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Studies on the Physicochemistry and Plankton of a Freshwaterbody in Owerri, Imo State, Nigeria

E. C. Osuebi[1], D. H. Ogbuagu[2], J. C. Okorie[3]
[1,3]Department of Environmental Management, Federal University of Technology, Owerri, Imo state, Nigeria
[2]Department of Biology, Federal University of Technology, Owerri, Imo state
([1]emmaosuebi@yahoo.com, [2]dike.ogbuagu@futo.edu.ng, [3]zobastin@gmail.com)

Abstract- This study investigated the interactions of some physicochemical attributes and plankton abundance and diversity in the upper and middle reaches of the Otamiri River in Owerri, Imo State. Plankton samples were collected at four sampling locations and identified through direct microscopy. Descriptive statistics, variation plots and correlation were used to analyze data at $p<0.05$ level. Mean levels of Dissolved Oxygen (DO), water temperature, electrical conductivity, and Total Dissolved Solids (TDS) (Sig. $F_{value}=0.000$ each), Biological Oxygen demand (BOD) (Sig. $F_{value}=0.035$), pH (Sig. $F_{value}=0.025$), Total Suspended solids (TSS) (Sig. $F_{value}=0.004$), turbidity (Sig. $F_{value}=0.005$), PO_4^{3-} ions (Sig. $F_{value}=0.029$) and SO_4^{2-} ions (Sig. $F_{value}=0.003$) all differed significantly across the sampling locations of the river at $p<0.05$. Phytoplankton abundance comprised of a total of 9 genera each of bacillariophyceae and cyanophyceae, 6 genera of chlorophyceae, 2 genera each of euglenophycea and xanthophycea, and 1 genus each of charophycea and pyrrophyceae. The most abundant diatom genus was *Diatoma*sp while that for cyanophyceae was *Aphanizomenonflos-Aquae*. Sampling location 3 (Ihiagwa/Umuchima) recorded the highest phytoplankton and zooplankton abundances (158 & 7 cells/organisms/mL) while the pristine/control location 1 (Egbu) had the least abundance of 108 & 2 cells/organisms/mL respectively. Significant spatial inequality was observed in abundances of the cladoceran (Sig. $F_{value}=0.030$), xanthophycean and euglenophycean (Sig. $F_{value}=0.011$ each) taxa at $p<0.05$. DO correlated with euglenophyceae ($r=-0.679$), xanthophyceae ($r=-0.673$) ($p<0.05$), and chlorophyceae ($r=-0.747$) ($p<0.01$), and TSS correlated with bacillariophyceae ($r=0.629$) ($p<0.05$). Low abundance of plankton recorded in the study most probably reflects a perturbed aquatic ecosystem lacking in vital nutrients and other factors necessary for a thriving biotic community.

Keywords- *Plankton, Biotic Index, Physicochemical Parameters, Otamiri River, Nutrients*

I. INTRODUCTION

The name plankton comes from the Greek word nλανκTOς ('Planktos'), meaning "wanderer" or "drifter" (Thurman, 1997). It is a collective term for a variety of marine and freshwater organisms that drift on or near the surface of the water. Their movement depends largely on tides, currents and winds, because they are too small or weak to swim against the currents. Many authors have since defined plankton as all those animals and plants which live freely in the water and which because of their limited powers of locomotion, are more or less passively drifted by water current (Newell and Newell, 1963); all those living organisms which float "wily-nilly" in free water and are independent of the shore and bottom; a mixed group of tiny plants and animals floating, drifting, or feebly swimming in water mass (Cole, 1978), and as drifting organisms that inhabit the water column of oceans, seas and bodies of freshwater (Maosen, 1978). According to Hallegraeff, the evolution of "the myriad of microscopic, one-celled life forms (plankton) floating on the rich biochemical soup of this planet's bodies of water" dates back to some 400 million years ago when there had not been "the fantastic permutation of multi-cellular life forms which have since developed through the millennia" (Hallegraeff, 1988).

Though some form of plankton are capable of independent movement and can swim hundreds of metres vertically in a single day- a behaviour called diel vertical migration, their horizontal position is primarily determined by the surrounding currents. All oxygen breathing organisms are indebted to plankton because of their significant contribution of oxygen through millennia of photosynthesis. Additionally, plankton are responsible for the formation of oil over pre-historic times when the sun shone on these microorganisms called plankton drifting in seas and produced, through photosynthesis, small globules of oil within their cells. Many microscopic fossils from sediments are extraordinarily related in nature or alike to living microscopic plankton. This shows that some species of plankton have remained virtually unchanged for many years (Fernando *et al*., 2002). Aside from representing the bottom levels of a food chain, plankton supports up to commercially important fisheries, even as they play a major role in the biogeochemical cycles of many important chemical elements including carbon cycle. Phytoplankton fixes carbon in sunlit surface water through the process of photosynthesis. Through zooplankton grazing, this carbon enters the plankton food web, where it is either respired to provide metabolic energy, or accumulates as biomass or debris (Valina *et al*., 2014). As organic materials, they are typically denser than water and tend to sink.

The abundance and distribution of plankton are strongly dependent on factors such as light (solar radiation), ambient nutrients concentrations, the physical state of the water column, and the abundance of other plankton.

II. MATERIALS AND METHOD

Owerri, the study area is located within the coordinates 5.485° Northing and 7.085° Easting (Fig.1). The city consists of 3 Local Government Areas which includes Owerri Municipal, Owerri North, and Owerri West local government areas. It has a population estimate of about 400,000 people in 2006 and land area of 40sq miles (100km square) (NPC, 2006). The terrain is almost flat to the West and small rolling hills run from the North to the South.

The Otamiri River that was investigated rises south from Egbu and courses past Owerri; through Nekede, Ihiagwa, Eziobodo, Olokwu Umuisi, Mgbirichi and Umuagwo (Fig.1), onto Ozuzu in Etche, Rivers State. In Etche, the river first confluences with Oge-Ochie River at Nihi, and further with the Imo River at Umuebulu. The length of the river from its source to its earlier, minor confluence with the Uramiriukwa River at Emeabiam in Imo State is 30km. The Otamiri watershed covers about 10,000km^2.

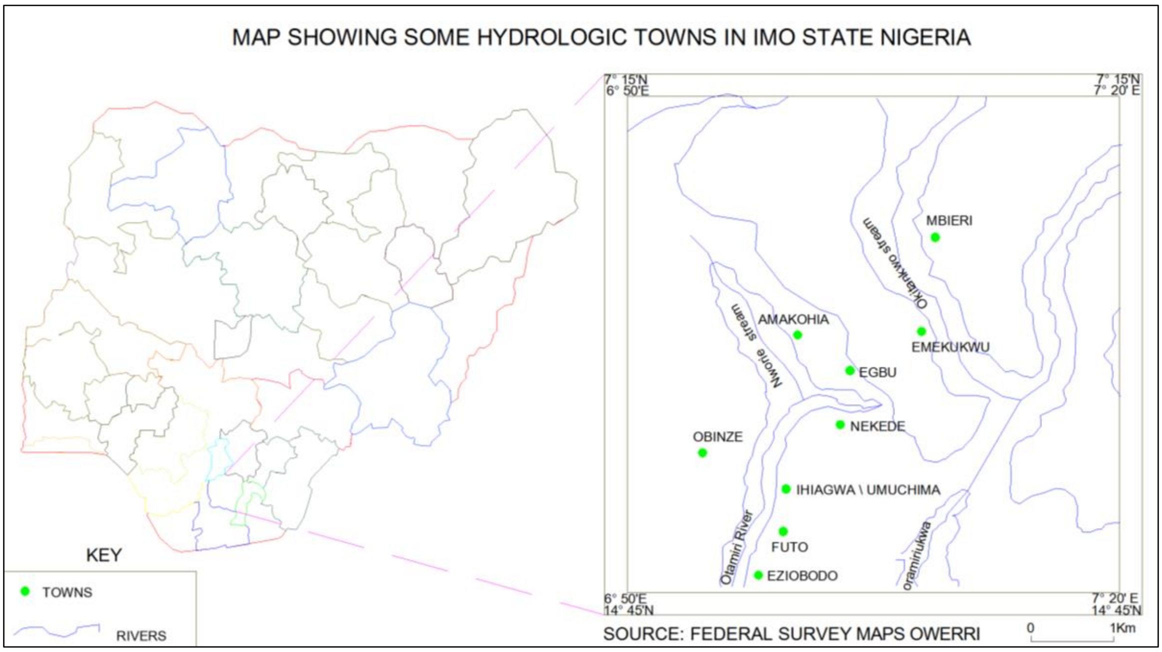

Figure 1. Map of the study area showing sampling locations

A. Water sample collections

The methods described by APHA (2000), Grant (2002), and Anene (2003) were adopted in collection of water and plankton samples.

Water samples for biological oxygen demand were collected in 250 mL brown bottles. Water samples for the other physicochemical parameters were collected in 500 mL sterile plastic containers. Samples were taken to the laboratory as soon as possible in an ice-cooler to maintain their integrity.

Water temperature, electrical conductivity, pH, turbidity, total dissolved solids, and dissolved oxygen were determined electrometrically *in situ* with the HANNA HI 9828 VI.4 PH/ORP/EC/DO meter that had been pre-calibrated with the standard HI 9828-25 kit calibration solution. The preferred parameter was read off the LCD of the meter.

B. Plankton sample collections

Sampling for plankton was done with plankton net of mesh size 55um. The net was towed aboard a canoe horizontally for 5 minutes during navigations downstream the river channel at each sampling point. Afterwards, the content of the net which contains mixed concentrations of plankton samples was transferred into a plastic container. Samples were preserved with 4% formaldehyde solution in the containers until needed for identification.

III. STATISTICAL ANALYSIS

Both bivariate and multivariate analyses as provided by the SPSS v.23.0 and MS Excel Version 2010 were utilized in the analyses of data. Descriptive statistics were used to explore minimum and maximum values as well as ranges, means and Standard Errors of the data set. Variation plots were used to represent mean values of the physical, chemical and biological attributes of the various reservoirs.

IV. RESULTS AND DISCUSSION

Physicochemical parameters-The Results of the physicochemical attributes of the Otamiri River in the study area across the sampling locations are shown in Table 1. Surface water temperature varied from 27.58 to 28.63 ^oC, with a mean of 27.92 ± 0.11 ^oC, pH ranged from 5.38 to 6.32, with a mean of 6.15 ± 0.01, while turbidity varied from 3.00-6.40, with a mean value of 4.62 ± 0.34 NTU during the study period.

The Total Suspended Solids (TSS) varied from 2.00-6.60, with a mean of 4.42 ± 0.45 mg/L, Dissolved Oxygen varied from 0.91-1.63, with a mean value of 1.35 ± 0.07 mg/L, and Biological Oxygen Demand (BOD) ranged from 0.88-1.41, with a mean value of 1.12 ± 0.05 mg/L. Electrical conductivity and Total Dissolved Solids (TDS) varied from 14.00-39.00 (27.00 ± 2.18) µS/cm and 7.00-20.00 (13.75 ± 1.07) mg/L, while the nutrients (NO_3^-, PO_4^{3-}, & SO_4^{2-} ions) varied from 0.20-0.70 (0.38 ± 0.03), 0.50-1.60 (1.11 ± 0.08), and 8.00-12.20 (10.33 ± 0.34) mg/L respectively.

Composition and abundance of plankton-A total of 47 genera of plankton were identified in the study. Of this, the phytoplankton composed of 43 genera while the zooplankton composed of 4 genera. These genera belong to 8 classes of phytoplankton which includes 10 genera of bacillariophyceae, 18 genera of cyanophyceae, 12 genera of chlorophyceae, 3 genera of xanthophyceae, 2 genera of euglenophyceae, and 1 genera each of pyrrophyceae, charophyceae, copepod, cladocera, protozoa and fish eggs.

Abundance of phytoplankton taxa-Two plankton groups-phytoplankton and zooplankton were studied in this research, and the pattern of their abundances varied spatially. Seven phytoplankton families- Bacillariophyceae, Cyanophyceae, Chlorophyceae, Euglenophyceae, Pyrrophyceae, Charophyeae and Xanthophyceae were identified in this study (Appendixes 3a-3d). Diatoms (Bacillariophyceae) counts ranged between 12 and 46 (27 ± 3) organisms/ml, blue-green algae (Cyanophyceans) ranged between 6 and 23 (14 ± 2) organisms/ml, while the green algae (Chlorophyceans) ranged between 2 and 19 (7 ± 1) organisms/ml. Of these, the diatoms were most abundant while charophyceans were least abundant. The order of abundance was Bacillariophyceae>Cyanophyceae>Chlorophyceae>Xanthophyceae>Euglenophyceae>Pyrrophyceae>Charophyeae.

Phytoplankton abundance comprised of a total of 9 each of diatoms and blue-green algae genera, 6 green algae genera, 2 each of euglenophycean and xanthophycean genera, and 1 each of charophycean and pyrrophycean genera. The most abundant diatom genera were *Diatoma* sp while that for cyanophyceae was *Aphanizomenon flos-Aquae*.

Abundance of zooplankton taxa- Four zooplankton classes were identified during the study period (Tables 2-5). The classes were cladocera, copepoda, protozoa and pisces (fish eggs). Zooplankton was lower in abundance than the phytoplankton assemblages. Maximum counts only were recorded for the zooplankton classes. The order of abundance of the classes was cladocera and copepoda>protozoa>fish eggs.

TABLE I. DESCRIPTIVE STATISTICS OF THE PHYSICOCHEMICAL PARAMETERS OF OTAMIRI RIVER IN OWERRI

Parameters	Minimum	Maximum	Mean	Standard error
Water Temperaure (^oC)	27.58	28.63	27.92	0.11
pH	5.32	6.32	6.15	0.01
Turbidity (NTU)	3.00	6.40	4.62	0.34
TSS (mg/l)	2.00	6.50	4.42	0.45
DO (mg/l)	0.91	1.63	1.35	0.07
BOD (mg/l)	0.88	1.41	1.12	0.05
TDS (mg/l)	19.00	38.00	27.63	0.42
Conductivity (µS/cm)	14.00	39.00	27.00	2.18
Nitrate (mg/l)	0.20	0.70	0.38	0.03
Phosphate (mg/l)	0.50	1.60	1.11	0.08
Sulphate (mg/l)	8.00	12.20	10.33	0.34

TDS= Total Dissolved Solids, TSS= Total Suspended Solids, DO= Dissolved Oxygen, BOD= Biological Oxygen Demand

TABLE II. ABUNDANCE AND DIVERSITY IN PLANKTON OF OTAMIRI RIVER AT EGBU (SAMPLING LOCATION 1)

Plankton Species	Sampling points			Total Occurrence/ml	% composition
	1	2	3		
PHYTOPLANKTON Bacillariophyceae (Diatoms) *Diatoma* sp *Melosira granulata* *Nitzschia kutzingiana* *Amphipleura pellucida*	 17 - 1 -	 18 - 3 -	 9 2 - 1		
Total	18	21	12	51	47.2
Cyanophyceae *Aphanizomenon flos-aquae* *Lyngbya limnetica* *Raphidiopsis mediterranea* *Phormidium tenue*	 5 - 1 -	 10 3 - -	 4 1 2 4		
Total	6	13	11	30	27.8
Chlorophyceae *Closterium lanula* *C. intermedium* *Spirogyra* sp *Tetrastrum elegans*	 2 - 5 -	 2 2 1 2	 7 - 4 -		
Total	7	7	11	25	23.2
Xanthophyceae *Ophiocytium* sp	 -	 1	 1		
Total	0	1	1	2	1.8
Grand Total				108	
ZOOPLANKTON Copepoda *Canthocamptus staphylinus*	 -	 1	 -		
Total	0	1	0	1	50.0
Pisces Fish eggs	 1	 -	 -		
Total	1	0	0	1	50.0
Grand Total				2	

TABLE III. ABUNDANCE AND DIVERSITY IN PLANKTON OF OTAMIRI RIVER AT NEKEDE (SAMPLING LOCATION 2)

Plankton Species	Sampling points			Total Occurrence/ml	% composition
	1	2	3		
PHYTOPLANKTON					
Bacillariophyceae (Diatoms)					
Diatoma sp	13	22	30		
D. elongatum	5	-	3		
Melosira varians	1	1	3		
M. granulata	-	2	1		
Nitzschia kutzingiana	2	-	-		
Amphipleura pellucida	1	-	3		
Stauroneis sp	2	-	-		
Total	24	25	40	89	57.4
Cyanophyceae					
Aphanizomenon flos-aquae	4	17	8		
Microcystis aeruginosa	2	2	-		
Oscillatoria princep	2	3	7		
Phormidium tenue	2	-	3		
P. angustissium	-	1	-		
Rivularia planctonella	-	-	2		
Total	10	23	20	53	34.2
Chlorophyceae					
Closterium lanula	1	-	4		
Netrium digitus	-	2	-		
Coleochaete sp	1	1	-		
Total	2	3	4	9	5.8
Pyrrophyceae(Dinoflagellata)					
Gymnodinium aeruginosum	1	-	3		
Total	1	0	3	4	2.6
Grand Total				155	
ZOOPLANKTON					
Cladocera					
Daphnia hyaline	1	1	-		
Total	1	1	0	2	50.0
Copepoda					
Canthocamptus staphylinus	-	-	2		
Total	0	0	2	2	50.0
Grand Total				4	

TABLE IV. ABUNDANCE AND DIVERSITY IN PLANKTON OF OTAMIRI RIVER AT UMUCHIMA (SAMPLING LOCATION 3)

Plankton Species	Sampling points			Total Occurrence/ml	% composition
	1	2	3		
PHYTOPLANKTON					
Bacillariophyceae (Diatoms)					
Amphipleura pellucida	2	-	-		
Cyclotella comta	-	-	1		
C. kutzingiana	-	2	-		
Diatoma sp	25	18	31		
D. elongatum	6	2	7		
Melosira varians	-	2	-		
M. granulata	-	-	2		
Nitzschia kutzingiana	3	-	4		
Amphipleura pellucida	1	-	1		
Total	37	24	46	107	67.7
Cyanophyceae					
Aphanizomenon flos-aquae	1	12	5		
Microcystis aeruginosa	3	3	-		
Phormidium tenue	-	-	2		
Rivularia planctonella	1	1	-		
Oscillatoria princeps	-	3	-		
O. lauterbornii	1	-	-		
Gloeotrichia sp	-	-	2		
Total	6	19	9	34	21.5
Chlorophyceae					
Closterium lanula	-	2	-		
C. kutzingiana	1	-	-		
Cosmacladium saxonicum	2	1	2		
Desmidium sp	-	2	1		
Onychonema filiforme	-	1	-		
Stichococcus scopulinus	1	-	1		
Total	4	6	4	14	8.9
Euglenophyceae					
Euglena tripteris	1	1	-		
Total	1	1	0	2	1.3
Pyrrophyceae(Dinoflagellata)					
Gymnodinium aeruginosum	-	-	1		
Total	0	0	1	1	0.6
Grand Total				158	
ZOOPLANKTON					
Cladocera					
Daphnia hyalina	1	-	3		
Total	1	0	3	4	57.1
Copepoda					
Canthocamptus staphylinus	2	-	1		
Total	2	0	1	3	42.9
Grand Total				7	

TABLE V. ABUNDANCE AND DIVERSITY IN PLANKTON OF OTAMIRI RIVER AT FUTO (SAMPLING LOCATION 4)

Plankton Species	Sampling points			Total Occurrence/ml	% composition
	1	2	3		
PHYTOPLANKTON Bacillariophyceae (Diatoms)					
Amphipleura pellucida	-	4	3		
Diatoma sp	8	11	12		
D. elongatum	2	14	3		
Fragilaria brevistriata	2	1	4		
Melosira pusilla	1	-	1		
Cyclotella comta	-	1	5		
C. kutzingiana	-	2	-		
Stauroneis sp	1	-	1		
Total	14	33	29	76	43.4
Cyanophyceae					
Aphanizomenon flos-aquae	3	10	8		
Anabaenopsis sp	2	4	-		
Phormidium tenue	1	-	1		
P. mucicola	-	1	-		
P. angustissium	2	2	7		
Oscillatoria lacustris	-	1	3		
O. lauterbornii	-	2	-		
Raphidiopsis curvata	1	1	-		
Chlorogloea microcystoides	-	-	2		
Total	9	21	21	51	29.1
Chlorophyceae					
Cosmacladium saxonicum	4	4	11		
Spyrigyra sp	2	4	7		
Netrium digitus	-	3	-		
Coleochaete sp	1	-	-		
Stichococcus scopulinus	-	1	1		
Total	7	12	19	38	21.7
Euglenophyceae					
Euglena tripteris	-	2	1		
Epithemia sp	1	-	-		
Total	1	2	1	4	2.3
Charophyceae					
Nitella sp	-	2	-		
Total	0	2	0	2	1.1
Xanthophyceae					
Tribonema vulgare	2	-	1		
T. viride	-	1	-		
Total	2	1	1	4	2.3
Grand Total				175	
ZOOPLANKTON Cladocera					
Daphnia hyalina	-	2	-		
Total	0	2	0	2	28.6
Copepoda					
Canthocamptus staphylinus	1	-	1		
Total	1	0	1	2	28.6
Protozoa					
Arcella arenaria	-	3	-		
Total	0	3	0	3	42.8
Grand Total				7	

A. Spatial Variation of physicochemical parameters

The physicochemical parameters measured in water also varied spatially. At Egbu (Control location), mean (±SE) Dissolved Oxygen (DO), Biological Oxygen Demand (BOD), Total Dissolved Solids (TDS) and Total Suspended Solids (TSS) were 1.47 (± 0.01), 0.92 (±0.03), 8.67 (±1.20) and 2.63 (±0.32) mg/L respectively (Fig. 2). At Nekede, their respective mean values were 1.57 (±0.03), 1.24 (±0.06), 18.00 (±1.15) and 3.67 (±0.45) mg/L. At Ihiagwa/Umuchima they were 1.40 (±0.09), 1.07 (±0.09), 14.67 (±0.33) and 5.93 (±0.22) mg/L. However, at FUTO, their mean values were 0.95 (±0.03), 1.25 (±0.08), 13.67 (±0.33) and 5.47 (±0.75) mg/L respectively.

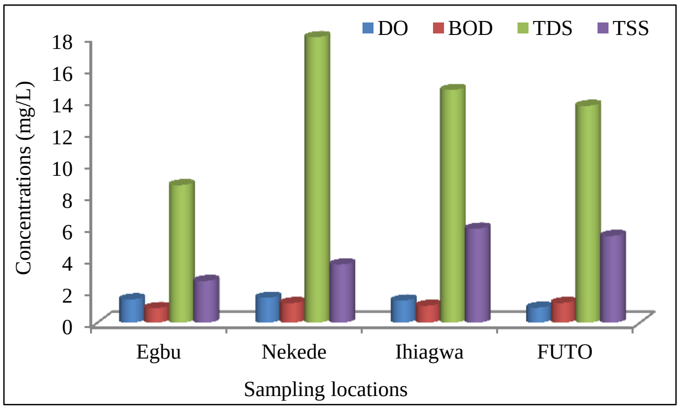

Figure 2. Spatial variations in mean dissolved oxygen, biological oxygen demand, total dissolved and total suspended solids of Otamiri River in Owerri

Figure 3 shows that at Egbu, mean (±SE) of hydrogen ion concentrations (pH), water temperature, electrical conductivity and turbidity were 6.78 (± 0.03), 28.51 (±0.06) ºC, 16.67 (±2.19) µS/cm and 3.03 (±0.03) NTU respectively. At Nekede, their mean values were 5.88 (±0.24), 27.81 (±0.02) ºC, 36.00 (±2.08) µS/cm and 4.50 (±0.29) NTU respectively. At Ihiagwa/Umuchima the respective mean values were 6.10 (±0.12), 27.70 (±0.01) ºC, 28.67 (±0.33) µS/cm and 5.43 (±0.48) NTU. However, at FUTO, their mean values were 5.87 (±0.26), 27.67 (±0.07) ºC, 27.00 (±0.58) µS/cm and 5.50 (±0.47) NTU respectively.

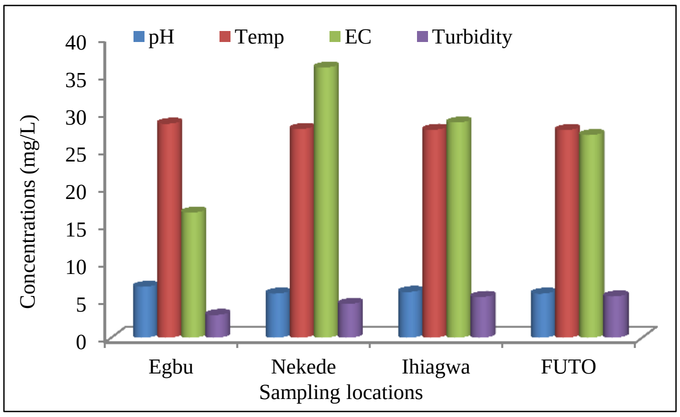

Figure 3. Spatial variations in mean pH, water temperature, electrical conductivity and turbidity of Otamiri River in Owerri

Mean concentrations of nitrate, phosphate and sulphate ions were 0.53 (±0.09), 1.13 (±0.12) and 8.77 (±0.43) mg/L (Egbu); 0.37 (±0.03), 1.40 (±0.12) and 11.40 (±0.49) mg/L (Nekede); 0.30 (±0.06), 0.77 (±0.15) and 10.13 (±0.18) mg/L (Ihiagwa/Umuchima); and 0.30 (±0.06), 1.13 (±0.07) and 11.00 (±0.12) mg/L (FUTO) (Fig. 4).

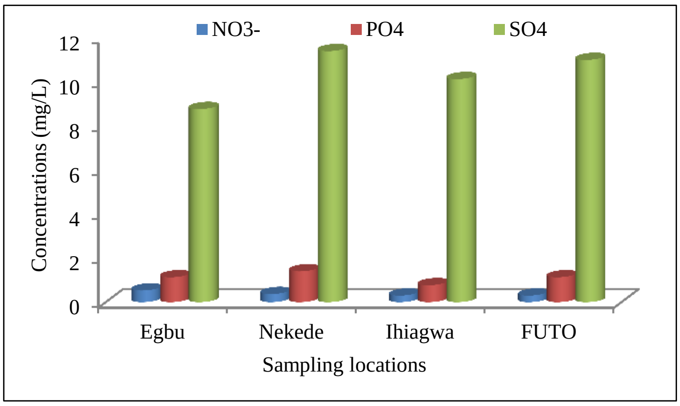

Figure 4. Spatial variations in mean nitrate, phosphate and sulphate ion concentrations of Otamiri River in Owerri

B. Spatial abundance in plankton taxa

Variations were also observed in plankton abundance across the sampling locations. Sampling location 3 (Ihiagwa/Umuchima) recorded the highest plankton abundance (158 organisms/ml) while Egbu had the least abundance of 108 organisms/ml .

Bacillariophycean counts were highest at Ihiagwa/Umuchima (107 organisms/ml; 67.7%) and least at Egbu (51 organisms/ml; 49.2%) (Fig 5). Highest abundance of 53 organisms/ml (34.2%) was recorded at Nekede for the blue-green algae (cyanophyceans), while Egbu recorded the least abundance of 30 organisms/ml (27.8%) for the taxa (Fig 6). The green algae was most abundant at FUTO (38 organisms/ml; 21.7%) and least abundant at Nekede (9 organisms/ml; 5.8%). However the other phytoplankton families were not identified at several sampling locations.

At sampling location 1 (Egbu), the order of abundance of the phytoplankton was bacillariophyceae (951; 49.2%)>cyanophyceae (30; 27.8%)>chlorophyceae (25; 23.2%)>xanthophyceae(2;1.8%)>euglenophyceae=pyrrophyceae=charophyceae (0; 0.0%). At Nekede, the order of the abundance was bacillariophyceae (89; 57.4%)>cyanophyceae (53; 34.2%)>chlorophyceae (9; 5.8%)>pyrrophyceae (4; 2.6%)>xanthophyceae= euglenophyceae = charophyceae (0; 0.0%). In sampling location 3 (Ihiagwa/Umuchima), the order of abundance was bacillariophyceae (107; 67.7%)>cyanophyceae (34; 21.5%)>chlorophyceae (14; 8.9%)>euglenophyceae = charophyceae (0; 0.0%). In location 4 (FUTO), the order of abundance was bacillariophyceae (76; 43.4%)>cyanophyceae (51; 29.1%)>chlorophyceae (38; 21.7%)> xanthophyceae=euglenophyceae (4; 2.3%)>charophyceae (2; 1.1%)> pyrrophyceae (0; 0.0%).

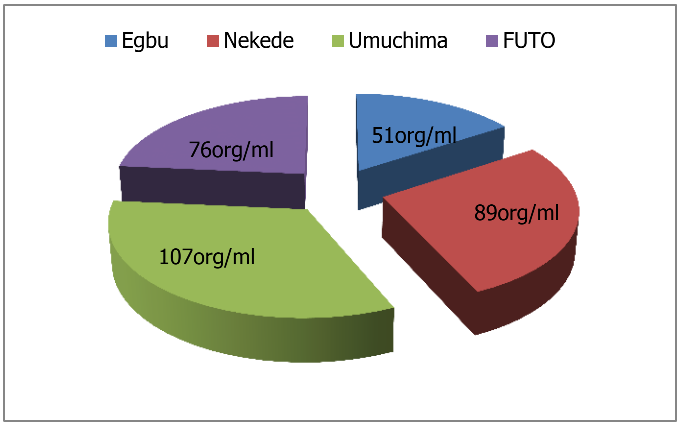

Figure 5. Spatial variation in bacillariophyceans of Otamiri River

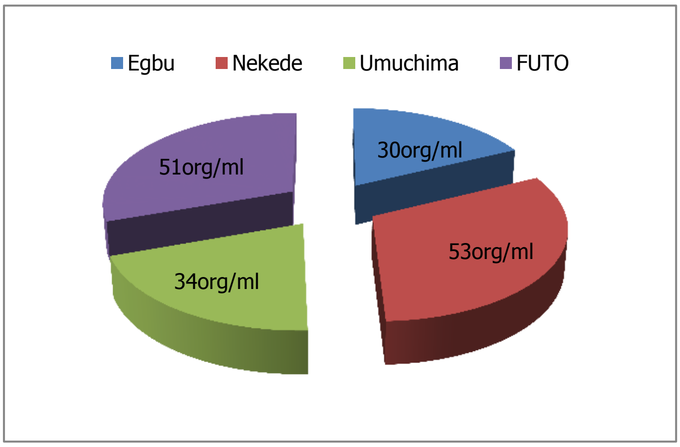

Figure 6. Spatial variation in cyanophyceans of Otamiri River

C. Pearson correlation matrix

Table 6 shows the Pearson correlationships (r) between the physicochemical characteristics measured and plankton taxa identified in the Otamiri River. Some physicochemical variables showed significant influences on plankton families. However, at p<0.05, DO correlated negatively with euglenophyceae (r=-0.679) and xanthophyceae (r=-0.673). At p<0.01, DO correlated negatively with chlorophyceae (r=-0.747).

At p<0.05, BOD correlated positively with cyanophyceae (r=0.619), and TSS correlated with bacillariophyceae (r=0.629). Other physicochemical parameters measured did not show significant influences on the plankton families identified.

TABLE VI. RELATIONSHIPS BETWEEN PHYSICOCHEMICAL VARIABLES AND PLANKTON ASSEMBLAGES

Plankto taxa/physicochemical	DO	BOD	pH	Temp	EC	TDS	TSS	Turbidy	NO_3^-	PO_4^{3-}	SO_4^{2-}
Bacillariophyceae	-0.023	0.136	0.435	-0.482	0.500	0.495	0.629*	0.510	-0.392	0.156	0.468
Cyanophyceae	-0.309	0.619*	0.206	-0.324	0.430	0.438	0.397	0.458	-0.392	0.295	0.565
Chlorophyceae	-0.747**	0.220	0.311	0.052	-0.429	-0.420	0.330	0.141	-0.091	-0.034	-0.099
Euglenophyceae	-0.679*	0.135	0.392	0.285	-0.005	-0.031	0.159	0.391	-0.066	-0.013	0.269
Pyrrophyceae	0.296	0.060	-0.104	-0.156	0.489	0.441	-0.031	0.122	0.019	0.507	0.489
Charophyceae	-0.513	0.073	0.330	-0.089	-0.045	-0.063	0.298	0.478	0.058	0.099	0.128
Xanthophyceae	-0.673*	-0.004	0.138	-0.011	-0.437	-0.453	-0.017	-0.034	0.149	-0.070	0.063
Cladocera	-0.123	-0.181	0.344	-0.342	0.260	0.273	0.428	0.366	0.272	-0.021	0.158
Copepoda	0.092	-0.015	0.016	-0.135	-0.012	-0.057	0.173	-0.087	-0.156	0.052	0.306
Protozoa	-0.513	0.073	0.330	-0.089	-0.045	0.063	0.298	0.478	0.058	0.099	0.128
Pisces (Fish eggs)	-0.444	-0.004	0.204	0.111	-0.126	-0.138	0.133	0.326	0.075	0.164	-0.079

*=significant at p<0.05 level; **=significant at p<0.01 level; DO=dissolved oxygen; BOD=biological oxygen demand; Temp=water temperature EC=electrical conductivity; TDS=total dissolved solids; TSS=total suspended solids; Turbid=turbidity

D. Discussions

Like any other aquatic ecosystem, the physicochemical characteristics and plankton abundance and diversity of the Otamiri River in Owerri is prone to ecological imbalances resulting from both natural and anthropogenic impacts arising from man's quest for the exploitation of natural resources. At the time of this investigation, there was ongoing intensive in-stream sand mining by local inhabitants along the course of the river, as well as other domestic activities in the catchments of the sampling locations.

The water temperature range in the present study was similar to those reported by Sowunmi (2001), Eze (2005), and Tamuno (2005) for natural inland water in the tropics.

Mean value of 4.62 ± 0.34 NTU Turbidity recorded in this study was below the NESREA 10.00 NTU limit for aquatic life in surface waters in Nigeria, even as the UNEP GEMS (2006) states that water bodies that have high turbidities (low transparencies) are not good for drinking.

Ongoing in-stream mining activities by local inhabitants could contribute suspended particulate materials along the river course. Tamuno (2005) had pointed out the contributory effect of sand mining and dredging on TSS of two Niger Delta water bodies in Kolo and Otuoke communities, and so did Eze (2005) and Egborge (1994), among others, in the Niger Delta.

TDS values were higher in the more impacted locations (Nekede, Ihiagwa/Umuchima and FUTO) than the control (Egbu). Mean TDS values were fairly inversely followed by pH; a trend that was also observed by Atobatele *et al.* (2005) and was attributed to increases in major ions dissolved in the water from underlying rocks or washed by rain which affects pH of aquatic systems.

According to Grant (2002), the pH of water is affected considerably as photosynthetic activity removes carbon (IV) oxide from water and shifts the carbonate-bicarbonate equilibrium. The slightly acidic pH range of this study conformed to values previously reported in Niger Delta freshwaters (Ikomah, 1999). The minimum range of pH in this study falls outside the NESREA 6.5–8.5 recommended limits for aquatic life. Slightly higher Do values were recorded in the impacted than pristine control location. This could indicate more turbulence of the river at those locations that incorporated oxygen than at the pristine location.

BOD range of this river indicated that the water was fairly clean, going by Moore and Moore (1976) ranking of levels less than 1.0 mg/l as clean, 3.0 mg/l as fairly clean, 5.0mg/l as doubtful, and 10.0mg/l as polluted. Also, going by NESREA recommended limit of 3.0 mg/l, the river was unsuitable for aquatic life. Though seemingly unobtainable in a natural ecosystem, Faurie *et al.,* (2001) recommends a BOD value of 0 mg/l for a best potable water supply.

Nitrate values corresponded with findings from the works of Chindah and Braide (2001) in a Swamp Forest stream, Obunwo *et al.* (2004) in Minichida stream, and Ogamba *et al.* (2005) in Elechi Creek, all in the Niger Delta. Some inhabitants of the study area are agrarian and so, through their occupations could contribute nitrates from farmland fertilizer applications into the water body. Nitrate values recorded in this study falls below the WHO 50 mg/l limits for drinking water and NESREA 9.10 mg/l for aquatic life.

The abundance and diversity of plankton taxa were to some extent influenced by the physicochemical characteristics of the river. However, many of the physicochemical parameters did not exert significant influences on the plankton abundance. Majority of the influences of these parameters on plankton abundance and diversity were from dissolved oxygen, biological oxygen demand and total suspended solids. The inverse relationships between BOD and TSS and the plankton groups indicates strict narrow requirements of the variables by these classes of organisms; excess availability of which may have become inhibitory to them. Edoghotu and Aleleye-Wokoma (2007) had observed negative correlations between DO and the bacillariophyceae, euglenophyceae and cyanophyceae of Ntawoba Creek in Port Harcourt. However, the negative correlations observed between plankton in the current study and TSS had also been recorded by Zabbey *et al.* (2008); that high suspended particles arising from sand dredging and seasonal flooding constitutes high turbidity in the Imo River in Oyigbo that affect species abundance and diversity indirectly through reduced productivity.

V. CONCLUSION

Increasing anthropogenic activities are suspected to be responsible for variations in plankton abundance along the course of the Otamiri River in Owerri. The present study indicates the need for comprehensive monitoring of plankton for proper management of a freshwater aquatic ecosystem. Sequel to this, concerned state authorities have to take appropriate actions to control indiscriminate sand mining along the course of the river. This is because this activity has potential to affect plankton abundance of the river.

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