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Specific physicochemical parameters influence on the plankton structure in agbarho-ogbe-ijoh stretch of Warri River, Nigeria

Kate Isioma Iloba*, Christiana Ebikaboere Akpoyibo

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

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Key words: Physicochemical parameters, Phytoplankton, Zooplankton, Diversity, Factor analysis, Warri River

Abstract

The continuous discharge of effluents into Warri River, impacts on its water quality parameters as well as plankton species which requires commensurate surveillance. This study focuses on its physicochemical characteristics and their influence on plankton composition and abundance. The surface water samples and plankton collected monthly from June to November 2014 were analyzed using standard methods. The physicochemical parameters showed variations among the stations. The ANOVA results revealed that water temperature, transparency, turbidity, TDS, conductivity, pH, acidity, Dissolved Oxygen and phosphate were significantly different (P <0.05) among the studied sites. A total of 849 plankton species identified; 814 species were phytoplankton consisting of four groups (Bacillariophyta> Chlorophyta> Euglenophyta> Cyanophyta, arranged in order of dominance. While zooplankton had 35 species grouped into 5 groups; Rotifera> Copepoda> Protozoa> Cladocera> Arachnida, in order of dominance. Pearson correlation revealed a significant correlation between different Plankton species population and some parameters (p<0.05). The principal component analysis labelled acidity, organic load, mineralization, nutrient, and organic pollution as influential factors governing plankton abundance in the studied area. These factors identify with materials from industries and human activities along the river, which results in the alteration of plankton composition, particularly *Melosira granulata* (Ehrenberg) Ralfs,1861. Inferred biological indicator of the water body. Diversity indices ranged from 0.28 to 1.39; Station 2 had the highest (1.39) and Station 1 the lowest species richness, a highly polluted river.

***Corresponding Author:** Kate Isioma Iloba ✉ kisyiloba@gmail.com

Introduction

Wastes and effluents disposal through the ways of the water has challenged humanity and water resources. This spoliation consequently results in the deterioration of the water resources (Renuka *et al*., 2014). The decline in water quality impacts on the physicochemical parameters and the biological components. Rivers are usually the recipients of wastes (Serajuddin *et al*., 2019).

Warri River, like any other river in developed and industrialized towns and cities, has suffered severe human-impacts since oil exploration in the area. Oil exploration in Warri attracted human settlements, so, the subsequent generation of huge domestic waste from surrounding homes and markets into the rivers increased by the day (Akogbeto *et al*., 2017). Moreover, such convergences are not without consequences once established. These human establishments ensure continuous production of discharges and receipt into the river systems. Thus it is paramount that these water bodies undergo continuous monitoring to forestall ecological-crisis and loss of water services as well as their option values (Malaran *et al*., 2019). These crises deteriorate the abiotic and biotic health of the river (Aghoghowvia, 2011; Gupta *et al*., 2017), and on the health of animals and human life depends on them. Plankton is a necessary biological indicator tool to monitor water quality due to their position in the food chain (Onyema, 2013). These organisms respond quickly to environmental changes in several ways that impact on their survival and growth rate, resulting in population decline and disappearance. The disappearance and resilience of some species or on their reproductive stages (Edward and Ugwumba, 2010) thus, fulfilling their attributes as environmental, biological indicators for water quality monitoring. Besides this surveillance attributes, plankton is crucial energy-anchors for lotic systems, a strain on anyone string transcends the entire ecosystem.

In aquatic ecosystems, the interactions between the non-living components (environmental factors) and living components (organisms) are crucial in the management strategies of the ecosystem. Studies have that variations in environmental factors (physicochemical parameters) have a significant influence on the survival of the organism (in this case; plankton). Thus, determining their occurrence, distribution and abundance in any water body (Haroon and Hussain, 2017).

The Warri River in the Delta State of Nigeria is a significant source of water for both industrial and domestic purposes. Despite its importance, effluents are discharged continuously into the river by the timber industries, companies and markets along the river course. Warri River because of its importance has attracted hydrological investigations (Arimoro *et al.,* 2007; Aghoghovwia, 2011; Idise *et al*., (2012), in the past but with continuous discharge of effluents into the water, there is need for periodic assessment of its water quality and the effects on the plankton characteristics. The present study evaluates the plankton of the Agbarho-Ogbe-Ijoh stretch of Warri River as the impact of the anthropogenic activities in the River for future sustainable management.

Materials and methods

Study Area

All studied stations were situated along the Agbarho-OgbeIjorh stretch of Warri River within latitude 5°211N to 6°001N and Longitude 5°241 to 6°021E (Fig.1). The River flows through the adjourning mangrove swamp forest area of the southern part of Nigeria, with the drainage and catchment area rich in decaying organic matter and humus. This river is about 150km long and occupies an area of about 255sqkm (NEDECO, 1961). Essential towns in this River stretch are Udu, Enerhen, Igbudu, Ovwian and Aladja, Warri ports and primary Warri market. Beyond the Warri port, the main channel of the river joins the Forcados estuary, which empties into the Atlantic Ocean. The relevant human activities in this river are, commercial sand dredging, fishing, washing, transportation, dumping site for sewage and refuse.

Sampling Stations

The three Stations (Agbarho, Udu Bridge and Ogbe-ijoh) were chosen to represent the different ambient and ecological variations within the river, to better understand the effects of natural and anthropogenic factors on the water quality and plankton biodiversity of the river. The station I upstream at Agbarho is a reference with negligible human activities. However mid-way into the research, a slaughterhouse was enacted a few kilometres from the sampling station. The vegetation in this Station fern plants (*Pentium puerperium*), oil palm trees (*Elaeis guineensis,* Jacq), *Azolla sp*. Station 2 is under Udu Bridge close to a sawmill industry which continuously discharges wood waste into the river. The vegetation in this Station is water hyacinth *Eichhornia crassipes* and oil palm *Elaeis guineensis* Jacq. Station 3 is at Ogbe-ijoh market with various activities including commercial dredging, fishing, transportation, washing to mention but a few. This Station becomes more of a dumping site for domestic, industrial and sewage effluents with high dense *Eichhornia crassipes* (von Martins) Solms vegetation cover.

Sample Collection and Analysis

Water Analysis

Two litres water samples were collected between June and November 2014 and analyzed using standard methods. Some environmental parameters determined in situ; Temperature was measured using Mercury-In- Glass thermometer. Transparency was by using a Secchi disk. Turbidity, Total dissolved solids, conductivity and pH were measured using Nephelometer (Model AIPL-568), Electrometric (Model TDS-3), Hanna conductivity meter (Model DOB-303A) and a pH meter (Model DDB-303A) respectively. While other variables were determined following (APHA, 1998); Alkalinity and Acidity were determined using titration method. Dissolved Oxygen and Biochemical Oxygen Demand were estimated using Winkler's method. Carbon dioxide, Chloride, Phosphate, and Potassium were determined using Spectrophotometer (Model AJICO3).

Plankton Analysis

For Plankton, 25µm mesh size plankton net towed against the water current for about 10 minutes samples, hauled in and samples preserved with 4% formalin. Plankton samples were examined and identified consulting different identification guides, including Jeje and Fernando (1986); Shiel (1995); Wehr and Sheath, 2003. The plankton density then expressed as the number of individuals per sample volume (Ind/l).

Statistical Analysis

A one-way Analysis of Variance test was performed to assess the monthly variations in the Physico-chemical parameters among the Stations using Statistix 8 statistical software. Statistix 8 was also used for Pearson's Correlation analyses, to determine the relationship between the physicochemical variables and the plankton abundance. Furthermore, Factor Analysis was applied to evaluate the relationships between the physicochemical and plankton abundance to determine the principal components influencing the water quality of the Warri River. All statistical analysis was performed using Statistix 8. Diversity indices such as Shannon-Weiner Index (H), Evenness (E), and Jaccard's coefficient (Cj), were used to determine the diversity of plankton.

Results and discussion

Values of the physicochemical parameters of the studied stations of the Warri River are in Table 1. The status of the air (22.00°C-31.00°C) and water temperatures (23.00-39.00°C) fluctuated within the ranges known for tropical rainforest (**Iloba, 2012**). As expected, the water temperature lagged behind the air temperature (Iloba and Ruejoma, 2014). The temperature range recorded in this study is still within the permissible limit of 21-32°C recommended for aquatic life in the tropical environment. However, water temperature fluctuations varied significantly among stations ($P < 0.05$), due to differences in geographical locations

The river's transparency was low (26.04-57.15cm) with a Grand mean of 44.94cm due to the relatively high turbidity (28-58NTU) particularly in effluentreceived Stations, is higher than the WHO's reference value (25NTU) besides the lower limit in station 1. Transparencies and turbidities were the only parameters that differed significantly among the stations ($p<0.05$), revealing stations laden with differences suspended solids loads (Mihaljevic *et al.*, 2010). The significant transparency and turbidity values revealed the diverse human activities observed in the stations and influences on the biota of the river (plankton). These twos are known organic load indicators of colloids, suspended solids in effluents of industries, market wastes and drainage channels into the river (Aghoghovwia, 2011; Akogbeto *et al.*, 2017). The turbidity range of 28-58 NTU in this present study was higher than 4.5-18.5 NTU of Arimoro *et al.*, (2008) in Warri River, a notification of marked deterioration of Warri River.

The stations were highly oxygenated (mean; 7.50mg/l) despite the associated high biological oxygen demand (2.97mg/l), characterizing the lotic status of the river. The extensive aeration of the river helps compensate for the impact of the significant BOD levels (0.06-8.50mg/l), with high variability (82.34%) among the stations. The BOD values in this study revealed a moderately polluted river as the BOD values are within the reference range of 2-9 mg-1 (USEPA, 1997). In addition to BOD, other organic-pollution associated parameters; conductivity, dissolved oxygen, phosphate, carbon dioxide (Table 1) are highly variable (CV>40%), indicating high bacterial activities and organic pollution of Warri River (Serajuddin *et al.*, 2019).

Table 1. Physicochemical Parameters of the stations of Warri River from June-Nov 2014. Values of Mean, Standard error, minimum and maximum are given in parentheses.

Parameters	Station 1	Station 2	Station 3	Mean	CV	F	P	WHO
Air Temperature (˚C)	24.55 ± 1.01 (22.00 - 29.00)	25.13 ± 1.11 (23.00 - 30.10)	25.55 ± 1.18 (23.20 - 31.10)	25.13	10.50	0.23	0.81	
Water Temperature (˚C)	24.82 ± 0 .61 (23.00 - 27.00)	25.73± 0 .68 (24.00 - 28.70)	26.07 ± 0.67 (24.00 - 29.00)	25.52	6.26	0.98	0.39	227.00
Transparency (cm)	54.39 ± 0.89 (52.07 - 57.15)	45.62 ± 2.83 (40.64 - 49.28)	34.82 ± 2.82 (26.04 - 42.79)	44.94	9.99	28.60	0.00*	
Turbidity (NTU)	4.67 ± 1.58 (8.00 - 28.00)	31.02 ± 4.47 (19.00 - 48.00)	44.50 ± 6.05 (18.00 - 58.00)	33.39	28.12	4.30	0.04*	25.00
TDS (.mgL^{-1})	12.50 ± 3.92 (4.00 - 31.00)	18.83 ± 2.89 (12.00 - 31.00)	9.17 ± 2.27 (1.00 -16.00)	13.50	56.32*	2.50	0.12	1000
Conductivity (μScm^{-1})	27.29± 8.08 (9.85 - 65.20)	40.58 ± 6.03 (26.20 - 66.50)	20.67 ± 4.49 (4.82 -34.50)	29.51	54.05*	2.53	0.11	900
pH	5.59 ± 0 .00(5.59 - 5.59)	5.59 ± 0.00 (5.59 - 5.60)	5.59 ± 0.00 (5.59 - 5.60)	5.59	0.06	1.15	0.34	6. 6.5-8.0
Alkalinity (mgL^{-1})	13.33 ± 3.99 (4.00 - 30.00)	17.00 ± 4.46 (4.00 - 36.00)	18.33 ± 3.3 (10.00 - 32.00)	16.22	60.85*	0.43	0.85	100
Acidity(mgL^{1})	177.33 ± 14.48 (120.00 -204.00)	260.33 ± 67.81 (14.00 - 488.00)	224.67 ±25.77 (176.00-346.00)	228.00	38.27	2.16	0.15	
Dissolved Oxygen (mgL^{-1})	9.78 ± 1.39 (7.70 – 15.30)	7.80 ± 0.76 (6.30 - 11.00)	4.70± 0.94 (4.90-15.30)	7.50	41.19*	1.05	0.37	5
Biochemical Oxygen Demand (mgL^{-1})	1.04 ± 0.55 (0.06 – 8.50)	2.08 ± 0.68 (0.70-8.10)	5.78 ± 0.91 (3.30-8.50)	2.97	82.39*	0.26	0.76	5
Phosphate (mgL^{-1})	0.04 ± 0 .03 (-0.08 - 0.11)	0.33 ± 0.26 (0.04 - 1.63)	0.16 ± 0.09 (-0.03 - 0.62)	0.18	176.41*	0.84	0.45	≥75
Carbondioxide(mgL^{-1})	0.01 ± 0 .05 (-0.09 - 0.24)	0.06 ± 0.05 (-0.05 - 0.22)	0.06 ± 0 .07 (-0.04 - 0.38)	0.04	353.25*	0.24	0.79	
Chloride (mgL^{-1})	0.14 ± 0.04 (-0.01 - 0.25)	0.11 ± 0.04 (-0.01-0.25)	0.14 ± 0 .03 (0.07 - 0.245)	0.13	71.06*	0.24	0.79	
Potassium ($mgL^{-)}$)	0.14 ± 0 .03 (0.02 - 0.20)	0.10 ± 0 .07 (-0.15 - 0.32)	0.15 ± 0.03 (0.06 - 0.22)	0.13	85.04*	0.29	0.75	
Salinity(‰)	0.28 ± 0 0.07 (-0.06 - 0.42)	0.23 ± 0.08 (-0.05 - 0.41)	0.29 ± 0.06 (0.10 - 0.41)	0.21	81.03*	0.20	0.82	2.50

*Significant at P<0.05)

The conductivity values in this study were relatively low (4.82 to 66.50µ Scm-1), lower than earlier reports in Warri River (Arimoro *et al.*, 2008; Aghoghovwia, 2011) but higher than Iloba and Ruejoma, (2014) and Okoye and Itejere, (2014). The highest conductivity values in Station 2 could be as a result of the sawmill waste discharged into the river. However, the present study conductivity values were significantly below the WHO limit of 900µ Scm-1. The chloride level in this research though low, but still within the acceptable level of 0-16mg/L. Inherently, the chloride values within 0-16mg/l are considered acceptable level, 17-36; suspicious and >36 problematics (Iloba and Ruejoma, 2014). The low chloride in the river is an indication of no accumulative pollutants in the river, due to its lotic nature. The low carbon dioxide values varied rapidly among the studied stations. Carbon dioxide variability in this study could be due to the plankton photosynthetic activities and biological degradation of organic loads. These by-products as well as the influx of humic substances from the markets, sawmills and titanic rural to urban shift and other anthropogenic activities, resulted to the acidic nature of this water body (Akogbeto *et al.*, 2017). The very low alkalinity and high acidity values in this study modulate the protons and anions from the effluents and waste in the river. These neutralization tendencies underpin the river's buffering capacity, which drives the water quality parameters within permissible limits (Iloba and Edeghagba, 2019).

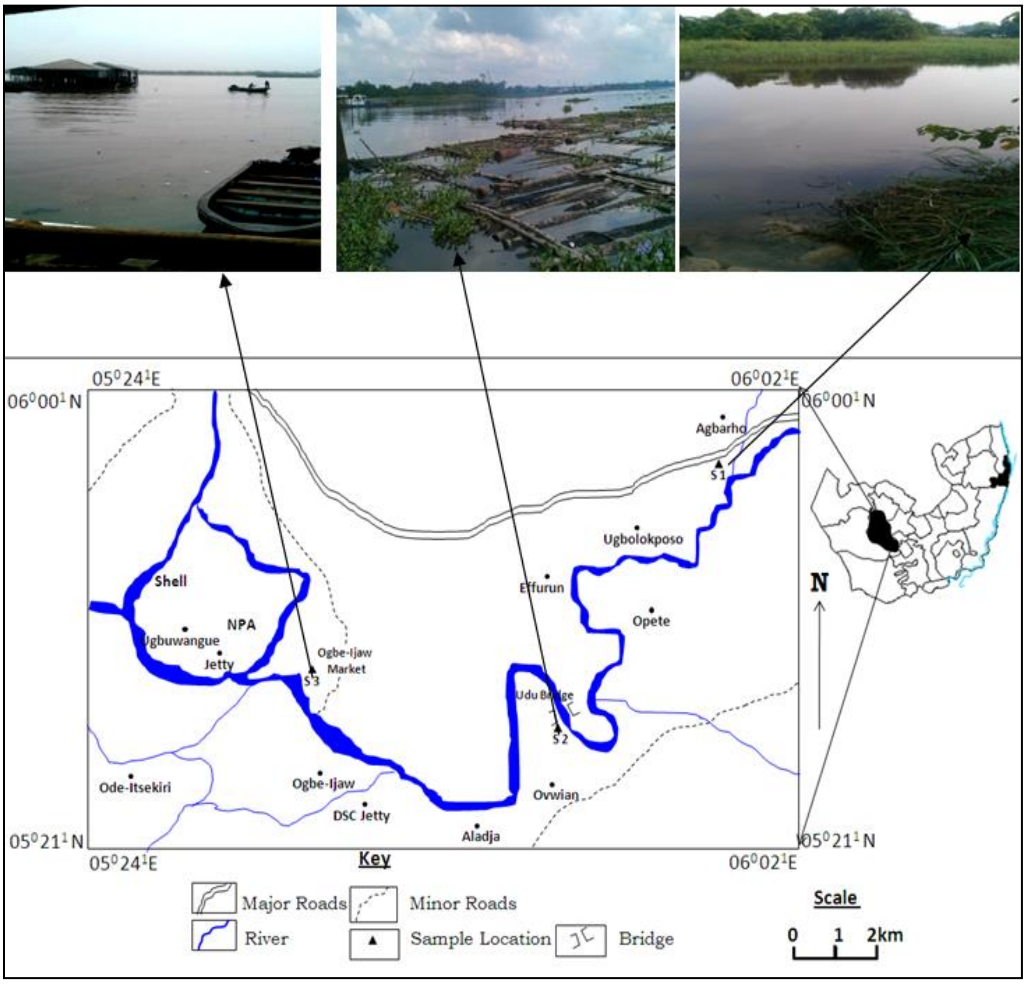

Fig 1. Map Showing Warri River with Sampled Locations.
SOURCE: Ministry of Land and Survey, Asaba, Delta State (Adapted From Nigeria Ports, Warri 2005).

The critical nutrient compound; Phosphate in this study (0.08-1.63mgL-1) agreed with the findings of Arimoro *et al.*, (2007) (0.009 and 1.88mgL-1) and those of Nigerian waters receiving waste from domestic and industrial activities (Adebisi, 1981; Iloba and Ruejoma, 2014). The study encountered low Potassium and salinity values contrary to reports of Akindele (2013) (2.51-9.09mgL-1) in Tiga Lake, Kano, Nigeria and Arimoro *et al.*, (2008) (13.65-52.0%) in Warri River.

Plankton Composition

From the plankton analyses, 849 individual naturally grouped into phytoplankton constituting; 814 individuals and 35 zooplankton individuals.

The Phytoplankton assemblage composed of 814 individuals made of 49 genera and 94 species. These constituted four major taxa, namely, Bacillariophyta (89.80%), Chlorophyta (5.53%), Euglenophyta (2.57%), Cyanophyta (2.09 %) (Table 2).

Among the Bacillariophyta (86.10%/ 89.80%) the *Melosira granulata* var. *curvata* (Grunow) contributed 56.16% of the total phytoplankton abundance, primarily from June samples, after that a notable declined subsequently, period coincided with the rains. Outside June, other records were low and sparse (Table 2 and Fig. 2a), probably due to the dilution factor as a result of rain (Malaran *et al.*, 2019). The Chlorophyta; *Chlamydomonas globosa* J.W. Snow (1.23%) dominated the group. Low desmids are synonymous with low productivity in the river, the reason for the insignificant number of Spirogyra in this study (Onyema, 2013). *Euglena proxima* P.A. Dangeard and *Strombomonas* Deflandre co-dominated among the euglenoids with 0.61% each of the total phytoplankton abundance while Oscillatoria brevis Kutzing ex Gomont dominated the blue-greens accounting 0.49% of the total algae abundance. The high oxygenation is attributable to the oxygen-deficient loving euglenoids. The inhibition of the growth of the Cyanophytes and Euglenoids in the system is principally due to the river's acidic nature and high flow velocity (Edward & Ugwumba, 2010).

Table 2. Checklist, Distribution, Percentage Composition and Abundance of Plankton in Stations sampled.

S/N	Species	Station 1	Station 2	Station 3	Total	Total Plankton Abundance (%)
1	PHYTOPLANKTON					
	BACILLARIOPHYTA	+	-			
	Achnanthes sp			-	2	0.24
2	*Amphora* sp	-	+	-	1	0.12
3	*Asterionella* sp	-	-	+	4	0.47
4	*Aulacoseira* sp	+	++	+++	27	3.18
5	*Biddulphia* sp	-	-	+	1	0.12
6	*Coscinodiscus* sp	-	+	+	4	0.47
7	*Denticula* sp	++	++	+++	28	3.30
8	*Diatoma* sp	+	-	-	1	0.12
9	*Eunotia* sp	-	+	-	1	0.12
10	*Fragillaria* sp	+	+	+	5	0.59
11	*Gomphomena* sp	-	-	+	2	0.24
12	*Gyrosigma* sp	+	-	-	4	0.47
13	*Hyalodiscus* sp	+	+	+	3	0.35
14	*Melosira* sp	++++++++++++	++++	++++	563	66.31
15	*Navicula* sp	+	++	+	8	0.94
16	*Pinnularia* sp	+++	++	+	22	2.59
17	*Pleurosigma* sp	-	-	+	1	0.12
18	*Stephanodiscus* sp	-	+	+	3	0.35
19	*Surirella* sp	+++	+++	++	39	4.59
20	*Strauroneis* sp	+	+	-	3	0.35
21	*Synedra* sp	-	+	+	3	0.35
22	*Tabellaria* sp	+	-	+	5	0.59
23	*Thalasiosira* sp	-	-	+	1	0.12
		584	70	77	731	86.10

Table 2. Cont.

S/N	Species	Station 1	Station 2	Station 3	Total	Total Plankton Abundance (%)
1	CHLOROPHYTA	-				
	Chara		-	+	1	0.12
2	*Chlamydomonas* sp	+	+	+	10	1.18
3	*Closterium* sp	-	+	+	12	1.41
4	*Eudorina* sp	+	-	+	7	0.82
5	*Haematococcus* sp	+	-	-	1	0.12
6	*Oedogonium* sp	-	-	+	1	0.12
7	*Pandorina* sp	-	+	-	1	0.12

S/N	Species	Station 1	Station 2	Station 3	Total	Total Plankton Abundance (%)
8	*Pleodorina* sp	+	-	-	2	0.24
9	*Roya* sp	+	+	-	4	0.47
10	*Scenedesmus* sp	-	+	-	1	0.12
11	*Selenastrum* sp	-	-	+	1	0.12
12	*Spirogyra* sp	-	-	+	1	0.12
13	*Volvox* sp	-	-	+	2	0.24
14	*Zygnema* sp	-	-	+	1	0.12
		13	11	21	45	5.32
1	CYANOPHYTA	+	+		3	0.35
	Calothrix sp			+		
2	*Lyngbya* sp	+	-	-	1	0.12
3	*Microcystis* sp	-	-	+	1	0.12
4	*Nostoc* sp	-	-	+	1	0.12
5	*Oscilatoria* sp	+	+	+	7	0.82
6	*Rivularia* sp	+	+	-	3	0.35
7	*Spirulina* sp	-	-	+	1	0.12
		4	7	6	17	2.00
1	EUGLENOPHYTA					
	Euglena sp	+	+	+	12	1.41
2	*Lepocinclis* sp	-	-	+	1	0.12
3	*Phacus* sp	-	+	+	2	0.24
4	*Strombomonas* sp	+	+	-	5	0.59
5	*Trachelomonas* sp	-	-	+	1	0.12
Total no of phytoplankton		7 608	8 96	6 110	21 814	2.48

Table 2. Cont.

S/N	Species	Station 1	Station 2	Station 3	Total	Total Plankton Abundance (%)
	ZOOPLANKTON					
	ARACHNIDA					
1	*Water mite*	+	-	-	1	0.12
	COPEPODA	+	+	+	4	0.47
1	*Nauplius larva (Juvenile)*					
2	*Tropocyclops prasinus (Fischer, 1860)*	-	+	+	4	0.47
		1	4	3	8	0.94
	PROTOZOA					
1	*Difflugia* sp	-	-	+	1	0.12
3	*Tintinidium* sp	-	-	+	2	0.24
4	*Tintinnopsis* sp	+	-	-	1	0.12
5	*Vorticella* sp	-	-	+	1	0.12
		1	0	5	6	0.72
	ROTIFERA					
1	*Keratella* sp	+	-	-	3	0.35
2	*Lecaneglypta*	+	-	+	2	0.24
3	*Polyarthra* sp	+	-	+	5	0.59
4	*Proales* sp	+	-	-	1	0.12
5	*Rotaria* sp	+	-	+	5	0.59
6	*Testudinella* sp	-	-	+	1	0.12
7	*Trichocercabi cristata*	-	-	+	1	0.12
		11	0	7	18	2.14
Total no of zooplankton		14`	5	16	35	4.12
Grand Total no of Plankton		622	101	126	849	

Key: + denotes species number 1-5, ++ (6-10), +++ (1-15), ++++ (16-20), +++++ (21-25), ++++++ (26-30), +++++++ (31-35), ++++++++ (36-40), +++++++++ (>40).

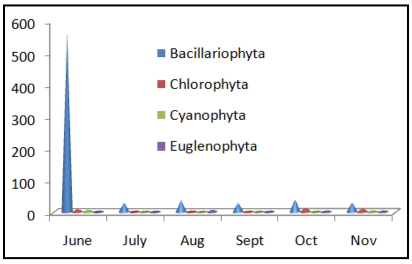

Fig. 2.a. Phytoplankton Monthly abundance in the studied area.

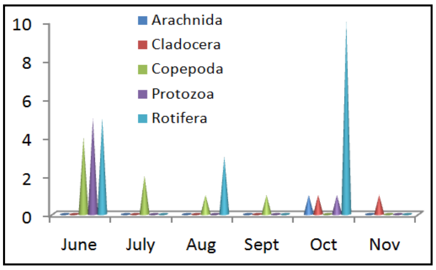

Fig. 2.b. Zooplankton monthly abundance in Warri River, June-Nov, 2014

In the present study, the algal status of the Warri River is low. This contrary to previous records as well as with other Nigerian and African freshwater ecosystems, a sign of an impaired water body, although the dominance of diatoms as tropical waters characteristics remained (Ali *et al.*, (2013); Nwoji *et al.*, 2010 and Anago *et al.* 2013). The domination of Bacillariophyta (particularly *Melosira granulata*) associated with tropical temperature regime and the river's nutrient status, inflows from fertilized farmlands and municipal effluents, evident from the highly significant positive correlation between the Bacillariophyta, temperature and phosphate (Sarr *et al.*, 2019).

Four groups of zooplankton in the present study include Rotifera (51.43%), Copepoda (22.86%), Protozoa (17.14), Cladocera (5.71%) and Arachnida (2.86%), were very poor and sparse in abundance (Table 2). No zooplankton records in station 2 except *Copepoda, Nauplia* in few samples. The present study noted that the Warri River is not rich in zooplankton. This paucity was not consistent with other Nigerian waters and African freshwater ecosystem, although identifying with the predominance of Rotifera (Fig. 3b). The paucity of zooplankton among the studied stations with the lotic nature of the water body (Iloba, 2012) and the dominance of Rotifers in the Warri River show one of the characteristics features of Nigerian aquatic ecosystem. Rotifers dominance is attributable to their opportunistic nature and reproduced under a broad temperature spectrum (Fishar *et al.*, 2019). Whiles the dominance of littoral-rotifers; *Polyarthra* sp (Ehrenberg,1834*)* and *Rotarianeptunia* (Ehrenberg,1832), and identifies the shallow nature of the river and substrates/ attachments generated from deposits into the system as well as the extensive water hyacinth *Eichhornia crassipes* (Fig. 1)

Correlation Matrix

The control of the environmental variables on the plankton species during the study is in Tables 3 and 4, 5 and 6. The tables revealed high correlation coefficients ($p<0.05$), signified their profound influence on the taxa, however, at varying degrees. The diatoms, desmids and blue-greens were the most influenced, $r > 0.80$. The study revealed that certain environmental variables showed a positive correlation with various taxa and contrariwise, too (Table 3). The correlated variables suggest climatic (Jiyenbekov *et al.*, 2019) and acid factor, mineralization (Afonina *et al.*, 2018), slits and organic load parameters. These are suggestive of effluents impact on the plankton (Akogbeto *et al.*, 2017; Jiyenbekov *et al.*, 2019).

Table 3. Correlation Coefficients between Physicochemical Parameters and Plankton Abundance in Warri River.

Plankton/ Variables	Air	Wat	Tras	Tur	TDS	Con	pH	Alk	Aci	DO	BOD	PO	CO_2	Chl	Pot	Sal
Bacillariophyta	0.96	0.88	-0.86	-0.96	-0.89	-0.89	1.00	0.99	0.95	0.94		0.99	0.99	-0.98	-0.98	0.98
Chlorophyta	0.94	0.87	-0.90	-0.89	0.84	0.85	1.00	0.85		0.94	-0.89	0.99				0.97
Cyanophyta	0.94	0.87		-0.89		0.98						0.99	0.95			
Euglenophyta	0.88	0.87														
Cladocera	0.94			-0.89	0.84	0.86		0.85								-0.89
Copepoda								0.91		0.87						-0.90
Protozoa								0.81			0.81					-0.90
Rotifera	0.94		-0.89													-0.90

Air, Air temperature; Wat, Water temperature; Tras, Transparence; Tur, turbidity; TDS, total dissolved solids; Alk, Alkalinity; Aci, Acidity; DO, dissolved oxygen; PO, Phosphate; CO2, carbon dioxide; Chl, Chloride; Pot, Poatssium;Sal, Salinity.

Table 4. Factor loadings for Physico-chemical parameters on the significant principal components in Station 1.Factor loadings ≥ 0.30.

Parameters	PC1	PC2	PC3	PC4	PC5
Eigen value	1322.57	521.50	36.67	9.90	4.02
% of Variance	69.8	27.5	1.9	0.5	0.2
Cum.% of Variance	69.8	97.3	99.3	99.8	100.0
Air Temperature (ºc)	-	-	-	-0.6673	-
Water Temperature (ºc)	-	-	-	-0.4055	-
Transparency (cm)	-	-	-	-0.5728	-
Turbidity (NTU)	-	-	-	-	-0.7435
TDS (.mgL^{-1})	-	-0.3868	-	-	-
Conductivity (µscm^{-1})	-	-0.8054	-	-	-
Alkalinity (mgL^{-1})	-	-	0.7887	-	-0.4408
Acidity (mgL^{1})	0.9618	-	-	-	-
DO (mgL^{-1})	-	-	-0.4094	-	-0.3513
B OD (mgL^{-1})	-	-	-0.3242	-	-
Melosira granulate var *curvata*	0.9912	-	-	-	-
Royaobtusa	-	0.3070	-	-	-
Sign Factor	Acid Factor	organic load	Biological oxidation/ Organic pollution	Climatic Factor	oxidation activity

Table 5. Factor loadings for Physico-chemical parameters on the significant principal components in Station 2. Factor loadings ≥0.30.

Parameters		PC1	PC2	PC3	PC4	PC5
Eigenvalue		6.02	3.767	3.09	1.68	1.43
% of Variance		37.6	23.6	19.4	10.5	8.9
Cum.% of Variance		37.6	61.2	80.6	91.1	100.0
Air Temperature (°C)		-	-0.3151	0.4049	-	-
Water Temperature (°C)		-	-0.3671	0.3580	-	-
Transparency (cm)		-	-	-	-	-0.7182
Turbidity (NTU)		-	-	-0.3328	-0.4730	-0.3655
TDS (.mgL^{-1})		-	-0.3272	-0.3102	-	-
Conductivity (µScm^{-1})		-	-0.3263	-0.3228	-	-
pH		-0.3556	-	-	0.3034	-
Alkalinity (mgL^{-1})		-	-0.3838	-0.3134	-	-
Acidity (mgL^{1})		-	-0.3619	0.3104	-	-
DO (mgL^{-1})		-0.3027	-	-	0.4669	-
BOD (mgL^{-1})		-0.3818	-	-	-	-
PPPP Phosphate (mgL^{-1})		-	0.3953	-	-	-
Carbondioxide(mgL^{-1})		-0.3093	-	-	-0.3071	-
Chloride (mgL^{-1})		-0.3758	-	-	-	-
Potassium (mgL$^{-)}$)		0.3118	-	-	-	-0.3839
Salinity(‰)		-0.3734	-	-	-	-
Chlamydomonas globosa	Chlorophyta	-0.3214	-	-	-	-
Closterium acutum		-	0.3706	-	-	-
Closterium ehrenbergii		-	-	0.3314	-	-
Closterium lineatum		-	0.3706	-	-	-
Closterium nitzsch		-	-	-	0.3516	-
Pandorina morum		-	-0.3214	-	-	-
Roya obtuse		-	-	-0.3342	-	-
Scenesdesmus quadricauda		-	0.3706	-	-	-
Calothrix sp	Cyanophyta	-	-	-	-0.4749	-
Oscillatoria bonetti		-	-0.385	-	-	-
Oscillatoria brevis		-	-	0.3167	-	-
Rivularia sp		-0.3313	-	-	-	-
Phacus longicauda	Euglenophyta	-	-	-0.4160	-	-
Euglena acus		-	-0.3478	-	-	-
Euglena proxima		-	-	-0.36002	-	-
Strombomonas deflande		-	-	-0.3602	-	-
Nauplius larva	Copepoda	-	-	-	-0.3362	-0.3568
Polyarthra sp	Rotifera	-	-	-	-0.3080	-
Polyathra vulgaris		-	-	-	-0.3080	-

Sign Factor	Organic Pollution/Min eratlizaion	Nutrient & Climatic	Mineralization & biological activity	Organic load

Table 6. Factor loadings for Physico-chemical parameters on the significant principal components in Station 3. Factor loadings ≥ 0.30.

Parameters		PC1	PC2	PC3	PC4
Eigenvalue		6.05	5.09	3.82	1.04
% of Variance		37.8	31.8	23.9	6.5
Cum.% of Variance		37.8	69.6	93.5	100.0
Air Temperature (°C)		-	-	-0.4919	-
Water Temperature (°C)		-	-	-0.4288	-
Transparency (cm)		-0.3458	-	-	-
Turbidity (NTU)		-	-	0.4679	-
pH		-	0.3685	-	-
Alkalinity (mgL^{-1})		-	-	0.3163	0.4051
Acidity (mgL^{1})		0.3128	-	-	-
DO (mgL^{-1})		-	-	0.3590	-
BOD (mgL^{-1})		-0.3687	-	-	-
PPP Phosphate (mgL^{-1})		-	-0.3051	-	-
Carbon dioxide(mgL^{-1})		-	0.3586	-	-
Chloride (mgL^{-1})		-	-	-	-
Potassium (mgL$^{-)}$)		-	0.3156	-	0.6783
Calothrix sp	Cyanophyta	-	-0.3573	-	0.3014
Microcystis webenergii		-	-	-	-0.4441
Oscillatoria bonetti		-	-	-	-0.4441
Bosmina longiristris	Cladocera	-	-	-0.3906	-
Difflugia sp		0.3055	-		-
Gromia sp	Protozoa	0.3055	-		-
Tintinidium pusilum		0.3055	-		-
Vorticella picta		-	-		-0.5368
Lecan egypta		-0.3271	-	-	-
Polyathra vulgaris	Rotifera	-0.3271	-	-	-
Rotatoria neptunia		-0.3049	-	-	-0.3563
Testudinella sp		-0.3271	-	-	-
Trichocercabi cristata		-0.3271	-	-	-
Sign Factor		Acid /organic pollution Factors	Nutrient/	organic	Mineralization

From the Factor analyses with weighed loads more than 3; Tables 4, 5 and 6, it was clear that most parameters loaded weakly (>3.0) and negatively except in station 1. The directions of the parameters and the plankton abundance indicate these parameters influence the plankton in the same direction or vice versa (Afonina *et al.*, 2018). Five principal components (PC) 1, 2, 3, .4 and 5 accounted for 69.8%, 27.5%, and 1.9%, 0.5% and 0.2% extracted 100% of the total variance. *Melosira granulatava rcurvata* and *Royaobtusa* population mostly influenced by acidification in station 1 while the other axes x-rayed other events governing the water quality of the upper Warri River (Table 4).

In station 2, five principal components were also extracted ,with PC1, PC2, PC3, PC4 and PC5 accounting for 37.6%, 23.6%, 19.4%, 10.5% and 8.9% respectively, of the total variance of plankton (Table 5). The extracted variables in PC1 (37.6%) implicated organic pollution and mineralization indicators (Afonina *et al.*, 2018). The blue-greens population varied along organic pollution and mineralization gradients. While PC 2 (23.6%) axis, implicated nutrient and climatic factors are regulating; *Closterium desmids and Scenedesmus quadricauda (Turpin)* and *Euglena acus* (O.F.Muller) (Table 4b). Biological activity and mineralization variables were paramount in explaining the 19.4% of them in PCs 3 (*Closteriumsp* Nitzsch ex Ralfs, 1848, *Roya obtusa, Oscillatoria brevis, Phacus longicauda* (Ehrenberg) Dujardin*, Euglena proxima*), and in PC 4 (*Closterium* Nitzsch ex Ralfs, 1848*, Calothrix* sp). The isolated zooplanktons were all influenced by the organic load factor (PC5). No diatom showed any association with any parameter in station 2 despites their preponderance, signifying other possible factors not accounted for in the present study (Malaran *et al.*, 2019).

In station 3, rotifers crucially influenced in PC 1 that explained 37.8% of their variance in Ogbe-ijorh section of Warri River, signaling acid factors and organic pollution factors (Fishar *et al.*, 2019). The latter is an essential gradient influencing the population of zooplankton in PC 3. The variables in PC 4 mostly influenced the blue-greens along mineralization axis or gradient (Table 6). Although different elements were isolated, all signalled similar and overlapping driving factors of hydrobiological events in the studied area, suggestive of effluents impact on the plankton (Lueang thuwa pranit *et al.*, 2011).

Biodiversity Measures

The phytoplankton and zooplankton species diversity and richness in the studied stations are low (Tables 7A and B). Station 3 showed the highest diversity indices and species richness probably due to food availability and better water quality.

The Bacillariophytes, Chlorophytes and the Euglenophytes in station 1 and cyanophytesin station 2 were low. The observed species sparsity due to environmental degradation resulted from effluent discharge and local disturbances such as dredging in the area (Heneash *et al.*, 2014). The same factors are responsible for exceptional low Cyanophyta in icky Station 2. In the present study, Bacillariophyta had the highest diversity indices when compared to other groups of phytoplankton. The rotifers displayed highest diversity indices among the zooplankton, richest in station 1 and poorest in station 3 and vice a vice for the protozoans. Copepoda was highest in Station 3 and lowest in Station 2. Low diversity indices depict stressful nature of the environment (Heneash *et al.*, 2014)

Table 7. Cont'A. Diversity Indices of Plankton Species; Phytoplankton (A) and Zooplankton (B) in the Sampling Stations in Warri River.

Phytoplankton	Bacillariophyta			Chlorophyta			Cyanophyta			Euglenophyta		
Ecological indices	stn 1	stn 2	stn 3	stn 1	stn 2	stn 3	stn 1	stn 2	stn 3	stn 1	stn 2	stn 3
Taxa (no of species)	27	31	32	5	8	12	4	4	6	4	4	6
Number of individuals	584	70	77	13	11	21	4	7	6	7	8	6
Shannon weiner index(h)	0.52	1.39	1.29	0.66	0.86	0.99	0.60	0.59	0.78	0.59	0.55	0.78
Evenness index(e)	0.29	0.93	0.86	0.59	0.95	1.00	1	0.98	1	0.98	0.91	1
Dominance (d)	0.66	0.04	0.07	0.23	0.16	0.12	0.25	0.27	0.17	0.66	0.31	0.17
Jaccard's coefficient (cj)		0.5			0.25			0.75			0.67	

Table 7. Cont'B.

Zooplankton	Arachnida	Cladocera		Copepoda			Protozoa		Rotifera	
Ecological Indices	STN 1	STN 2	STN 3	STN 1	STN 2	STN 3	STN 1	STN 3	STN 1	STN 3
Taxa (no of species)	1	1	1	1	2	2	1	4	8	5
Number of individuals	1	1	1	1	4	3	1	5	11	7
Shannon wiener index(h)	0.00	0.00	0.00	0.00	0.30	0.28	0.00	0.58	1.04	0.64
Evenness index(e)	0.00	0.00	0.00	0.00	1.00	0.92	0.00	0.96	1.13	0.92
Dominance (d)	0.00	0.00	0.00	0.00	0.50	0.56	0.00	0.14	0.24	0.27
Jaccard's coefficient (cj)					0.5					

The species evenness in this present study was equally distributed in the Stations and was higher than 0.5 (USEPA 1997); this is attributable to the low species richness (Table 7B). Jaccard's Coefficient (Cj) revealed the similarity of taxa among Stations, with values equal to 1 for the Bacillariophyta, Cyanophyta and Euglenophyta. While these taxa affinities are different from the Chlorophytes affinities are different from other taxa with Jaccard's Coefficient value of less than 1, to reveal the taxon uniqueness. In this study, only the Copepoda were similar among the stations (Table 7B).

Conclusion

In this study, the physicochemical parameters were highly variable (CV>40%), which indicates water quality impairment of the Warri River. The ecological indices indicated that the Warri River was organically polluted attributable Anthropocene. The organic pollution revealed by the diversity indices, moderate biodiversity and the low number of species recorded quantitatively. The zooplankton was sparse and weak. The zooplankton abundance and species in this study did not reflect the river's trophic nature, phytoplankton richness abundance despite the vital role as food for zooplankton in the river. The Warri River, dominated by *Melosira granulata* (Ehr) Ralfs; a diatom bio-nutrient indicator, is an indication that the river is moderately eutrophic with pH less than 9.0, shallow and well-mixed.

Crucial environmental factors such as temperature, TDS, Conductivity, pH, Alkalinity, DO, Phosphate, Carbon dioxide, Salinity positively influenced the plankton. While Transparency, Turbidity, Chloride and Potassium the essential factors which negatively influence the abundance of plankton in this study. These environmental variables primarily implicated as acids, organic loads, mineralization, nutrient, biological activity and buffering capacity and Climatic factors identified by the principal component analysis and the inferred factors structured the plankton community of the studied section of the Warri River. These components were ultimately from the human wastes and effluents from industries along the river course.

Recommendation

The Warri River much perturbed by the anthropogenic and human activities around the river discharging untreated waste into the water body. In other words, appropriate measures must be taken to minimize the adverse effects of their actions on both human and aquatic biodiversity of the river.

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