Effect of anthropogenic activities on algal assemblages in Umiew river, Meghalaya.

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Abstract

The present paper deals with the response of algal assemblages to the changes in water quality resulting in Umiew river, the main source of water supply in the region. The river is undergoing changes at a very fast pace due to deposition of agricultural wastes and remains of lime and sand quarrying at different points. Deposition of agricultural runoff from the neighboring catchment area increased the nutrient level of the river water which favoured the growth of Chlorophyceae members and effectively enhanced species diversity index (1.9 - 3.3), species richness (229 species) and cell abundance (18.5-613.65/ ml) in Nongkrem (site 2) whereas deposition of remains from lime and sand quarrying area increased siltation, turbidity and calcium concentration of the river water in Umtyngngar (site 3) which favoured the growth of Bacillariophyceae members. Species richness, diversity in this site was higher from the other two sites (site 1 and 4). Totally, 347 algal species spreading over 8 families have been identified from 4 selected sites of the river. Dry spring season was the appropriate season for the growth of algae in the river due to low water current. Canonical correspondence analysis (CCA) showed that total nitrogen (TN) was the principal factor determining the algal assemblages of the river in site 2 (receiving agricultural waste) and increased turbidity (Tur), calcium (Ca), electrical conductivity (EC), silica (SiO_2), dissolved oxygen (DO) and water current (WC) were the main factors in site 3 (receiving remains of lime and sand quarrying) and depth was the influential factor in site 4 (reservoir) and in site 1 (source), none of the factors played major role in composition of algal assemblages.

Keywords: Algal assemblages, Agriculture runoff, CCA, Lime quarrying, Meghalaya

Introduction

The structure of algal assemblages which are the primary producers in lotic systems mainly rivers and streams depend on variations in ambient environmental factors (physical and nutrient concentration) prevailing in that area (Buzzi, 2002; Celekli and Kulkoyluoglu, 2007; Pilkaitite and Razinkovas, 2007). Diversity and abundance of algae have since long been considered as indicator of water quality as they are known to reflect the ecological conditions of aquatic systems (Palmer, 1969; Cascallar *et al.*, 2003, Denicola *et al.*, 2004). The presence of different algal groups in different proportions provides a precise idea about the health of the ecosystem and thus has been used as means to detect the anthropogenic impact in an aquatic system (Ector and Rimet, 2005).

In Indian sub continent, substantial studies have been made on the algal assemblages in relation to environmental factors by many algologists, although most of the studies were concentrated to phytoplanktons of lakes, pond and large rivers (Anand, 1998; Jena *et al.*, 2005; Misra *et al.*, 2005; Sharma *et al.*, 2007; Sah and Joshi, 2010; Selvin-Sameul *et al.*, 2012).

Meghalaya, a state in North Eastern India is home to varieties of aquatic systems which include rivers, streams, springs and lakes. During heavy rainfall, runoff from agricultural fields situated on the banks enters the river and get deposited. Lime stone is one of the important mineral resources of the state. Extensive quarrying of lime stone and sand have changed the physical and chemical nature of the aquatic systems mainly the rivers by releasing the residue into the water bodies and compressing the volume of water. Recording of algal communities in the changing scenario is of urgent need. Literature available from the region on algal potential is meager (Ramanujam and Siangbood, 2009) and hence the present work was undertaken to study the effect of anthropogenic activities on algal assemblages in relation to its water quality.

Materials and methods

Study site

Umiew River located in Meghalaya (20.1°-26.5° N, 85.49°-92.52° E) is basically the second order south-flowing major river which is mostly used for drinking, washing and irrigation purposes. The river originates from Shillong peak in the East Khasi Hills at an altitude of 1912 m.s.l. (meter above sea level) and flows southwards over a total stretch of 400 km and finally enters Bangladesh (figure 1).

The river is dominated by sequences of long boulders or cobble riffles interspersed with shorter runs and pools. Four sites were selected for the present study which differs from each other in geomorphological characteristics. At all the sites, the river bed consisted of silt to fine sand, granite and quartzite rocks ranging in diameter from a few centimeters to a few meters.

Site-1 (S-1). The location of this site is known as Pamlakrai (25°31'45.6"N; 91°52'30.44"E). It is located at an elevation of 1808 m.s.l. Here, the river is narrow and shallow and passes through a shaded area. The depth and width of the river at this site is only a few centimeters to a few meters respectively. Water is transparent and the river bed is clearly visible.

Site-2 (S-2). This site known as Nongkrem (25°30'34.3"N; 91°53'10.1"E). It is located downstream 5 km of Pamlakrai at an elevation of 1768 m.s.l. where the river runs through open agricultural catchment area and therefore during rainy season, lots of agricultural wastes were deposited into the river bed. River in this site is 5-7 m wide and 0.2- 0.4 m deep. Water is highly transparent due to low depth.

Site-3. Water flows further downstream (8 km), reaches a location known as Umtyngngar (S-3). The location of this site is 25°27'58.0"N; 91°49'34.53"E and located at an elevation of 1673 m.s.l. Here the river joins with another river (river Umtyngngar) whereby the width of the river increases. It becomes 16-18 m wide and 0.4- 0.6 m deep. The water here is highly turbid and the river bed is slushy due to the deposition of sand, silts and remains of lime quarrying carried over by the river from upstream. As the river Umtyngngar converges with river Umiew, the color of the river water changes to milky green.

Site- 4 (S-4). This site is located in Mawphlang (25°26'45.0"N; 91°45'57.4"E) at an elevation of 1584 m.s.l. and 13 km downstream of Umtyngngar. In this location, a concrete dam has been constructed for the purpose of supplying drinking water. Here, the free flowing river is suddenly obstructed, making the river very wide (60-70 m) and deep (0.4-100 m). Therefore, this particular site is completely different from the other three sites. Samples from this site were collected from the river bank only where the water level was low.

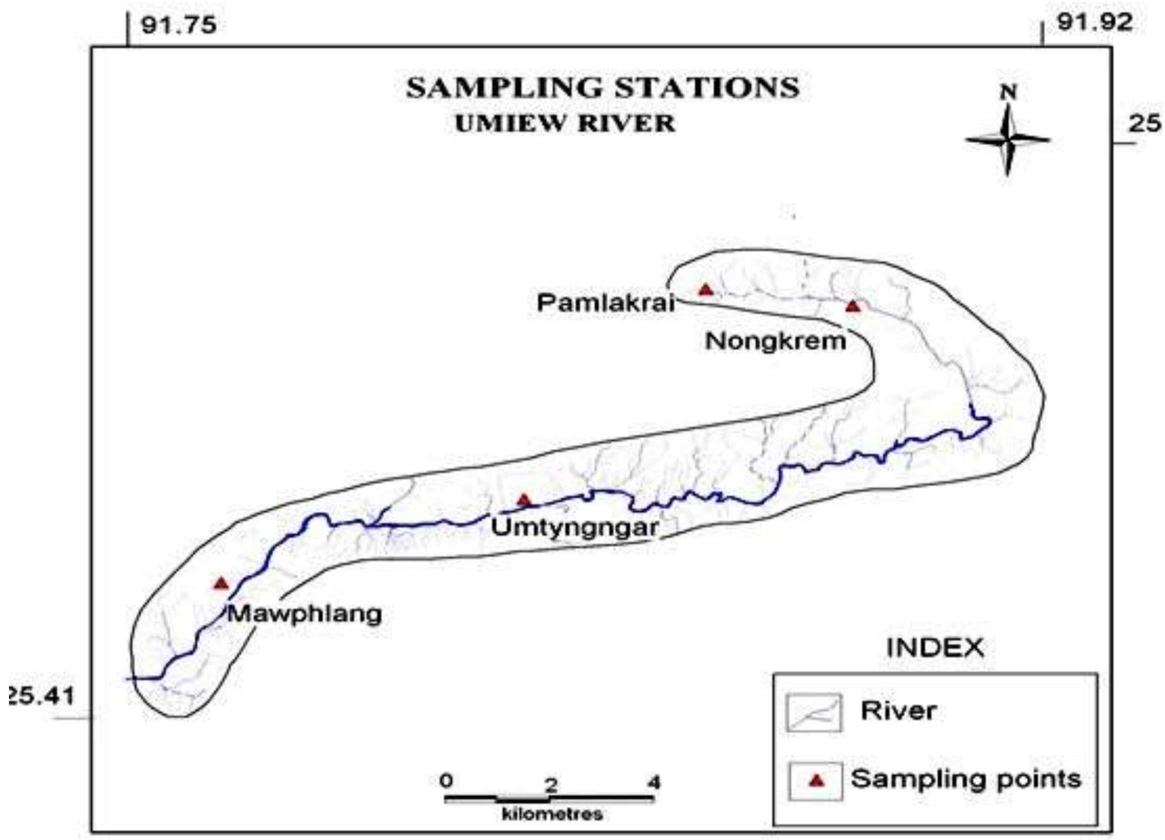

Figure 1. Map showing the locations of the study sites in Umiew river

Sample collection and analysis

Algae and surface water samples were collected monthly from the four selected sites from April 2008 to March 2010 by following the method prescribed in APHA, (2005). Phytoplankton was collected from surface water by using plankton net (45 µm). Periphytic algae were collected from different substrata like stones, rocks, pebbles, dead leaves and sediments with the help of scalpel and tooth brush. The algal samples were preserved in 4% formaldehyde and brought into the laboratory for qualitative and quantitative analysis. Enumeration was done by Lackey's Drop Method. Algal samples were examined in temporary preparations under a trinocular microscope (Olympus-BX41) and photographed with the help of digital camera directly fitted to the microscope. Diatoms were cleaned prior to examination by acid oxidation with concentrated sulfuric acid (H_2SO_4), potassium dichromate ($K_2Cr_2O_7$) and hydrogen peroxide (H_2O_2) (Barber and Haworth, 1981). Permanent slides were made using Naphrax with refractive index of 1.74. Around 400 diatom valves were examined, measured and photographed. Taxonomic identification up to species level wherever possible were carried out with the help of floras and monographs (Tiffani and Britton 1952, Desikachary 1959, Prescott, 1982 Gandhi, 1998, John *et al.,* 2002 and Krammer and Lange-bertalot, 1986-1991 and taxonomy was updated using the online database Algae Base [World-wide electronic publication, National University of Ireland, Galway (available on internet at http://www.algaebase.org)].

Different parameters like depth, water temperature, water current, turbidity, electrical conductivity, pH, dissolved oxygen, calcium, magnesium, phosphate, nitrite, nitrate and silicate were measured and estimated following APHA, (2005). The collected data were expressed on seasonal basis based on the rainfall pattern prevailing in the region. The total annual rainfall received during the study period was 2439.9 mm (April, 2008 to March, 2009) and 1885.4 mm (April, 2009 to March, 2010) respectively.

Data Analysis

Different community indices such as Shannon-Weaner diversity index (H'), Simpson's dominance index (D) and species richness index (S) were calculated. The significance of differences among the sites and different attributes like species diversity, cell abundance and species richness of algal assemblages were tested using one-way analysis of variance (ANOVA). Canonical correspondence analysis (CCA) was employed to establish the relationship between algal assemblages and the water parameters at different sites. For CCA, listed algal samples were screened and the rare taxa (species with a relative abundance of one or more than 3% was regarded as a rare taxon) were removed from further analyses. Significant (at $p<0.05$) water parameters were included in the analysis. Prior to the analysis the parameters were log transformed and algal taxa were square root transformed in order to meet the assumptions of homoscedasicity. The statistical mean of each variable was tested with a Monte Carlo permutation test (500 permutations). Statistical significance was set at $\alpha=0.05$. All statistical analysis was performed using computer software XLSTAT version 2009.

Results

Water quality-physical and chemical aspects

Variation in different physico chemical parameters in different selected sites of Umiew river and one way ANOVA performed are given in Table 1. pH of Umiew river in 4 different sites ranged from slightly acidic to mildly alkaline (5.30 to 7.46). Acidic ph was recorded from site 1 and alkaline ph was recorded from site 3. Water temperature showed seasonal variation where maximum temperature was recorded in spring (24.8 °C) in site 3 and minimum in winter (11.3 °C) in site 1. Water turbidity was maximum in site 3 with a range of 0.09 to 0.33 NTU and in site 1, 2 and 4 it ranged from (0.01 to 0.07 NTU) throughout the study period. A significant temporal variation in current velocity was observed with high values recorded from site 2 and 3 (0.51 to 0.53 m/sec) during rainy season minimum current velocity value was recorded from site 4 with an average of 0.01 m/sec. Electrical conductivity was maximum in site 2 (126 μS/cm) during spring and minimum in site 4 (16 μS/cm) during winter. Dissolved oxygen ranged from 4.07 to 8.64 mg/l. DO concentrations generally increases with rain. Maximum DO was recorded in site 3 during post monsoon season and minimum in site 4 during winter. Calcium content ranged from 7.63 to 24.37 mg/l. Calcium was high in site 3 in all the seasons and varied significantly from all other sites. Magnesium content ranged from 3.04 to 12.36 mg/l and showed significant seasonal differences. Nitrate and nitrite contents were more in site 2 (1.39 and 0.21 mg/l respectively) with significantly higher values during rainy season. Phosphate varied from 0.13 to 0.52 mg/l. Maximum value was recorded from site 3 and site 4 during monsoon. Significant seasonal variations were observed during the study period. Silica content varied significantly among the sites and seasons with a maximum values (5.79 mg/l) recorded from site 3 during low flow period.

Table 1. Physico-chemical characteristics of Umiew river in all the sites with One way ANOVA of physico-chemical parameters to assess the variations in between sites and seasons.

Parameters	Study sites				Sites		Seasons	
	S1	S2	S3	S4	F-value	P-value	F-value	P-value
Depth (m)	0.08-0.28	0.2- 0.4	0.4- 0.6	0.4-100	54.8**	2.00E-08	0.19	0.89
Temperature (°C)	11.9-20.66	12.81-21.93	14.03 - 21.61	13.35 - 21.61	1	0.42	13.09**	0.0004
Turbidity (NTU)	0.01-0.04	0.03-0.08	0.09-0.33	0.02-0.07	14.25**	0.001	0.76	0.546
WC (m/sec)	0.07-0.19	0.15-0.44	0.17-0.51	0.001-0.09	3.02	0.07	1.74	0.21
pH	5.47-6.39	6.02-6.8	6.72-7.46	6.47-7.24	4.96*	0.03	0.892	0.485
EC (mS/cm)	25.5-37.33	33.0 - 126.66	31.0- 93.0	16.0- 44.0	4.14*	0.047	0.064	0.6
DO (mg/l)	4.87-7.09	5.06 -7.6	6.1-8.67	4.07-6.41	0.87	0.49	2.31	0.15
Ca (mg/l)	7.67-12.32	12. 7-19.6	15.4-24.47	8.5-16.59	18.94**	0.0005	0.22	0.87
Mg (mg/l)	8.44-12.05	4.81- 11.81	4.77-12.36	6.18 11.22	0.34	0.79	8.21*	0.007
NO_3 (mg/l)	0.63 -0.96	0.85 -1.39	0.66 -0.93	0.66 -1.01	0.78	0.53	6.44*	0.015
NO_2 (mg/l)	0.03 -0.2	0.04- 0.42	0.03- 0.25	0.025 - 0.205	0.52	0.679	5.34*	0.025
PO_4 (mg/l)	0.15- 0.35	0.13 -0.42	0.28- 0.47	0.18- 0.52	0.54	0.66	27.71**	0.0001
SiO_2 (mg/l)	2.74-3.8	3.25 -5.35	3.75 -5.90	2.85- 3.73	3.4	0.05	1.61	0.23

* indicates significant different at $p < 0.05$; ** significant at $p < 0.001$

Composition of algal community

A total number of 347 algal taxa have been identified from Umiew river spreading over 8 families, out of which 151 species were recorded from Chlorophyceae, 112 species from Bacillariophyceae, 55 species from Cyanophyceae, 20 species from Euglenophyceae, 3 species from Chrysophyceae and 2 species each from Xanthophyceae, Dinophyceae and Cryptophyceae respectively. In Bacillariophyceae, the genus *Navicula* Bory was represented by 21 species and most of the diatom species were pennate forms. Among Chlorophyceae desmids were represented by 71 species in which *Cosmarium* Corda ex Ralfs was the most abundant taxa with 27 species. *Oscillatoria* Vaucher (14 species) and *Euglena* (9 species) Ehrenberg were the other taxa under Cyanophyceae and Euglenophyceae respectively. Dinophyceae, Cryptophyceae and Xanthophyceae were represented by only few members. *Spirogyra* sp. Link, a filamentous green alga was found abundantly in site 2 and 3 during spring and occurred mostly as free floating mats. Other than *Spirogyra* sp. *Oedogonium* sp., was found in abundant in site 3, and was mainly found attached to the substrata.

Bacillariophyceae was the most dominant group in site 1, 3 and 4 whereas in site 2 it was dominated by Chlorophyceae. Maximum numbers of taxa were recorded during spring and minimum during monsoon to post monsoon. Cell abundance was maximum during spring when water current was subsiding in all the sites. A distinct seasonal variation in species richness and Shannon's diversity index were recorded from Umiew river. Species richness ranged from 154 (site 4) to 229 (site 2), Shannon's diversity index ranged from 1.39 (site 4) to 3.37 (site 2) and cell abundance was higher in site 2 with a range of 18.5 x 10^2 to 613.65 x 10^2cells/ml and lower in site 4 with a ranged of 40.23 x 10^2 to 460.97 x 10^2cells/ml (table 2). Species richness, diversity and cell abundance was maximum in site 2 in spring season and was significantly higher than other three sites (table 3).

Table 2. Diversity, richness and cell abundance of algal assemblages in Umiew river in all the sites.

	S1	S2	S3	S4
Diversity index	1.3-2.5	1.9-3.3	1.8-2.5	1.7-2.4
Richness	173	229	205	154
Cell abundance (x 10^2 cells/ml)	56.12-410.95	18.5-613.65	58.3-405.6	40.23-460.9

Table 3. One way ANOVA for diversity, richness and abundance to show the variations among sampling sites.

	Diversity		Richness		Abundance	
	F-value	*P*-value	F-value	*P*-value	F-value	*P*-value
S1;S2	8.959**	0.004	17.673**	0.0001	9.564**	0.003
S1;S3	0.067	0.796	2.175	0.147	0.729	0.397
S1;S4	0.167	0.684	1.360	0.249	0.000004	0.994
S2;S3	9.396**	0.003	12.497**	0.000	5.801*	0.020
S2;S4	13.181**	0.000	10.725**	0.002	9.607**	0.003
S3;S4	0.552	0.461	0.0001	0.990	0.742	0.393

*significant at $p<0.05$; ** significant at $p<0.001$.

Canonical correspondence analysis

Canonical correspondence analysis of algal assemblage and water parameters produced an ordination in which the first two axes were statistically significant ($p<0.0001$) with eigen values of 0.176 and 0.102 respectively. The cumulative percentage of variance in the species-environment relationship explained by the first two axes was 58.27% (figure 3). The CCA axis 1 accounted for 36.93% of the explained variation in algal composition and was correlated with WC, turbidity, DO, Ca, EC, SiO_2, depth and TN (table 4). The CCA axis 2 accounted for 21.33% of the explained variance in which algal assemblage associated with change in ph and PO_4 (table 4). Sites located on the lower left side of the ordination (figure 2) represented site 4 with higher depth as the main influential parameter and other parameters were less important. The most common species in this site was *Cyclostella pseudostelligera* Hustedt (figure 3). Site 1 was positioned on the upper left side of the ordination diagram where none of the water parameters played any significant role. The main taxa in this site were *Graticula cuspidata* Kutzing, *Cosmarium cucurbita* Brebisson and *Golenkinia radiata* Ghodat (figure 3). The right hand quadrate of the ordination diagram was characterized by site 2 and 3. TN (nitrate + nitrite) and EC were the main important parameters which influenced the algal assemblage in site 2 whereas turbidity, Ca, SiO_2, DO and WC influencing the algal assemblage in site 3. The most common taxa in site 2 were *Ankistrodesmus falcatus* (Corda) Ralfs, *Spirogyra pratensis* Transeau, *Cosmarium subcrenatum* Hantzsch in Rabenhorst, *Navicula cryptocephala* Kutzing, *N. Radiosa* Kutzing, *N. Viridis* Kutzing, *Surirella elegans* Ehrenberg *N tripunctata* (O. F. Muller) Bory, *N. Radiosa* Kutzing *Graticula cuspidata* Kutzing, *Synedra ulna* (Nitzsch) Ehrenberg and *Euglena gracilis* G.A. Klebs (figure 3). In site 3 the most common species were *Oedogonium* sp. Link, *Cymbella amphicephala* Naegeli in Kutzing, *C. Naviculiformis* (Auerswald) Cleve, *C. Cistula* (Ehrenberg) Kirchner, *C. Tumida* (Brebisson) V. Heurck, *Surirella robusta* Ehrenberg, *Gomphonema parvalum* (Kutzing) Kutzing, *Gomphonema olivaceum* (Hornemann) Brebisson and *Oscillatoria curvicep* C. Agardh ex Gomont (figure 3).

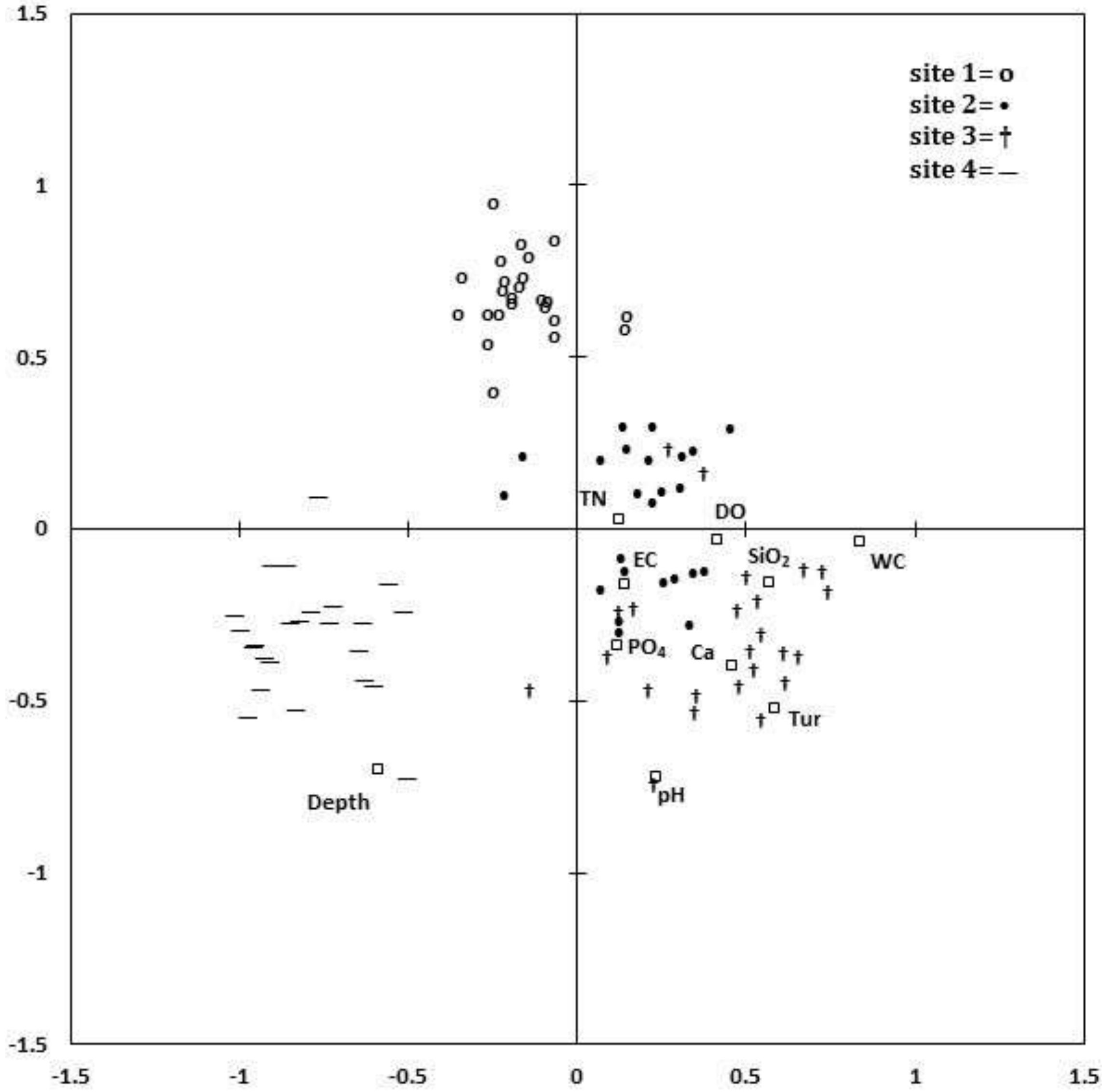

Figure 2. CCA (Canonical Correspondence Analysis) ordination diagram of selected environmental gradients correlated with different sites in Umiew river change along CCA axes 1 and 2.

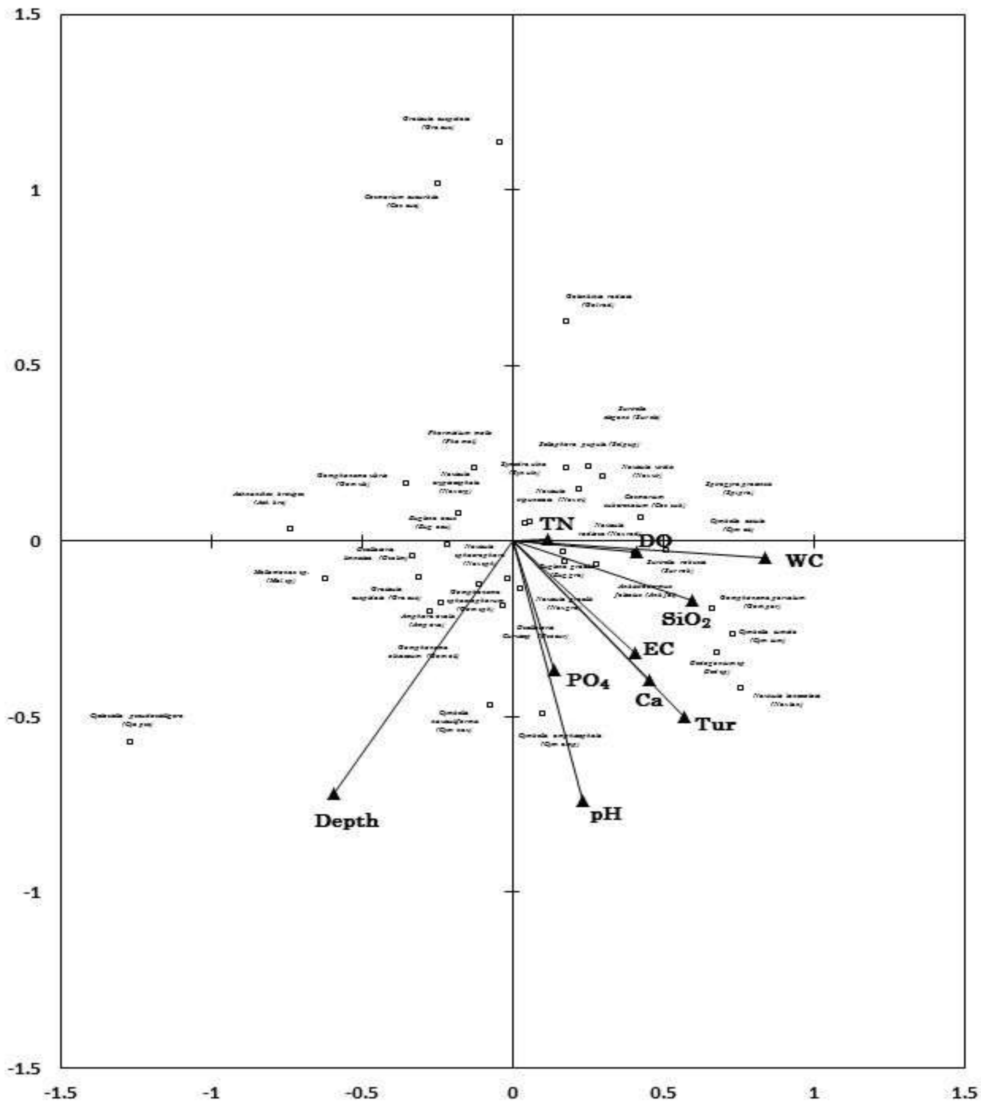

Figure 3. CCA (Canonical Correspondence Analysis) ordination diagram of selected environmental gradients correlated with algal assemblages in Umiew river change along CCA axes 1 and 2.

Table 4. Correlation coefficients or intraset coefficients of environmental variables with the first two axes (F1 and F2) of canonical correspondence analysis (CCA).

Axis Variable	F1 axis	F2 axis
pH	0.097	0.236
WC	0.351	0.015
TUR	0.240	0.160
DO	0.172	0.010
Ca	0.191	0.127
PO_4	0.057	0.117
EC	0.172	0.101
SiO_2	0.251	0.054
Depth	0.250	0.230
TN	0.050	0.002

Discussion

Analysis of water parameters clearly indicated that different variables like depth, water current, turbidity, pH , electrical conductivity, dissolved oxygen, level of total nitrogen, phosphorus, calcium and silica were the main parameters which influenced the algal assemblages at different sites in Umiew river.

The prominent temporal and spatial seasonal variations in algal species diversity and cell abundance observed with maximum values in dry spring season and minimum in monsoon was in concurrence with the findings of Bishop, (1973); Mosisch and Bunn, (1997); Dudgeon, (2000); Davies, *et al.,* (2008) which was common in monsoonal Asia and tropical countries. The poor growth of algae during monsoon was due to shearing effect produced by high water current which was one of the prominent physical factors in lotic system. The negative effect of current velocity on algal colonization had been reported by many researchers (Biggs, 1996; Potapova *et al.,* 2005) although some authors were of the opinion that few algal species mainly the stalked and chain-forming diatoms and filamentous green algae which are susceptible to physical disturbance were often found in this type of habitat (Acs *et al.,* 2000; Rusanov *et al.,* 2012).

The number of algal species collected from the river was doubled as compared to the previous records which were found to be 117 species (Ramanujam and Siangbood, 2009). This could be due to the increase in the number of sampling sites. Majority of the species encountered in the river was found to be cosmopolitan. From the present findings, it was clearly revealed that the algal assemblases of Umiew river was generally dominated by Bacillariophyceae and Chlorophyceae which were similar to the previous findings. Similar findings had been reported by many workers in different river systems (Saadet and Sahin, 2009, Spackova *et al.,* 2009; Sahin *et al.,* 2010; Baba *et al.,* 2011 and Hussein and Gharib, 2012). Dominance of diatom in the river maybe due to adequate concentrations of silica in the river water which aid to frustules formation (Wetzel and Likens, 2000). According to Lund, (1954), silicate content should be above 0.5 mg/l for the rich growth of diatoms and the concentration obtained in the present study exceeds that content.

Moderately high pH and phosphate in site 3 and 4 preferred the growth of blue green algae which indicated the alkaline nature of water at this site (Nayak and Prasanna, 2007; Okogwu and Ugwumba, 2009). However in general, the contribution of blue green algae to the total algal assemblages of the river in terms of species number and cell counts was relatively small and possibly due to low nutrient content of river water wholly (Maurice *et al.,* 1987; Shapiro, 1997). Similar reason may be related to the low contributions of chrysophycean group in the river (Nedbalova *et al.,* 2006).

In site 2, the dominance of Chlorophyceae member may be due to the slight increased in the level of nutrients particularly nitrogen. The results obtained from CCA revealed that many green algae like *Ankistrodesmus falcatus* (Corda) Ralfs, *Spirogyra pratensis* Transeau, *Cosmarium subcrenatum* Hantzsch in Rabenhorst, etc prefer to grow in this condition. The presence of indicator diatom species like *Cymbella cistula* (Ehrenberg) Kirchner, *C. tumida* (Brebisson) van Heurck. in site 3 with high calcium concentration clearly indicated that this site has been affected by lime quarrying to some extent. Celekli and Kulkoyluoglu, (2007) reported that *Cymbella* and *Achnanthes* sp. could tolerate high calcium concentration in water and they were known as calciphiles or calcium loving organisms.

Significantly high species diversity and abundance in site 2 could be due to enhanced nutrient content that entered the river water through runoff during heavy rainfall period from the adjoining agricultural field. Similar findings had been reported by Yu and Lin, (2009) in subtropical mountain stream where total cell numbers were significantly higher in stream running through larger area of agriculture. The availability of more surface area due to the presence of huge rocks, boulders and pebbles in site 1 and 2 could be the other reasons for better algal growth. Shading effect produced by the riparian vegetation in site 1 and higher depth in site 4 along with low nutrient level of the water columns might be the reason for low abundance of algae in those two sites. Majority of the algal assemblages in Umiew river showed negative correlation with depth except *Cyclostella pseudostelligera* Hustedt which occurred mostly on the water surface in site 4 (Kiss *et al.,* 2012).

From the present study, the analyzed river water indicated that the water in river Umiew is low in nutrients and oligotrophic. The algal assemblages of Umiew river with dominance of Bacillariophyceae and Chlorophyceae and with many desmid species confirmed the oligotrophic nature of the river water. Agricultural activities along the catchment increased the nutrient concentrations particularly nitrogen which influenced the algal assemblages of the river positively whereas quarrying of lime stone increased the calcium content and turbidity in the river and favour the growth of Bacillariophyceae group.

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