The physico-chemical variables and phytoplankton of Ufiobodo and Ebonyi Reservoirs, Ebonyi State, Nigeria

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Abstract

The water quality and phytoplankton of Ufiobodo and Ebonyi River reservoirs were studied for nine months from March to November, 2019 to evaluate the suitability of the reservoirs for domestic water supply and habitat for aquatic organisms. Temperature, pH, conductivity, total dissolved solid (TDS), transparency, dissolved oxygen (DO) and depth were measured *in situ*, while water samples were collected for determination of nitrate, iron, silicate and phosphate in the laboratory. Phytoplankton samples were also collected concurrently using plankton net of mesh size 45µm and mouth diameter (0.26m) and identified in the laboratory using standard keys. The results showed that mean conductivity (32.33µS/cm), TDS (16.00mg/l), nitrate (33.99mg/l), depth (10.36m) and phosphate (4.81mg/l) were higher at Ebonyi than Ufiobodo Reservoir but DO was lower at Ebonyi Reservoir (2.77mg/l) than at Ufiobodo Reservoir (6.67mg/l). Mean DO level was below the permissible limit for drinking water at Ebonyi Reservoir while nitrate, phosphate and iron concentrations exceeded permissible limits in both Reservoirs. Five phytoplankton Phyla were encountered, predominated by Chlorophyta (107 individuals/l, H=2.80 and d=3.85) and Bacillariophyta (81 individuals/l, H=2.39 and d=2.50) at Ufiobodo and Ebonyi Reservoirs, respectively. Principal Component Analysis (PCA) showed that temperature, conductivity, TDS, depth, DO, nitrate and phosphate were the major factors influencing phytoplankton abundance and diversity of the reservoirs. Thus, the reservoirs should be protected to maintain/improve the water quality for domestic use and to support the socio-economic and ecological services they provide.

Keywords: Phytoplankton, pollution indicators, Ufiobodo and Ebonyi River Reservoirs, water quality parameters.

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Introduction

Rivers and lakes are the major sources of freshwater for domestic uses, agriculture, hydroelectric power generation and industrial processes. They provide several ecosystem services such as climate moderation, recharging of ground water, reduction of flood damage, source of water for irrigation and habitat for variety of life forms at all levels (Bikangaga *et al* 2007; Omofonmwan and Odia 2009). To optimize the provision of the goods and services from rivers and lakes that are interconnected to large or small rivers, they are dammed.

Dams are made across flowing water bodies to control their flow and enhance water storage (Nestmann and Stelzer 2007; Youdeowei *et al* 2019) for a variety of purposes such as electricity generation, irrigation, flood control, drinking water supply, sewage assimilation, fisheries and aquaculture (Manatunge *et al* 2001). There are about 30 major dams in Nigeria most of which were constructed for hydroelectric power generation, water supply and irrigation. Aside the major dams, several other small dams such as the Ufiobodo and Ebonyi River dams in Ebonyi State were constructed to supply water for irrigation and domestic use to the riparian communities. Unsustainable utilization of the services provided by the dams poses threats to the health status of the ecosystem through changes in the water quality and its biota.

Water quality assessment have been carried out on most of the reservoirs across the country some of which include the works of Irenosen *et al* (2012), Hyeladi and Nwagilari (2014), Okunlola *et al* (2014), Mohammed *et al* (2017), Ojelabi*et al* (2018), and Rabiu *et al* (2018) in Owena Multipurpose Reservoir, Alau, Gurara and Kainji lakes, and Eleyele and Watari reservoirs, respectively. These studies showed that the reservoirs were under pollution pressure due to anthropogenic activities and are not suitable for domestic use unless treated. Mohammed *et al* (2017) asserted that Kanji dam hydropower operations had no negative effect on the water quality but adduced high nutrient levels recorded at the lake to socio-economic activities of the riparian communities.

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Meanwhile, these studies did not consider the effects of changes in physicochemical variables on the phytoplankton community of the ecosystems. Hence, this study examined the relationship between physico-chemical variables and phytoplankton abundance and diversity of Ufiobodo and Ebonyi reservoirs in order to assess their pollution status. So, we hypothesize that there may be changes in the water quality of the reservoirs, which will affect the phytoplankton structure during the study period. So, the study will hopefully provide valid database that will promote sustainable management of the reservoirs.

Materials and methods

Study area

This study was carried out at Ufiobodo, and Ebonyi River reservoirs. Ufiobodo Reservoir lies between 6º 24´ 24.9´´N; 7º 56´ 39.3´E and 6º 24´ 21.2´´N; 7º 56´ 47.6´´E in Ohaukwu Local Government Area (LGA) while Ebonyi River Reservoir is at 6º 19´ 31.8´´N; 8º 08´ 21.8´´E in Abakaliki LGA, both in Ebonyi State (Figure 1), Nigeria. Ufiobodo Reservoir was built to supply water for domestic use and irrigation of palm seedlings at the Institute of Agricultural Research, Ezzamgbo while Ebonyi River Reservoir was constructed to supply drinking water to Abakaliki town and its immediate environment. Since the riparian communities are agrarian, intensive rain-fed farming activities that involve the use of fertilizer and herbicides take place around the two reservoirs as the capacity may not carry year-round irrigation. Artisanal fishing also takes place at the study sites often. Four accessible stations were mapped for sampling in each reservoir as shown in Figure 1.

Water sample collection and measurement of physico-chemical parameters

Water samples were collected monthly at each station for determination of physico-chemical parameters from March to November, 2019. The sampling periods covered the onset of farming (March to May), farming (June to August) and harvesting (September to November). These periods were carefully selected in order to ensure that the influence of agricultural activities on the reservoirs through runoffs from farms is underscored.

At each station, water temperature, conductivity and total dissolved solids (TDS) were measured *in situ* using Hanna conductivity and TDS meter with an in-built digital thermometer (Model HI 98303). The pH was measured using Hanna pH meter (Model HI 77700P) while transparency and dissolved oxygen (DO) were measured using Secchi disc and Hanna DO meter (Model HI 9142), respectively. Depth was measured using calibrated pole. Nitrate, phosphate, iron and silicate concentrations were determined in the Applied Biology laboratory of Ebonyi State University using standard procedures of APHA (2012). All the measurements were taken in triplicate.

Collection and identification of phytoplankton samples

Phytoplankton samples were collected concurrently with water samples from each station**.** The phytoplankton samples were collected at 0.10 m below the water surface by towing plankton net of mesh size 45µm and mouth diameter (0.26m) horizontally against water current. The method was modified by the researchers from the phytoplankton sampling protocol of the Canadian Council for Ministers and Environment, CCME (2011), preserved immediately in 4% formalin and identified in the laboratory using Olympus binocular microscope (Model: XSZ-107E) at ×400 magnification and standard guides of Prescott (1978) and Nwankwo (2004). Species identified were confirmed using Algae Base (Guiry and Guiry 2021).

Estimation of phytoplankton diversity indices

Phytoplankton were quantified by cell counting (Ovie 1993) and diversity, species richness and evenness were calculated using the Shannon-Weiner diversity index (H'), Margalef's index and evenness, respectively (Pielou 1966; Shannon 1948).

Statistical analyses

Data collected from the field measurement and laboratory analysis of water samples were summarized using descriptive statistics and presented as mean and standard deviation. Spatial and temporal variations in mean values of the measured variables were also tested using two-way analysis of variance and were considered significant at $p<0.05$. Principal Component Analysis (PCA) was used to evaluate physicochemical variable-plankton relationship. All statistical analyses carried out using PAST version 1.0.

Results

Water quality parameters

The results of the water quality parameters measured for the two reservoirs are in Table 1. Mean water temperature was higher (33.70ºC) between March and May, 2019 at Ufiobodo Reservoir and least (27.17ºC) between June and July at Ebonyi River Reservoir. Mean conductivity (32.33µS/cm) and TDS (16.00mg/l) were higher at Ebonyi River Reservoir between March and May, 2019. Mean pH (7.93) and transparency (0.39m) were higher between September to November, 2019 at Ufiobodo Reservoir while dissolved oxygen was lowest (2.77mg/l) at the same period in Ebonyi River Reservoir. Mean depth was 0.34m between March to May, 2019 in Ufiobodo Reservoir and 10.36m between June to August, 2019 in Ebonyi River Reservoir.

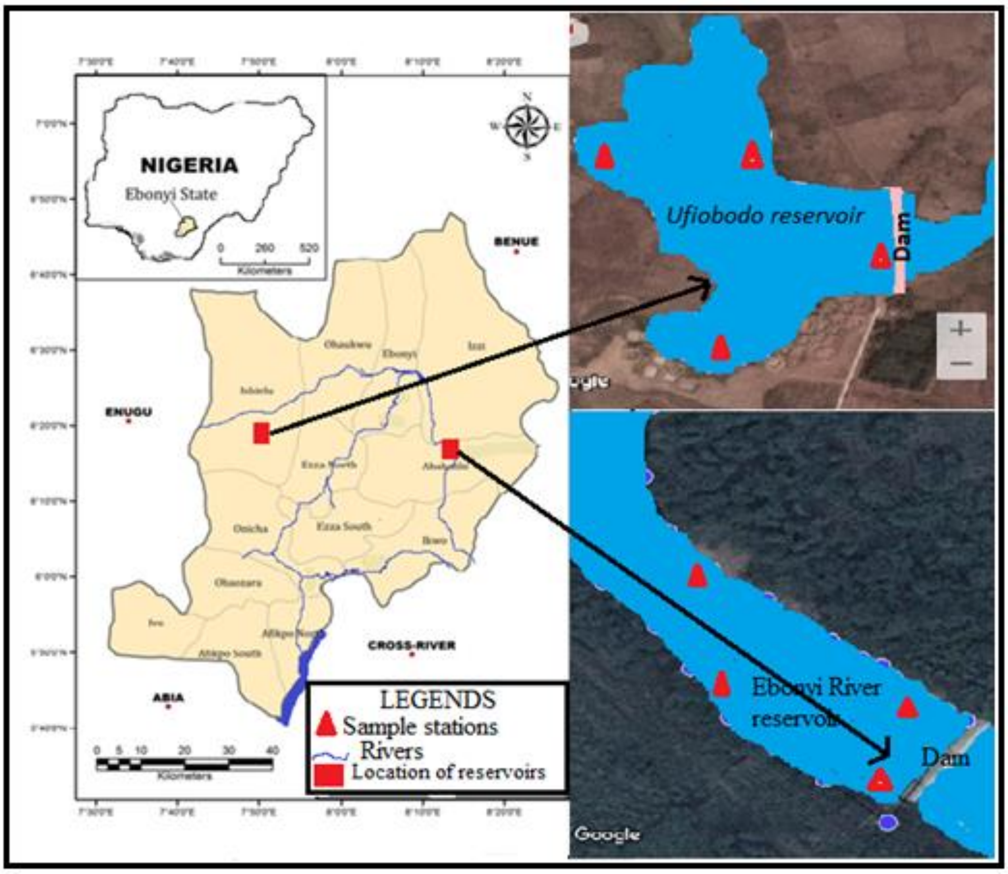

Figure 1: Map of Ebonyi State showing the locations of the dams and reservoirs with an insert map of Nigeria

Table 1: Mean and standard deviation of water quality parameters of Ufiobodo and Ebonyi reservoirs

Parameters	Ufiobodo Reservoir			Ebonyi Reservoir			p -value between reservoirs/ periods	WHO (1993)
	Pre-planting period (Mar-May)	Planting period (Jun-Aug)	Post-Planting period (Sept-Nov)	Pre-planting period (Mar-May)	Planting period (Jun-Aug)	Post-Planting period (Sept-Nov)		
Temperature (ºC)	33.70±0.55^a	30.56±3.50^a	30.80±0.75^a	33.20±0.79^a	27.17±0.89^a	30.27±2.06^a	0.15	30.00-35.00
pH	6.23±0.15^a	6.93±0.37^b	7.93±0.55^c	6.50±0.30 ^{a}	6.85±0.45^b	7.66±0.30^c	0.72	6.50- 8.50
Conductivity (µS/cm)	22.33±2.52^a	26.00±7.00^a	31.00±2.65^a	32.33±2.52^a	20.33±10.41^a	24.6±6.43^a	0.83	***
TDS (mg/l)	11.00±1.00^a	13.33±3.21^a	15.33±1.53^a	16.00±1.00^a	9.00 ±3.00^a	11.33±0.58^a	0.50	2000.00
Transparency (m)	0.17 ±0.00^a	0.34 ±0.14^a	0.39 ±0.19^a	0.12 ±0.02^b	0.08 ±0.03^b	0.16 ±0.00^b	0.007	***
DO (mg/l)	4.33 ±0.61^a	6.67 ±0.42^a	4.33 ±0.41^a	3.43 ±0.60^b	3.67±0.72^b	2.77 ±0.55^b	0.0004	4.00
NO_3^- (mg/l)	23.87±1.40^a	28.17±1.26^a	30.10±1.13^a	32.39±0.42^b	33.99±0.93^b	32.43±2.71^b	0.0007	10.00
Fe^{2+} (mg/l)	3.38 ±0.16^a	3.52 ±0.09^a	3.61 ±0.08^a	1.85±0.03^b	1.94 ±0.05^b	1.95 ±0.02^b	0.00	1.00
SiO_3^- (mg/l)	2.77 ±0.25^a	3.32 ±0.31^b	3.85^c±0.04^c	1.75 ±0.05 ^{d}	2.69 ±0.50 ^{e}	3.41±0.10^f	0.00	***
PO_4^- (mg/l)	3.78 ±0.34^a	4.50 ±0.48^b	4.78±0.28^c	2.67 ± 037^a	4.46 ±0.53^b	4.81±0.16^c	0.08	3.50
Depth (m)	0.84 ±0.04^a	1.51 ±0.41^a	0.97 ±0.10^a	8.58 ±1.03^b	10.36 ±0.82^b	8.24 ±0.87^b	0.00	***

Means with different superscripts across rows are significantly different ($p<0.05$). *** No standard.

Mean concentrations of nitrate (33.99mg/l) was higher between June to August 2019 and phosphate (4.81mg/l) between September to November, 2019 in Ebonyi River Reservoir while iron (3.61mg/l) and silicate (3.85mg/l) were highest at the same period in 2019 at Ufiobodo Reservoir. Mean dissolved oxygen level at Ebonyi River Reservoir was below WHO recommended permissible limit for drinking water while nitrate, phosphate and iron level were above the permissible limit. ANOVA results showed that differences in mean transparency, dissolved oxygen, depth, nitrate, iron and silicate were significant ($p<0.05$) between the reservoirs.

Phytoplankton composition and abundance

Five phytoplankton phyla namely; Bacillariophyta, Chlorophyta, Chrysophyta, Cyanophyta and Euglenophyta were recorded in the reservoirs during the study (Table 2). Chlorophyta was the most abundant (107/L, 19 species) phylum at Ufiobodo Reservoir and Bacillariophyta (81/L, 12 species) at Ebonyi River Reservoir while Chrysophyta was the least (4/L, 1 and 2 species, respectively) in the reservoirs (Table 2). *Anabaena subvariabilis*, *Aulacoseira granulata*, *Euglena* spp., *Fragilaria* spp., *Gonatozygon* species. *Lepocinclis* spp., *Microcystis aeruginosa*, *Navicula* spp., *Oscillatoria* species., *Phacus* spp., *Pinnularia* species., *Spirogyra* spp., *Spirulina* spp., *Synedra* species were some of the indicators of organic pollution (nitrate and phosphate) recorded in the reservoirs, most of which were the highest (>3.5) in percentage relative abundance (Table 2).

Table 2: Species composition of phytoplankton identified at Ufiobodo and Ebonyi River Reservoirs during the study

Phytoplankton Phyla	Ufiobodo reservoir		Ebonyi River reservoir	
	Abundance (No/l)	% Relative Abundance	Abundance (No/l)	%Relative Abundance
Bacillariophyta				
Amphora ovalis (Kutzing) Kutzing 1844	***	***	8	4.79
Asterionella formosa Hassall 1850	5	1.58	***	***
Aulacoseira granulata (Ehrenberg) Simonsen 1979	***	***	8	4.79
Cyclotella meneghiniana Kützing 1844	10	3.16	***	***
Cymbella tumida (Brébisson) Van Heurck 1880	9	2.85	10	5.99
Diatoma vulgaris Bory 1824	8	2.53	***	***
Epithemia turgida (Ehrenberg) Kützing 1844	4	1.27	***	***
Eunotia cholnokyi H.P.Gandhi 1966	6	1.9	***	***
Eunotia tetraodon Ehrenberg 1838	6	1.9	4	2.4
Fragilaria capucina Desmazières 1830	***	***	12	7.19
Fragilaria virescens Ralfs 1843	***	***	8	4.79
Melosira varians C.Agardh 1827	12	3.8	***	***
Meridion circulare (Greville) C.Agardh 1831	2	0.63	***	***
Navicula digitoradiata (W.Gregory) Ralfs 1861	5	1.58	9	5.39
Navicula tripunctata (O.F.Müller) Bory 1822	***	***	7	4.19
Nitzschia acicularis (Kützing) W.Smith 1853	4	1.27	3	1.8
Nitzschia palea (Kützing) W.Smith 1856	***	***	3	1.8
Pinnularia brevistriata Grunow 1880	***	***	6	3.59
Synedra ulna (Nitzsch) Ehrenberg 1832	12	3.8	3	1.8
Tabellaria vulgaris Ehrenberg 1839	5	1.58	***	***
Total abundance (No./l)	**88**	**27.85**	**81**	**49.09**
Chlorophyta				
Ankistrodesmus falcatus (Corda) Ralfs 1848	***	***	6	3.59
Chlorella volutis C.Bock, Krienitz & Pröschold 2011	9	2.85	***	***
Chlorococcum acidum P.A.Archibald & Bold 1970	5	1.58	***	***
Chodatella ciliata (Lagerheim) Lemmermann 1898	3	0.95	***	***
Closterium didymotocum Corda ex Ralfs 1848	***	***	4	2.4
Closterium parvulum Nägeli 1849	***	***	5	2.99
Cosmarium moniliforme Ralfs 1848	7	2.22	5	2.99
Cosmarium pachydermum P.Lundell 1871	***	***	4	2.4
Crucigenia truncate G.M.Smith 1920	3	0.95	***	***
Desmococcus olivaceus (Persoon ex Acharius) J.R.Laundon 1985	10	3.16	***	***
Eudorina elegans Ehrenberg 1832	7	2.22	***	***
Gonatozygon monotaenium De Bary 1856	4	1.27	***	***
Monostroma hariotii Gain 1911	8	2.53	***	***
Oocystis marssonii Lemmermann 1898	2	0.63	***	***
Pediastrum duplex Meyen 1829	***	***	4	2.4
Planktosphaeria gelatinosa G.M.Smith 1918	5	1.58	***	***
Pleurotaenium caffrorum Claassen 1961	9	2.85		***
Sphaerocystis schroeteri Chodat 1897	4	1.27	***	***
Spirogyra africana (F.E.Fritsch) Czurda 1932	3	0.95	***	***
Spirogyra nitida (O.F.Müller) Dumortier 1822	***	***	5	2.99
Spirogyra singularis Nordstedt 1880	***	***	4	2.4
Tetraselmis subcordiformis (Wille) Butcher 1959:	2	0.63	***	***
Tetraspora gelatinosa (Vaucher) Desvaux 1818	7	2.23	***	***
Tetrastrum heteracanthum (Nordstedt) Chodat 1895	5	1.58	***	***
Ulothrixzonata (F. Weber & Mohr) Kützing 1833	12	3.8	***	***
Volvoxaureus Ehrenberg 1832	1	0.32	***	***

Phytoplankton Phyla	Ufiobodo reservoir		Ebonyi River reservoir	
	Abundance (No/l)	% Relative Abundance	Abundance (No/l)	%Relative Abundance
Total abundance (No./l)	**107**	**33.86**	**37**	**22.42**
Chrysophyta				
Dinobryon sertularia Ehrenberg 1834	***	***	1	0.6
Mallomonas caudata Iwanoff [Ivanov] 1899	4	1.27	***	***
Paraphysomonas vestita (A. Stokes) De Saedeleer 1930	***	***	3	1.8
Total abundance (No./l)	**4**	**12.64**	**4**	**2.42**
Cyanophyta				
*Anabaena subvariabilis*R.E.M. Archibald 1967	13	4.11	5	2.99
Anabaenopsis arnoldii Aptekar 1926	9	2.85	***	***
Dactylococcopsis acicularis Lemmermann 1900	4	1.27	***	***
Gloeotrichia echinulata P.G. Richter 1894	7	2.22	***	***
Planktolyngbya limnetica (Lemmermann) Komárková-Legnerová & Cronberg 1992	5	1.58	***	***
Merismopedia affixa P. Richter 1895	3	0.95	***	***
Microcystis aeruginosa (Kützing) Kützing 1846	13	4.11	***	***
Nostoc commune Vaucher ex Bornet & Flahault 1888	***	***	4	2.4
Oscillatoria limosa C.Agardh ex Gomont 1892	11	3.48	4	2.4
Polycystis aeruginosa (Kützing) Kützing 1849	1	0.28	***	***
Spirulina agilis Kufferath 1914	13	4.11	***	***
Spirulina meneghiniana Zanardini ex Gomont 1892	***	***	6	3.59
Woronichinia naegeliana (Unger) Elenkin 1933	6	1.9	***	***
Total abundance (No./l)	**93**	**29.43**	**19**	**11.51**
Euglenophyta				
Euglena acus (O.F. Müller) Ehrenberg 1830	***	***	7	4.19
Euglena rubra A.D. Hardy 1911	***	***	5	2.99
Euglena sanguinea Ehrenberg 1832	***	***	5	2.99
Euglenopsis rhynchata H. Christen 1962	6	1.9	***	***
Lepocinclis globules Perty 1849	4	1.27	***	***
Lepocinclis playfairiana (Deflandre) Deflandre 1932	***	***	7	4.19
Phacus nordstedtii Lemmermann 1904	3	0.95	***	***
Phacus limnophilus (Lemmermann) E. W. Linton & Karnkowska 2010	11	3.48	***	***
Total abundance (No/l)	**24**	**7.59**	**24**	**14.55**

*** species not present at the sampling period

Phytoplankton diversity indices

Phytoplankton diversity indices showed that Chlorophyta was the most diverse (H´=2.80 bit/ind) phylum and highest in species richness (d)=3.85) at Ufiobodo Reservoir (Table 3). On the other hand, Bacillariophyta was the most diverse (H´=2.39bit.ind^{-1}) phylum and highest in species richness (d=2.50) in Ebonyi River Reservoir (Table 2). The species recorded were more evenly distributed at Ebonyi River Reservoir than Ufiobodo Reservoir with evenness values of 0.91, 0.99, 0.99 and 0.99 for Bacillariophyta, Chlorophyta, Cyanophyta and Euglenophyta, respectively.

Relationship between physico-chemical parameters and phytoplankton abundance

The PCA analysis showed that axes 1 and 2 accounted for 70.55% of the total variation physico-chemical variables-phytoplankton association in the reservoirs (Figure 2). The dominant factors were temperature (0.71), dissolved oxygen (0.97), depth (-0.73), nitrate (-0.58) and phosphate (-0.77) on axis 1 and conductivity (0.73), TDS (0.68) and nitrate (0.62) on axis 2. The biplot separated the reservoirs into the periods covered and conductivity, TDS, DO and phosphate were the dominant factors at Ufiobodo Reservoir while depth and nitrate were dominant at Ebonyi River Reservoir.

Discussion

The water quality of Ufiobodo and Ebonyi river reservoirs were studied to assess their suitability for domestic use and as habitats for aquatic biota. The results obtained showed that the DO level was below the WHO permissible limit for drinking water while nitrate, iron and phosphate concentrations were above the permissible limit. Low dissolved oxygen level recorded could be due to microbial breakdown of organic matter to release nitrate and phosphate and deplete oxygen in the reservoirs (Nwonumara and Okogwu 2013; Umar 2020). High nitrate and phosphate concentrations recorded could be due to runoff of fertilizer applied on crops at the riparian farmlands and wetlands used mainly for cultivation of rice, yam and cassava by local farmers. Fertilizer runoffs and reduced flowrate due to dam construction could have contributed to nutrient accumulation and consequent increase in nitrate and phosphate levels in the reservoirs. High nitrate and phosphate concentrations support the growth of phytoplankton, especially the noxious Cyanophyta such as *Anabaena subvariabilis*, *Microcystis aeruginosa*, *Oscillatoria* species (Onyema, 2013), which may make the water unfit for domestic use due to the production and release of harmful toxins into the water.

Table 3: Diversity indices of phytoplankton at Ufiobodo and Ebonyi reservoirs during the study

Phytoplankton phyla/ Diversity indices	Ufiobodo Reservoir	Ebonyi River Reservoir
Bacillariophyta		
Abundance (No./l)	88	81
Number of species	13	12
Shannon-Weiner diversity (H´, bit/ind)	2.46	2.39
Species richness (d)	2.68	2.50
Evenness	0.90	0.91
Chlorophyta		
Abundance (No./l)	107	37
Number of species	19	8
Shannon-Weiner diversity (H´, bit/ind)	2.80	2.07
Species richness (d)	3.85	1.94
Evenness	0.86	0.99
Chrysophyta		
Abundance (No./l)	4.00	4.00
Number of species	1.00	2.00
Shannon-Weiner diversity (H´, bit/ind)	0.00	0.56
Species richness (d)	0.00	0.72
Evenness	1.00	0.88
Cyanophyta		
Abundance (No./l)	93.00	19.00
Number of species	11.00	4.00
Shannon-Weiner diversity (H´, bit/ind)	2.30	1.37
Species richness (d)	2.21	1.02
Evenness	0.91	0.99
Euglenophyta		
Abundance (No./l)	24.00	24.00
Number of species	4.00	4.00
Shannon-Weiner diversity (H´, bit/ind)	1.26	1.37
Species richness (d)	0.94	0.94
Evenness	0.88	0.99

The five phyla of phytoplankton encountered in the reservoirs have also been reported in different water bodies by other researchers (Mohammed and Saminu, 2012; Agouru and Audu 2012; Okogwu and Ugwumba 2013; Nwonumara and Okogwu 2021). Among the species recorded in the reservoirs during the study were *Anabaena subvariabilis, Aulacoseira granulata, Euglena* spp., *Fragilaria* spp., *Gonatozygon* species, *Lepocinclis* spp., *Microcystis aeruginosa, Navicula* spp., *Oscillatoria* species, *Phacus* spp., *Pinnularia* species, *Spirogyra* spp., *Spirulina* spp., *Synedra* sp. that are indicators of organic pollution. Most of these species such as *Anabaena subvariabilis, Microcystis aeruginosa, Oscillatoria* species are not palatable to zooplankton and herbivorous fishes because they produce toxins (Wilson *et al* 2006).

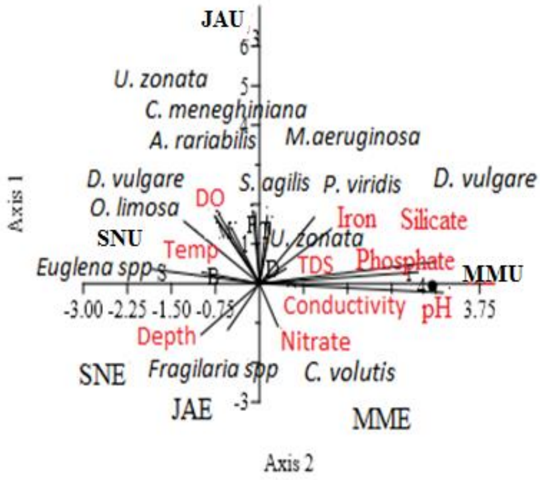

Figure 2. Ordination plot of principal component analysis of dominant physico-chemical parameters and phytoplankton abundance

MMU – March to May (Ufiobodo Reservoir), JAU – June to August (Ufiobodo Reservoir), SNU – September to November (Ufiobodo Reservoir), MME (March to May (Ebonyi River Reservoir), JAE – June to August (Ebonyi River Reservoir), SNE (September to November (Ebonyi River Reservoir).

They have also been reported to clog the feeding apparatus of zooplankton and are known to be deficient in vital nutrients that support zooplankton growth (Gliwicz and Lampert 1990; Muller-Navarra *et al* 2000). Since they are not consumed by zooplankton, they may bloom leading to accumulation of massive cells. The senescence, death and degradation of these cells cause oxygen depletion, and the release of toxins and odorous materials into the water (Okogwu *et al* 2014), which makes the water unsuitable for domestic use. This also may affect the productivity of the ecosystem as energy flow from producers (phytoplankton) to consumers (zooplankton, fishes) may be disrupted. Studies by Edward and Ugwumba (2010); Onyema (2013) and Nwonumara and Okogwu (2021) have reported such species in stressed ecosystem. According to Schindler (1987), phytoplankton are among the most sensitive indicators of stress in aquatic ecosystem as they are the first to respond to changes in water quality since they are primary producers. Hence, changes in the species composition of small phytoplankton are quick responses to changes in water quality due to their fast rate of reproduction, easy and wide distribution in the ecosystem and their sensitivity to different compounds and some trace elements (Schindler 1987).

The species diversity of phytoplankton in the reservoirs was low during the study. This is with reference to the assertion of McDonald (2003) that Shannon-Weiner diversity value between 1.50-3.40 implies low diversity. This indicated that the reservoirs are under pollution pressure, hence the proliferation and dominance of few species that thrive under such nutrient condition. Poor phytoplankton diversity translates to low species richness, which are indications of ecosystem stress.

The PCA ordination showed that the major drivers of phytoplankton abundance in the reservoirs were conductivity, TDS, DO, depth, nitrate and phosphate. High nitrate and phosphate may be responsible for the proliferation of pollution indicator species such as *Anabaena subvariabilis, Microcystis aeruginosa, Oscillatoria* species., *Spirulina* spp, *Aulacoseira* spp., *Fragilaria granulate* and *Euglena* spp. at Ufiobodo Reservoir.

Conclusion

The study showed that the reservoirs were enriched with nutrients (nitrate and phosphate), iron and several phytoplankton species. Some of the phytoplankton species are known indicators of pollution. The poor phytoplankton diversity at the reservoirs during the study was an indication of pollution pressure. Therefore, the water from Ufiobodo and Ebonyi River reservoirs is unfit for human use unless treated properly.

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