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Green Technology **26**

Nutrient removal of Secondary Treated Water through Algal ponds

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Freshwaters are becoming increasingly scarce. At the same time the existing freshwater resources are deteriorating both in terms of quality and quantity. The quality of such freshwater systems as ponds and lakes depends upon interaction of various biotic and abiotic componenets where the physic-chemical environment plays a major role. In ponds systems the nutrients decide the productivity where algae act as indicators of the nutrient status of water. The present study focuses on treatment of secondary treated water by algal pond systems and transitions in physico-chemical parameters. In the study water and algal samples were collected weekly from the wastewater treatment plant and the algal pond at IISc, Bangalore for two seasons. Inorganic parameters as major ions, dissolved metals and organic parameters like biochemical oxygen demands were measured following standard protocols. The samples were also checked for temperature, pH, dissolved oxygen, electrical conductivity on site. During the initial phases of the study *Microcystis auregonosa* sp. were abundant indicating N limiting conditions. However, after the biomanipulation of introducing the duckweed sp., significant transitions in nutrient regime were observed. This led to the dominance of *Chlorococcum* sp. due to higher organic matter because of higher detrital C as a result of duckweed steeling and decay. Further changes in the inflow parameters aided in the prolific growth of chlorophycean members. This reveals the changes in the algal communities with the changes in the environmental parameters and nutrient regime. This study emphasizes the role of algal communities as indicators as well as agents of nutrient remediation that can be sustainably used for secondary wastewater treatment economically.

Keywords: Lake, physico-chemical parameters, freshwater algae, nutrients, wastewater.

1.0 INTRODUCTION

Algae are an essential component of fresh water ecosystems like Lakes and Ponds. It governs the water by its photosynthetic ability of fixing carbon from various sources. They are highly efficient in nutrient (N and P) uptake and assimilation and can be considered as reserves of nutrient that immobilize them temporarily (Ramachandra et al., 2006; Mahapatra et al, 2010). These algae grow profoundly in nutrient rich waters and often cause anoxia due to higher growth, death and decay resulting in higher oxygen demand. At the same time these algae when allowed to grow at optimal nutrient regimes often bioaccumulate nutrients in a sustainable fashion.

Voluminous waste water is generated every day due to domestic and industrial activities (Mahapatra et al., 2010). This waste water is primarily untreated and reaches fresh water body in the vicinity of urban areas. Many waste water treatment technologies have been developed for the treatment of domestic waste water (Mahapatra et al., 2012). However, these technologies are energy and cost intensive and are unsuitable for developing nations like India. This technology requires a huge infrastructure cost together with enormous operations and maintenance cost. For the technical intricacies, skilled labor is a requirement for such technologies.

Algal pond based system are simple economic and less energy intensive method for complete treatment of domestic waste waters. These pond based system are being used globally for municipal waste water treatment due to its higher fidelity and adaptability to different regions. The pond based system provides an easy solution for nutrient uptake and consequent municipal waste water effluent treatment by virtue of its algal bacterial symbiosis and other abiotic factors like wind, sunlight and temperature. In the present study, one such pond situated as at IISc campus was investigated for its role in waste water treatment through algal nutrient uptake.

The objective of the present study were

a) To study the nature of waste water algae.
b) To analyze the physico-chemical parameters and nutrient uptake by algae in the pond.
c) To study the linkage between nutrient regimes and algal population.

MATERIALS AND METHODS

Study Area: Centenary Pond (The study area: Figure 1) is located at Indian Institute of Science (IISc) Bangalore, Karnataka. The pond (13^0.01’16.78” N and 77^0 34’ 14.96” E) was created in April 2008 in the Jubilee Garden at Indian Institute of Science (IISc, Bangalore) in order to harvest rain water and provide habitat for aquatic flora and fauna.

Water Sample Collection: Water samples were collected from two different sites (S1 and S2) for a period of five months from February 2012 to June 2012 for the analysis of physico-chemical parameters and phytoplankton identification. The Site 1(S1; Inflow end) and Site 2 (S2; rear end) were considered for sampling in the Centenary pond between 10.00 to 12.00 a.m.

Algal Sampling, Identification and Enumeration: Phytoplankton samples were collected from the surface water at S1and S2. Algae were identified and counted microscopically. 100 ml of sample were collected from the selected locations. 15 ml samples were taken and were centrifuged at 3000 rpm at room temperature. From the concentrate, ~20 µl of the sample were taken onto glass slide and were counted and enumerated under light microscope (40 X) following drop count method (Trivedy and Goel, 1986). Representative images were taken at 100 X magnification. The identification of algal species was carried out based on the morphological features, according to Prescott (1959), Desikachary (1959).

Analysis of Physico-Chemical Parameters: The water temperature, pH, electrical conductivity and DO were determined on site at the time of sampling. Other parameters like ammonia, nitrate, nitrite, orthophosphate, total phosphate, optical density, total alkalinity, calcium and magnesium hardness, total hardness, chlorides, chemical oxygen demand (COD), biochemical oxygen demand (BOD), sodium and potassium were analysed using standard methods prescribed by Trivedi and Goel (1986), APHA (1998) and following Hach Protocols.

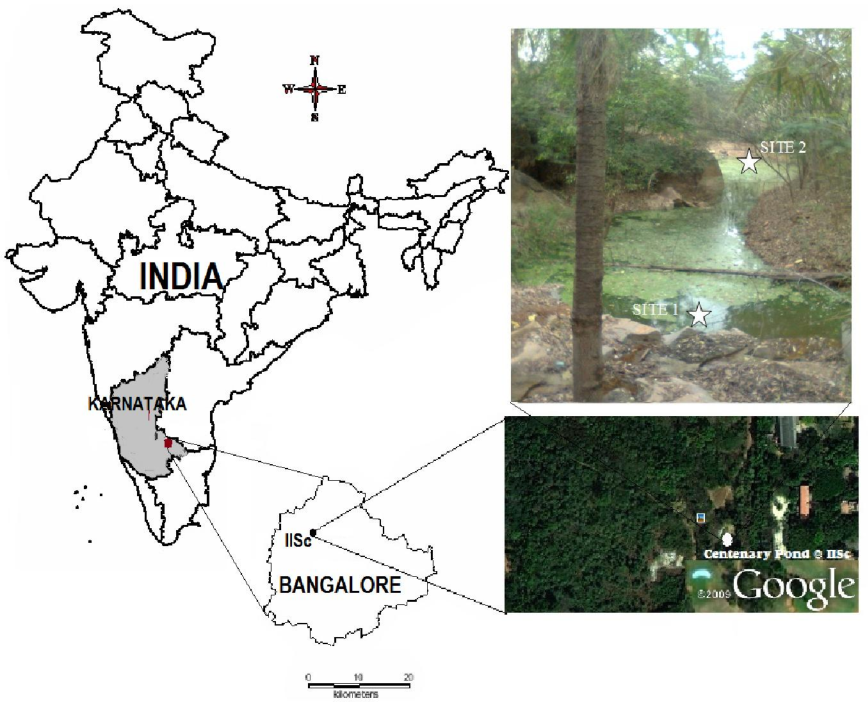

Figure 1: Centenary Pond in Jubilee Garden, IISc Bangalore, Karnataka India

RESULTS AND DISCUSSION

Water Quality Parameters

Temperature: Water temperature plays an important role in aquatic ecosystems. The variations in temperature are influenced by the factors such as air temperature, humidity, wind and solar energy. The monthly average temperatures at various sites were recorded as: at S1 is 21.96-27.3^{0}Cand at S2 is 21.7-28.2^{0}C.

Electrical Conductivity: Electrical Conductivity denotes the ability of an aqueous solution to carry electric current, which depends on the presence of ions, their total concentration, mobility, valence, relative concentrations and temperature. The monthly average electrical conductivity values at different sites are recorded as 690-810µS/cm (S1) and 670-837µS/cm (S2) respectively.

pH: pH is defined as the intensity of the acidic or basic character of a solution at a given temperature. Its range from 0 to 7 is diminishingly acidic, whereas values of 7 to 14 are increasingly alkaline. pH of the water is largely governed by carbon dioxide, carbonates and bicarbonates equilibrium. The monthly average value of pH is found to be 7.9-9.43 (S1) and 8.45-9.68 (S2).

Dissolved Oxygen (DO): The oxygen content of water varies with temperature, turbulence, salinity, increased photosynthetic activity and respiration by microalgae and atmospheric pressure. The DO in water affects the oxidation-reduction state of many of the chemical compounds such as nitrate, ammonia, sulphate and sulphite, ferrous and ferric ions. The monthly average values of different sites are 2.84-4.17 mg/l (S1) and 3.8-9.13 mg/l (S2).

Biochemical Oxygen Demand (BOD): BOD is the amount of oxygen utilized by microorganisms to stabilize the organic matter under aerobic conditions. BOD determines the strength of sewage effluent and other polluted waters and provides data on the pollution load in all natural waters. The monthly average values of BOD were found as 3.44-17.55 mg/l in S1 and 3.82-21.21 mg/l in S2.

Chemical Oxygen Demand (COD): COD determines the amount of oxygen required for the chemical oxidation of most organic matter and oxidizable inorganic substances with the help of strong chemical oxidant. The COD average value varied during the study period like 9.6-27.52mg/l (S1) and 8.8-31.04 mg/l (S2).

Optical Density: The colour of water is determined by the measurement of optical density (absorptivity) on a spectrophotometer at various wavelength of the passing light. The average values of optical density (OD) at different sites are 0.04-0.11 Abs at S1 and 0.05-0.19 Abs at S2.

Total Alkalinity: Alkalinity of the water is the capacity to neutralize strong acids, which is primarily a function of carbonate, bicarbonate and hydroxide content and formed due to dissolution of CO_2 in water. The average value of total alkalinity throughout the study period is observed as 164-238 mg/l at S1 and 159-230mg/l at S2.

Chloride: Chloride is found widely distributed in nature in the form of salts of sodium, potassium and calcium. The high chloride concentration of the pond water may be due to high rate of evaporation or due to organic wastes present in water. The average chloride concentration was observed as 97.63-123.26 mg/l (S1), and 99.05-119.71 mg/l (S2).

Total Hardness: Hardness is generally caused by the calcium and magnesium ions present in the water. The average value was observed as 155-229 mg/l (S1) and 140.5-232 mg/l (S2). The photosynthetic activity, loss of CO_2 due to high pressure, or precipitation of calcium carbonate increases the water temperature and contributes to the depletion of calcium (Chapman, 1992). The average value for calcium hardness was observed as 42.84-55.31 mg/l (S1) and 44.13-53.31 mg/l (S2). Magnesium is essential for the growth and development of planktons (Wetzel, 1983). The values of magnesium hardness varied at all sites: S1 (27.25 mg/l to 42.21 mg/l) and S2 (23.42 mg/l to 43.42 mg/l).

Potassium and Sodium: Sodium and potassium are essential nutritional element for aquatic biota, and is usually present at less than 10 mg/l in natural waters (Chapman, 1992). The monthly average value of potassium varies from S1 (27.38-33.6 mg/l) and S2 (27.45-34.35 mg/l) respectively. The monthly average value for sodium, varies from S1

(102.45-126.09 mg/l) and S2 (102.75-118.95 mg/l) respectively.

Nitrate and Nitrite: Nitrate is the oxidized form of nitrogen and end product of aerobic decomposition of the organic nitrogenous matter. In the environment, inorganic nitrogen occurs in a range of oxidation states as nitrate (NO_3^-), nitrite (NO_2^-), ammonium ion (NH_4^+) and molecular nitrogen (N_2). The nitrate values were S1 (0.98-3.15 mg/l) and S2 (0.54-2.25 mg/l) respectively. The nitrite values were S1 (0.02-1.03 mg/l) and S2 (0.01-0.48 mg/l) respectively.

Ammonia: Ammonia is produced as a result of the breakdown of nitrogenous organic and inorganic matter in soil and water. The excretion of biota may also contribute to the ammonia levels in water. The higher concentration of ammonia indicates organic pollution. Free ammonia (NH_3) is toxic to fish and NH_4^+ ions (Ammonium) are non-toxic. The monthly average value varies from S1 (1.34-9.81 mg/l) and S2 (1.25-7.59 mg/l) respectively.

Total phosphates: Phosphorus occurs in many inorganic and organic forms, and does not occur in the environment in its elementary form. The monthly average value varies from S1 (5.72-16.13 mg/l) and S2 (6.9-13.25 mg/l) respectively.

Orthophosphate: This is the form of phosphours that is soluble in water and is diversely utilized by aquatic biota. The monthly average value varies from S1 (3.54-11.87 mg/l) and S2 (3.08-10.89 mg/l) respectively.

Algal Dynamics

Detailed microscopic examination of phytoplankton revealed the presence of four algal groups throughout the study period in the order Cyanophyceae>Chlorophyceae>Bacillariophyceae> Euglenophyceae. The following species were found in the Centenary pond (Sampling sites: S1 & S2) *Microcystis* sp., *Closterium* sp., *Chlorococcum* sp., *Chlamydomonas* sp., *Cosmarium* sp., *Navicula* sp., *Nitzschia* sp., *Cyclotella* sp. *(Centric diatom), Pandorina* sp., *Euglena* sp., *Phacus* sp., *Fragillaria* sp., *Phormidium* sp. and *Chlorella* sp. Initial nutrient limiting conditions during the months of February and March led to the abundance of Cyanophycean sp. i.e., *Microcystis aeruginosa* after the biomanipulation by the introduction of duckweeds (Lemna sp.). There was succession from Cyanophyceae to Chlorophyceae, whereas *Chlorococcum* sp. dominated. This type of succession indicates higher nutrient regimes in the inflow water consequent to poor performance of the Wastewater treatment plant. Higher concentrations of phosphates and nitrates in the water resulted in abundance of surface films mostly comprising of *Chlorococcum* sp., beneath to which *Microcystis* sp. were found. The algal species composition has been observed to change with environmental parameters as well as feed parameters (Sekadende, 2004). In the Centenary pond, the growth of algae and duck weeds were responsible for ~45 % of nutrient removal and could be the best possible option to treat the secondary treated water in the campus after feed rate optimization and strategic algal growth, suitable to the nutrient conditions.

CONCLUSION

The analysis of different physico-chemical characteristics of water collected from the IISc Campus, Centenary pond, Bangalore showed a significant improvement of water quality owing to algal and duckweed uptake. The growth of algae and duck weeds accounted for ~45 % of nutrient removal. Furthermore indigenous algal consortia played important role in nutrient removal by their abilities to adapt and grow at variable nutrient regimes. A transition in nutrient uptake was observed during April, due to variability in the feed rate and higher sediment upwelling resulting in anoxic conditions. Initial cyanophycean members (*Microcystis* sp.) in the ponds were succeeded by chlorophycean (*Chlorococcum* sp.) members due to alterations in their bio-chemical environment. Thus with careful feed rate management and optimal algal group selection, secondary treated wastewaters can be economically treated and reused for domestic and other purposes.

Acknowledgement

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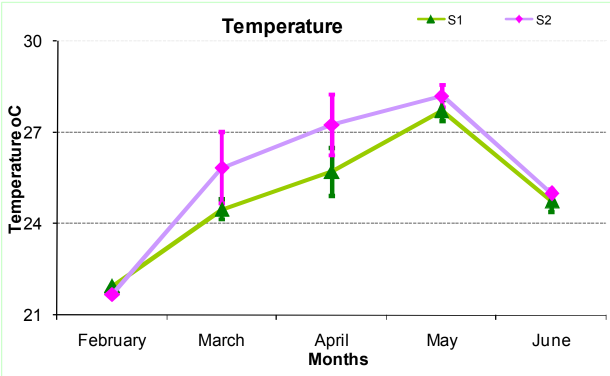
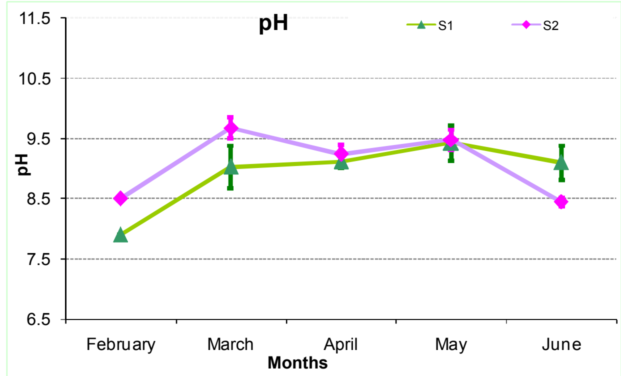
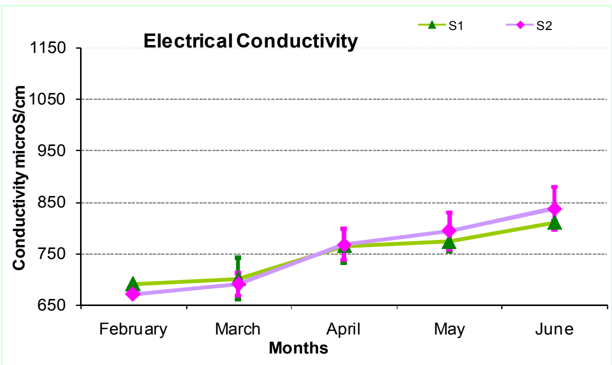
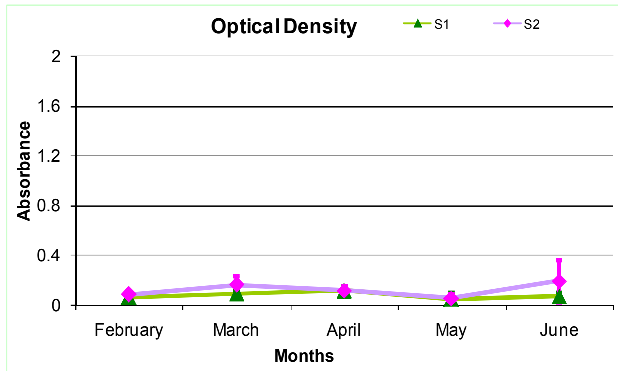
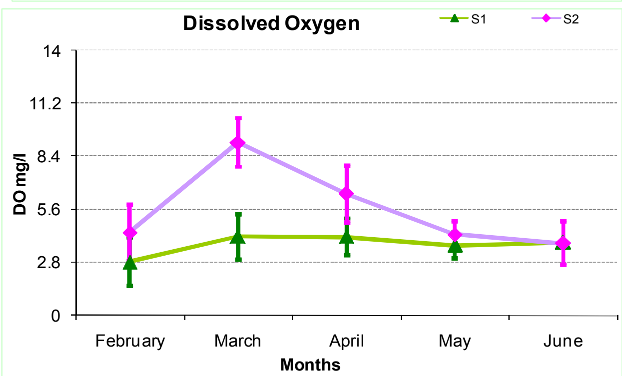
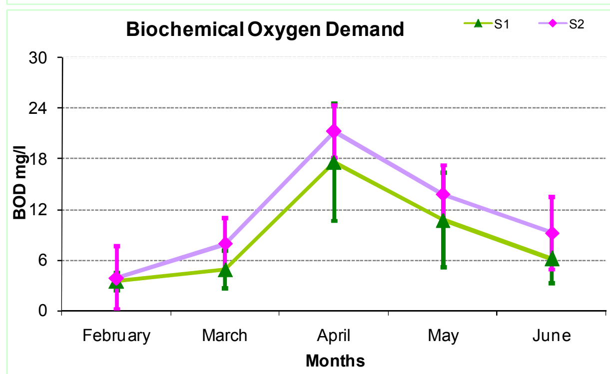

Temperature
S1
S2
Temperature oC
30
27
24
21
February
March
April
May
June
Months

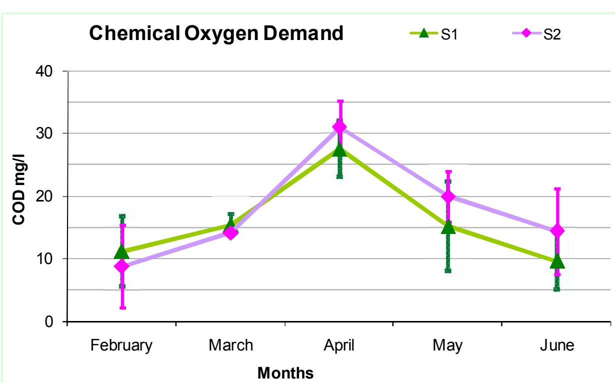

pH
S1
S2
pH
11.5
10.5
9.5
8.5
7.5
6.5
February
March
April
May
June
Months

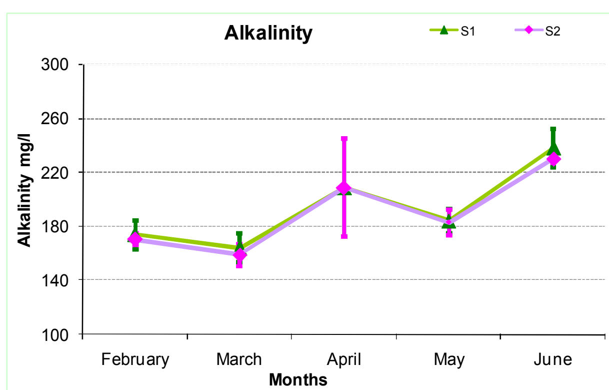

Electrical Conductivity
S1
S2
Conductivity microS/cm
1150
1050
950
850
750
650
February
March
April
May
June
Months

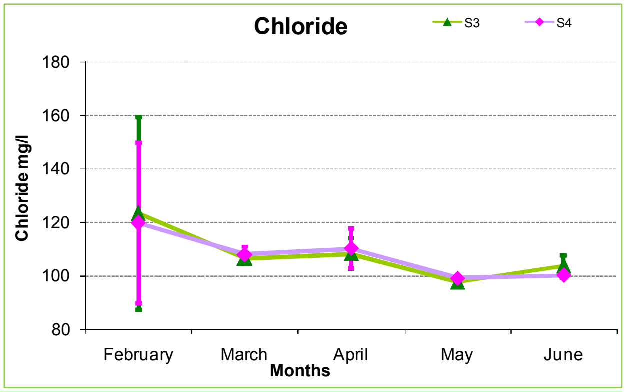

Optical Density
S1
S2
Absorbance
2
1.6
1.2
0.8
0.4
0
February
March
April
May
June
Months

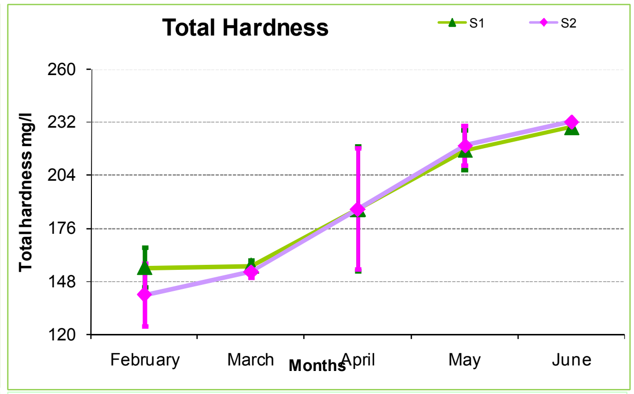

Dissolved Oxygen
S1
S2
DO mg/l
14
11.2
8.4
5.6
2.8
0
February
March
April
May
June
Months

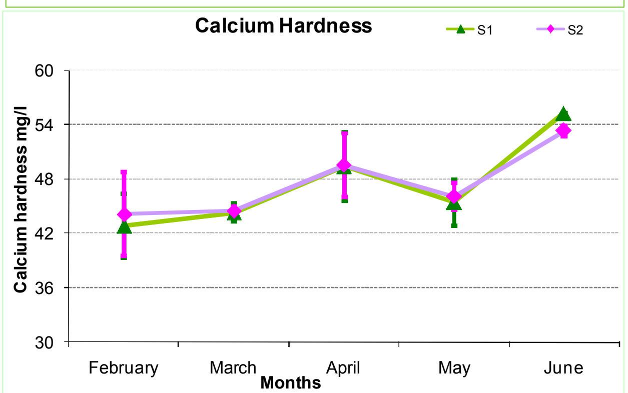

Biochemical Oxygen Demand
S1
S2
BOD mg/l
30
24
18
12
6
0
February
March
April
May
June
Months

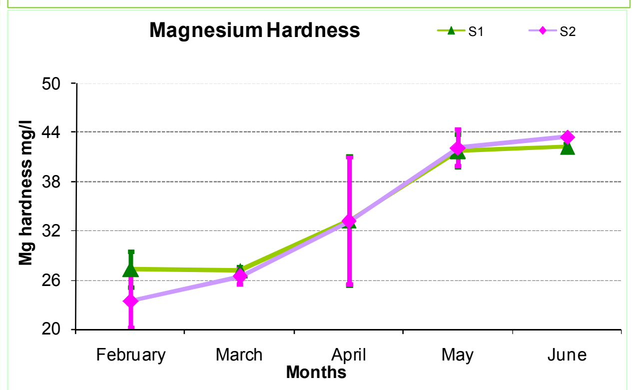

Chemical Oxygen Demand
S1
S2
COD mg/l
40
30
20
10
0
February
March
April
May
June
Months

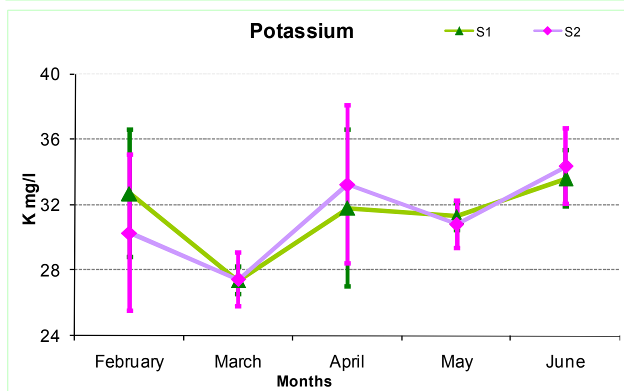

Alkalinity
S1
S2
Alkalinity mg/l
300
260
220
180
140
100
February
March
April
May
June
Months


Chloride
S3
S4
Chloride mg/l
180
160
140
120
100
80
February
March
April
May
June
Months


Total Hardness
S1
S2
Total hardness mg/l
260
232
204
176
148
120
February
March
April
May
June
Months


Calcium Hardness
S1
S2
Calcium hardness mg/l
60
54
48
42
36
30
February
March
April
May
June
Months


Magnesium Hardness
S1
S2
Mg hardness mg/l
50
44
38
32
26
20
February
March
April
May
June
Months


Potassium
S1
S2
K mg/l
40
36
32
28
24
February
March
April
May
June
Months

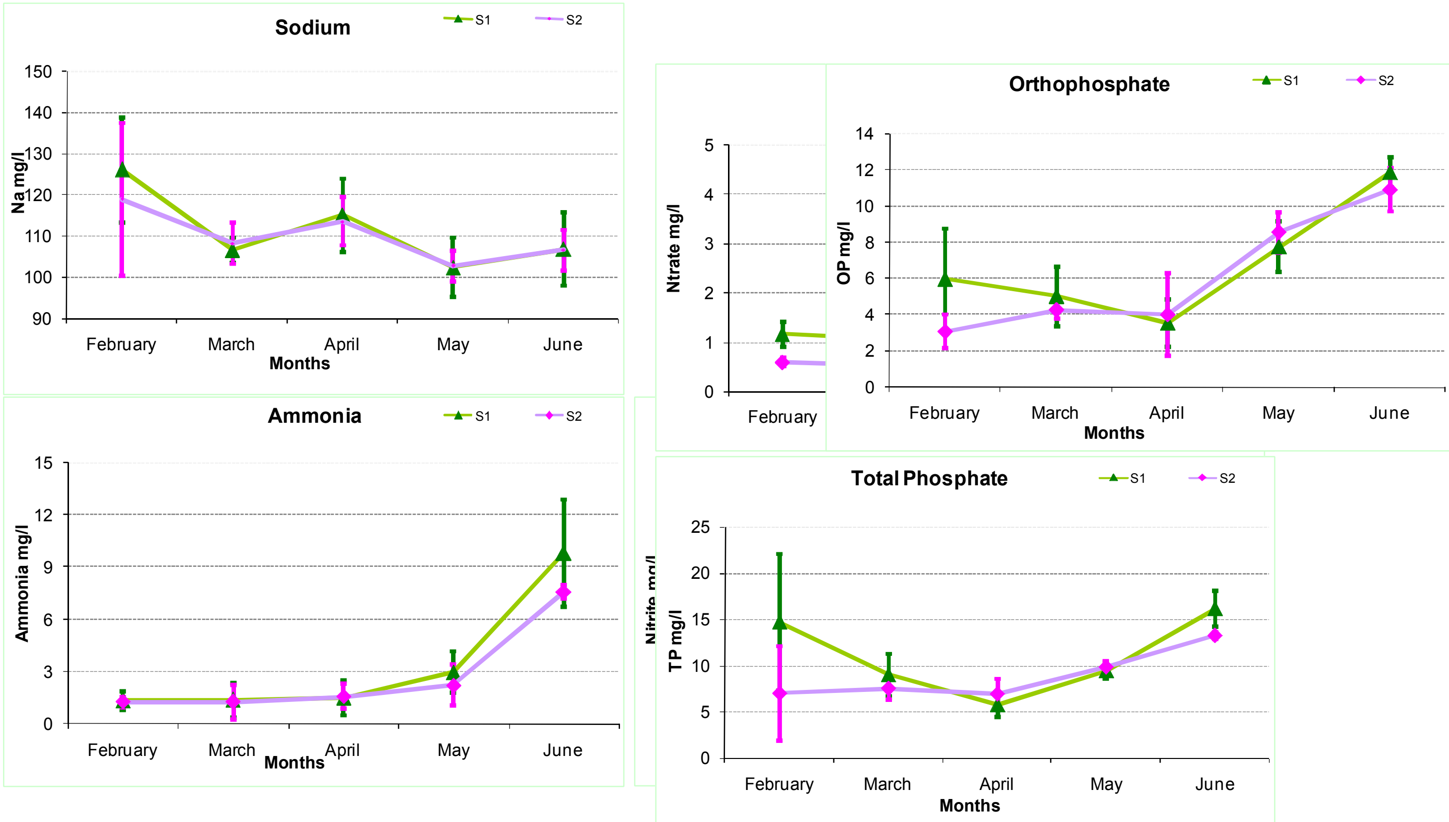


Figure 2: Monthly Physico-chemical variations in Water quality parameters
*The whiskers indicates standard deviation (st. dev) across the mean(μ)

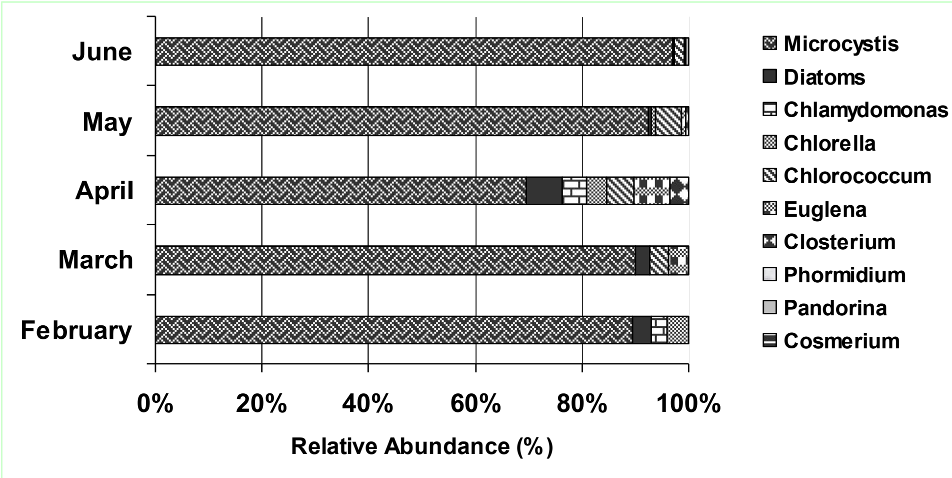


Figure 3: Site 1. Relative abundance of microalgae community

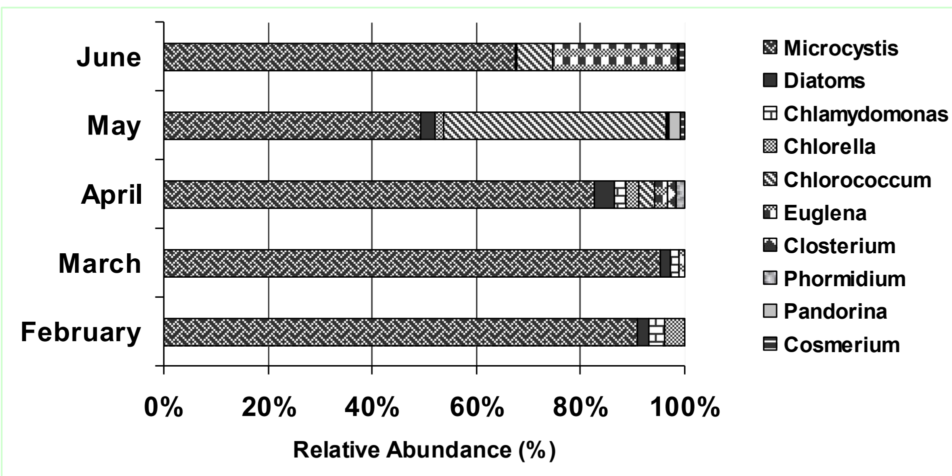


Figure 4: Site 2. Relative abundance of microalgae community