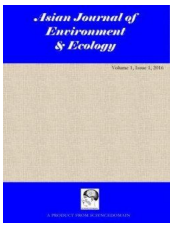

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Evaluating the Physico-chemical Characteristics and Plankton Diversity of Nwaniba River, South-South Nigeria

I. K. Esenowo[1*], A. A. A. Ugwumba[2] and A. U. Akpan[1]

[1]Department of Zoology, University of Uyo, Uyo, Nigeria.
[2]Department of Zoology, University of Ibadan, Ibadan, Nigeria.

Authors' contributions

This work was carried out in collaboration between all authors. Author IKE designed the study, performed the statistical analysis, wrote the protocol, and wrote the first draft of the manuscript. Author AUA managed the analyses of the study. Author AAAU managed the literature searches. All authors read and approved the final manuscript.

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ABSTRACT

The physicochemical characteristics and plankton diversity of Nwaniba River, Uruan, Akwa Ibom, Nigeria were studied between April and September 2013. Surface water samples were collected for physicochemical parameter and plankton analysis according to standard methods. The results of the physicochemical parameters were within recommended limits of the National Environmental Standards and Regulations Enforcement Agencies (NESREA) for aquatic life. Twenty plankton species belonging to five taxa were encountered in the following order of dominance; Bacillariophyceae (69.23%) > Chlorophyceae (18.38%) > Cyanophyceae (11.97%) > Dinophyceae (0.85%) > Rotifera (0.43%). The most abundant phytoplankton was *Coscinodiscus radiates*, accounting for 47.7%, the least were *Peridinium bipes, Pediastrum duplex, Rivularia spp, Gonatozon monalaenum, Navicular peroltelti, Tabelaria spp, Epithemia zebra* and accounting for less than 1% respectively, while *Lacane bulla* was the only species for zooplankton. High Diversity

**Corresponding author: E-mail: imehesenowo@yahoo.com;*

indices values were recorded for Chlorophyceae =1.36 while the least was Cyanophyceae = 1-21. The presence of certain plankton-pollution tolerant species such as *Anabaena circularis*, *Navicula peroltelti*, and *Peridinium bipes* suggests a low level of organic pollution in the river.

Keywords: Physico-chemical; plankton; diversity; Nwaniba river.

1. INTRODUCTION

Water is an essential element for life on earth. It covers about 70% of the earth surface and serves as habitat for numerous organisms. However, it is one of the most poorly managed resources in the world [1,2].

Several studies in Nigeria have identified anthropogenic activities as the easy source of water pollution [3,4,5], as natural water bodies are constantly used as receptacles for untreated wastewater or poorly treated effluents from industrial, agricultural, commercial, or domestic activities [6]. Therefore, the increase in anthropogenic inputs, through erosion, leaching, and weathering of crystal materials, has led to the rapid degradation of surface water and has thus rendered most water bodies unsuitable for their multipurpose use such as artisanal fishing and domestic activities [7].

The use of algae as biomonitors for freshwater bodies have already been recognized in the mid-19th century [8]. The relationship of these organisms to water quality was more clearly defined by Kolkuritz and Marsson [9]. Since then, several methods for deducing water quality, such as the bio-assay have been used in the laboratory [10]. The presence of an algae species in an aquatic habitat readily reflects the characteristics of the environment in which they exist, showing that one or more ecological variables are within its tolerance range [10].

The plankton community is a dynamic system that would quickly respond to changes in the physical and chemical properties of the water environment, as they represent the base-line of the food chain in the aquatic ecosystem [11]. The position they occupy in the trophic level makes them more vulnerable and highly sensitive to even a small degree of environmental changes, hence they act as indicators of water quality [12]. The concept of employing plankton as indicator species is extended beyond the presence/absence of a given species, to also include their abundance and biomass or growth (blooms) of algal species because of anthropogenic activities [6].

Due to several favorable features such as small size, short generation time and a relatively homogenous habitat, plankton organisms are considered ideal for theoretical and experimental population ecology [13]. The physicochemical characteristics of water bodies in south-south Nigeria are well reported [14,15,16], but there is few or no information on the physicochemical characteristics and plankton diversity of Nwaniba River, therefore, for proper management of the river, evaluation of the physicochemical characteristics and plankton diversity of Nwaniba River is needed.

2. MATERIALS AND METHODS

2.1 Study Area

This study was carried out between April and September 2013 in Nwaniba River located in Uruan Local Government Area of Akwa Ibom State, Nigeria (Fig. 1). Nwaniba River lies between latitude 5°2'51"N and longitude 8°2'41"E. The annual rainfall received here is about 2500 mm with a mean annual temperature of 32°C and a relative humidity of 75%. The banks of the river were mostly covered with grass and other tropical marginal vegetations.

2.2 Samples Collection

Temperature, transparency, and depth of water were measured in-situ, using a digital thermometer for temperature, an Extract meter model Extik EC400 for conductivity, TDS, and salinity respectively. A locally fabricated metal Sacchi disc with a diameter of 20cm and an improvised metal pole of the total length of 10m were used for the determination of transparency and depth respectively. Water sample for dissolved oxygen concentration was collected in 250 mL bottles and determined using the azide modification of the iodometric method. Samples for plankton were also collected into 250 mL bottles using plankton net with mesh size of 55 mm. The water samples were stored in plastic bottles and fixed with 4% formalin in the field immediately before it was taken to the laboratory for identification and analysis. Guides keys provided by Nedham and Nedham [17], Jeje and

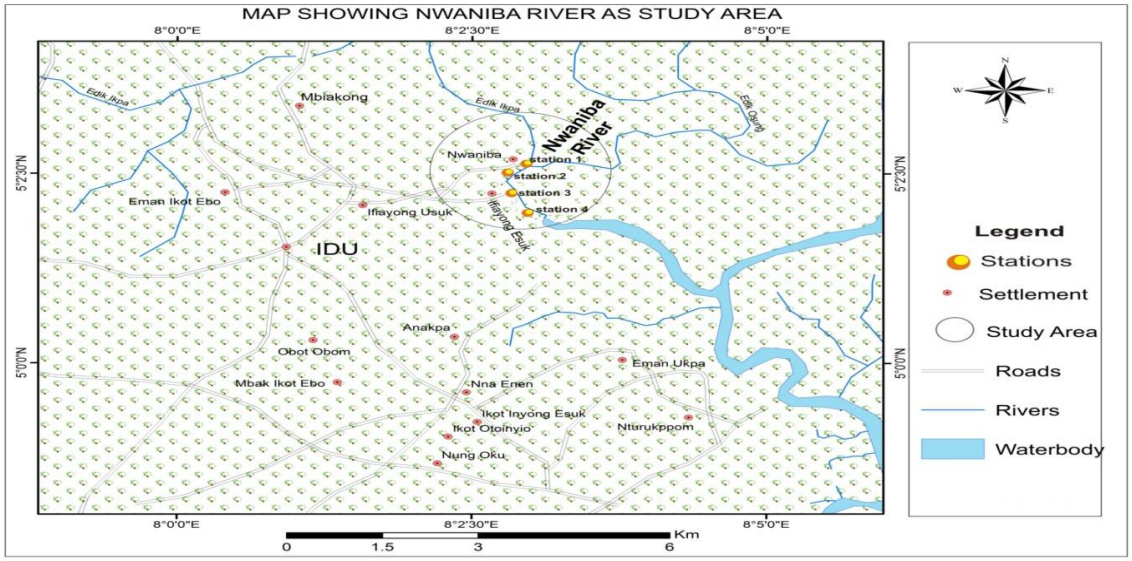

Fig. 1. Map of study area showing sampling stations from station 1 to station 4

Fernando [18,19], APHA/AWWA/WEF [20], Nwankwo [21], were used for identification of the plankton specimen encountered. Microsoft Excel (2007) was used for Data analysis, while version 3 of PAST Software Design was used to determine the Diversity index of the plankton community and Canonical Correspondence Analysis (CCA) to determine the pattern of distribution of plankton groups related to physical and chemical parameters.

3. RESULTS

3.1 Physico-chemical Parameters

The mean, standard error, and range of the physicochemical parameters of Nwaniba River measured during the study period are shown in Table 1, while Table 2 shows the spatial variation in the physicochemical parameters.

3.2 Plankton Composition and Abundance

A total of twenty species of plankton belonging to four taxa were encountered (Table 3). The abundance of phytoplankton was in the following order; Bacillariophyceae (69.23%) > Chlorophyceae (18.38%) > Cyanophyceae (11.97%) > Dinophyceae (0.85%) > Rotifera (0.43). The most abundant phytoplankton species was *Coscinodiscus radiates*, accounting for 47.7% while the least were *Peridinium bipes, Pediastrum duplex, Rivularia spp, Gonatozygon montaenium, Navicular peroltelti, Tabelaria* spp and *Epithemia zebra*, accounting for less than 1% respectively. Only one taxa of zooplankton was recorded.

3.3 Diversity Indices

High values of Shannon-Wiener Index_H were recorded for Chlorophyceae (1.36) and low

Table 1. The range, mean, and std. the error of physico-chemical parameters of Nwaniba River

Physico-chemical parameters	Range	Mean ± Std error
Water Temperature (˚C)	26.00 – 31.00	28.02 ±0.330
Dissolved Oxygen (mg/L)	1.40 – 4.95	4.00 ±0.220
Biological Oxygen Demand (mg/L)	0.00 – 0.96	0.66 ±0.640
pH	5.70 – 8.10	6.61 ±0.120
Salinity (ppt)	0.01 – 0.04	0.02 ±0.001
Conductivity (µS/cm)	16.60 – 74.40	25.27 ±2.280
Total Dissolved Solute (mg/L)	9.10 – 31.00	12.67 ±0.890
Transparency (m)	0.10 - 0.90	0.63 ±0.040
Water depth (m)	0.20 - 8.40	3.75 ±0.570

Table 2. The mean and std. error of physico-chemical parameters across the sampling stations in Nwaniba River

Physico-chemical variables	Station 1	Station 2	Station 3	Station 4
Water Temperature (˚C)	27.83 ±0.700	27.91 ±0.780	28.16 ±0.650	28.02 ±0.700
Dissolved Oxygen (mg/L)	4.01 ±0.480	4.06 ±0.410	3.92 ±0.430	3.93 ±0.520
Biological Oxygen Demand (mg/L)	0.65 ±0.130	0.68 ±0.140	0.60 ±0.120	0.69 ±0.140
pH	6.53 ±0.210	6.60 ±0.210	6.60 ±0.240	6.74 ±0.350
Salinity (ppt)	0.014 ±0.001	0.013 ±0.001	0.014 ±0.001	0.02 ±0.005
Conductivity (µS/cm)	20.97 ±1.500	23.52 ±1.910	23.29 ±1.310	33.31 ±8.360
Total Dissolved Solute (mg/L)	11.23 ±0.510	12.62 ±0.750	12.11 ±0.840	14.73 ±3.400
Transparency (m)	0.65 ±0.070	0.65 ±0.090	0.62 ±0.070	0.63 ±0.110
Water depth (m)	4.70 ±1.050	6.0 ±1.450	2.54 ±0.600	1.8 ±0.470

values for Cyanophyceae (1.20). Highest values for species dominance_D were recorded for Dinophyceae and Rotifer (1.0) respectively and lowest for Chlorophyceae (0.27). Evenness ranged from (0.84) in Cyanophyceae to (1) in Dinophyceae and Rotifer (Table 4).

3.4 The Relationship between Physico-chemical Variables and Plankton Abundance

The Canonical correspondence analysis (CCA) ordination diagram was employed to show the relationships existing between biological assemblage and the physicochemical variables. The CCA triplot ordination diagram consists of four (4) sampling site-points with different colors labeled ST_1 (Blue), ST_2 (Yellow), ST_3 (Pink), ST_4 (Green). Plankton groups are labeled by the abbreviation of their first few letters, and the arrow points to the various physicochemical variables that were measure during the course of the study (Fig. 2).

4. DISCUSSION

4.1 Physico-chemical Parameters

The mean value of the water temperature of Nwaniba River was within the NESREA

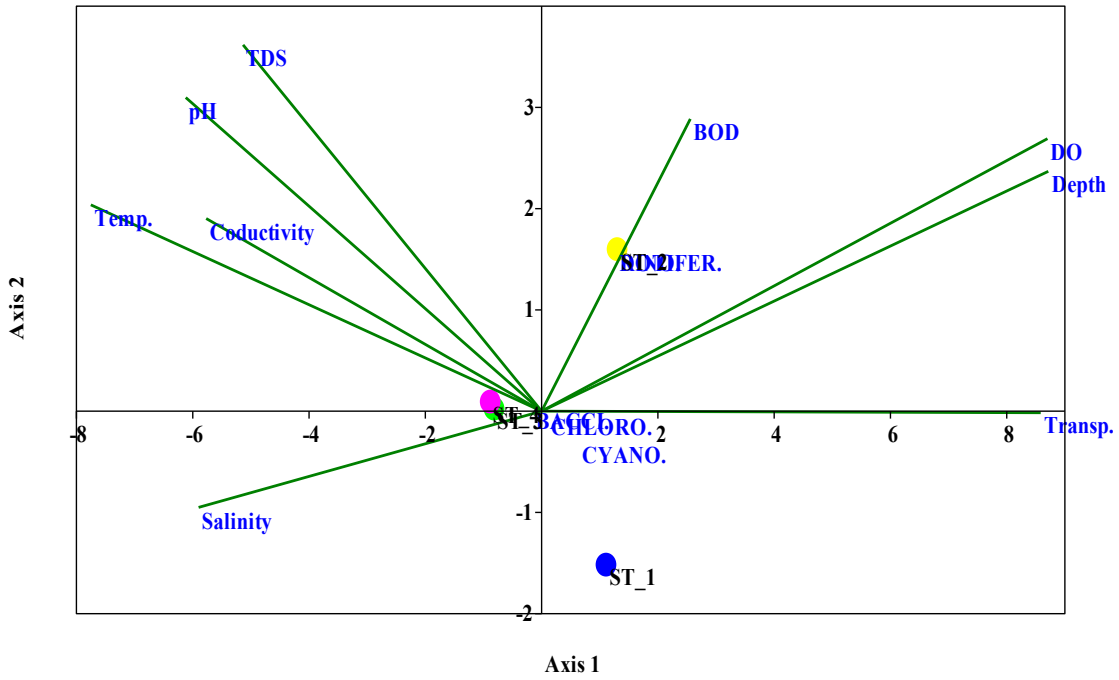

Fig. 2. Canonical correspondence analysis (CCA) triplot ordination diagram with 5 plankton groups, 9 quantitative variables and sampling station 1 to 4

Table 3. Percentage abundance of plankton species encountered during the study period

	Stations						
Plankton diversity	**1**	**2**	**3**	**4**	**Total**	**% Composition**	
CYANOPHYCEAE							
Phomidium sp (TAX: 1199)	105	35	-	-	140	1.71	11.54%
Aphanizomenon sp Morren ex Bornet et Flahault 1888	245	105	-	70	420	5.13	
Dactylococcopsis acicularis [Hansgrig, 1888]	35	105	105	-	245	2.99	
Anabaena circularis [Bornet and Flahault 1886]	70	-	35	-	105	1.28	
Rivularia sp [C. Agardh, 1886]	-	-	35	-	35	0.43	
Sub-total	**455**	**245**	**175**	**70**	**945**		
CHLOROPHYCEAE							
Closterium kuetzingii [Brébisson 1856]	105	175	490	210	980	11.96	18.37%
Pediastrum duplex [Meyen 1829]	-	105	-	-	105	1.28	
Gonatozygon monotaenium De Bary 1856	-	-	-	35	35	0.43	
Mongeotia sp [C. Agardh, 1886]	105	35	-	-	140	1.71	
Tribonema sp [Derbés and Solier, 1851]	175	-	35	35	245	2.99	
Sub-total	**385**	**315**	**525**	**280**	**1505**		
BACILLARIOPHYCEAE							69.23%
Coscinodiscus radiates [Ehrenberg 1840]	60	490	2065	770	3885	47.43	
Pinnularia mayor [Ehrenberg 1840]	-	105	210	-	315	3.85	
Pleurosigma elongatum [W. Smith 1852]	-	-	-	70	70	0.85	
Gyrosigma attenuatum [Kutzing] Rabenhorst 1853	385	140	210	280	1015	12.39	
Navicula sp Bory de Saint-Vincent 1822. (Guiry and Guiry 2012)	-	-	35	-	35	0.43	
Tabellaria sp (Lyngbye) Kutzing 1844	35	-	-	-	35	0.43	
Epithemia zebra (Ehrenbery) Kutzing 1844	-	-	-	35	35	0.43	
Grammatophora angulosa Ehrenberg 1840	-	175	-	105	280	3.42	
Sub-total	**980**	**910**	**2520**	**1260**	**5670**		
DINOPHYCEAE							
Peridinium bipes Stein 1883	-	70	-	-	**70**	0.85	0.85%
ROTIFER							
Lacane bulla Harring and Myers 1926	**-**	35	**-**	**-**	**35**	0.43	0.43%
Grand Total	**1,820**	**1,540**	**3,220**	**1,610**	**8,190**		

Table 4. Diversity index

S/n	Index	BACC.	CHLORO.	CYANO.	DINO.	ROTIFER.
1.	Shannon_H	1.29	1.36	1.21	-	-
2	Dominance_D	0.30	0.27	0.34	1	1
3.	Evenness_e^H/S	0.91	0.97	0.84	1	1

recommended range limits of 25°C - 31°C for surface water in the tropical region, but the observed monthly variation during the study period could be attributed to seasonal variation and rainfall pattern, as reported by Akpan and Offem, [15]. The Dissolved Oxygen value of 4.0

±0.22 mg/L was slightly lower compared to the National Environment Standards and Regulations Agency (NESREA) limits of 5.0 mg/L for surface water. This indicates a less oxidized aquatic ecosystem. According to Anago et al. [22], the depression in dissolved oxygen level could be due to chemical and biological oxidation processes in water. This may also depend on the rate of solubility, respiration processes by aquatic organisms, decay processes by aerobic bacteria and decomposition of dead decaying sediments [23]. Rani et al. [24] also reported lower values of dissolved oxygen in summer season as a result of high rate of decomposition of organic matter and limited flow of water in low holding environments due to a higher temperature. The lower dissolved oxygen level in the river may also be attributed to the vegetative decomposition of plants that have been exacerbated by a heavy point source of fresh water inflows carrying excess nutrients into this river system [25].

Biological oxygen demand is an important parameter that is required for the degradation of organic matter. The value of the biological oxygen demand of Nwaniba River ranged between 0 and 0.86 mg/L, with a mean 0.66 ±0.64 mg/L. However, other physicochemical parameters of the river such as pH, salinity conductivity, TDS, and transparency were within recommended limits as stipulated by NESREA for aquatic life.

4.2 Plankton Community Structure

The diversity and abundance of plankton in Nwaniba River show spatial variations. The percentage abundance of the phytoplankton groups was in the following order: Bacillariophyceae (diatoms) (69.23%) > Chlorophyceae (18.38%) > Cyanophyceae (11.97%) > Dinophyceae (4.2 %.). Similar trends in abundance of plankton groups were also reported by Abowei et al. [26] and Ogbuagu et al. [27] in Koluama River, Bayelsa State, and Imo River, in Etche Local Government Area, Rivers State, Nigeria respectively.

The dominance of Bacillariophyceae (Diatoms) in the present study agrees with the reports of Onyema [28] and Esenowo and Ugwumba [29] that diatoms are the most obvious representatives of the phytoplankton in rivers, seas, and lakes. The more frequent occurring plankton species encountered during the study was *Coscinodiscus radiatus*. This shows consistency with the work of Adeyemi-ale et al. [6] who reported the prominence of *Coscinodiscus radiates* in Osere Stream, Ilorin, Kwara State, Nigeria. Several other researchers have added to the impressive array of the cosmopolitan nature of these species which are prevalent in prominent Nigerian water bodies [30,16,31,28].

Onyema et al. [32] reported the presence of some phytoplankton species such as *Navicula* spp*, Nitzchiz* spp*, Anabana* spp and *Synedra* spp., as good indicators of organic pollution in any aquatic ecosystem. Thus, lower percentage abundance of *Navicula* and *Anabaena* species in Nwaniba River may suggest a mild level of organic pollution. This may also be a clear indication that the river may be undergoing a gradual pollution stress as a result of anthropogenic activities such as effluents from laundry, bathing, and saw-milling which may pose a severe negative impact on the water parameters.

An important application of diversity indices in phytoplankton studies is in the assessment of pollution. According to Shekhar et al. [33] and Ganai and Parveen, [34], the Shannon-Weiner diversity index for clean fresh water bodies are proposed as diversity index greater than 4; between 3-4 is proposed as mildly polluted water while less than 2 as heavily polluted water. The Shannon-Weiner diversity index ranged between 1.36 and 1.21 indicating heavily polluted water.

The correlation between the plankton groups, the physicochemical parameters and the sampling station (using the distance rule, which states that the site-points closer to the species-point tends to have a higher effect on the abundance of the species in question than sites farther from the species points) shows that transparency, temperature, dissolved oxygen, depth, TDS, and pH, were found to have the greatest effect on the distribution of plankton diversity, while conductivity, BOD, and salinity had lesser influences on the distribution of plankton groups. According to ter Braak and Verdonschot [35], the difference in length of the environmental variable arrows is equal to the amount of their corresponding effect on the ordination scores (species score or site score). The ordination diagram in Fig. 2 reveals that the order of importance of the measured physicochemical parameter was as follows: Transparency >Depth > DO > Temperature > pH > TDS > Salinity > Conductivity > BOD with the following

correlations with axis 1, (0.95, 0.97, 0.97, -0.86, -0.68, -0.57, -0.66, -0.64, 0. 28) respectively.

5. CONCLUSION

The temporal variations in the physicochemical parameters may be attributed to rainfall patterns, while the spatial variations are due to the influence of various anthropogenic activities around this area. Although the physicochemical parameters were within limits as recommended by NESREA for tropical aquatic life, the presence of certain plankton-pollution tolerant species such as *Anabaena circularis*, *Navicula peroltelti*, and *Peridinium bipes* suggests a low level of organic pollution in the river.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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