THE POLLUTION STATUS OF SIX LOTIC WATER BODIES IN DELTA STATE USING PALMER'S POLLUTION INDEX

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Palmer's pollution index (PPI) was used to investigate the pollution status of six essential rivers in Delta State. These rivers were selected based on the human activities in the study localities. The locations include Anwai, Atakpo, Ovu, Ugbolu, Niger and Ugbuwangwe rivers. The study identified four algal taxa, namely Bacillariophyta, Chlorophyta, Cyanophya and Euglenophya, with diverse species' composition and abundance. Application of the Palmer's pollution index on the algal structures revealed that the water bodies were organically polluted except Ovu. The Pollution index ranged from organic PPI score of 15- 20 to high organic pollution score of >20. River Niger had the highest PPI score (25), followed by Ugbuwangwe (23), Atakpo (22), Ugbolu(20), Anwai (16) and lastly Ovu (6). The present investigation reveals the deplorable state of our water bodies. The presence of high organic pollution-algae such as *Microcystis* and *Euglena* sp is of serious health concern and requires government intervention.

Key words: Algal community, organic pollution, Palmer's pollution index, water quality and rivers.

INTRODUCTION

Delta State is blessed with an enormous wealth of water resources with great benefits, among which are fishing, transportation, farming, agriculture, aquaculture, sand dredging, and haulage. These beneficial exploits are unavoidable due to the pivotal economic position of water in the sustenance of the nation's economy and individuals' means of subsistence (Prashant, 2017). Thus, water opulence concentrates humans and industries around water resources. Besides urbanization, water is linked to human lives right from creation. Water is the origin of life, source of creation, mini-god to be trusted for providence, protection, reverenced and worshipped (Adu and Oyeniyi, 2019; Iloba et al. 2019). These human-related activities performed in and around water bodies impact water quality and biota. Thus, water quality and biota is an index of the activities in and around water bodies. Interactions between water properties and biota, noted by early researchers since the mid 19th century, categorized algae into water quality bioindicators (Abdulwahid, 2016).

Of the various biotas in the aquatic ecosystem, algae are essential life-forms used to evaluate organic pollution concerning the water status of the aquatic ecosystem. Algae as a biological indicator are due to their prompt response and sensitivity to minute changes in water variables due to their trophic position (Poormina et al., 2017). Organic pollution is one of the challenges of the nation's water system, which must be addressed to avoid fatal effects inter-linked with man's survival. The world and Delta State, in particular, are currently facing extensive/huge aquatic loss and its associated benefits for centuries now. As a result, researchers have evolved the development of several methods of assessing water quality status (Chen et al., 2016).

Several indices have been developed based on biological communities. These indices are employed to evaluate the organic menace deteriorating our unexploited water resources, and its full options values (Kshirsagar 2013; Noel and Rajan, 2015; Pinilla Agudelo, 2016). Among the indices are the diversity indexes (D), Organic Pollution Index (O.P.I) and Palmer's Algal Index, generally called Palmer's Pollution Index (PPI)

(Palmer, 1969). PPI was developed by Palmer in 1969 to evaluate the pollution status of water bodies using algae. Palmer's index has been employed by several researchers to assay the pollution status of water bodies. PPI is simple, rapid, precise and dependable (Salem et al., 2017). PPI pollution assay is rapid and straightforward. Thus, PPI provides water condition during usage, management and policy formulation. The current study employs the PPI scale to assay the organic pollution status of six relevant industry-community feeder water bodies; Anwai, Atakpo, Ovu, Ugbolu, Niger and Ugbuwangwe in Delta State, Nigeria. This is done to ascertain the health, security and sustainability of these water bodies.

MATERIALS AND METHODS

Study area

The present study was conducted in six rivers in the three senatorial districts of Delta State, Nigeria (Figure 1) between 2014 and 2019. The sites were chosen to reflect the various industrial and traditional activities along with these water bodies in Delta State. These sites were Atakpo, Anwai, Ugbolu and the Asaba end of the River Niger Ugbolu Ovu from the Central axis while Ugbuwangwe from the Southern axis of the State.

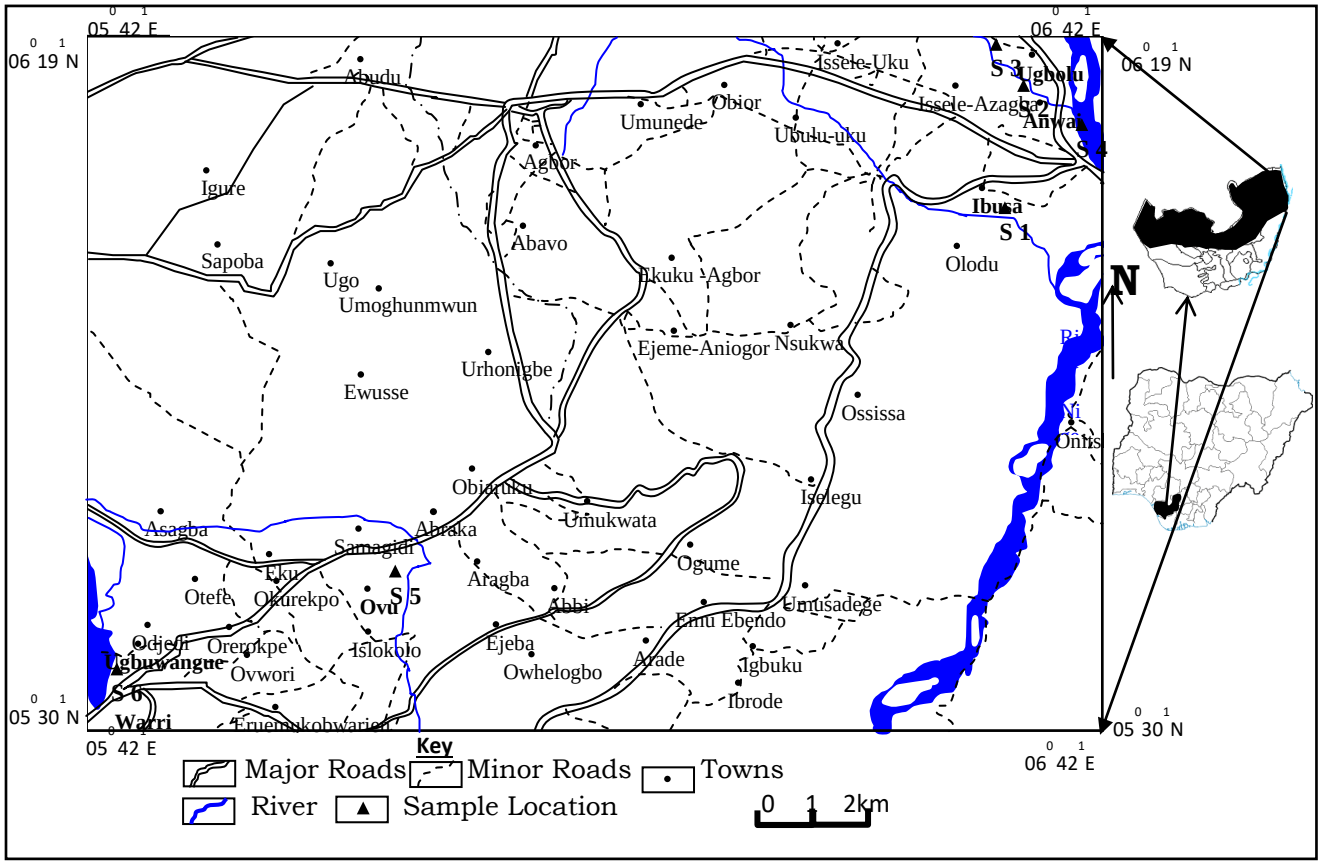

Figure 1. The six studied water bodies in Delta State.

Sampling

These sites were selected based on the human activities in the localities. The stations in the Northern senatorial district include Anwai River and River Niger in Oshimili South Local Government; Atakpo and Ugbolu rivers in Oshimili North Local Government Area; Ovu in Ethiope East Local Government Area in the Central axis. While Ugbuwangwe River is in Warri South Local Government Area of the Southern axis of Delta State. A total of 18 sites were sampled from the six rivers. Three sites were sampled for each river from 2012-2019. Pytoplanton samples were collected using 25 µm

plankton net and preserved with 4% formaldehyde in a 250 ml plastic plankton bottle. The algae and water samples collected from the subsurface waters were poured into a glass beaker and left to stand for 48 h undisturbed. The samples were finally concentrated to 50ml. The filtrate was counted using a counting chamber of 1ml with a compound microscope (model) under magnification of 10X and 40X. The encountered algae were identified and counted. Identification was by reference to standard literature (Wehr and Sheath, 2003). The water samples collected monthly were used to determine DO, pH, temperature, conductivity, alkalinity, phosphate and Nitrate using standard methods outlined in APHA (1998). Although, some parameters such as temperature, pH, TDS were determined using digital meters on the site spot.

Data analysis

The PPI algal genera scores given below were applied to evaluate the rate of organic pollution of these vital water bodies based on the palmer pollution index; Pollution index classification of Palmer (1969): Pollution Index< 15(very light organic pollution; 15-20(organic pollution); >20 (High organic pollution). Diversity indices were applied to confirm the organic pollution status of the various rivers.

RESULTS AND DISCUSSION

The results of the environmental variables of the water bodies are presented in Table 1. The table revealed differences among the studied areas. The air temperature within locations varied from 26.4-28.6°C. The air temperature around the water bodies showed higher air temperatures than water temperatures in all stations. The temperature difference is ideal for tropical regions recording time lag between air and water temperatures. This temperature differential may be due to the inability of water to absorb heat fast (Iloba, 2012).

Table 1. Mean and standard error (standard deviation) of the physicochemical variables in the different water bodies.

Parameter	Stations/Values					
	Atakpo	Anwai	Ugbolu	Niger	Ovu	Ugbuwangwe
Air T °C	28.3±2.02	28.6±2.11	28.4±1.39	26.4±2.09	28.1±0.4	31.3±1.17
Water T °C	25.3±1.76	26.1±1.01	25.3±0.35	24.6±1.89	24.7±0.42	27.7±1.87
Cond µS/cm	23.0±12.0	23.85±10.5	22.75±2.2	64.55±1.1	25.0±1.1	38±9.34
pH	5.98±0.49	7.16±0.34	7.11±0.26	6.78±0.04	5.43±1.9	7.33±0.51
TDS mg/L	10.0±0.01	10.9±5.8	7.43±0.52	0.42±0.01	15.0±	20.0±1
DO mg/L	13.5±6.66	4.04±1.81	2.83±0.11	5.84±0.44	3.85±4.0	5.52±3.17
Alkalinity mg/$CaCO_3$	22.8±12.9	19.8±26.40	5.66±0.31	11.56±2.4	2.60±0.82	57.75±15.26
Acidity mg/$CaCO_3$	35.92±16.1	27.6±15.31	23.13±0.61	31.34±1.56	20.0±0.12	48.05±8.46
PO_4 mg/L	0.45±0.10	0.06±0.13	0.05±0.49	0.35±0.08	0.16±0.01	6.06±1.60

The conductivity values were relatively low except in River Niger and Ovu Ugbunwagwe. These relatively higher values revealed higher electrical conducting loads in these water bodies. In contrast, the low loads in other rivers depict their geographical locations (Gupta et al., 2017). The total dissolved solids (TDS) values suggest a low amount of organic matter in solution further confirmed by the relatively low values of conductivity, total dissolved solids, alkalinity and acidity levels of the various rivers. Conductivity, total dissolved solids, alkalinity and low acidity values are an indictment of low dissolved cations and anions in the rivers (APHA, 1998). These cations and anions in the rivers are critical determinants of these properties in aquatic systems. The river did not reveal the anthropogenic loads evident in the study sites. The preservation of the low levels of these parameters denotes the natural underlying factors, particularly their lotic nature. The nutrient parameter (phosphate) studied was high in

Ugbuwangwe River, followed by Atakpo then River Niger. Phosphate would have contributed to the significant growth of organic tolerant of organisms in these systems. These environmental conditions naturally interact with biological components to provide the prevalent array of algae in the ecosystem (Noel and Rajan, 2015).

This study identified four primary taxonomic groups viz, Baciliarophyta, Cyanophyta, Chlorophyta and Euglenopyta. The spatial distributions of the algae in these six water bodies are in Table 2. A total of sixty-three algal genera are identified; 37 allotted to the diatoms, 19 desmids, 10 blue-greens, 4 euglenoids while other genera; Chrysophyta, Rhodophyta = Pyrrophycophyta had one each (Table 2). The study registered more diatoms at the different stations, while the other genera are equal or alternate dominance. The dominance of diatoms is due to their ubiquitous nature, prevailing in microhabitats of diatoms.

Table 2. Spatial distribution of algal composition in the six water bodies studied.

S/N		Species	Atakpo	Anwai	Ugbolu	Niger	Ovu	Ugbuwangwe
		BACILLARIOPHYTA						
1		Achanthes sp	-	-	14	-	15	-
2		Achnanthidium sp		20				
3		Actinoptychus sp			11			225
4		*Amphipleura* sp						15
5		*Asterionella* sp	56		10			
6		*Cocconeis* sp *(PWQ)*						
7		*Coscinodiscus* sp	100			26		387
8		*Crucigenis* sp	-	-	-	-	3	
9		*Cyclotalla* sp			10	20	10	567
10		*Diadesmis* sp		8				
11		*Diatoma* sp		1	5	40		13
12		*Epithemia* sp					5	
13		*Eunotia* sp		5	35			47
14		*Fragillaria* sp	10	9	98	27	10	
15		*Gomphonema* sp				5		
16		*Leptocylindrus* sp				5		
17		*Melosira* sp	9	5		200		577
18		Navicula sp	5	34	10	31	-	10
19		*Nitzchia* sp *1*	5			23		
20		*Pinnularia* sp*1*	7	6			3	
21		Pleurosigma sp	-	-	-	-		51
22		Scenedesmus sp	27	-	-	-	-	78
23		Selenastrum sp	20	-	-	-	-	
24		Skeletonema	3	-	-	-	-	
25		*Staphanodiscus* sp	7		20			
26		*Surirella* sp	6	30	23			24
27		*Synedra acus*	4		5	25		3
28		*Tebellaria* sp	38	-	-	-	-	52
29		Thalasiosira sp	35	-	-	-	-	
		CHLOROPHYTA						
29	1	*Chara* sp	3	-	-	-	-	
30	2	*Characium* sp		13	-	-	-	-
31	3	*Pediastrum* sp	6	-	-	-	-	
32	4	*Cladophora* sp	3	-	-	-	-	
33	5	*Closterium* sp	28	15	-	215	-	10
34	6	*Eudorina* sp	5	-	-	-	-	47
35	7	*Genicularia* sp	-	-	-	-	12	
36	8	*Gonotozygon* sp	5		4	-	-	-

Table 2. Continue

37	9	*Hylotheca* sp		2	-	-	-	-
38	10	*Micrasterias* sp	5	-	-	-	-	-
39	*11*	*Mougeotia* sp	1		6	-	-	-
40	*12*	*Oedogonium* sp	13				2	-
41	*13*	*Pandorina*	5	-	-	10	-	-
42	*14*	Spi*rogyra* sp	33	-	-	-	37	-
43	*15*	*Stigeoclonium*			10			
44	*16*	*Straurastrium* sp	63	-	-	-		-
45	*17*	*Ulothrix* sp	-	-	-	-	6	-
46	*18*	*Volvox* sp	-	-	-	5	9	-
		CYANOPHYTA	-	-	-			-
47	1	*Anabaena* sp	-	-	10	70	58	-
48	2	*Aphanotheca* sp	17	-		-		-
49	3	*Arthrospira* sp		-	44	-		-
50	4	*Calothrix* sp		10		37		-
51	5	*Microcystis* sp	750	16	6			-
52	6	*Nostoc* sp	5	-	-		11	-
53	7	*Oscillatoria* sp	3	2	33	24	4	189
54	8	*Phormidium* sp	2	-	5	161	2	-
55	9	Spi*rulina* sp	19		21		20	
56	10	*Trichodesmium* sp	2	-	-	-	-	
		EUGLENOPHYTA						
57	1	*Euglena* sp		2	6	53		368
58	2	*Phacus* sp	6	4	10	24		5
59	3	*Strombomonas* sp			3			-
	4	*Trachelomonas* sp	3	1		88		-
		CHRYSOPHYTA						
	1	*Synura* sp	-	-	-	-	24	-
		RHODOPHYTA						
	1	*Batrachospermum* sp	100	-	-	-	-	-
		PYRROPHYCOPHYTA						-
	1	*Peridinium* sp		12	-	-	-	-

The genera at the different locations are presented in Figure 2. Atakpo had the highest taxa with Bacillariophyta> Chlorophyta> Cyanophyta > Cyanophyta; in Anwai, Bacillariophyta>Chlorophyta= Cyanophyta= Euglenophyta; in Ugbolu, a shift was observed, which differred from the previously mentioned sequence. River Niger's dominance sequence is the same as Ugbolu; that of Ovu was the same with that of Anwai with no record of euglenoids. Ugbuwangwe was second in diatom dominance, greater Chlorophyta= Euglenophyta > Cyanophyta; Chlorophyta = Euglenophyta. The algal population abundance at the various sites was predominantly diatoms besides Atakpo, although at varying degrees (Figure 3). Atakpo algal population was 94% blue-greens. The blue-greens were predominantly *Microcystis* sp; a known indicator of eutrophic waters (Sakset and Chankaew, 2013). *Microcystis* population in Atakpo system was favoured by the calm nature of the system, and the impacts from cassava fermentation and its associated products (Yu et al., 2017). The organically tolerant genera; *Oscillatoria*, *Phacus* and *Phormidium* sp generated a significant proportion of the PPI score in Atapko.

The algal populations at River Niger, Anwai,

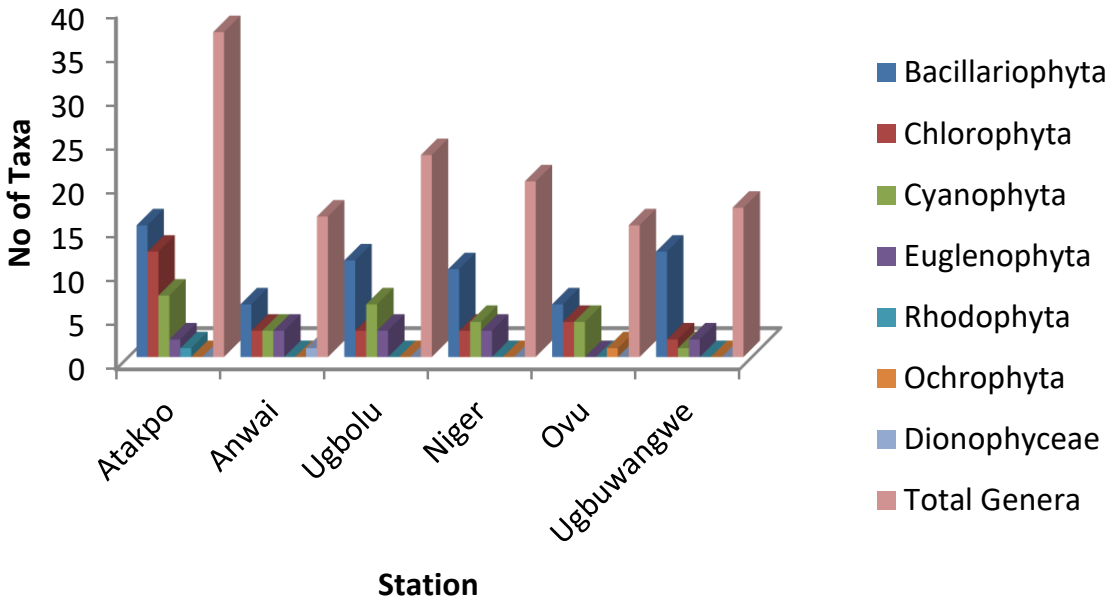

Figure 2. Taxa Distribution at the different stations.

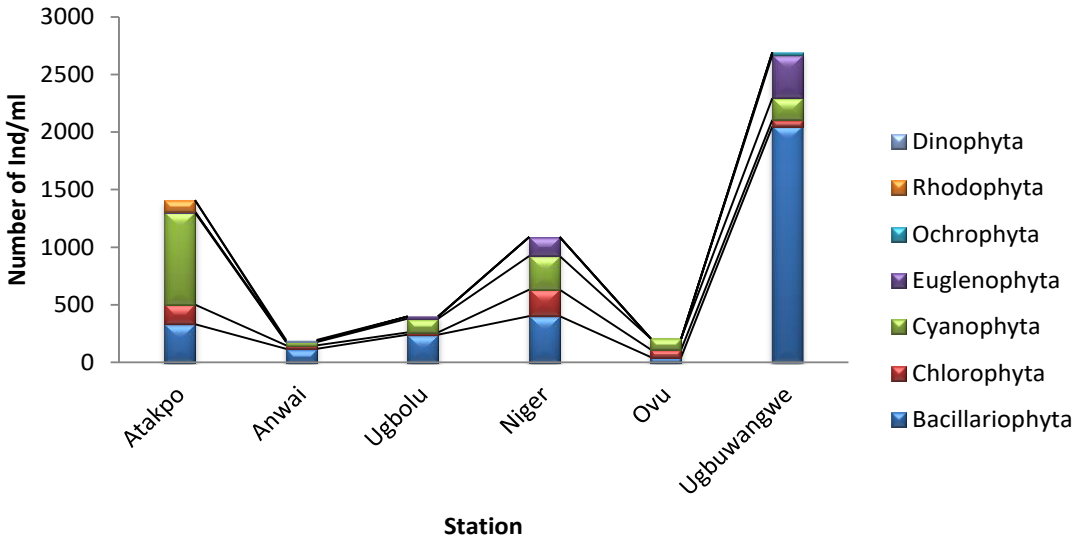

Figure 3. Abundance of the identified phytoplankton taxa at the various stations.

Ugbolu, and Ugbuwangwe were predominantly diatoms constituting 36.9, 60.5, 60.4, and 76.8% of the specific site algal population respectively (Figure 3). Differences in diatom composition and abundance were due to the different river ecotones and ecological environment impacted by different human activities at the stations (Roshith et al., 2018). Ugbuwangwe was 76.8% diatoms, constituting sizable abundance of organic pollution indicator genera including *Cyclotella*, *Melosira* and *Scenedesmus*. The nutrient-laden Ugbuwangwe (Table 1) favoured the growth of the nutrient indicator species; *Cyclotella*, *Melosira* and *Scenedesmus*, the impact of Petroleum- related activities in the Jetty (Kshirsagar, 2013; Abdulmumini et al., 2014). The only genus *Oscillatoria* sp of the group Cyanophyta and *Euglena* (Euglenophyta) generated appreciable percentages (7.1 and 13.8% respectively) of the Ugbuwangwe algal population (Table 4). The preponderance of diatoms signifies favourable environmental conditions in these systems.

The results of the PPI calculated in all stations are in Table 3. The PPI varied from 6-25,

Table 3. List of identified algae in the six studied stations.

S/N	Genera	Pollution index	Atakpo	Anwai	Ugbolu	Niger	Ovu	Ugbuwangwe
1	Anacystis	1	-	-	-	-	-	-
2	Ankistrodesmus	2	-	-	-	-	-	-
3	Chlamydomonas	4	-	-	-	-	-	-
4	Chlorella	3	-	-	-	-	-	-
5	Closterium	1	1	1	-	1		1
6	Cyclotella	1	-		1	1	1	1
7	Euglena	5	-	5	5	5	-	5
8	Gomphonema	1	-	-	-	1	-	-
9	Lepocinclis	1	-	-	-	-	-	-
10	Melosira	1	1	1	-	1	-	1
11	Micractinium	1	-	-	-	-	-	-
12	Navicula	3	3	3	3	3	-	3
13	Nitzschia	3	3	-	-	3	-	-
14	Oscillatoria	4	4	4	4	4	4	4
15	Pandorina	1	1	-	-	1	-	-
16	Phacus	2	2	2	2	2		2
17	Phormidium	1	1	-	1	1	1	-
18	Scenedesmus	4	4	-	-	-	-	4
19	Stigeoclonium	2	-	-	2	-	-	-
20	Synedra	2	2	-	2	2	-	2
	Total	**43**	**22**	**16**	**20**	**25**	**6**	**23**

Table 4. Diversity metrics at the different sampled sites.

	Atakpo	Anwai	Ugbolu	Niger	Ovu	Ugbuwangwe
Total Genera						
Taxa_S	37	19	23	20	16	18
Individuals	1409	195	399	1089	225	2668
Dominance_D	0.3006	0.09496	0.1027	0.1145	0.1293	0.1465
Simpson_1-D	0.6994	0.905	0.8973	0.8855	0.8707	0.8535
Shannon_H	2.06	2.576	2.685	2.486	2.345	2.166
Evenness_e^H/S	0.212	0.6916	0.6372	0.6008	0.6524	0.4848
Equitability_J	0.5705	0.8748	0.8563	0.8299	0.8459	0.7495
Bacillariophyta						
Taxa_S	15	9	11	10	6	13
Individuals	332	118	241	402	46	2049
Dominance_D	0.1572	0.193	0.2139	0.282	0.2212	0.2071
Simpson_1-D	0.8428	0.807	0.7861	0.718	0.7788	0.7929
Shannon_H	2.181	1.846	1.94	1.728	1.626	1.822
Chlorophyta						
Taxa_S	12	3	3	3	4	2
Individuals	170	30	20	230	60	57
Dominance_D	0.2134	0.4422	0.38	0.8762	0.4439	0.7107
Simpson_1-D	0.7866	0.5578	0.62	0.1238	0.5561	0.2893
Shannon_H	1.885	0.8895	1.03	0.2826	1.018	0.4644
Evenness_e^H/S	0.549	0.8113	0.9334	0.4422	0.6919	0.7955
Cyanophyta						
Taxa_S	7	3	6	4	5	1
Individuals	798	28	119	292	95	189
Dominance_D	0.8844	0.4592	0.2561	0.3843	0.4327	1

Table 4. Continue

Simpson_1-D	**0.1156**	**0.5408**	**0.7439**	**0.6157**	**0.5673**	**0**
Shannon_H	0.3121	0.876	1.522	1.138	1.094	0
Evenness_e^H/S	0.1952	0.8004	0.7632	0.78	0.597	1
Euglenophyta						
Taxa_S	2	3	3	3	0	2
Individuals	9	7	19	165	0	373
Dominance_D	0.5556	0.4286	0.4017	0.4088	0	0.9735
Simpson_1-D	0.4444	0.5714	0.5983	0.5912	0	0.02645
Shannon_H	0.6365	0.9557	0.9933	0.9805	0	0.07112
Evenness_e^H/S	0.9449	0.8668	0.9	0.8886	0	0.5369

showing differences in organic pollution status of the rivers. The differences in PPI signal intensity and type of contaminants received by the studied sites (Abdulmumini et al., 2014). The study identified mostly the high scoring organic pollution indicator genera (Palmer, 1969). Of the 20 genera used for the PPI computation, River Niger ranked first with 12 genera scoring 25; Ugbuwangwe had 9 genera to score 23, Atakpo scored 22 with 10 genera. Ugbolu scored 20 with 8 genera, Anwai summed 16 with 6 genera and lastly Ovu scored 6. The PPI scores in the present study are lower than that of Nafiu et al. (2017) in Watari Dam in Kano, compensated by the rivers' lotic nature (self-purification).

According to The PPI scores interpretation, five of the six water bodies showed that they were organically polluted except Ovu. River Niger is the most organically polluted of the water bodies, followed by Ugbuwangwe, Atakpo, Ugbolu, Anwai and Ovu. The study identified two common genera; *Oscillatoria* and *Phacus* were implicating suggestive bioindicator of rivers in these axes as well as similar aquatic systems (Kshirsagar, 2013). The organic pollution status of the rivers revealed the free dumping of effluents and contaminants into the rivers, particularly in rivers Niger and Ubguwangwe with the bee-hive of industries along the rivers (Abdulmumini et al., 2014). The various diversity metrics employed substantiated the organic statuses of these rivers concerning the primary taxa presented in Table 4. These indices varied from 0.2826 to 2.181; they revealed moderate to heavy organic pollution, and confirmed the precision and dependency of PPI evaluation of pollution status in the rivers.

Conclusion

Palmer Pollution Index classified five of the six studied water bodies in Delta State as organically polluted. The highly organic tolerant species *Navicula shows the pollution status of these rivers; Melosira, Oscillatoria, Euglena, Phacus were* prevalent in the systems using Palmer's Pollution Index. However, there are other typical eutrophic-pollution tolerant species not included in the evaluation. One of such is Microcystics accounting for over 90% of the algal population at Atakpo River. Deductively, the rivers would have had higher pollution scores, inferring the water bodies' severe deterioration. These water bodies are under different types of organic pressure viz traditional, natural and industrial. There is an urgent need for the government to enact policies to address the traditional, rapid urban and industrial activities around the water bodies for future posterity.

CONFLICT OF INTERESTS

The author has not declared any conflict of interests.

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