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Biomonitoring of Selected Freshwater Bodies Using Diatoms as Ecological Indicators

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Abstract

Lakes supply water for irrigation, drinking, fisheries, etc. and thus have significant economic and recreational value. In order to determine impacts of human activities on aquatic ecosystem it is important to distinguish anthropogenic impact and natural variation. In limnetic ecosystem, water quality is influenced by physical, chemical, and biological factors. Freshwater communities are very much sensitive to environmental variables. The algal flora constitutes a vital link in the food chain and its productivity depends on water quality at a given time. Diatoms in particular are of utmost importance, as potential indicators of water quality due to their sensitivity and strong response to many physical, chemical and biological changes. Occurrence of diatom communities in selected fresh water bodies of Goa along with physico-chemical parameters have been studied for a period of two consecutive years and the data has been used in biomonitoring. Using OMNIDIA GB 5.3 software, Louis Leclercq IDSE/5 index is derived and the level of degradation due to organic and anthropogenic pollution has been found out. Findings showed seasonal variations in physico-chemical parameters and diatom population. The diversity of diatoms was considerably high in Syngenta, Lotus and Curtorim lakes compared to Khandola Pond. *Gomphonema parabolum*, *Navicula halophila*, *Navicula microcephala*, *Navicula mutica* indicates organic pollution in the water bodies. *Amphora ovalis*, *Stauroneis phoenicenteron, Synedra ulna* indicates anthropogenic pollution in Syngenta, Lotus and Curtorim lakes while *Navicula rhynocochephala* indicate anthropogenic pollution in Khandola Pond. Biomonitoring has been proven to be necessary and hence the importance of diatoms as ecological indicators of water quality has been stressed.

Keywords: Anthropogenic pollution; Biomonitoring; Diatoms; Ecological indicators; Louis-Laclercq; Organic pollution

Introduction

Freshwater communities are very much sensitive to environmental variations [1]. Phytoplankton dynamics influence trophic levels and portability of water for human uses [2,3]. Monitoring of water quality with regards to physical and chemical parameters reflects instantaneous measurements while, biotic parameters developed during the recent years have served as an excellent tool in the area of water pollution studies and provides better evaluation of environmental changes [4]. Diatoms are potential indicators of water quality due to their sensitivity and strong response to physico-chemical and biological changes [5]. Juttner et al. [6] studied environmental changes using diatom assemblages, relationship between diatoms and the water chemistry parameters. According to him fluctuation of diatom species to various environmental changes can be early warning towards freshwater ecological problems. Their sensitivity to small changes in water quality makes them powerful indicators. Several studies on diatoms as bioindicators of pollution have been carried out earlier [7-12].

Biological monitoring is a fast and cost-effective approach for assessing the effects of environmental stressors, making it an essential tool [13]. Various indices have been developed for monitoring pollution in water bodies. One of the simplest and effective water quality index, utilizing diatom population is IDSE/5-the index of Saprobity-Eutrophication. This index is obtained from the OMNIDA GB 5.3 software which indicates the quality of water in terms of organic pollution as well as anthropogenic eutrophication. The design of OMNIDA Software for computation of diatom indices has facilitated the use of diatom based biomonitoring [14]. The software is a comprehensive data base having an inbuilt ecological data for 13,000 diatom species. Present study discusses diatoms as indicators of water quality of selected water bodies using Louis-Leclercq Diatomic Index of Saprobity-Eutrophication (IDSE/5) and the quality of water in terms of organic pollution as well as anthropogenic eutrophication.

Materials and Methods

Two water bodies each from North Goa (Syngenta Lake and Khandola Pond) and South Goa (Lotus Lake and Curtorim Lake) were selected for the study from January 2014 to December 2015 on monthly basis. Water samples were collected in the early hours as daily vertical migrations of organisms occur in response to sunlight and nutrient concentrations from the surface near the landward margins. Physico-chemical parameters such as pH, temperature, nitrates and phosphates were analysed using standard procedures [15]. For phytoplankton study one litre of water sample was collected in sterile plastic bottles (three replicates were taken) and Lugol's solution (0.7 mL/100 mL of sample) added immediately for sedimentation. The bottles were subsequently left undisturbed for 24 h. The phytoplankton fixed and settled at the bottom of the containers after decanting the supernatant fluid were collected and preserved in bottles containing 4% formaldehyde. Enumeration of diatoms was done by modified Lackey's drop method [16]. Dimensions were measured using micrometry technique and photomicrographs were taken using Nikon DS Fi 2 camera. Various taxonomic guides were consulted [17-20]. Each taxon was coded

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with acronyms as per the rules of OMNIDA GB 5.3 software. Diatom species counts were entered into diatom database and index calculation tool, OMNIDIA version 5.3 [14]. The output of the software provides various metrics of water quality through the indices and ecological characteristics. The Louis Leclercq IDSE/5 index was calculated using this software [21]. Seven ecological indicator values given by Van Dam et al. [8] were derived for selected water bodies using the OMNIDIA GB 5.3 software and were used for interpretation of results. These values indicate the conditions required for growth and survival of diatoms. These include pH, salinity (H), nitrogen uptake (NU), oxygen requirements (OR), saprobity (SP), trophic state (TS) and moisture (M) and also determine the water quality. Each parameter is measured on a scale of 1-7. OMNIDIA is also used to compute degradation (D) using IDSE/5 Louis Leclercq index for organic pollution (OP) and anthropogenic eutrophication (AE).

Syngenta Lake is in the premises of M/s Syngenta Agro Chemicals at Corlim Tiswadi taluka located on the banks of Cumbarjua canal. Khandola pond is situated between 15.5^{0}N Latitude 73.9^{0}E Longitude of Marcela. It is a source of irrigation to areca nut plantation in surrounding areas. Lotus Lake is situated between 15.2^{0}N Latitude and 73.9^{0}E Longitude, Lake is polluted and has abundant growth of aquatic weeds. Curtorim lake is Situated between 15.2^{0}N Latitude and 74.0^{0}E Longitude. All four water bodies differ in dimensions, size, nutrients concentration, nature of aquatic life, usage and level of human disturbance.

Results and Discussion

The list of diatoms encountered in selected water bodies with their acronyms are tabulated in Table 1. Indicator species of organic and anthropogenic pollution, IDSE/5 Louis Leclercq index derived from OMNIDA software are presented in Table 2, while standard ecological values by Van Dam et al. [8] are presented in Table 3. Variations in pH, temperature, nitrate and phosphate levels are presented in Tables 4-7. The pH of water varied in different water bodies *viz.*

Syngenta Lake (5.9-6.8), Khandola Pond (6.0-7.1), Lotus Lake (5.7-7.8) and Curtorim Lake (5.5-7.7) with pH range given in parenthesis. Similarly the phytoplankton diversity varied in different water bodies. Physico-chemical and biological characteristics of water bodies are known to influence each other and pH range of 5 to 8.5 was reported to be ideal for phytoplankton growth [22].

The water temperature of study sites ranged from 25 to 32°C, with maximum temperature recorded in May (late summer and early rainy season) and minimum in January (winter season). Water temperature of water plays an important role in controlling the occurrence and abundance of phytoplanktons [23]. Nitrate levels in all the selected water bodies varied and ranged from 0.20 to 0.73 mg/L in Syngenta Lake, 0.21 to 0.58 mg/L in Khandola Pond, 1.43 to 4.55 mg/L in Lotus Lake and 0.80 to 2.76 mg/L in Curtorim Lake. Similarly phosphate concentrations also showed variations and ranged from 0.07 to 0.31 mg/L in Syngenta Lake, 0.01 to 0.30 mg/L in Khandola Pond, 0.01 to 2.41 mg/L in Lotus Lake and 0.01 to 1.72 mg/L in Curtorim Lake. It was observed that during monsoon season, pollutants like nitrates and phosphates enter the water bodies from the surrounding area, especially from farmlands, resulting in elevated concentrations of nitrates and phosphates [24]. Eutrophic conditions are observed during pre- and post-monsoon seasons at Syngenta, Lotus and Curtorim Lakes, supporting the growth of phytoplankton. During the study period 21 species of diatoms belonging to 12 genera were recorded. An α-mesosaprobous form were found to be occurring in Syngenta, Lotus and Curtorim Lakes while in Khandola pond β-mesosaprobous forms were recorded. Both α and β mesosaprobous organisms indicate presence of moderately polluted water. Nautiyal and Mishra [25] reported alkaliphilic, fresh-brackish, β-mesosaprobic and eutraphentic condition in water body that is under anthropogenic influence. Trophic state was eutrophentic in Syngenta, Lotus and Curtorim lakes and mesoeutrophantic in Khandola pond indicating the deteriorating water quality. This deteriorating water quality of water bodies is mainly because of organic and anthropogenic pollution caused due to disturbances created by human activities such as cattle washing, fishing, unrestricted entry of huge quantity of sewage and effluents from the surrounding residential areas and industries. Such activities caused low dissolved oxygen levels and high biological oxygen demand (BOD) which in turn is making the water bodies eutrophentic [26].

S. No.	Species name	Acronym
1	*Pinnularia graciloids* Huste	PGRA
2	*Pinnularia dolosa* H.P.Gandhi	PDOL
3	*Navicula halophila*(Gurnow)Cleve	NHAL
4	*Cocconeis placentula* Ehrenberg	CPLA
5	*Navicula mutica* Kutzing	NMUT
6	*Gomphonema parabolum* Kutzing	GPAR
7	*Ahninthes exigua* Grunow.	AEXI
8	*Cymbella chandolensis* Gandhi.	CCHA
9	*Synedra ulna* (Nitzsch) Ehrenberg.	SULN
10	*Pinnularia gibba* Ehrenberg	PGIB
11	*Melosira islandica* O.Muller	MISL
12	*Amphora ovalis* (Kützing) Kutzing	AOVA
13	*Stauroneis phoenicenteron*(Nitzsch) Ehrenberg	SPHO
14	*Navicula microcephala* Grunow	NMIC
15	*Diploneis elliptica* (Kutzing) Cleve	DELL
16	*Stauroneis anceps* Ehrenberg	SANC
17	*Navicula sphaerophora* Kutzing	NSPH
18	*Navicula radiosa* Kutzing	NRAD
19	*Gomphonema subtiles* Ehrenberg	GSUB
20	*Navicula rhynococephala* Kutzing	NRHY
21	*Eunotia tumida* Gandhi	ETUM

Table 1: Diatom species with their acronyms.

		January to December 2014				January to December 2015			
Sr.No.	**Parameter / criteria**	**SL**	**KP**	**LL**	**CL**	**SL**	**KP**	**LL**	**CL**
1	Number of genera	10	2	12	12	10	2	11	10
2	population	78862	96925	14155	10763	11124	95525	99119	13000
3	Diversity	3.64	2.07	3.65	3.7	3.65	2.05	3.72	3.62
4	Evenness	0.98	0.89	0.98	0.97	0.96	0.88	0.98	0.95
5	Number of species	13	5	14	14	14	5	14	14
6	pH (R)	4-Alkaliphilous mainly occurring at pH >7	3-Circumneutral mainly occurring at pH 7	3- Circumneutral mainly occurring at pH 7	3- Circumneutral mainly occurring at pH 7	3- Circumneutral mainly occurring at pH 7	3-Circumneutral mainly occur-ring at pH 7	3-Circumneutral mainly occurring at pH 7	3-Circum-neutral main-ly occurring at pH 7
7	Salinity (H)	Fresh to brackish	2-Fresh to br brackish	2-Fresh to brackish	2-Fresh to brackish	2- Fresh to brackish	2, Fresh to brackish	2-Fresh to brackish	2-Fresh to brackish
8	Nitrogen Uptake metabolism (N)	2- Nitrogen autotrophic taxa tolerating elevated levels of organically bound nitrogen	2- Nitrogen autotrophic taxa tolerating elevated levels of organically bound nitrogen	2- Nitrogen autotrophic taxa tolerating elevated levels of organically bound nitrogen	2-Nitrogen autotrophic taxa tolerating elevated levels of organically bound nitrogen	2-Nitrogen autotrophic taxa tolerating elevated levels of organically bound nitrogen	2-Nitrogen autotrophic taxa tolerating elevated levels of organically bound nitrogen	2-Nitrogen autotrophic taxa tolerating elevated levels of organically bound nitrogen	2- Nitrogen autotrophic taxa tolerating elevated levels of organically bound nitrogen
9	Oxygen Requirement (O)	3-Moderate (above 50% saturation)	2- Fairly high(above 75% saturation)	3- Moderate (above 50% saturation)	3- Moderate (above 50% saturation)	2- Fairly high(above 75% saturation)	2- Fairly high(above 75% saturation)	3- Moderate (above 50% saturation)	3- Moderate (above 50% saturation)
10	Saprobity (S)	3-Alfa mesosaprobous	2- B mesosaprobus	3-Alpha mesosap-robous	3- Alpha meso-saprobous	3- Alfa mesosap-robous	2- B mesosaprobus	3-Alpha meso-saprobous	3-Alpha me-sosaprobous
11	Trophic state	5-Eutrophantic	4-Mesoeutrophantic	5- Eutrophentic	5- Eutrophentic	5- Eutrophantic	4-Mesoeutro-phantic	5- Eutrophentic	5- Eutrophentic
12	Moisture retention (M)	2- Mainly occurring in water bodies	2-Mainly occurring in water bodies	2- Mainly occurring in water bodies	2- Mainly occurring in water bodies	2- Mainly occurring in water bodies	2- Mainly occurring in water bodies	2- Mainly occurring in water bodies	2- Mainly occurring in water bodies
13	IDSE/5(Louis Leclercq Index)	3.31	3.52	3.53	3.46	3.47	3.52	3.16	3.47
14	% Indicators of organic pollution	30.65%	22.12%	21.23%	20.87%	19.63%	15.29%	32.59%	19.63%
15	Indicator organisms	GPAR, NHAL, NMIC, NMUT	NMUT	GPAR, NHAL, NMUT	GPAR, NHAL, NMUT	GPAR, NHAL, NMUT	NMUT	GPAR, NHAL, NMUT	GPAR, NHAL, NMUT
16	% indicators of anthropogenic eutrophications	27.19%	27.19%	15.28%	23.48%	15.32%	20.98%	18.71%	15.32%
17	Indicator organisms	AOVA, SPHO, SULN	NRHY	AOVA, SPHO, SULN	AOVA, SPHO, SULN	AOVA, SPHO, SULN	NRHY	AOVA, SPHO, SULN	AOVA, SPHO, SULN

Table 2: Ecological indicator values for selected water bodies (data derived from OMNIDA GB5.3 Software).

Therefore, effective and strong conservative measures should be taken to prevent the lakes from entering hypereutrophentic state and to ensure the sustenance of aquatic flora and fauna. IDSE/5 index range of 3.31 to 3.53 in 2014 and 3.16 to 3.52 in 2015 indicate low to moderate degradation of all water bodies. The utilisation of indicator species is one of the water quality assessment defined by their optima and tolerances to environmental variables such as pH, temperature and phosphorus have been developed for many diatom taxa [27]. Indicator species of diatoms for organic pollution *viz. Gomphonema parabolum, Navicula halophila*, *Navicula microcephala, Navicula mutica* and anthropogenic pollution *viz. Amphora ovalis, Stauroneis phoenicenteron, Synedra ulna* were recorded in Syngenta, Lotus and Curtorim lakes. Indicator species for organic pollution *viz. Navicula mutica* and anthropogenic pollution *viz. Navicula microcephala* was recorded in Khandola pond.

Conclusion

From the results it is concluded that there deterioration of water quality of the water bodies undertaken for the study. Diatoms encountered during study are most powerful ecological indicators of degradation levels and also the ecological conditions of selected water bodies. They are right tools for biomonitoring, as indicator value of diatoms is well accepted and highly used across the continents. It is an ideal means by which progress towards integrated water resources management can be monitored.

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1	Acidobiontic	Optional occurrence at pH <5.5
2	Acidophilous	Mainly occurring at pH <7
3	Circumneutral	Mainly occurring at pH – values about 7
4	Alkaliphilous	Mainly occurring at pH >7
5	Alkalibiontic	Exclusively occurring at pH >7
6	Indifferent	No apparent optimum

pH (R).

S.No.	Water quality	Cl (mg/L)	Salinity
1	Fresh	<100	<0.2
2	Fresh brackish	<500	<0.9
3	Brackish fresh	500-1000	0.9-1.8
4	Brackish	1000-5000	1.8-9.0

Salinity (H).

S. No.	Nitrogen uptake
1	Nitrogen-autotrophic taxa tolerating very small concentrations of organically bound nitrogen
2	Nitrogen-autotrophic taxa tolerating elevated concentrations of organically bound nitrogen
3	Facultatively bound nitrogen-heterotrophic taxa needing periodically elevated concentrations of organically bound nitrogen
4	Obligately nitrogen-heterotrophic taxa needing continuously elevated concentrations of organically bound nitrogen

Nitrogen uptake (NU).

1	Oligosaprobous
2	β-mesosaprobous
3	α-mesosaprobous
4	α-meso-/polysaprobous
5	Polysaprobous

Saprobity (SP).

1	Never or only very rarely occurring outside water bodies
2	Mainly occurring in water bodies, sometimes on wet places
3	Mainly occurring in water bodies also rather regularly on wet and moist places
4	Mainly occurring on wet and moist or temporarily dry places
5	Nearly exclusively occurring outside water bodies

Moisture (M).

1	Oligotrophentic
2	Oligo-mesotrophentic
3	Mesotrophentic
4	Meso-eutrophentic
5	Eutrophentic
6	Hypereutrophentic
7	Oligo-to eutrophentic (hypoeutrophentic)

Trophic State (TS).

1	Continuously high (about 100% saturation)
2	Fairly high (above 75% saturation)
3	Moderate (above 50% saturation)
4	Low (above 30% saturation)
5	Very low (about 10% saturation)

Oxygen requirements (OR).

Table 3: Classification of ecological indicator values.

Months of study	Syngenta Lake	Khandola Pond	Lotus Lake	Curtorim Lake
Jan'14	6.1	7.14	7.8	6.8
Feb'14	5.9	6.1	6.6	6.9
Mar'14	6.2	6	6.46	6.7
Apr'14	6.2	6.1	6	6.9
May'14	6.3	6	5.9	6.72
June'14	6.4	6.8	6	7.60
July'14	6.8	6.4	6.73	7.68
Aug'14	6.4	6.2	6	7.68
Sept'14	6.23	6.4	6.5	7.52
Oct'14	6.09	6.4	6	7.68
Nov'14	6.5	6.45	6.6	6.4
Dec'14	6.7	6.47	6	6.9
Jan'15	6.12	7.12	6.8	6.6
Feb'15	6	6.15	6.66	6.7
Mar'15	6.2	6.1	6.46	7.19
Apr'15	6.22	6.1	6	6.7
May'15	5.9	6	5.87	6.89
June'15	6.2	6.19	6	6.72
July'15	6.25	6.3	6.7	6.6
Aug'15	6.45	6.2	6.78	6.68
Sept'15	6.47	6.4	6	6.5
Oct'15	6.3	6.38	5.4	6.18
Nov'15	6.17	6.4	6.2	5.45
Dec'15	6.37	6.44	6.5	6.33

Table 4: Variations in pH of selected water bodies.

Months of study	Syngenta Lake	Khandola Pond	Lotus Lake	Curtorim Lake
Jan'14	25	25	25.5	25.5
Feb'14	28	28	29	29
Mar'14	28	28	29	29
Apr'14	30	30	30	30
May'14	31	31	31	31
June'14	30.8	30.8	30	30
July'14	28.4	30.8	30	30
Aug'14	27.4	28.4	26.2	26.2
Sept'14	28.4	27.4	28.4	28.4
Oct'14	29	28.4	29	29
Nov'14	29	29	29	29
Dec'14	28	28	28	28
Jan'15	23	23	25	25
Feb'15	25	25	29	29
Mar'15	29	29	29	29
Apr'15	30	30	30	30
May'15	32	32	32	32
June'15	31	31	31	31
July'15	28	28.2	30	30
Aug'15	27.5	27.5	26	26
Sept'15	28	28.1	28.4	28.4
Oct'15	29	29	29.1	29
Nov'15	29	29	29	29.1
Dec'15	28	28	28.4	31

Table 5: Variations in temperature (^{0}C) of selected water bodies.

Months of study	Syngenta Lake	Khandola Pond	Lotus Lake	Curtorim Lake
Jan'14	0.2	0.27	1.43	0.8
Feb'14	0.72	0.23	1.58	1.27
Mar'14	0.82	0.56	1.66	1.5
Apr'14	0.31	0.47	1.76	1.78
May'14	0.54	0.36	1.81	2.57
June'14	0.33	0.5	2.16	1.32
July'14	0.41	0.58	4.55	2.27
Aug'14	0.5	0.34	3.16	2.76
Sept'14	0.53	0.38	3.38	1.43
Oct'14	0.48	0.31	4.45	1.27
Nov'14	0.31	0.3	3.06	1.19
Dec'14	0.29	0.29	2.38	1.27
Jan'15	0.21	0.21	1.76	0.93
Feb'15	0.34	0.23	1.65	1.43
Mar'15	0.73	0.5	1.75	1.67
Apr'15	0.24	0.49	1.7	1.51
May'15	0.32	0.32	1.81	1.55
June'15	0.37	0.35	2.24	2.3
July'15	0.43	0.28	2.95	2.45
Aug'15	0.59	0.33	3.19	2.64
Sept'15	0.57	0.38	3.38	2.4
Oct'15	0.53	0.32	2.55	1.73
Nov'15	0.45	0.29	2.17	1.65
Dec'15	0.37	0.27	2.02	2.57

Table 6: Variations in nitrates (in mg/L) of selected water bodies.

Months of study	Syngenta Lake	Khandola Pond	Lotus Lake	Curtorim Lake
Jan'14	0.1	0.01	0.01	0.01
Feb'14	0.12	0.02	0.03	0.02
Mar'14	0.23	0.01	0.1	0.01
Apr'14	0.1	0.04	0.25	0.04
May'14	0.24	0.02	0.25	0.12
June'14	0.27	0.02	0.3	0.15
July'14	0.25	0.3	2.41	1.72
Aug'14	0.19	0.25	1.92	0.49
Sept'14	0.2	0.15	0.78	0.55
Oct'14	0.15	0.15	0.6	0.3
Nov'14	0.19	0.1	0.19	0.19
Dec'14	0.1	0.02	0.1	0.1
Jan'15	0.11	0.01	0.27	0.19
Feb'15	0.07	0.02	0.2	0.3
Mar'15	0.09	0.01	0.21	0.48
Apr'15	0.1	0.04	0.18	0.4
May'15	0.2	0.02	0.25	0.47
June'15	0.25	0.02	0.39	1.15
July'15	0.29	0.01	1.01	1.22
Aug'15	0.31	0.02	1.62	1.54
Sept'15	0.28	0.04	1.7	0.95
Oct'15	0.22	0.03	1.03	0.4
Nov'15	0.17	0.02	0.17	0.2
Dec'15	0.12	0.01	0.11	0.12

Table 7: Variations in phosphates (in mg/L) of selected water bodies.

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