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Effect of anthropogenic activities on diatom community in Umiam Reservoir, Meghalaya, India

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ABSTRACT

Umiam reservoir is an important tourist attraction in Meghalaya. Recent research by National water quality monitoring program (NWMP, 2019) state that water in the Umiam Reservoir is polluted and unfit for any domestic use except irrigation without conventional primary treatment. The pollution problem is further compounded with increased level of silt. Occurrence of algal bloom dominated by genera like Microcystis in few parts of the reservoir supported the CPCB norms (2014). Therefore, the present work was under taken to assess the water quality of the reservoir taking Diatoms present in the sediment as indicator algal group.The study of Diatom community structure in relation to sediment characteristics revealed the presence of 53 diatom species in the sediment collected from three selected sites. Species diversity value 3.64 in sediments in the undisturbed area confirmed the oligo-mesotrophic nature of the reservoir. But the trophic diatom index value of 60.00 in the sediment at river entry point where two rivers Umkhrah and Umsyrpi enter the lake with large amount of domestic waste from Shillong city clearly indicated the gradual degradation of the lake water. Therefore, taking appropriate measures to stop the deposition of wastes into two major rivers which ultimately reached the reservoir is an urgent need to maintain its pristine nature.

Keywords: Species diversity, Trophic Diatom Index, Algal bloom

INTRODUCTION

Lakes/reservoirs represent a very important component of aquatic ecosystem. Though relatively small in size, they provide significant environmental, social and economic functions, ranging from being a source of drinking water, recharging ground water, acting as sponge to control flood and supporting large biodiversity, maintain environmental sustainability particularly in urban environments as centre for recreation (Bronmark & Hansson, 2002). Depending on the size, they serve for the needs of many sectors of economy such as agriculture, domestic and industrial. But in today's context these lakes are facing the challenges of excessive exploitation from various anthropogenic activities (Yang *et al*., 2013).

As concern over environmental health of an aquatic system escalates, the keystone and pivotal role played by algae becomes more apparent (Stankovic *et al*., 2012). The algal community is one of themost sensitive structural components and play the most important role in functional dynamics of aquatic ecosystems (Schaumburg *et al*., 2004). Knowledge of algal diversity is considered essential to frame the proposals for developing monitoring strategies and biodiversity conservation activities. Cyanobacteria bloom mainly caused by large colonial Cyanobacterial genera like *Microcystis* (Cayelan *et al*., 2012; O'Neil *et al*., 2012) is recognized as a major symptom of eutrophication which harm lake ecosystems through food web disturbance and anoxia. Massive bloom events affect human health (water supply, food contamination), the economy (fishing industry), and finally, social activities, as for example, the recreational use of lakes. Recently, Diatoms in sediments which are more static are preferred tool for interpreting the trophic status of water bodies.Presence or absence of particular diatoms; shifts in diatom assemblage composition have frequently been used as indicator (Taylor, 2004; Walsh &Wepener, 2009; Crossetti *et al*., 2013). Trophic Diatom Index (TDI) developed by Kelly and Whitton, (1995) in response to increased nutrient concentrations have gained enormous importance in water quality assessment and are extensively used in developing monitoring programs.

The state Meghalaya is very rich in its aquatic resources. The climate in general is very favorable for the growth of algal communities. Report of 227 algal species from river Umiew, indicated the rich algal potential of the region (Siangbood & Ramanujam, 2014) and a reduction in species number from 113 in un-impacted stream to 34 species in coal mine impacted stream (Das & Ramanujam,2010) indicated the fast rate of degradation due to unscientific methods of coal mining. In the present case, according to NWMP norms for lakes,Umiam Reservoir is polluted and water is unfit for any domestic use except irrigation without conventional primary treatment. The occurrence of algal bloom in few parts of the reservoir supported the NWMP norms. Therefore, anassessment of water quality of the reservoir has been done using Diatoms as indicator.

Description of Umiam Reservoir:

Umiam Reservoir, popularly known as Umiam lake is an important reservoir in Meghalaya is located 15 km downstream from Shillong. The lake is situated at an altitude of 940 m (MSL), latitude 25°39'30" N and longitude 91°43'51" E. The area of the lake is 10.27sq km having an area of catchment of 221.5 sq km. It originated as an artificial reservoir for the first hydro electrical project in the North-East, Umiam-Umtru Hydro Electric Power Project. It is an important tourist spot as well as good source of fish production and energy production. Two important rivers Umshyrpi and Umkhrah which flow through Shillong city, carry huge amount of garbage and have an entry to the lake. villager living around Umiam Lake regularly use water from this lake for drinking and all other domestic activities. Downstream irrigation, fisheries and drinking water from the lake cater to local needs.Selling of fishes caught from the lake is a major commercial activity among the villagers. Other activities like boating by tourists, picnic are common features which add to the pollution effect of the reservoir.

Site 1 **Site 2** **Site 3**

MATERIALS AND METHODS

Three sampling sites representing the following three areas were selected after a thorough survey covering the entire reservoir.

1. Area of the reservoir where the river Umiam enters carrying effluents. (Site 1)
2. Area of the reservoir exposed to tourism and other anthropogenic activities. (Site 2)
3. Area not disturbed. (Site 3)

Analysis of Physico-chemical parameters of water:
Physico-chemical parameters such as water temperature, transparency, pH, conductivity were measured in the field randomly from different parts of the reservoir. Other parameters like dissolved oxygen, free CO_2, alkalinity, total hardness, calcium, phosphate and nitrogen were estimated in the laboratory from water samples collected from different parts randomly following standard methods described in APHA, (2012).

Estimation of nutrients in sediment:
10 sediment samples were collected from $10 cm^2$ area from a depth of 0-5cm from each site of the three selected sites of the reservoir, i.e. rivers entrance area, area disturbed by boating and undisturbed area. Sediment samples collected from each site were air dried, ground to fine powder with the help of mortar and pestle and sieved and used for measuring total organic matter, phosphate, calcium, silica and nitrate following standard methods described in APHA, (2012).

Diatoms analysis from sediment:
For extraction of diatoms, sediment samples collected from three selected sites were homogenised with acid by following the procedure of Hendey (1974). Diatoms were observed under trinocular microscope (Olympus-BX41) photographed and identified with the help of algal flora and monograph of Tiffany and Britton (1952), Gandhi (1998) and online ADIAC (Automatic Diatom identification and classification).

Data Analysis:

a) Species richness index (S) and Shannon–Weaver diversity index (H') were calculated following the formulae mentioned in APHA, (2012).
b) Trophic Diatom Index (TDI) is calculated following the formula developed by Kelly and Whitton (1995)

The index is computed using a "weighted average" equation and was calculated as follows:

TDI = (WMS × 25) -25.

Where,

"WMS" is given by the equation:

$$WMS = \frac{\sum_{j=1}^{n} aj \times vj \times sj}{\sum_{j=1}^{n} aj \times vj}$$

aj= abundance of species j in sample.
sj= pollution sensivity (1-5) of species j.
vj= indicator value (1-3).
Values of sensitivity(s) are as follows
1= Favoured by very low nutrient concentration.
2= Favoured by low nutrient concentration.
3= Favoured by intermediate concentration of nutrient.
4= Favoured by high concentration of nutrient
5= Favoured by very high nutrient concentration

RESULTS

Physico-chemical parameters of the lake water collected from three different sites 1(entry point of the rivers), site 2 (disturbed by boating), site 3 (Undisturbed), did not vary significantly in different parameters considered but organic matter, nitrate and phosphate in sediments collected from river point site were significantly higher than other two sites (Table 1).

Algal bloom was observed during the month of January, February and March in the river entrance site and the disturbed site.The dominant algal species of the bloom were *Anabaenopsis* sp, *Microcystis aeruginosa* and *Microcystis flos-aquae.*
Totally, 53 diatom species could be recorded from sediment of three study sites of Umiam Reservoir. Maximum number (44) was recorded from undisturbed area and minimum (35) species were recorded from rivers entrance area. From sediment of area disturbed by boating 40 diatom species could be recorded. *Cymbella* and *Navicula* were represented by high number of species with 9 and 8 species respectively. In rivers entrance area *Cyclotella* and *Melosira* members were high in number. *Achnanthidium, Pinnularia, Navicula* members were present in good number in undisturbed area. Species of *Cyclotella*, *Cymbella*, *Fragillaria, Gomphonema*, *Melosira*, have been recorded from sediment of all the three sites (Table2).

Table 1: Physico-chemical parameters of Umiam lake water and sediment

Water Parameters	Site1 (River entry area)	Site 2 (Disturbed by boating)	Site 3 (Undisturbed area)
Water temperature (^{0}C)	23.0 ± 2.0	23. 2 ± 2.0	23. 9 ± 2.0
Transparency (cm)	80.0± 0.4	100± 0.6	100.0 ± 0.4
pH	8.4 ± 0.5	8.3 ± 0.6	8.2 ± 0.4
Conductivity (mS/cm)	0.07 ± 0.006	0.06 ± .007	0.06 ± 0.006
Dissolved oxygen(mg/L)	5.66±0.7	4.29 ±2.9	6.22±0.2
Free Co_2(mg/L)	8.5 ± 2.0	10.1 ± 2.0	11.0 ± 2.0
Alkalinity (mg/L)	54.3 ± 6.0	49.2 ± 6.0	51.7 ± 4.0
Calcium (mg/L)	16. 4 ± 3.0	16. 8 ± 3.4	16. 6 ± 2.7
Total Hardness (mg/L)	94. 2 ± 16.0	107. 4 ± 22.0	90. 3 ± 20.0
Phosphate (mg/L)	0.09 ± 0.06	0.09 ± 0.06	0.05 ± 0.02
Total nitrogen (mg/L)	0.64±0.2	0.63±0.04	0.40±0.06
Sediment			
Total organic matter (mg/g)	*1.66 ± 0.01	*1.59 ± 0.02	1.08 ± 0.04
Silica (mg/g)	2.47 ± 0.13	2.98 ± 0.36	3.03 ± 0.02
Calcium (mg/g)	0.23 ± 0.04	0.27 ± 0.02	0.19 ± 0.05
Phosphate(mg/g)	*0.42 ± 0.07	*0.36 ± 0.06	0.24 ± 0.01
Nitrate(mg/g)	*1.56 ± 0.03	*1.07 ± 0.04	0.95 ± 0.01

*significant at 0.05 level

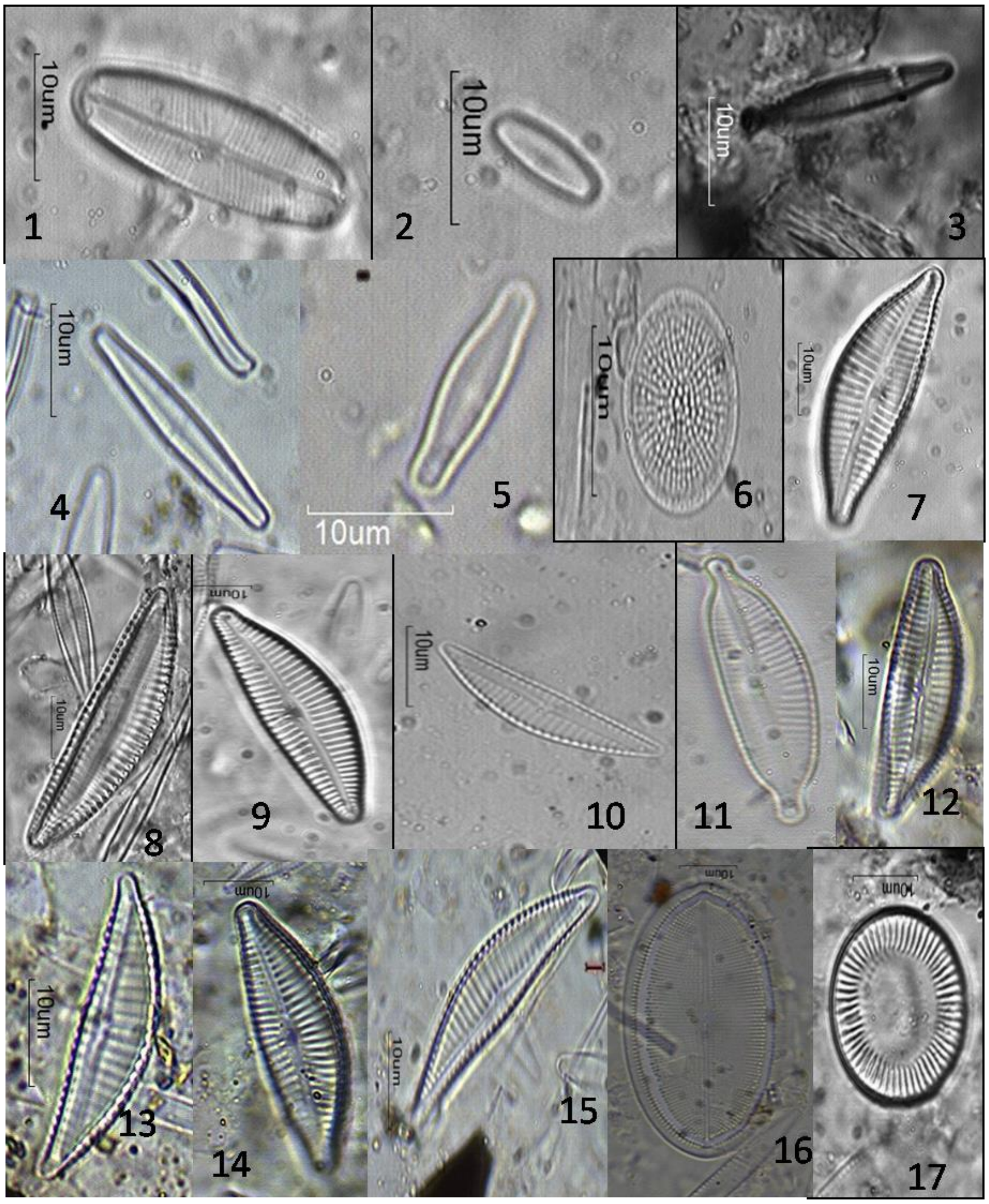
Table 2: List of Diatoms recorded from sediment of Umiam reservoir

	Bacillariophyceae	Sensitivity value(s)	Indicator value (v)	Site 1	Site 2	Site 3
1	*Achnanthidium caledonicum* (Lange-BertalotLange-Bertalot	3	1	+	+	+
2	*Achnanthidium deflexum* (Reimer) Kingston	0	0	_	_	+
3	*Achnanthidium lemmemannii* Hustedt	3	1	+	+	+
4	*Achnanthidium microcephala* Kütz	2	1	_	+	+
5	*Achnanthidium minutissima* (Kützing) Czarnecki	2	2	_	+	+
6	*Actinocyclus niagarae* H.L.Smith	0	0	-	+	-
7	*Cocconeis placentula* Ehrenberg	3	2	-	+	+
8	*Cyclotellaantique* W.Smith	5	1	+	_	+
9	*Cyclotella bodanica* Eulenstein ex Grunow	5	2	+	+	-
10	*Cyclotella melosiroides* (Kirchner) Lemmermann	5	1	+	+	+
11	*Cyclotella meneghiniana* Kützing	5	1	+	+	+
12	*Cymbella affinis* Kützing	1	3	+	+	_
13	*Cymbella amphicephala* Nägeli	1	3	+	+	+
14	*Cymbella arctica* (Lagerstedt) Schmidt	1	3	+	+	+
15	*Cymbella cistula* (Ehrenberg) O.Kirchner	1	3	+	_	+
16	*Cymbella laevis* Nägeli	1	3	+	+	_
17	*Cymbella tumida* (Brébisson) Van Heurck	1	3	+	+	+

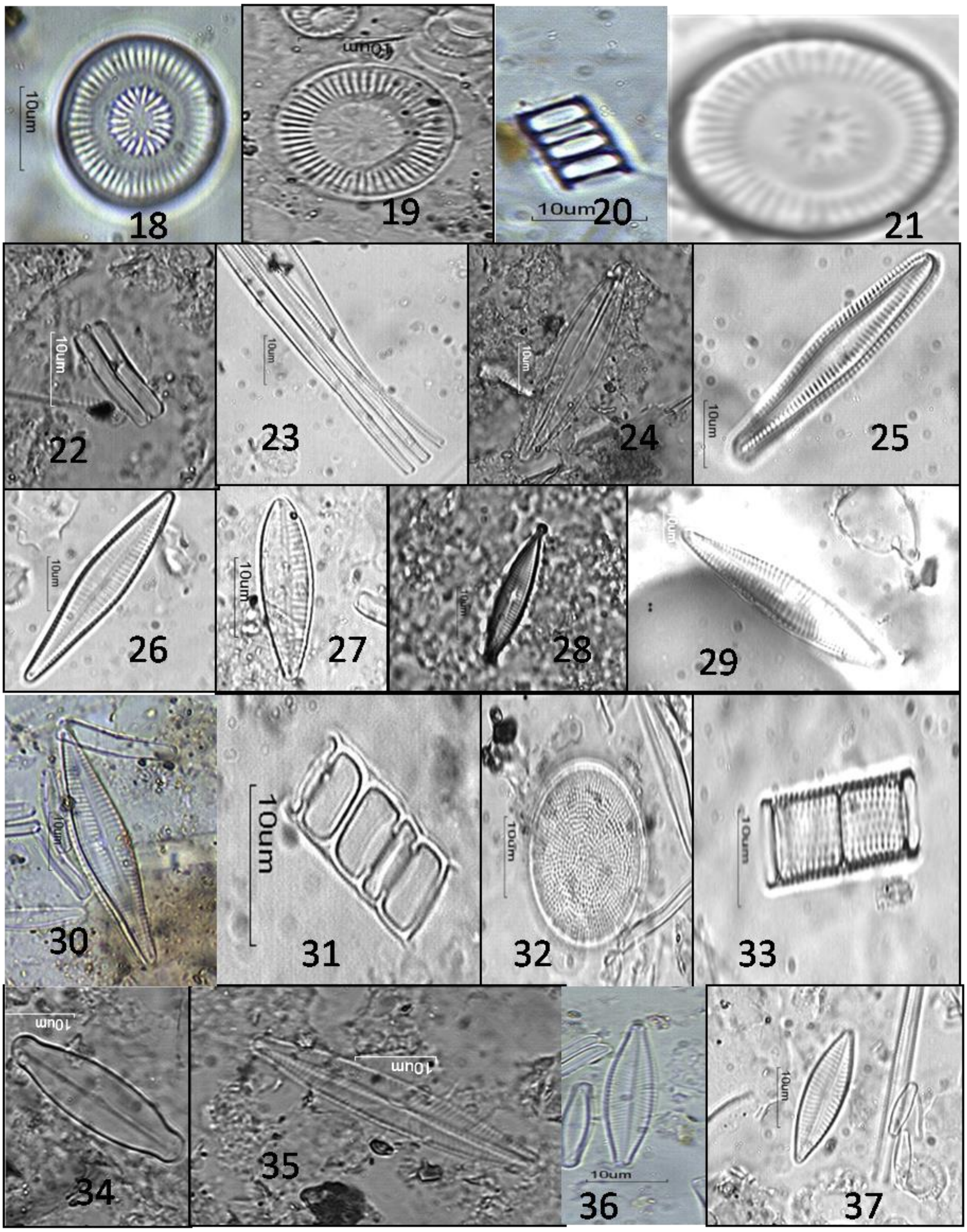
18	*Cymbella turgid* W.Gregory	0	0	+	_	+
19	*Cymbella turgidula* Grunow	0	0	_	+	+
20	*Cymbella ventricosa* (C.Agardh) C.Agardh	2	1	+	+	+
21	*Discostella stelligera* (Cleve &Grunow) Houk& Klee	0	0	+	_	_
22	*Fragillaria capucina* Desmazières	2	2	+	+	+
23	*Fragillaria crotonensis* Kitton	0	0	_	+	+
24	*Frustulia rhomboids* (Ehrenberg) De Toni	1	2	_	+	_
25	*Gomphonema angustatum* (Kützing) Rabenhorst	1	2	+	+	+
26	*Gomphonema gracile* Ehrenberg	3	1	+	+	+
27	*Gomphonema lanceolatum* Kützing, nom. illeg.	3	1	+	+	+
28	*Gomphonema olivaceum* (Hornemann) Brébisson	5	2	+	_	+
29	*Gomphonema parvulum* (Kützing) Kützing	5	3	+	+	_
30	*Gomphonema shaerophorum* Ehrenberg	3	1	+	+	+
31	*Melosira arentii* (Kolbe) Nagumo & Kobayashi	4	2	+	+	+
32	*Melosira crenulata* (Ehrenberg) Kützing	4	2	+	_	+
33	*Melosira varians* C.Agardh	4	2	+	+	+
34	*Navicula bacillum* Ehrenberg	4	1	+	+	+
35	*Navicula crytocephala* Kützing	4	1	+	+	+
36	*Navicula detenta* Hustedt	4	2	+	_	+
37	*Navicula naviculiformis* (Auerswald) Cleve	4	1	+	_	+
38	*Navicula radiosa* Kützing	4	1	+	+	+
39	*Navicula salinarum* Grunow	4	1	_	+	_
40	*Navicula vulpine* Kützing	4	1	_	+	+
41	*Neidium amphirhyncus* (Ehrenberg) Pfitzer	2	3	-	+	+
42	*Nitzchia lineavis* W. Smith	4	1	_	+	+
43	*Nitzschia closterium* (Ehrenberg) W.Smith	4	1	+	+	+
44	*Nitzschia intermedia* Hantzsch	4	1	+	+	_
45	*Nitzschia palea* (Kützing) W.Smith	5	1	_	_	+
46	*Pinnularia viridis* (Nitzsch) Ehrenberg	1	3	_	+	+
47	*Pinnularia appendiculata* (C.Agardh) Schaarschmidt	1	3	_	_	+
48	*Pinnularia braunii* Cleve, nom. illeg.	1	3	_	+	+
49	*Pinnularia gibba* Ehrenberg	1	3	_	_	+
50	*Pinnularia interupta* W.Smith	1	3	_	_	+
51	*Pinnularia major* (Kützing) Raben horst	1	3	_	+	+
52	*Stauroneis anceps* Ehrenberg	4	1	+	+	_
53	*Synedra ulna* (Nitzsch) Ehrenberg	3	1	+	+	+
				35	**40**	**44**

Table 3: Species diversity, Abundance and Trophic diatom index of Diatoms collected from sedimentsof three sites of the lake

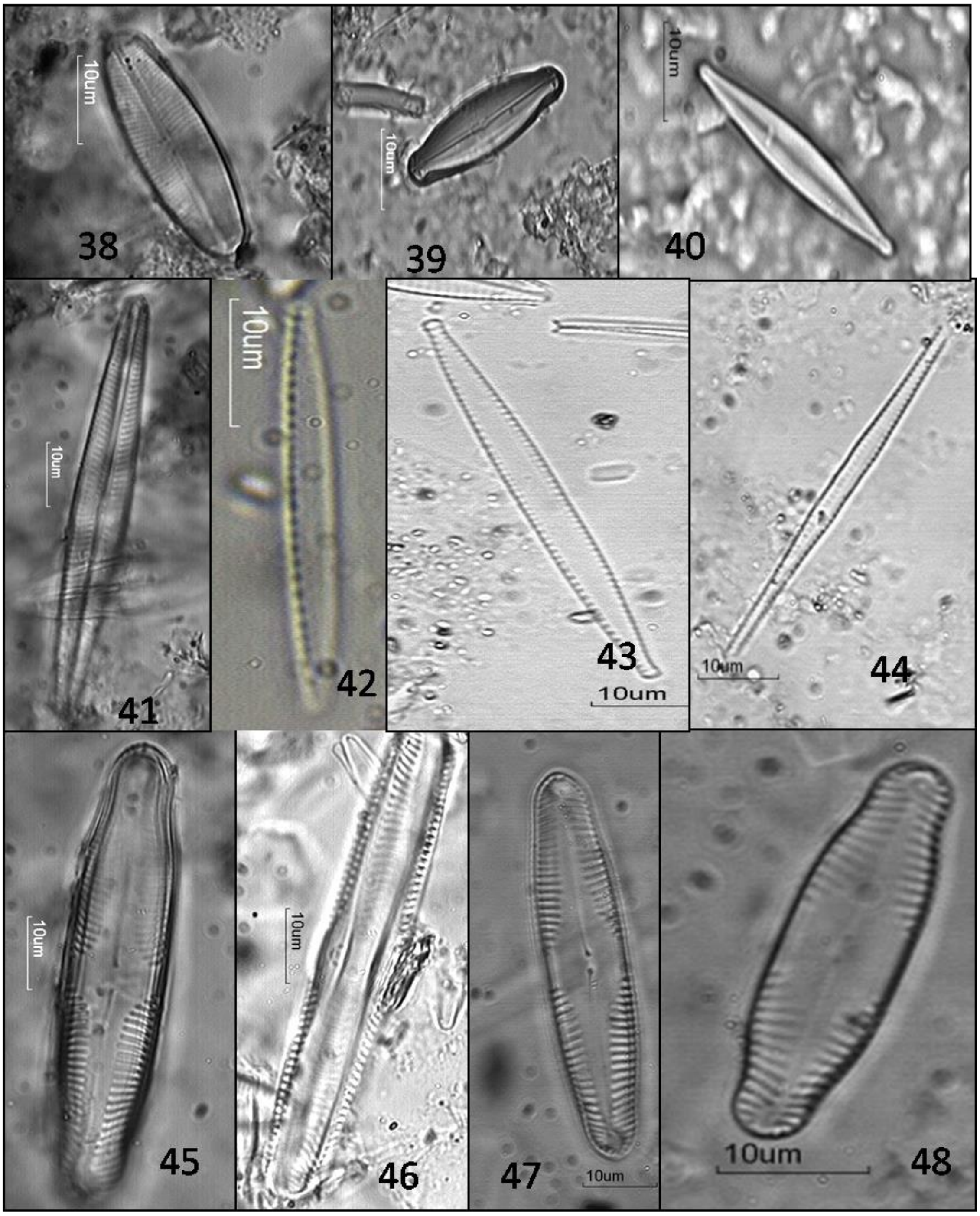
Indices	Site 1	Site 2	Site 3	P-value
Species richness (S)	35	40	44	0.04
Abundance (no. of individual/ml)	378	418	428	0.7
Species diversity index (H')	2.38	2.72	3.64	0.78
Trophic diatom index	60.12	45.37	43.98	0.03



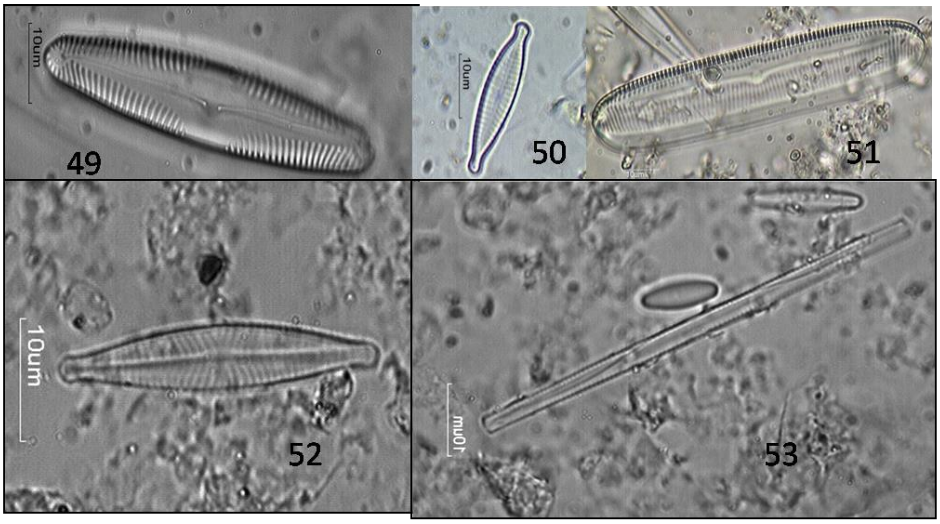
1.Achnanthidium deflexum,2. Achnanthidium lemmemannii,3. Achnanthidium caledonicum, 4. Achnanthidium microcephala, 5. Achnanthidium minutissima,6. Actinocyclus niagarae, 7. Cymbella affinis, 8. Cymbella cistula, 9. Cymbella amphicephala, 10. Cymbella laevis, 11.Cymbella naviculiformis, 12.Cymbella tumida,13.Cymbella turgida, 14.Cymbella turgidula, 15.Cymbella ventricosa, 16.Cocconeis placentula, 17. Cyclotella meneghiniana.



18.Cyclotella antiqua, 19.Cyclotella bodanica, 20.Cyclotella melosiroides, 21.Discostella stelligera, 22.Fragilaria capucina, 23.Fragilaria crotonensis, 24.Frustulia rhomboids, 25.Gomphonema angustatum, 26.Gomphonema gracile, 27. Gomphonema olivaceum, 28. Gomphonema parvulum, 29.Gomphonema sphaerophorum, 30.Gomphonema lanceolatum, 31. Melosira varians, 32. Melosira arentii, 33. Melosira crenulata, 34. Navicula detenta, 35.Navicula vulpine, 36.Navicula cryptocephala, 37. Navicula salinarum,



***38.Navicula bacillum*, 39. *Navicula detenta*, 40. *Navicula radiosa*, 41.*Nitzschia palea*, 42. *Nitzschia linearis*, 43. *Nitzschia intermedia*, 44. *Nitzschia closterium*, ,45. *Neidium amphirhyncus*, 46. *Pinnularia virudis*, 47. *Pinnularia gibba*, 48. *Pinnularia interupta*,**



49. Pinnularia appendiculata, 50. Pinnularia braunii, 51. Pinnularia major, 52. Stauroneis anceps, 53. Synedra ulna

Species richness (44), abundance (428) and species diversity index (3.64) values of Diatoms were significantly higher from sediments of undisturbed site compared to disturbed sites. Trophic diatom index (TDI) value was high in rivers entrance area (site 1) with 60.12 and low in undisturbed area (site 3) with 43.98. In disturbed area (site 2) TDI was found to be 45.37 (Table 3).

DISCUSSION

Moderate temperature, alkaline nature of the water with high dissolved oxygen, low conductivity and low nutrients mainly nitrogen and phosphate clearly indicated that all the factors are very conducive for algal growth. But comparing the nutrient status in the sediment samples collected from three different sites, the level of both the nutrients which are the main indicator of eutrophication were higher in sediment at river entry site and the disturbed site compared to undisturbed site.This clearly indicated a sign of nutrient accumulation and degradation in water quality. But occasional bloom formation and dominance of species of *Microcystis* in the bloom in parts of the lake is an obvious sign of cultural eutrophication which is basically caused by deposition of domestic waste in the river entry point. Algal bloom due to sewage effluents have been reported by many (Smith, 2003). Silica is one of the most important limiting nutrients for diatom community and its concentration is largely related to diatom distribution and structure. Silica concentration was found more in undisturbed area which could be responsible for higher abundance of diatom in undisturbed area. Dominance of *Cymbellaceae* and *Naviculaceae* indicated the mixed status of the reservoir. Taylor *et al.,* (2009) considered presence of *Cyclotella meneghiniana, Nitzschia palea* and *Cocconesis placentula* as characteristic of extreme polluted water. Hosmani (2012) reported dominance of organic pollution indicator diatom species like, *Cyclotella automus, Cyclotella meneghiniana, Melosira varians, Navicula cryptocephala, Nitzschia intermedia* from 7 polluted lakes in Mysore.Tokatli (2013) reported presence of *Cyclotella meneghiniana, Nitzschia palea* and *Cocconesis placentula* from eutrophic water of Porsuk dam lake. Presence of organic pollution indicator diatom species like *Cyclotella meneghiniana, Melosira varians, Navicula cryptocephala, Nitzschia intermedia* in large number in the sediment of Umium lake, highest TDI value (Trophic diatom index) in rivers entrance site (60.1) indicated the initiation of eutrophication in the reservoir.Therefore it could be suggested that measures should be taken urgently to stop the deposition of the wastes in the rivers to maintain the pristine nature of the reservoir.

CONCLUSION

The nutrient analysis of the sediment collected from three different sites showed higher level of nitrate and phosphorus in the river entry site where rivers enter the reservoir with waste in large quantity. The diatom community analysis in the sediments collected from 3 different selected sites varies significantly. The status of the reservoir is in mesotrophic to eutrophication. The composition of the diatom community indicated presence of many pollution indicator species indicating a gradual degradation of water quality.

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Conflict of Interest

The author declares that there is no conflict of interest.

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