International Journal of Ecology and Environmental Sciences
www.ecologyjournal.in
Online ISSN: 2664-7133, Print ISSN: 2664-7125
Received: 15-07-2021, Accepted: 29-07-2021, Published: 16-08-2021
Volume 3, Issue 3, 2021, Page No. 126-134

Application of multimetric index on water quality assessment of Qua Iboe River Estuary, Akwa Ibom State, Nigeria

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Abstract
The present study was to assess the deteriorating level of water quality status of Qua Iboe River Estuary; Southern Nigeria between November, 2018 and August, 2019. Water Quality Index and Family Biotic Index approach were used to check the water in five sampling stations. Ten parameters were evaluated and compared with standard water quality of World Health Organization. The some physico-chemical parameters recorded exceeded the acceptable limits excluding water temperature, pH, NO_3^- and $S0_4^{2-}$. LSD test indicated significant differences in some parameters between the stations. A total of 1,324 species, comprising of 3 phyla and 19 families of macro invertebrates were identified. Arthropod was the highest recorded phylum accounted for 55.89 percentage composition, Mollusc (38.59%) and Annelid (5.52%). Station 3 was recorded the highest number species (331, 25%), Station 2 (316, 23.87%), station 1 (234, 17.67), station 4 (222, 16.77%), station 5 (221, 16.69%). The water quality index (WQI) values obtained across the stations were >100 based on weighted arithmetic method, range between 351.83 and 491.37.The family biotic index values were between the ranges of 5.85 and 6.73 (station 1: 6.73, > 2: 6.71, >4: 6.59, >3: 6.38, >5: 5.85).The obtained values in calculated WQI, FBI and the occurrence of pollution indicators species in this study proved that the water is heavily deteriorating, not suitable for domestic usages and for survival of certain aquatic biota, owing to severe anthropogenic activities surrounding the water body and on the catchments areas. This calls for urgent attention by relevant authorities to check and control the possible sources of pollutants into the water body.

Keywords: water quality index, Family biotic index, pollution, assessment, anthropogenic

Introduction

Water is important for health and essential for life on earth; most economic developmental activities in aquatic system depended on the prevailing water quality. The activities of mankind on the waterways and adjoining environments have impoverished the natural habitat. Related study within the Nigerian coastal area pointed anthropogenic activities as a major threat to aquatic (Jonah *et al.*, 2020a) [1]. These, in turn altered the intrinsic physical, chemical nature and biological structure of inhabitant biota including invertebrates (Jonah *et al.*, 2020b) [2]. Aquatic macro-invertebrates are susceptible to any modification and alteration in their habitat structure (Al-Shami *et al.*, 2011) [3]. Macro-invertebrates are used potentially to appraise the health status of water bodies [4], because of their highly sensitive to environmental changes associated with organic pollutants, rather than measuring the chemical concentration of surface water (Butcher *et al.*, 2003) [5]. Members of the order Ephemeroptera (mayflies), Placoptera (stonflies) and Trichoptera (caddisflies) are considered intolerant species, with physiological deficit to adapt to environmental stress, and their presence signified relatively clean water (Oku *et al.*, 2014) [6], while groups of macro-invertebrates like Chironomids (Biting midges), Hirudinea (Leeches), Crustaceans (Crayfish and amphipods), Mollusca (Aquatic snails), Oligochaetes (Tubifex sp) and Polychaetes (Capitella sp) are considered as pollution tolerant groups (Andem *et al.*, 2015) [7]. The concepts of biotic indices for the purpose of monitoring the water quality are based on the presence and absence of major taxa and abundance of particular taxa due to the effect of pollutants accumulation in the water (Reece and Richardson, 2000) [8]. More so, the use of Family Biotic Index (FBI) and Water Quality Index (WQI) to assess the health status of water bodies are the most effective tools, which communicate the level of deterioration of water quality. Qua Iboe River Estuary is located in the urban area and is receiving wastes from municipal runoff, industrial and agricultural activities. The proliferation of urban and commercial establishments along the shores of the estuary means that considerable amounts of industrial and municipal effluents are being added to the water body which could have substantial effects on water quality. Therefore, the objectives of this study are to evaluate the health status of Qua Iboe River Estuary using multimetric index tools (WQI and FBI) and to assess the diversity and abundance of macro-invertebrates species.

Methodology

Study area and Sampling stations

The study was carried out in Qua Iboe River Estuary is located in the South-East of the Niger Delta in Akwa Ibom State, Nigeria. The study area lies within latitude 4^0 45'31 North and longitude 7^0 55'0 East; the water body was divided into five stations for the purpose of this study, covering two Local Government Areas (Figure 1). In this study, five sampling stations were selected; the criteria used for the selection was based on human activities and ecological settings. Station one was near the mouth of the estuary opening into the Atlantic Ocean; the observed activity was fishing. The station is close to a market and residential area featuring sandy to muddy substrate. Station two was at the middle zone of the estuary, 3km away from station one. The area is characterized by high anthropogenic activities such as off-loading of refined petroleum products, laundry and fishing; receiving wastes from inhabitants of the watershed and other domestic activities. The substrate is muddy and clay. Station three was also located at the middle zone, 2km away from sampling station two. The observed human activity was fishing, while station four was 2km distance from station three. The activities identified were lumbering, dredging, boat construction, fishing and laundry. Station five was located toward the upper reaches of the river and 3km distance from station four; human activities observed were fishing and sand mining. The substrate is muddy and clay. The dominant mangrove plants across the sampling stations was *Nypa frutican*, *Rhizophora racemosa*, *Avicannia africana* and other riparian vegetation.

Fig 1: Map of Qua Iboe River Southern Nigeria showing sampling stations

Data collection

Surface water and macro-invertebrates samples were collected monthly; between November 2018 and August 2019. Sterilized plastic bottles (one litre) were used in water sample collections between the hours of 8.00am to 12.00 noon. The samples were collected using washed and sterilized plastic bottles (1-litre). Some parameters (Water temperature, Dissolved oxygen (DO), Hydrogen ion (pH), Electrical conductivity (EC) and Turbidity) were determined *in-situ* using Hanna Portable Meter Sampler (HI 9811-5 model). Other parameters were analyzed *ex-situ* using standard laboratory methods (AOAC, 2000; APHA, 2005) [9, 10]. The macro-invertebrates samples were collected by using Van-veen grab (0.05m^2) and standard hand net (0.5mm mesh size), in four (4) replicates. Some species were handpicked during the low tide at the intertidal shoreline. The pooled sediment samples from each station were thoroughly washed in 0.05mm sieve net. Retained residue were transferred into wide-mouth plastic containers and preserved with 10% formaldehyde. Preliminary identification was carried out in the field before taken to the laboratory for accurate identification and confirmation using appropriate taxonomic keys and materials of Edmondson (1959) [11] and Merritt *et al*. (2008) [12]. The macro-invertebrates encountered were counted according to their respective phylum, class, order, family and species in each sampling station.

Statistical analysis

The results obtained were subjected to statistical analysis. One-way ANOVA was used for statistical analysis of the data for significant differences at 0.05 probability levels; significant variations were isolated using least significant difference (LSD) test and percentage abundance per phylum, taxa and stations were calculated using standard methods. All statistical analysis was performed with PAST software package -Version 3.24 (Hammer *et al*., 2001) [13].

Determination of pollution status

Pollution status of the estuary was determined using modified Multimetric index such as Water Quality Index (WQI) and Family Biotic Index (FBI) per stations. The rating of the water quality values are shown in Table 1. Ten (10) parameters were evaluated with standards range for drinking water quality as recommended by World Health Organization. Weighted arithmetic index method was used to compute WQI (Brown *et al*., 1972) [14]. Three (3) steps were adopted to compute WQI: The first step was to assign each parameter a weight (Wi) according to its relative importance in the overall quality of water for drinking purposes. In the second step, the relative weight (Wr) was computed using the following equations:

$$Wr = \frac{Wi}{n} \quad (1)$$

Where; Wr = relative weight; Wi = weight of each parameter; n = number of parameters.

In step three, a quality rating scale (qi) for each parameter was assigned by dividing its concentration in each water sample by its respective standard according to the permissible limits of WHO (2011) [15] and the result multiplied by 100.

$$qi = \frac{Ci}{Si} \times 100 \quad (2)$$

Where; qi = quality rating; Ci = concentration of each parameter; Si = WHO drinking water standards for each parameter. For computing the WQI, the Si was first determined for each parameter, which was then used to determine the WQI sing the following equations:

$$Si = Wi \times qi$$
$$\sum Si = WQI \quad (3)$$

Where; Si = Sub-index of each parameter; qi = rating based on the concentration of each parameter; WQI= water quality index

Family Biotic Index (FBI) was computed using the modified standard methods of Hilsenhoff (1987) [16]. The index (FBI) gives numerical scores to specific "indicator" organisms at particular taxa; also reveals varying levels of organic pollution in the water body. The rating of water quality is shown in Table 2. Values obtained were thereafter compared with established standard values. The formula is shown below:

$$BI = \sum \left(\frac{xi \, X \, ti}{n} \right) \quad (4)$$

Where, xi = number of individuals within a species; ti = tolerance value of species; n = total number of organisms in the sample.

Table 1: Classification of water quality based on Weighted Arithmetic WQI method

Water Quality Index value	Water quality status	Grading
0 – 25	Excellent water quality	A
26 – 50	Good water quality	B
51 – 75	Poor water quality	C
76 – 100	Very poor water quality	D
>100	Unsuitable for drinking	E

Source: Brown *et al*. (1972) [14].

Table 2: Water Quality Rating of Family Biotic Index

Family Biotic Index (FBI)	Water Quality	Degree of Organic Pollution
0.00 – 3.75	Excellent	No apparent organic pollution
3.76 – 4.25	Very good	Possible slight organic pollution
4.26 – 5.00	Good	Some organic pollution probably
5.01 – 5.75	Fair	Fairly significant organic pollution
5.76 – 6.50	Fairly poor	Significant organic pollution
6.51 – 7.25	Poor	Very significant organic pollution
7.26 – 10.00	Very poor	Severe organic pollution

Source: Bode *et al*. (1996) [17]

Results

The mean values and standard error of physicochemical parameters are presented in Table 3. Water temperature ranged from 26.11 to 28.43^{0}C. The lowest mean value of 26.11^{0}C was recorded in station 4, while the highest of 28.43^{0}C was observed in station1. All values obtained were within the range (24-30^{0}C) acceptable for survival of aquatic organisms. ANOVA showed no significant difference between the stations (> 0.05). DO had its ranged from 1.8 to 4.46; with highest mean value in station 5 (3.87mg/l). ANOVA test indicated significant differences between the mean values among the stations (P< 0.05). pH had its range between 6.2 and 8.8; mean values between 6.7 and 8.9. Highest value was recorded in station 2. EC had its highest mean values ranging from 3472.53 to 3961.68µs/cm; with higher value in station 1(3961.68µs/cm). ANOVA test showed no significant difference between the mean of EC per stations (P> 0.05). Turbidity had its highest mean value in station 3 (45.10 NTU), and the lowest in station 5 (22.23 NTU). Analysis of variance pointed significant the mean of turbidity differences between the stations (P<0.05). Mean values of BOD ranged between 3.16 to 5.61 mg/l, with the lowest value in station 4 and highest in station 3. ANOVA shows significant difference between the stations. The mean values of NH_3 varied across the stations; high mean value were recorded in all the stations, far above the recommended range of 0.5 mg/L set by WHO. There was a significant difference between the stations (p< 0.05). The range of $N0_3^-$ was between 4.91 and 9.15 mg/l, with the highest value in station 4 (9.15 mg/l) and the lowest in station 5 (4.91 mg/l). Statistical analysis confirmed significant differences between the stations (p< 0.05). Mean values $P0_4^{3-}$ ranged from 5.13 to 8.34 mg/l; highest value was recorded in station 2 (8.34 mg/l), while the least was obtained in station 5 (5.13 mg/l). ANOVA showed significant difference of the mean values between the stations (p < 0.05). SO_4^{2-} had it range from 104.4 to 342.1mg/l); the mean values during the study was high in station 2 (363.31mg/l) and the lowest (208.07 mg/l) was recorded in station 5. There was a significant difference between the stations (p< 0.05). The composition and relative abundance of macro-invertebrates fauna are presented in Table 5. A total of one thousand three hundred and twenty four (1324) individuals of macro-invertebrates belonging to three (3) phylum and five (5) classes were identified. The phylum Arthropoda was represented by fifteen (15) taxa, followed by Mollusca (7), Annelid had the least recorded taxa (4). In terms of percentage abundant, the phylum arthropoda recorded with the highest number of individuals species (740) accounted for 55.89% of total population; Mollusca (511, 38.59%), while Annelida had 73(5.52%). Arthropoda was represented by two classes, namely: Malacostraca and Insecta; the most abundant species of Malacostraca was *Afruca tangeri* with 151 individuals accounted for 11.40% of total population.

Table 3: Range, mean values and standard error of physicochemical parameters of Qua Iboe River Estuary

Param.	X± SEM (STN 1)	X±SEM (STN 2)	X±SEM (STN 3)	X±SEM (STN 4)	X±SEM (STN 5)	WHO [15]
Temp.(°C)	28.43±0.41 (24.9-29.4)	26.22±0.27 (24.0-28.8)	27.28±0.24 (24.6-28.0)	26.11±0.3 (25.0-27.8)	27.39±0.49 (25.0-27.3)	24-30
DO mg/l	3.13±0.14^a (2.5-4.2)	2.20±0.19^b (2.2-3.6)	2.16±0.11^b (2.9-3.8)	2.14±0.09^b (1.8-3.1)	3.87±0.18^a (2.5-4.6)	5.0
pH	6.8±0.11 (6.2 – 8.8)	8.9±0.21 (6.3 – 8.3)	7.6 ±0.18 (6.5 – 8.0)	7.3±0.34 (6.2- 8.8)	6.7 ±0.16 (6.3 – 7.9)	6.5 – 9.5
EC µs/cm	3961.68±529.12 (76.34-39642.2)	3472.53±512.2 (58.00-48934.3)	3715.74±463.4 (67.30-52931.2)	3614.48±551.8 (86.42-51637.8)	3548.26±641.3 (56.00-49971.3)	1400
Turb.NTU	41.04±1.53^a (23.13-5.32)	37.22± 1.34^a (22.16-5.18)	45.10±2.21^a (19.24-53.10)	33.16±1.53^b (22.10-44.01)	22.23±1.03^c (18.32-33.50)	<5
BOD mg/l	3.24±0.30^a (2.9-4.8)	5.04±0.37^b (2.4- 6.2)	5.61±0.18^b (3.8-5.10)	3.16±0.28^a (2.5-4.12)	3.49±0.16^a (2.2-4.10)	>3.0
NH_3 mg/l	17.44±0.34^a (13.68 – 29.3)	10.28±0.58^b (14.0 – 26.0)	11.45±0.32^b (9.3 – 28.7)	15.64±0.44^a (11.00 – 18.41)	18.96±0.31^a (16.34 – 28.00)	0.5
NO_3 mg/l	6.44±0.16^a (1.99 – 5.54)	7.33±0.19^a (2.46 – 6.06)	8.16±0.13^a (2.82 – 6.86)	9.15±0.32^a (2.20 – 6.33)	4.91±0.12^b (1.42 – 5.13)	50
PO_4^{3-} mg/l	5.55±0.27^a (2.12 – 8.36)	8.34±0.22^b (3.10 – 9.24)	6.22±0.09^b (2.96 - 9.01)	8.14±0.16^b (3.64 – 8.12)	5.13±0.30^a (2.86 – 7.38)	5.0
SO_4^{2-}mg/l	347.48±0.39^a (160.9 – 311.5)	363.31±0.51^a (124.8 – 342.1)	233.18±0.42^b (104.4 – 297.7)	253.03±0.56^b (193.41-264.2)	208.07±0.65^c (182.48 – 276.5)	500

X= mean values; SEM= standard error of mean; a, b, c = means with different superscripts across the rows are significantly different at $p<0.05$

Table 4: Water quality index values for Qua Iboe River Estuary, during the study period

Param.	WHO	Wi	Wr	Quality rating (qi) per station					Sub Index Values (Si= wr×qi)				
				Stn1	Stn2	Stn3	Stn4	Stn5	Stn1	Stn2	Stn3	Stn4	Stn5
Temp	24 – 30	4	0.01	105.3	97.2	101.0	96.7	101.4	10.5	9.72	10.1	9.67	10.2
DO	5.0	4	0.01	62.6	44.0	43.2	42.8	77.4	6.26	4.40	4.32	4.28	7.74
pH	6.5 – 9.5	4	0.01	97.2	127.2	108.6	104.3	95.7	9.72	12.7	10.8	10.4	9.57
EC	1400	4	0.01	282.9	248.0	265.4	258.2	253.4	28.3	24.8	26.5	25.8	25.4
Turb.	<5.0	3	0.01	820.0	744.4	902.0	663.2	444.6	57.4	52.1	63.2	46.4	31.2
BOD	>3.0	4	0.01	108.0	168.0	187.0	105.3	116.3	10.8	16.8	18.7	10.5	11.6
NH_3	0.5	4	0.04	3488	2056	2290	3128	3792	348.8	205.6	229	312.8	379.2
NO_3^-	50	5	0.01	12.8	14.6	16.3	18.3	9.82	1.536	1.752	1.956	2.196	1.178
SO_4^{2-}	500	4	0.01	69.5	72.6	46.6	50.6	41.6	6.95	7.26	4.66	5.06	4.16
PO_4^{3-}	5.0	4	0.01	111.0	166.8	124.4	162.8	102.6	11.1	16.7	12.4	16.3	10.3
		Σ40							WQI= 491.37	WQI= 351.83	WQI= 381.64	WQI= 443.42	WQI= 490.55

Wi = Weight of each parameter; Wr = Relative weight; WQI = Water Quality Index value per stations

The most abundant species of class Insecta was while the least was *Tabanus sp* (27, 2.04 %%), while the least abundant was *Psychoda larvae* (7) individuals, accounted for 0.53% of total population. The phylum Mollusca was represented by Gastropods, which the most abundant species was *Tympanotonus fuscatus (*192) individuals, accounted for 14.50 %, while the least abundant species was *Turritella annulata* (17, 1.28%) individuals and percentage composition respectively. Polychaeta and Clitellata were the represented classes in the phylum Annelida. The class Polychaeta was represented by *Capitella capitata with* 22 (1.66%) individuals, while Clitellata was represented by *Aulophorus furcatus* (15, 1.13%), *Limnodrilus sp.* (14, 1.07%) and *Tubifex tubifex* with 22 individuals, accounted for 1.66% of total population. Stations 2 and 3 had the highest number of individuals species (316 and 331) respectively.

The range values of water quality index (WQI) are presented in Table 4; the values recorded in this study were between 351.83 and 491.37. The highest WQI values were recorded in station 1 (491.37) and 5 (490.55); while the lowest was in station 2 (351.83). The water quality values recorded across the stations are poor according to the rating of water quality by Weighted Arithmetic WQI method (Table 1). The calculated Family Biotic Index (FBI) values from the pollution tolerance score value of the macro-invertebrates recorded during the study are presented in Table 6. Going by the modified Hilsenhoff biotic index; the biotic index value ranged from 5.85 to 6.73. The index revealed that the water quality in stations 1, 2 and 4 are poor with very significant organic pollutant, while stations 3 and 5 had fairly poor water quality indicating significant organic pollution (Table 2).

Table 5: Macro-invertebrates Identified during the study period (November 2018 - August 2019)

Group	Family	Taxa	STN 1	STN2	STN3	STN4	STN 5	Tot.	%
Arthropoda									
Class: Malacostraca									
Order: Decapoda	Pandalidae	*Pandalus borealis*	11	5	-	6	21	43	3.25
	Nephropidae	*Homarinus capensis*	8	-	-	12	-	20	1.51
		Homarinus armericanus	4	6	4	6	5	25	1.88
	Gecarcinidae	*Cardiosoma armatum*	10	4	18	10	-	42	3.17
	Palaemonidae	*Nematopalaemon sp*	15	-	35	8	37	95	7.17
		Macrobrachium sp	37	22	40	29	8	136	10.3
	Ocypodidae	*Afruca tangeri*	18	56	31	11	35	151	11.4
	Portunidae	*Callinectes amnicola*	21	39	15	18	8	101	7.63

Class: Insecta									
Order: Diptera	Chironomidae	*Chironomus larvae*	6	14	3	3	-	26	1.96
		Chironomus salinarius	8	6	6	2	-	22	1.66
	Tabanidae	*Tabanus sp*	-	2	15	4	6	27	2.04
	Psychodida	*Psychoda larvae*	-	4	3	-	1	7	0.53
Order: Coleoptera	Dytiscidae	*Hydroporus pubescens*	-	-	-	-	8	8	0.60
Order: Hemiptera	Gyrinidae	*Gyrinus sp*	-	-	-	-	15	15	1.13
	Gerridae	*Halobates sp*	-	-	-	-	22	22	1.66
		Total	138	158	169	109	166	740	55.89
Mollusca									
Class: Gastropoda	Neritidae	*Neritina natalensis*	2	3	8	4	1	18	1.36
		Neritina usnea	5	12	1	5	-	23	1.74
		Neritina rubricate	15	44	18	6	7	90	6.79
	Thiaridae	*Melanoides turberculata*	15	7	8	-	-	30	2.26
	Potamididae	*Tympanotonus fuscatus*	26	55	37	41	33	192	14.5
	Lymnaeidae	*Lymnaea sp*	15	20	57	38	11	141	10.6
	Turritellidae	*Turritella annulata*	-	-	8	6	3	17	1.28
		Total	78	141	137	100	55	511	38.59
Annelida									
Class:Polychaeta	Capitellidae	*Capitella capitata*	6	7	3	6	-	22	1.66
Class: Clitellata									
Order: Haplotaxida	Naididae	*Limnodrilus sp*	4	2	8	-	-	14	1.07
		Aulophorus furcatus	-	6	2	7		15	1.13
		Tubifex tubifex	8	2	12	-	-	22	1.66
		Total	18	17	25	13	0	73	5.52
		No. of taxa	19	20	21	19	16	26	100
		No. of individuals	234	316	331	222	221	1324	
		Relative abund. (%)	17.67	23.87	25.00	16.77	16.69		

Table 6: Assessment of water quality of Qua Iboe River Estuary using Family Level Biotic Index (FBI)

Family	Species	Station 1			Station 2			Station 3			Station 4			Station 5		
		Xi	Ti	XiTi	Xi	Ti	XiTi	Xi	Ti	XiTi	Xi	Ti	XiTi	Xi	Ti	XiTi
Pandalidae	*Pandalus borealis*	11	6	66	5	6	30	0	6	0	6	6	36	21	6	126
Nephropida	*Homarinus capensis*	8	6	48	0	6	0	0	6	0	12	6	72	0	6	0
-	*Homarinus armericanus*	4	6	24	6	6	36	4	6	24	6	6	36	5	6	30
Gecarcinidae	*Cardiosoma armatum*	10	6	60	4	6	24	18	6	108	10	6	60	0	6	0
Palaemonidae	*Nematopaemon hastatus*	15	6	90	0	6	0	35	6	120	8	6	48	37	6	222
-	*Macrobrachium sp*	37	6	222	22	6	132	40	6	240	29	6	174	8	6	48
Ocypodidae	*Afruca tangeri*	18	6	108	56	6	336	31	6	186	11	6	66	35	6	210
Portunidae	*Callinectes amnicola*	21	6	126	39	6	234	15	6	90	18	6	108	8	6	48
Chironomidae	*Chironomus larvae*	6	8	48	14	8	112	3	8	24	3	8	24	0	8	0
-	*Chironomus salinarius*	8	8	64	6	8	48	6	8	48	2	8	16	0	8	0
Tabanidae	*Tabanus sp*	0	5	0	2	5	10	15	5	75	4	5	20	6	5	30
psychodida	*Psychoda larvae*	0	8	0	4	8	32	2	8	16	0	8	0	1	8	8
Dytiscidae	*Hydroporus pubescens*	0	5	0	0	5	0	0	5	0	0	5	0	8	5	40
Gyrinidae	*Gyrinus elongates*	0	4	0	0	4	0	0	4	0	0	4	0	15	4	60
Gerridae	*Halobates sp*	0	4	0	0	4	0	0	4	0	0	4	0	22	4	88
Neritidae	*Neritina natalensis*	2	7	14	3	7	21	8	7	56	4	7	28	1	7	7
-	*Neritina usnea*	5	7	49	12	7	84	1	7	7	5	7	35	0	7	0
-	*Neritina rublicate*	15	7	105	44	7	308	18	7	126	6	7	42	7	7	49
Thiaridae	*Melanoides turberculata*	15	7	105	7	7	49	8	7	56	0	7	0	0	7	0
Potamididae	*Tympanotonus fuscatus*	26	7	182	55	7	385	37	7	259	41	7	287	33	7	231
Lymnaeidae	*Lymnaea sp*	15	7	105	20	7	140	57	7	399	38	7	266	11	7	77
Turritellidae	*Turritella annulata*	0	7	0	0	7	0	8	7	56	6	7	42	3	7	21
Capitellidae	*Capitella capitata*	6	8	48	7	8	56	3	8	24	6	8	48	0	8	0
Naididae	*Limnodrilus sp*	4	8	32	2	8	16	8	8	64	0	8	0	0	8	0
-	*Aulophorus furcatus*	0	8	0	6	8	48	2	8	16	7	8	56	0	8	0
-	*Tubifex tubifex*	8	10	80	2	10	20	12	10	120	0	10	0	0	10	0
Total		234		1576	316		2121	331		2114	222		1464	221		1295
FBI Value		6.73			6.71			6.38			6.59			5.85		
Remark		Poor			Poor			Fairly poor			Poor			Fairly poor		

Discussions

The range of water temperature values obtained in the study is similar with the range reported by Akpan and Etim (2015) and Ukpatu *et al*. (2018) [18, 19]. The slight variation of this parameter recorded attributed to differences in weather condition at the time of sampling and location of the stations. The low values of DO across the stations could be attributed to consistent discharge of wastes from various anthropogenic sources into the water body. The remarkable values recorded in station 2, 3 and 4 could be ascribed to buildup of organic and inorganic pollutants associated to human illicit activities (Jonah *et al*., 2020c) [20]. The microbial decomposition of wastes suggests the reduced DO levels in all the stations (Murphy and basin, 2007) [21]. Anago *et al*. (2013) [22] asserted that the depression in DO values could be due to chemical and biological oxidation processes in the water. Ayabohan *et al*. (2014) [23] affirmed that fluctuations of DO values can be attributed to the presence of organic pollutants in the water body majorly through human activities. The values obtained in this were varied across the stations; this could attribute to geogenic influence (Anyanwu and Ihediwah, 2015) [24] and human activities within the watershed (Jonah *et al*., 2020a) [1]. Studies (seiyaboh *et al*., 2013; Amah-Jerry *et al*., 2017) [25, 26] reported dredging and mining of sand being one of the human activities in the water as a factor leading to lowering and elevation of pH level. The higher value recorded in station 2 may suggest to the buffering capacity of seawater (Desai *et al*., 2020) [27]. The range values of pH obtained were consistent with the report of George and Akpan (2020) [28] in a similar study. The mean values of EC recorded across the stations were significantly higher when compared with WHO limits (1400µs/cm). This could be certified to the consistent discharge of wastes from various anthropogenic sources into the water body (Jonah *et al*., 2020b) [2]. High values of EC have been reported associated with sand mining activities and dredging (Akankali *et al*., 2017; George *et al*., 2017) [29, 30]. Similar values were reported by Ajibade (2004) [31] in a tropical estuarine mangrove swamp. The high values of turbidity recorded in all the stations could be traceable to the impact of dredging, usual waste dumping, surface run-offs from the immediate environment and other domestic activities inside the water body. Wakawa *et al*. (2008) [32]; Bhatti and Latif (2011) [33] reported significant increased in turbidity values from Nigerian rivers linked to surface run-offs, industrial discharge and domestic activities on the river. Biochemical oxygen demand (BOD) is one of the essential parameters used to assess the pollution load in water bodies. BOD values were significantly higher in station 2 and 3; this may be linked to an accumulation of organic and inorganic pollutants via human activities which dissolved oxygen are utilized in large amounts during biodegradation these pollutants resulted in high BOD (Anyanwu *et al*., 2019) [35]. This finding synchronizes with the findings of Jonah *et al*. (2019) [34] for Ikpe Ikot Nkon River. High values of NH_3 were recorded in all the stations, significant values were observed in station in 1, 4 and 5. The elevation may suggest to high surface runoffs and corresponds with the high agricultural activities and adjoining land carrying massive load of nutrients in to the estuary. High nitrate values noticed in stations 3 and 4 and phosphate in station 2 and 4 may be linked to combined effects of precipitation, land used for agricultural activities and other coastal activities. The findings are in agreement with the reports of Mandal *et al*. (2012) [36] who propose that phosphate contamination is as a result anthropogenic activities like laundry, discharge of contaminated sewage, and runoffs laden with fertilizers and pesticides. The finding values of nitrate and phosphate were relatively higher than values recorded by Kuniz *et al*. (2014) [37] in Merbok Estuary, Kedah, Malaysia. Nitrate values in this study were within acceptable limit (<50mg/l), while phosphate values were above the acceptable limit (5.0mg/l) set by WHO. The significant difference observed in sulphate values may be related to the consistent discharged of sulphate-rich wastes in to the water; although the values were within the acceptable limit (500 mg/l) set by WHO.

The WQI values across the stations were above the acceptable limit, not fit for human consumption and other domestic purposes set by WHO. The values obtained in this study were consistent with the findings from Ramakrishnaiah *et al*. (2009); Yisa and Jimoh (2019); George and Inyang-Etor (2017b) [38, 39, 40], who reported WQI values above the acceptable limit (>100). The turbidity, ammonia and electrical conductivity of water sampled contributed to the high WQI values recorded in this study. The unreasonable values recorded were an indication of high concentration of organic pollutants in the water body arising from anthropogenic activities within the water body like indiscriminate dumping of refuses materials, sewage and industrial wastes discharged into the water body, including other domestic activities. Insecticides and detergent pollutants are basically toxic to water including chemical fertilizers; they have more obvious and severe affects in the constituted waters.

In this study, the 26 species of macro-invertebrates recorded is consistent with the earlier assertion by George and Inyang-Etor (2017b) [40] for Qua Iboe River estuary. The number (26) is low when compared with 43 taxa recorded by Hart (1994) [41] from mangrove swamp of Niger Delta and forty six (46) taxa identified by Olomukoro and Oviojie (2015) [42] from Obazuwa Lake in Benin City, Nigeria. The observed variability in compositions of macro-invertebrates suggests differences in natural habitat characteristics, water quality, anthropogenic influence, food availability and period of investigation. The dominance of arthropods across the sampling stations suggests their ubiquitous nature and most species of this group recorded belonging to facultative pollution-tolerant group. The finding is in line with the report from Jonah *et al*. (2020c) [20] for Uta Ewa Estuary, Nigeria. However, the high occurrences of species such as *Nematopalaemon, Macrobrachium macrobrachium, Afruca tangeri* and *Callinectes amnicola* across the stations may suggest to favorable habitat, substrate and food availability (Akpan *et al*., 2019) [43]. The occurrence of *Hydroporus pubescens*, *Gyrinus* sp and *Halobates* species in station 5 only suggest minimal human activities, while constant alteration of inherent physico-chemical quality may link to the absence of these species in other stations. Diptera was represented by four species (*Chironomus larvae*, Chironomus *salinarius, Tabanus sp*. and *Psychoda larvae*). It is well known that member of Diptera specially Chironomidae species are considered highly tolerant to organic pollution (Thome and Williams, 1997; Tyokumbur *et al*., 2002) [44, 45]. The occurrence of *Chironomus* sp. *Limnodrilus hoffmeisteri*, *Tubifex tubifex*, *Capitella capitata* and *Aulophorus furcatus* in stations 1 to 4 suggests accumulation of organic pollutants due to occurrence of human activities within these stations (Emere and Nasiru, 2007; Sharma and Chowdhary, 2011) [46, 47]. The abundance of Gastropod *Tympanotonus fuscatus* suggests food availability, favorable sediment type, water quality and levels of its tolerance to organic pollution (George and Inyang-Etor, 2017b) [40]. However, the absence of Plecoptera and Trichoptera in this study may suggest poor water quality, which further explained the ecological status of the estuary (Wallace and Webster, 1996) [48]. The values of FBI obtained showed that the water quality during this study were poor. Going by the rating proposed by Hilsenhoff (1987) [16]; good water quality should have a range of 0.00 to 5.00. The poor water quality status observed in all the stations reflects the accumulation of substantial organic pollutants allied to the consistent discharged of organic wastes and other considerable amounts of industrial and municipal effluents being added to the water body which have substantial effects on water quality.

Conclusion

Based on the water quality index and family biotic index values recorded in this study, it concluded that estuary is extremely polluted; these in turn influence the abundance of non-tolerant species of macro-invertebrate and further secured the accrual of pollutant tolerant species. The dominance of pollution-tolerant species during the study period indicates that the estuary is deteriorating which confirms the computed water quality index and biotic index values. This study suggests continuous monitoring of water bodies; this will enhance early identification of pollution sources and mitigation them to avert and evade loss of biodiversity.

Acknowledgements

Authors are thankful to the Department of Zoology and Environmental Biology Akwa Ibom State University, for providing necessary laboratory space to carry out this research. The authors also acknowledge the contribution of Mr Utibe Michael Usanga of Department of Geography, University of Uyo, Nigeria for map production.

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