Biomonitoring of selected freshwater bodies using diatoms as ecological indicators

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INTRODUCTION

- Water - one of the vital issues of the 21st century - life of people will depend on the wise management of the water resources.

- Precious aquatic environment is getting polluted - warrants urgent action to prevent further degradation.

- Anthropogenic activities degrade freshwater ecosystems - affecting ecological integrity, functioning and subsequently their use for domestic, industrial and agricultural purposes.

INTRODUCTION

- Freshwater communities - very sensitive to environmental variables.
- Monitoring of water quality with regards to physical and chemical parameters reflects instantaneous measurements - biotic parameters developed during the recent years - serve as an excellent tools in water pollution studies - provides better evaluation of environmental changes.
- Biological monitoring - fast and cost-effective approach for assessing the effects of environmental stressors.
- Phytoplanktons - used as indicators of water quality mainly due to their sensitivity and strong response to physical and chemical changes in waters.

INTRODUCTION

- Diatoms - potential indicators of water quality due to their sensitivity and strong response to physico- chemical and biological changes.

- Ubiquitous in distribution - their cells remain unchanged for years under varied environmental conditions – hence used as water quality indicators.

- Various indices - developed for monitoring pollution in water bodies.

INTRODUCTION

- **IDSE/5 - simplest and effective water quality index, utilizing diatom population - 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 (Leconite *et al.,* 1993).**

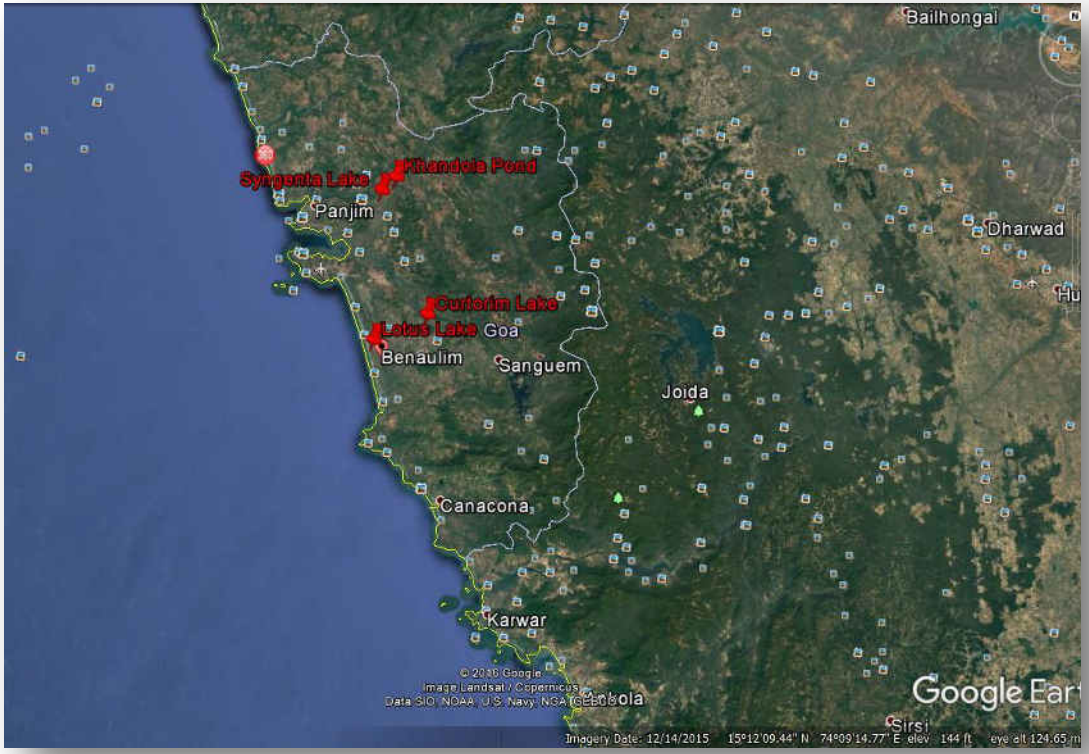
- **This software - a comprehensive database having an inbuilt ecological data for 13,000 diatom species.**

AIMS AND OBJECTIVES

- To ascertain the level of degradation in the selected water bodies due to organic and anthropogenic pollution,
- To identify the diatom species indicating organic and anthropogenic pollution in the selected water bodies, and
- To derive Louis Leclercq index of Saprobity- Eutrophication (IDSE/5) using OMNIDIA GB 5.3 software and know the trophic state of the selected water bodies.

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.



Location of study sites

VIEW OF SYNGENTA LAKE

Syngenta Lake is in the premises of M/s Syngenta Agro Chemicals

(15.5^{o} N Lat. 73.94^{o}E Long.)

VIEW OF KHANDOLA POND

Khandola Pond is in Marcela village - source of irrigation to areca nut plantation.

(15.51^{o} N Lat. 73.95^{o}E Long.)

VIEW OF LOTUS LAKE

Lotus Lake is in Benaulim village - source of irrigation for paddy crop.
(15.24^{0}N Lat. and 73.92^{0}E Long.)

VIEW OF CURTORIM LAKE

Curtorim Lake is situated in Curtorim village - source of irrigation for paddy crop

(15.28^{0}N Lat. and 74.01^{0}E Long.)

MATERIALS AND METHODS

- 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 -pH, temperature, nitrates and phosphates were analyzed using standard procedures (APHA, 2012).

- For diatom study 1l of water sample - collected in sterile plastic bottles (in triplicate) and Lugol's solution (0.7ml/100 ml of sample) added immediately for sedimentation.

MATERIALS AND METHODS

- The bottles were subsequently left undisturbed for 24 h. The diatoms 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 - modified Lackey's drop method (Suxena, 1987). Dimensions measured using micrometry technique and photomicrographs were taken using Nikon DS Fi 2 camera.

MATERIALS AND METHODS

- Various taxonomic guides consulted (Gandhi, 1998; Sarode and Kamath, 1984; Kramer and Lange - Bertalot, 2003; Karthick *et al*., 2010).

- Each taxon was coded with acronyms as per the rules of OMNIDA GB 5.3 software. Diatom species counts were entered index calculation tool, OMNIDIA version 5.3 (Lecointe *et al*., 1993).

- 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 (Leclerq and Maquet, 1987).

MATERIALS AND METHODS

- Seven ecological indicator values (that indicate the conditions required for growth and survival of diatoms and also determines the water quality) given by Van Dam *et al.,* (1994) were derived for selected water bodies using the OMNIDIA GB 5.3 software and were used for interpretation of results.

- These include pH, salinity (S), nitrogen uptake (NU), oxygen requirements (OR), saprobity (SP), trophic state (TS) and moisture (M). 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).

RESULTS

Sr. No.	Species	Acronym
1	*Pinnularia graciloids* Huste	PGRA
2	*Pinnularia dolosa* H.P. Gandhi	PDOL
3	*Navicula halophila*(Gurnow)Cleve	NHAL
4	*Cocconeis placentula* (Gurnow) Cleve	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* (Kutzing) Kutzing	AOVA
13	*Stauroneis phoenicenteron* (Nitzsch) Ehrenberg	SPHO
14	*Navicula microcephala* Grunov	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

Diatom species with their acronyms.

During the study period 21 species of diatoms belonging to 12 genera were recorded.

Diatoms species

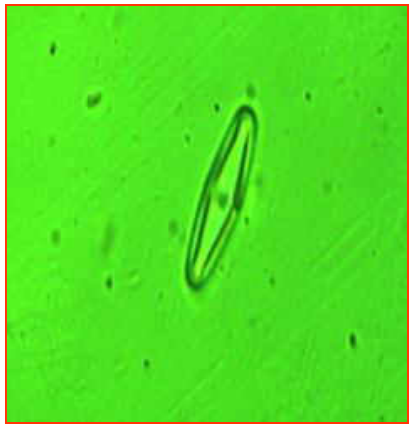
Ahninthes exigua

Cocconeis placentula

Cymbella chandolensis

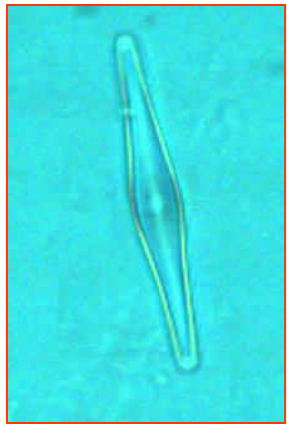
Cocconies placentula

Cymbella turgidula



Diploneis elliptica

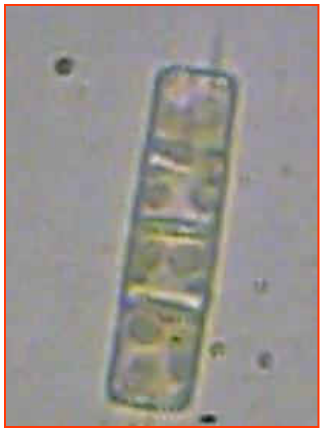
Eunotia tumida



Gomphonema subtiles

Diatoms species

Gomphonema parabolum



Melosira indica

Navicula halophila

Navicula mutica

Navicula radiosa

Navicula rhynococephala

Navicula microcephala

Diatoms species

Synedra ulna

Pinnularia dolosa

Pinnularia gibba

Pinnularia graciloids

Stauroneis anceps

Stauroneis phoenicenteron

Classification of Ecological Indicator values (VanDam, Martens and Sinkeldam (1994)

(R) pH (1-6)

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

(N) Nitrogen Uptake (1-4)

1	Nitrogen-autotrophic taxa tolerating very small concentrations of orgaically 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

(M) Moisture (1-5)

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

(O) Oxygen requirements (1-5)

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)

(H) Salinity (1-4)

	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

Saprobity (1-5)

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

Trophic State (1-7)

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

Ecological indicator values for selected water bodies (As per Van Dam *et al.*, 1994)

(Data derived from OMNIDA GB5.3 Software)

January to December 2014					
Sr.No.	**Parameter /criteria**	**SL**	**KP**	**LL**	**CL**
1	Number of genera	**10**	**2**	**12**	**12**
2	population	78862	96925	14155	10763
3	Diversity	3.64	2.07	3.65	3.7
4	Evenness	0.98	0.89	0.98	0.97
5	Number of species	**13**	**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
7	Salinity (H)	Fresh to brackish	2-Fresh to br 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
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)
10	Saprobity (S)	**3-Alfa mesosaprobous**	**2- B mesosaprobus**	**3-Alpha mesosaprobous**	**3- Alpha mesosaprobous**
11	Trophic state	**5-Eutrophantic**	**4-Mesoeutrophantic**	**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
13	IDSE/5(Louis Leclercq Index)	**3.31**	**3.52**	**3.53**	**3.46**
14	% Indicators of organic pollution	30.65%	22.12%	21.23%	20.87%
15	Indicator organisms	**GPAR, NHAL, NMIC, NMUT**	**NMUT**	**GPAR, NHAL, NMUT**	**GPAR, NHAL, NMUT**
16	% indicators of anthropogenic eutrophications	27.19%	27.19%	15.28%	23.48%
17	Indicator organisms	**AOVA,SPHO,SULN**	**NRHY**	**AOVA,SPHO,SULN**	**AOVA,SPHO,SULN**

Ecological indicator values for selected water bodies (As per Van Dam *et al.*, 1994)

(Data derived from OMNIDA GB5.3 Software)

January to December 2015					
Sr. No.	**Parameter /criteria**	**SL**	**KP**	**LL**	**CL**
1	Number of genera	**10**	**2**	**11**	**10**
2	population	11124	95525	99119	13000
3	Diversity	3.65	2.05	3.72	3.62
4	Evenness	0.96	0.88	0.98	0.95
5	Number of species	**14**	**5**	**14**	**14**
6	pH (R)	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
7	Salinity (H)	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
9	Oxygen Requirement (O)	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 mesosaprobous**	**3-Alpha mesosaprobous**
11	Trophic state	**5- Eutrophantic**	**4-Mesoeutrophantic**	**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
13	IDSE/5(Louis Leclercq Index)	**3.47**	**3.52**	**3.16**	**3.47**
14	% Indicators of organic pollution	19.63%	15.29%	32.59%	19.63%
15	Indicator organisms	**GPAR, NHAL, NMUT**	**NMUT**	**GPAR, NHAL, NMUT**	**GPAR, NHAL, NMUT**
16	% indicators of anthropogenic eutrophications	15.32%	20.98%	18.71%	15.32%
17	Indicator organisms	**AOVA,SPHO,SULN**	**NRHY**	**AOVA,SPHO,SULN**	**AOVA,SPHO, SULN**

Variations in pH of selected water bodies

Months of study	Syngenta Lake	Khandola Pond	Lotus Lake	Curtorim Lake
Jan'14	6.1	7.1	7.8	6.8
Feb'14	5.9	6.1	6.6	6.9
Mar'14	6.2	6.0	6.4	6.7
Apr'14	6.2	6.1	6.0	6.9
May'14	6.3	6.0	5.9	6.7
June'14	6.4	6.8	6.0	7.6
July'14	6.8	6.4	6.7	7.6
Aug'14	6.4	6.2	6.0	7.6
Sept'14	6.2	6.4	6.5	7.5
Oct'14	6.0	6.4	6.0	7.6
Nov'14	6.5	6.4	6.6	6.4
Dec'14	6.7	6.4	6.0	6.9
Jan'15	6.1	7.1	6.8	6.6
Feb'15	6.0	6.1	6.6	6.7
Mar'15	6.2	6.1	6.4	7.1
Apr'15	6.2	6.1	6.0	6.7
May'15	5.9	6.0	5.8	6.8
June'15	6.2	6.1	6.0	6.7
July'15	6.2	6.3	6.7	6.6
Aug'15	6.4	6.2	6.7	6.6
Sept'15	6.4	6.4	6.0	6.5
Oct'15	6.3	6.3	5.4	6.1
Nov'15	6.1	6.4	6.2	5.4
Dec'15	6.3	6.4	6.5	6.3

- ✓ In the present study, the pH of water was ranging from acidic to alkaline; varied in different water bodies *viz.*, Syngenta Lake (5.9 - 6.8), Khandola Pond (6.0 - 7.1), Lotus Lake (5.4 - 7.8) and Curtorim Lake (5.4 - 7.6).
- ✓ Diatom population also showed variations which may be attributed to the change in pH values.
- ✓ Robert *et al.*, (1974) suggested that pH range from 5 to 8.5 - ideal for phytoplankton growth.

Variations in temperature of selected water bodies

Months of study	Syngenta Lake	Khandola Pond	Lotus Lake	Curtorim Lake
Jan'14	**25**	**25**	**25**	**25**
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	30	30	30
July'14	28	30	30	30
Aug'14	27	28	26	26
Sept'14	28	27	28	28
Oct'14	29	28	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	30	30
Aug'15	27	27	26	26
Sept'15	28	28	28	28
Oct'15	29	29	29	29
Nov'15	29	29	29	29
Dec'15	28	28	28	31

- ✓ **The water temperature ranged from 25 to 32°C, with maximum in May (summer) and minimum in January (winter).**
- ✓ **Water temperature plays an important role in controlling occurrence and abundance of phytoplanktons (Nazneen, 1980).**

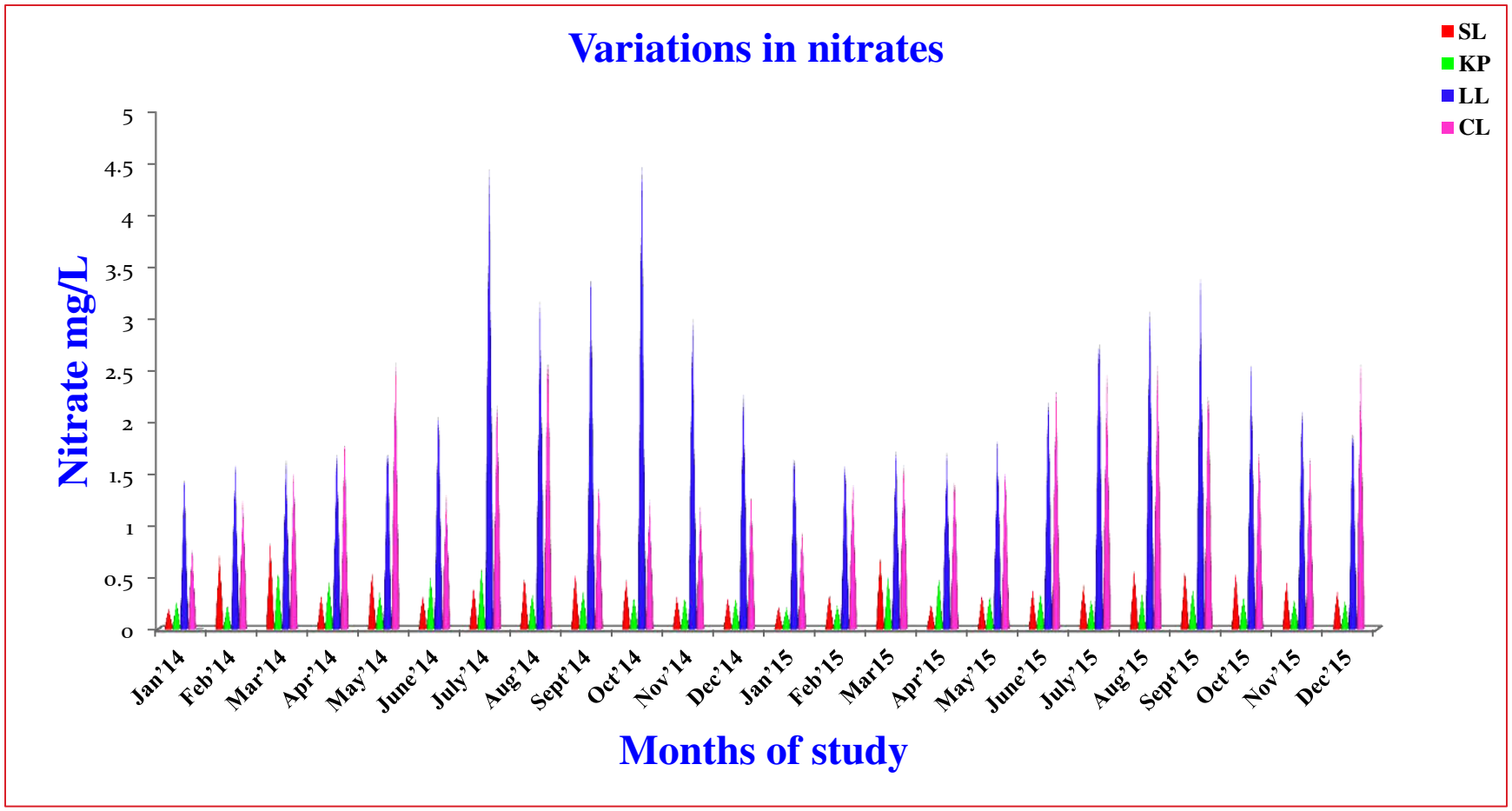
Variations in nitrates of selected water bodies

Months of study	Syngenta Lake	Khandola Pond	Lotus Lake	Curtorim Lake
Jan'14	**0.20**	0.27	**1.43**	**0.80**
Feb'14	0.72	0.23	1.58	1.27
Mar'14	0.82	0.56	1.66	1.50
Apr'14	0.31	0.47	1.76	1.78
May'14	0.54	0.36	1.81	2.57
June'14	0.33	0.50	2.16	1.32
July'14	0.41	**0.58**	**4.55**	2.27
Aug'14	0.50	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	0.30	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	0.50	1.75	1.67
Apr'15	0.24	0.49	1.70	1.51
May'15	0.32	0.32	1.81	1.55
June'15	0.37	0.35	2.24	2.30
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	2.40
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

Legend: Values expressed in mg/L

✓**Nitrate levels in the selected water bodies varied; ranged from 0.20 to 0.73 mg/ L in Syngenta Lake, 0.20 to 0.73 mg /L in Khandola Pond, 1.43 to 4.55 mg /L in Lotus Lake and, 0.80 to 2.76mg /L in Curtorim Lake.**

Variations in nitrates of selected water bodies



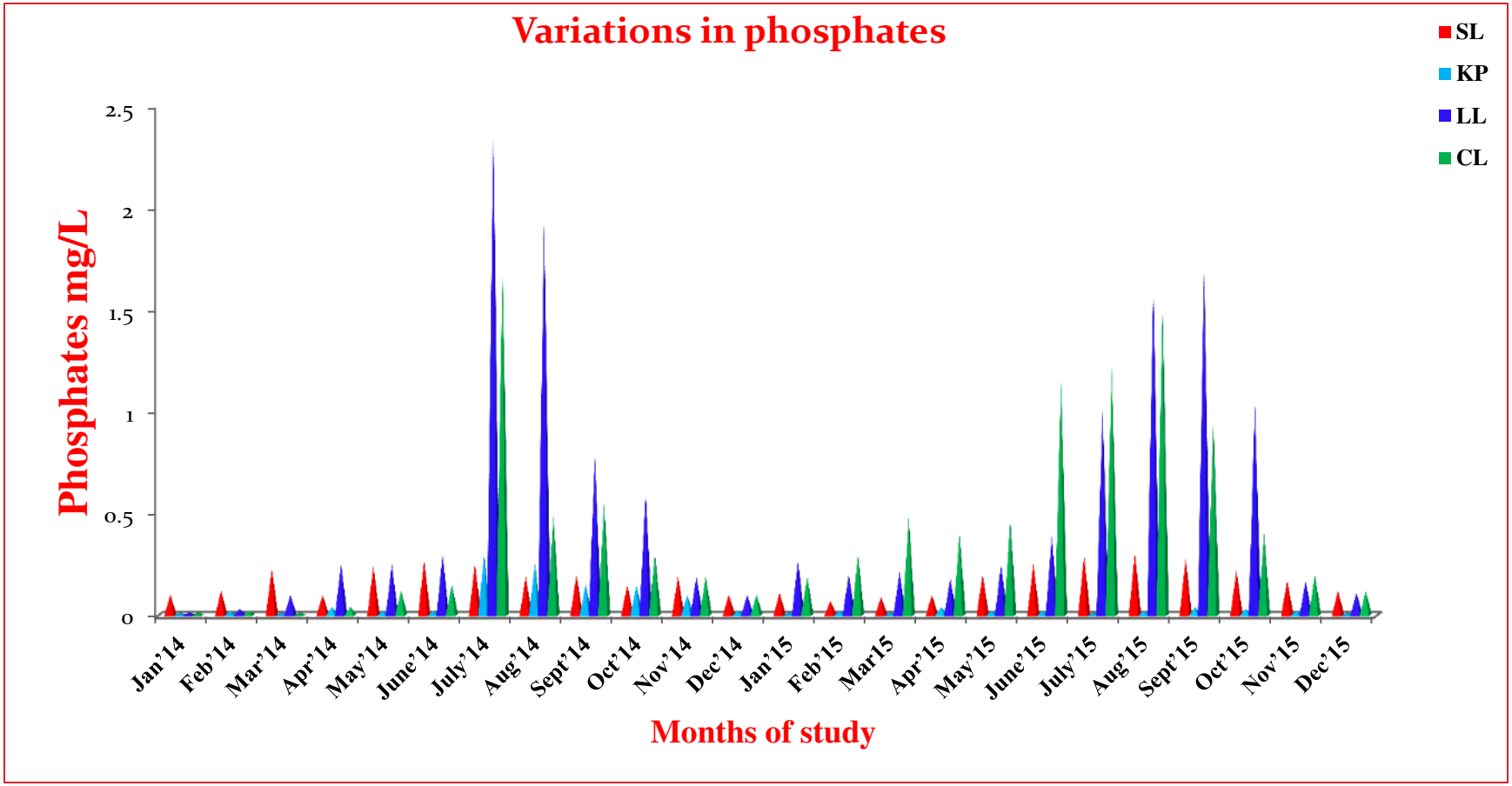
Variations in phosphates of selected water bodies

Months of study	Syngenta Lake	Khandola Pond	Lotus Lake	Curtorim Lake
Jan'14	0.10	**0.01**	**0.01**	**0.01**
Feb'14	0.12	0.02	0.03	0.02
Mar'14	0.23	0.01	0.10	0.01
Apr'14	0.10	0.04	0.25	0.04
May'14	0.24	0.02	0.25	0.12
June'14	0.27	0.02	0.30	0.15
July'14	0.25	**0.30**	**2.41**	**1.72**
Aug'14	0.19	0.25	1.92	0.49
Sept'14	0.20	0.15	0.78	0.55
Oct'14	0.15	0.15	0.60	0.30
Nov'14	0.19	0.10	0.19	0.19
Dec'14	0.10	0.02	0.10	0.10
Jan'15	0.11	0.01	0.27	0.19
Feb'15	**0.07**	0.02	0.20	0.30
Mar'15	0.09	0.01	0.21	0.48
Apr'15	0.10	0.04	0.18	0.40
May'15	0.20	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	1.70	0.95
Oct'15	0.22	0.03	1.03	0.40
Nov'15	0.17	0.02	0.17	0.20
Dec'15	0.12	0.01	0.11	0.12

Legend: Values expressed in mg/L

- ✓ **Phosphate concentrations 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.**
- ✓ **During monsoon season, nutrients like nitrates and phosphates enter the water bodies from the surrounding area, especially from farmlands and sewage, resulting in their elevation (Sawaiker and Rodrigues, 2016).**

Variations in phosphates of selected water bodies



RESULTS AND DISCUSSION

- ✓ α - mesosaprobous form were found to be occurring in Syngenta, Lotus and Curtorim Lakes while β- mesosaprobous forms were recorded from Khandola Pond.

- ✓ Both α and β mesosaprobous organisms indicate presence of moderately polluted water.

- ✓ Nautiyal and Mishra (2013) reported alkaliphilic, fresh-brackish, β-mesosaprobic and eutraphentic condition in water body that was under anthropogenic influence.

RESULTS AND DISCUSSION

- ✓ IDSE/5 index ranged from 3.31-3.47 in Syngenta Lake, 3.52 in Khandola Pond during both years of study, 3.16-3.53 in Lotus Lake and 3.46-3.47 in Curtorim Lake indicating low to moderate degradation of all water bodies. (IDSE index range is between 1- 5 {1 - worse and 5 - best}).

- ✓ Trophic state was eutrophentic in Syngenta, Lotus and Curtorim Lakes and mesotrophantic in Khandola Pond indicating the deteriorating water quality.

RESULTS AND DISCUSSION

- ✓ **Indicator species of diatoms for organic pollution *viz.*, *Gomphonema parabolum, Navicula halophila, N. microcephala, N. mutica* and anthropogenic pollution *viz.*, *Amphora ovalis, Stauroneis phoenicenteron, Synedra ulna* were recorded from Syngenta, Lotus and Curtorim Lakes.**

- ✓ **Indicator species for organic pollution *viz.*, *Navicula mutica* and anthropogenic pollution *viz.*, *Navicula microcephala* were recorded from Khandola Pond.**

CONCLUSION

- There is deterioration of water quality in selected water bodies.
- The deterioration of water quality is due to organic and anthropogenic pollution - due to human activities such as cattle washing, fishing, unrestricted entry of huge quantity of sewage and effluents from the surrounding residential areas and industries.
- Diatoms encountered during study are most powerful ecological indicators of degradation levels and are proper tools for biomonitoring.

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