	27.74±3.99^a	292.72±56.64^a	3.97±0.81^b	548.69±95.00^a	1489.00±475.31^a	9.69±2.63^a	44.99±7.08^a	17.72±3.51^b
Point 6	6.78±0.08^a	22.75±6.03^a	332.81±57.46^a	4.02±0.92^b	619.36±110.91^a	987.00±384.53^a	10.75±3.02^a	48.96±8.04^a	25.30±5.50^a
Point 7	6.41±0.43^a	26.41±3.68^a	301.89±58.41^a	3.42±0.78^b	585.83±98.40^a	1262.50±450.66^a	10.19±2.79^a	40.61±6.16^a	19.29±3.67^b
Point 8	6.38±0.43^a	33.10±4.27^a	289.85±64.65^a	3.42±0.79^b	617.42±95.00^a	1184.58±453.09^a	10.01±2.85^a	47.35±6.85^a	24.17±4.98^a
Point 9	6.40±0.44^a	34.62±4.03^a	291.28±62.12^a	3.25±0.78^b	573.50±92.62^a	1135.88±500.78^a	10.16±2.84^a	43.85±6.97^a	20.08±3.66^b
Point 10	6.45±0.44^a	30.09±4.13^a	301.27±58.53^a	3.67±0.79^b	594.33±95.41^a	1016.70±425.36^a	9.95±2.87^a	46.01±6.74^a	21.70±4.84^b
Point 11	6.51±0.47^a	28.43±4.67^a	316.83±54.29^a	3.76±0.77^b	586.08±96.65^a	1325.65±636.40^a	10.22±2.82^a	45.70±7.44^a	19.19±4.02^b
Point 12	6.64±0.46^a	30.73±4.56^a	289.30±58.68^a	6.95±2.98^a	572.17±108.95^a	1153.92±456.58^a	10.47±2.77^a	41.42±8.42^a	20.13±5.56^b
Point 13	6.59±0.46^a	35.57±3.79^a	311.47±53.74^a	4.45±0.88^b	599.42±99.90^a	1242.25±491.91^a	10.23±2.85^a	45.19±7.87^a	21.26±3.69^b
Point 14	6.59±0.46^a	39.69±4.66^a	301.12±46.47^a	4.57±0.91^b	614.92±104.74^a	1152.50±434.43^a	12.18±2.93^a	49.99±8.37^a	24.49±5.81^a
Point 15	6.62±0.47^a	43.14±3.66^a	305.68±43.31^a	4.64±0.93^b	616.58±105.75^a	1384.58±581.00^a	15.48±2.91^a	51.64±8.00^a	17.14±3.80^b
FEPA, 2001	7 - 8.5	10	≤ 5.0	10	1,000	500	≤ 35		500
WHO, 2011	6.5 - 8.5			7.5	≤ 500	≤ 500	≤ 35		≤ 100

^{abcd}Mean (±Standard error of mean) in the same columns having similar superscripts were not significantly different at $P > 0.05$

Keys; BOD – Biochemical Oxygen Demand; COD – Chemical Oxygen Demand; DO – Dissolved Oxygen; TH - Total Hardness; TDS - Total Dissolved Solids; Cl^- – Chloride; SO_4 – Sulphate

Water pH was slightly acidic which contradicted the report of Emmanuel and Oyema (2007) in University of Lagos creek, Nigeria. Meanwhile, it was within the range reported by Tepe and Mutlu (2005) as common for most aquatic ecosystems. The slight acidic nature of the estuary as opined by Ajao and Fagade (2002) may be attributed to the influence of anthropogenic activities on the water body. Meanwhile, Mustapha (2008) opined that moderate alkaline conditions were observed in most freshwater system in Nigeria due to higher volume of water and greater retention of its properties.

DO was significantly higher ($p < 0.05$) at point 12, while point 2, 3, 6, 13, 14 & 15 were within the range reported in Nigerian Rivers (Tisser *et al.*, 2008; Oladunjoye *et al.*, 2020). The DO concentrations might be attributed to the presence of primary producers in high biomass, therefore, enhancing the rates of oxygen production which helps in oxygenating the water column and at the same time reducing respiration by aquatic organisms (Emmanuel and Onyema, 2007; Olele and Ekelemu, 2008). High BOD may be a reflection of the amount of decompositional materials in the river arising from the surrounding rich riparian mangrove vegetation (Emmanuel and Onyema, 2007).

However, PO_4, nitrogen, NO_3-N, NH_4-N, TPH, rainfall, sunshine and humidity values were not significantly different ($p > 0.05$) among the points. PO_4 were significantly ($p < 0.05$) higher and above FEPA (2001) and WHO (2011) limit, while SO_4, NH_4-N, NO_3-N and chloride were below the standard. Meanwhile, TH values were below FEPA (2001) and above WHO (2011) standard limits. Also, organic carbon and organic matter were above WHO (2011) standard limit. Phosphate concentrations in this study align with the findings of Emmanuel and Onyema (2007) and Ndimele (2012), while higher PO_4 was reported by Ibrahim *et al.* (2010) and Atobatele and Olutona (2013) which can lead to eutrophication (Erhunmwunse *et al.*, 2013). NO_3-N concentrations were in line with Ibrahim *et al.* (2010) and Jayalakshmi *et al.* (2011) as he suggested < 1mgl^{-1} for good aquatic life.

Salinity of 9.69±2.63 - 15.48±2.91 ppt recorded tells how much fresh water has mixed with sea water and indicates that Majidun river is a brackish water environment which conform with Lawson *et al.* (2013) findings. It shows increased tidal seawater incursion, coupled with reduced flood, water inflow from associated rivers, creeks and freshwater. These salinities values were typical of creeks, estuaries, lagoons and mangrove swamps that associated with brackish waters in Nigeria (Lawson, 2011; Udoh *et al.,* 2013). Significantly higher TPH might be due to runoff from oil spill area such as Arepo river which link Majidun River at point 7, through commercial transportation system on the water body, local boat by artisanal fishing and heavy motor traffic across the river.

Metal Concentrations in the Water

Metal concentrations in Majidun River are presented in Table 4. No significant difference ($p > 0.05$) in all the metals studied affirmed Bolawa and Gbenle (2012) and Awoyemi *et al.* (2014) findings, but was not in agreement with Badr *et al.* (2013) findings that showed that all metals (except Zn) is significantly high ($p < 0.05$) with values exceeded the acceptable limits. Meanwhile, only Fe, Pb, Cd and Cr were higher than WHO (2011) and USEPA (2007) standard limits. Highest and least concentrations of Fe, Zn, Pb, Cu, Mn, Cd and Cr was found in point 7 and 12, 7 and 6, 7 and 4, 7 and 1, 3 and 11, 7 and 1, 8 and 12 respectively.

Table 4: Metal Composition in Majidun River (mgl^{-1}) throughout the Sampling Points

	Fe	Zn	Pb	Cu	Mn	Cd	Cr
Point 1	0.71±0.11ᵃ	0.04±0.01ᵃ	0.16±0.02ᵃ	0.03±0.00ᵃ	0.15±0.01ᵃ	0.09±0.02ᵃ	7.29±0.11ᵃ
Point 2	0.71±0.10ᵃ	0.04±0.01ᵃ	0.13±0.01ᵃ	0.03±0.00ᵃ	0.15±0.01ᵃ	0.10±0.01ᵃ	7.33±0.11ᵃ
Point 3	0.72±0.09ᵃ	0.04±0.00ᵃ	0.14±0.01ᵃ	0.04±0.00ᵃ	0.17±0.01ᵃ	0.11±0.02ᵃ	7.35±0.13ᵃ
Point 4	0.69±0.10ᵃ	0.03±0.00ᵃ	0.11±0.01ᵃ	0.03±0.00ᵃ	0.15±0.01ᵃ	0.09±0.01ᵃ	7.36±0.12ᵃ
Point 5	0.68±0.09ᵃ	0.04±0.00ᵃ	0.12±0.01ᵃ	0.03±0.00ᵃ	0.15±0.01ᵃ	0.09±0.01ᵃ	7.34±0.10ᵃ
Point 6	0.72±0.11ᵃ	0.03±0.00ᵃ	0.12±0.01ᵃ	0.04±0.00ᵃ	0.14±0.01ᵃ	0.09±0.01ᵃ	7.38±0.14ᵃ
Point 7	0.73±0.10ᵃ	0.05±0.01ᵃ	0.19±0.07ᵃ	0.04±0.00ᵃ	0.15±0.01ᵃ	0.11±0.01ᵃ	7.39±0.12ᵃ
Point 8	0.70±0.10ᵃ	0.04±0.01ᵃ	0.13±0.01ᵃ	0.04±0.00ᵃ	0.15±0.01ᵃ	0.10±0.02ᵃ	7.42±0.11ᵃ
Point 9	0.70±0.09ᵃ	0.03±0.00ᵃ	0.13±0.01ᵃ	0.03±0.00ᵃ	0.14±0.01ᵃ	0.09±0.01ᵃ	7.39±0.10ᵃ
Point 10	0.71±0.10ᵃ	0.04±0.00ᵃ	0.12±0.01ᵃ	0.04±0.00ᵃ	0.14±0.01ᵃ	0.09±0.01ᵃ	7.34±0.10ᵃ
Point 11	0.70±0.09ᵃ	0.04±0.00ᵃ	0.12±0.01ᵃ	0.04±0.00ᵃ	0.13±0.01ᵃ	0.09±0.01ᵃ	7.25±0.08ᵃ
Point 12	0.65±0.11ᵃ	0.04±0.01ᵃ	0.13±0.02ᵃ	0.04±0.01ᵃ	0.15±0.02ᵃ	0.11±0.02ᵃ	6.68±0.61ᵃ
Point 13	0.69±0.09ᵃ	0.04±0.01ᵃ	0.12±0.01ᵃ	0.04±0.00ᵃ	0.16±0.01ᵃ	0.11±0.01ᵃ	7.23±0.11ᵃ
Point 14	0.72±0.09ᵃ	0.04±0.00ᵃ	0.12±0.02ᵃ	0.04±0.00ᵃ	0.15±0.01ᵃ	0.11±0.02ᵃ	7.15±0.14ᵃ
Point 15	0.71±0.09ᵃ	0.04±0.01ᵃ	0.11±0.01ᵃ	0.04±0.00ᵃ	0.14±0.01ᵃ	0.09±0.01ᵃ	7.09±0.13ᵃ
WHO, 2011	0.3	3	0.01	2	0.5	0.01	0.05
USEPA, 2007	0.3	5	0.005	1	0.05	0.005	0.1

[abcd]Mean (±Standard error of mean) in the same columns having similar superscripts were not significantly different at $P > 0.05$
Keys; Fe – iron; Zn – zinc; Pb – lead; Cu – copper; Mn – manganese; Cd – cadmium; Cr – chromium

The fluctuation in the metals concentrations among the points might be due to the ecological condition, type and rate of pollution, bioremediation ability and climatic conditions during that period (Banadda *et al.,* 2011; Nhapi *et al.,* 2011; Bolawa and Gbenle, 2012). Higher concentrations in some metals documented concur with the findings of Lawson (2011), Nhapi *et al.* (2012), Badr *et al.* (2013) and Fafioye *et al.* (2017) which might be due to intense anthropogenic activities such as washing, swimming, bathing, transportation and waste disposal.

Metal Concentrations in the Fish Species

No significant difference ($p > 0.05$) was found in Pb and Cr concentration in *Oreochromis niloticus* of Majidun River as presented in Table 5. On the other hand, significantly higher ($p < 0.05$) Fe was in fish at Point 2, followed by Points 9, 10 and 7 respectively. Zn was not significantly different ($p > 0.05$) in the fish between Points 2, 7, 14 and 15, but was significantly higher ($p < 0.05$) than other points. Cd in *O. niloticus* was significantly ($p < 0.05$) higher at point 7, while Cu and Mn were both significantly ($p < 0.05$) higher in the fish at Points 7 and 15. All the metals in *O. niloticus* at each point were lower than standard regulatory limits of the WHO (2011) and USEPA (2007). Several findings around the world water bodies have shown different fish species to have accumulated varying metal concentrations below (Mol *et al.,* 2010; Olowu *et al.,* 2010) and above (Shinn *et al.,* 2009; Alinnor and Obiji, 2010; Oladunjoye *et al.,* 2020) standard permissible limits.

Generally, *O. niloticus* accumulate metals in descending order as Fe > Zn > Cr > Pb > Mn > Cu > Cd which was in line with George *et al.* (2013) and Fafioye *et al.* (2017) researches on different Nigerian water fish species. Variability and significant difference in the metals of the fish species may be as a result of differences in the animal diet and habitat as opined by Kim *et al.* (2009 and 2010) and Kamaruzzaman *et al.* (2010) which suggest a relationship exist among metal concentrations and several other intrinsic factors in fish such as size, genetic composition and age.

Bioaccumulation Factor

Bioaccumulation factors of the metals in both the fish and water samples at each point are shown in Table 6. Zinc recorded highest bioaccumulation factor at each point, which was followed by Fe, Cd and Cu which were greater than one (> 1), while, Pb, Mn and Cr were lower than one (< 1).

Table 5: Metals Concentration (mg/g) of *Oreochromis niloticus* from Majidun River, Nigeria in Each Points

	Fe	Zn	Cu	Pb	Cd	Cr	Mn
Point 1	1.26 ± 0.14^{c}	0.43 ± 0.07^{c}	0.05 ± 0.01^{b}	0.08 ± 0.01^{a}	0.004 ± 0.00^{b}	0.20 ± 0.03^{a}	0.06 ± 0.01^{b}
Point 2	6.14 ± 0.95^{a}	1.23 ± 0.16^{a}	0.07 ± 0.01^{b}	0.10 ± 0.01^{a}	0.006 ± 0.00^{b}	0.37 ± 0.05^{a}	0.09 ± 0.01^{b}
Point 3	1.52 ± 0.18^{c}	0.64 ± 0.08^{c}	0.03 ± 0.01^{c}	0.06 ± 0.01^{a}	0.004 ± 0.00^{b}	0.20 ± 0.03^{a}	0.06 ± 0.01^{b}
Point 4	1.81 ± 0.19^{c}	0.75 ± 0.12^{b}	0.03 ± 0.01^{c}	0.08 ± 0.02^{a}	0.005 ± 0.00^{b}	0.33 ± 0.05^{a}	0.07 ± 0.01^{b}
Point 5	1.75 ± 0.19^{c}	0.76 ± 0.11^{c}	0.06 ± 0.01^{b}	0.10 ± 0.03^{a}	0.005 ± 0.00^{b}	0.30 ± 0.04^{a}	0.09 ± 0.01^{b}
Point 6	2.27 ± 0.56^{c}	0.93 ± 0.16^{b}	0.04 ± 0.01^{b}	0.10 ± 0.03^{a}	0.006 ± 0.00^{b}	0.24 ± 0.03^{a}	0.08 ± 0.01^{b}
Point 7	3.62 ± 0.48^{b}	1.36 ± 0.18^{a}	0.09 ± 0.01^{a}	0.15 ± 0.04^{a}	0.011 ± 0.00^{a}	0.36 ± 0.03^{a}	0.13 ± 0.01^{a}
Point 8	1.57 ± 0.32^{c}	0.62 ± 0.12^{b}	0.06 ± 0.01^{b}	0.10 ± 0.02^{a}	0.005 ± 0.00^{b}	0.32 ± 0.04^{a}	0.08 ± 0.01^{b}
Point 9	3.82 ± 0.77^{b}	0.82 ± 0.14^{b}	0.06 ± 0.01^{b}	0.09 ± 0.01^{a}	0.005 ± 0.00^{b}	0.31 ± 0.05^{a}	0.09 ± 0.01^{b}
Point 10	3.68 ± 0.91^{b}	0.97 ± 0.14^{b}	0.05 ± 0.01^{b}	0.08 ± 0.01^{a}	0.005 ± 0.00^{b}	0.23 ± 0.03^{a}	0.07 ± 0.01^{b}
Point 11	1.80 ± 0.17^{c}	0.65 ± 0.11^{b}	0.02 ± 0.00^{c}	0.06 ± 0.01^{a}	0.004 ± 0.00^{b}	0.29 ± 0.04^{a}	0.05 ± 0.01^{b}
Point 12	1.99 ± 0.19^{c}	0.84 ± 0.12^{b}	0.05 ± 0.01^{b}	0.12 ± 0.03^{a}	0.006 ± 0.00^{b}	0.34 ± 0.05^{a}	0.09 ± 0.01^{b}
Point 13	1.71 ± 0.38^{c}	0.81 ± 0.13^{b}	0.05 ± 0.01^{b}	0.07 ± 0.01^{a}	0.005 ± 0.00^{b}	0.21 ± 0.03^{a}	0.07 ± 0.01^{b}
Point 14	2.98 ± 0.57^{c}	1.10 ± 0.18^{a}	0.06 ± 0.01^{b}	0.14 ± 0.04^{a}	0.008 ± 0.00^{b}	0.33 ± 0.03^{a}	0.10 ± 0.01^{b}
Point 15	2.93 ± 0.47^{c}	1.11 ± 0.16^{a}	0.08 ± 0.01^{a}	0.14 ± 0.04^{a}	0.009 ± 0.00^{b}	0.37 ± 0.04^{a}	0.12 ± 0.01^{a}
WHO, 2011		150		1.5	0.2		2.5
USEPA, 2007	0.01	5	1	0.05			0.05

[abcd]Mean (±Standard error of mean) in the same columns having similar superscripts were not significantly different at $P > 0.05$
Keys; Fe – iron; Zn – zinc; Pb – lead; Cu – copper; Mn – manganese; Cd – cadmium; Cr – chromium

Table 6: Metal Bioaccumulation Factors (mg/g) in Majidun River, Nigeria in Each Point

	Fe	Zn	Pb	Cu	Mn	Cd	Cr
Point 1	1.77	10.31	0.31	2.67	0.00	2.16	0.01
Point 2	8.64	27.83	0.55	3.25	0.07	3.64	0.01
Point 3	2.12	16.71	0.21	1.71	0.00	1.78	0.01
Point 4	2.63	21.93	0.28	2.67	0.00	3.67	0.01
Point 5	2.58	19.00	0.49	3.42	0.00	3.42	0.01
Point 6	3.17	27.68	0.34	2.82	0.07	2.72	0.01
Point 7	4.94	30.22	0.47	3.68	0.07	3.32	0.02
Point 8	2.25	14.87	0.46	2.86	0.07	3.17	0.01
Point 9	5.47	24.62	0.47	2.92	0.00	3.41	0.01
Point 10	5.17	21.95	0.42	2.29	0.07	2.58	0.01
Point 11	2.57	17.33	0.16	1.68	0.00	3.34	0.01
Point 12	3.08	21.93	0.39	3.00	0.07	3.24	0.01
Point 13	2.48	19.42	0.41	1.91	0.00	1.91	0.01
Point 14	4.13	25.40	0.49	3.81	0.07	3.14	0.01
Point 15	4.11	25.11	0.71	4.00	0.07	3.97	0.02

Keys; Fe – iron; Zn – zinc; Pb – lead; Cu – copper; Mn – manganese; Cd – cadmium; Cr – chromium

Conclusion

Majidun River showed marked trends of physico-chemical variations across the sampling points. Salinity varied across each point in close proximity to Lagos Lagoon which categorizes Majidun River from low to mid brackish water. Points 4, 5, 6, 7 and 8 showed high pollution index, while Point 7 is the most polluted. Points 4 and 7 were inflow into Majidun River from a tributary of River Ogun and Arepo River. Majidun River had been polluted by natural pollution sources such as urban runoffs, neighbouring inflow water and anthropogenic pollution such as domestic wastes, littering, oil spillage, organic wastes (faecal matters) and commercial water Transportation by boat, construction, heavy motor traffic and uncontrolled fishing methods among others as evident at point 4 and 7.

High metal concentration in tissues of *O. niloticus* was attributed to the trophic characteristics of the species and considered to be suitable as bio-monitors of the trace metals. It affirmed that fish is considered as a good bio-indicator of metal pollution in ecosystem and marked relationship among metal contents. Therefore, metal concentrations in the fish species found to be within the safe limits for human consumption should be used for future monitoring programs and to evaluate the metal pollution in the River water

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