# Algal population growth and dynamics of Asan Wetland

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**Abstract-** A one year study of the phytoplankton community composition was carried out in the Asan wetland, a reservoir fed by River Yamuna in Uttarakhand India. In terms of bio-volume, phytoplankton community was generally dominated by Bacillariophyceae. Mean phytoplankton standing crops were highest in the wetland. The frequency and severity of algal blooms was increased significantly. To control their expansion, it was essential to identify the factors responsible for blooming of waters. Nutrient enrichment (mainly due to anthropogenic activities) and environmental factors (including the climate change) were considered the major catalyst for onset, proliferation and development of blooms. The phytoplankton of the Asan wetland was studied for one year with physical and chemical variables in relation to a pollution gradient. Analysis of the physical and chemical variables and phytoplankton density indicated that the wetland is experiencing heavy pressure of pollution due to anthropogenic activities. The dominant phytoplankton community mainly comprises of family, Chlorophyceae, Bacillariophyceae and Myxophyceae. Physical factors, though vital, had an indirect effect in facilitating the interaction among various available nutrients. In terms of phytoplankton density and diversity common genera observed include *Chlorella, Chlaymydomonas, Spirogyra, Ulothrix, Hydrodictyon, Cladophora, Cosmarium, Chlorococcum, Oedogonium, Microspora, Desmidium, Chara, Zygenema, Syndesmus, Volvox, Ceratoneis, Amphora, Caloneis, Fragilaria, Navicula, Synedra, Diatoms, Gomphonema, Pinnularia, Melosira, Tabellaria, Denticula, Cymbella, Cyclotella, Nostoc, Anabaena, Oscillatoria, Rivularia, Coccochloris and Phormidium.* Several genera were found most prominent during the study period having no seasonal impact on their abundance and variation. The spatial and temporal patterns observed in some of these dominant species were attributable to patterns in key environmental variables including temperature, flow, pH, dissolved oxygen and nutrient concentrations.

**Keywords:** Asan wetland, Algal blooms, Bacillariophyceae, Phytoplankton and Nutrient enrichment.

## Introduction

Since last few decades, phytoplankton blooms and factors regulating their development have been a central theme in limnological research. In the last 20 years, the incidence of harmful algal blooms in surface waters due to increased nutrient loading mainly arising out of human activities (Anderson et al. 2002) has increased dramatically all over the world (Onderka 2007). Due to eutrophication, water become turbid, phytoplankton biomass increases, diversity of the community decreases and finally single or a few species dominate (Oliver and Gnaf 2000). The overwhelming growth of organisms known as 'blooms' harm ecosystems, fishery resources, human health, and al sore creational use of water through smothering of benthic habitats (Fouzia, *et al*. 2013). Cyanobacteria (blue-green algae), a group of oxygen producing photosynthetic prokaryotes are natural component of phytoplankton community, especially in tropical zones. They play a detrimental role in aquatic food web and are the most notorious bloom formers (Paerl et al. 2001). Under favorable growth conditions, cyanobacteria dominate the aquatic biota and cause blooming of water bodies, which adversely affect the domestic, industrial, and recreational use of water. In addition to producing odor and degrading the quality of water, cyanobacterial blooms produce a variety of toxins that cause hepatotoxicity, asthma, dermatitis, and eye irritation in humans and pose a serious risk to public health (Codd et al. 2005).

Factors responsible for algal bloom formation are yet to be established. A multitude of factors such as nutrients, light, temperature, pH, dissolved oxygen, buoyancy regulation, and stratification of algal species, selective grazing, viral infection, parasitism, and antibiosis interact in structuring phytoplankton community of water bodies (Paerl et al. 2001). In addition to the two well-known growth limiting nutrients, nitrogen and phosphorous, carbon plays a vital role in regulating the algal growth. During the course of bloom formation, a continuous release and biodegradation of organic matter takes place (Paerl et al. 2001).Carbon dioxide produced by bacterial oxidation is utilized by algae during photosynthesis, and $O_2$ is released. This way the cycle of nutrients operates and leads to eutrophication of water bodies. Competition for limiting nutrients is an important factor controlling the dynamics of phytoplankton community (diversity, abundance, and species succession; Chapra 1997). Species with high affinity for nutrients generally occupy oligo trophic waters, while low-affinity forms harbor eutrophics. The question, to what extent nutrients are involved in phytoplankton dominance of eutrophic water bodies, remains unresolved. In tropical regions, eutrophication of water bodies has become a menace due to conditions favorable for microbial growth. There is a need to identify the factors and processes involved in blooming of water bodies. The present study based on2 years data on the water chemistry and phytoplankton composition of Asan wetland (reservoir) attempts to evaluate the environmental factors that are responsible and favoured the algal growth. The present work also describes the dominant physical–chemical variables and their relation with phytoplankton density and community.

## Material and Method

### *Study area*

The Asan wetland is a small man-made wetland of ca. 4 sq km area, located 40 km west of Dehradun, in Doon valley on Dehradun-Paonta road. Geographically it is situated between latitude 30º 24'-30º 28' N and longitude 77º 40'-77º 44' E, near the confluence of the two perennial rivers, River Asan and Yamuna. The Asan wetland has a barrage which is 287.5 m long, the river bed being 389.4 m above sea level, with minimum and maximum water levels respectively at 402.4 m and 403.3 m asl. The other name of Asan wetland in Dehradun is Asan barrage or Asan lake or Dhalipur lake. It was created in 1967 as a result of the construction of Asan barrage at the confluence of the river Yamuna and Asan through Dhalipur power house. Asan wetland has all type of facilities and services that can entertain the visitors to their hearts content like water skiing, boating, rowing, kayaking, canoeing etc. It is the hub of numerous migratory birds and chooses this water resort as their home and dwell there for the whole winter season. The Asan wetland attracts 53 species of water birds of which 19 are winter migrants from Eurasia.


**Figure- 1 Satellite view of Asan wetland**

**Figure-2 Asan wetland**

### *Sampling strategy*

The present study was carried out monthly during the year August 2011 to July 2012. Physico-chemical parameters viz. temperature, velocity, conductivity, total dissolved solids (TDS), pH, total alkalinity, total hardness, chloride, dissolved oxygen (DO), biochemical oxygen demand (BOD), phosphate, nitrate, sodium and potassium were analyzed by following the standard methodology of APHA (1998). For analysis and enumeration of phytoplankton, samples were collected with the help of plankton net of bolting silk no. 25 with a mesh size of 55µm attached with a collection tube at the base of net. For this a known volume (10 L) of water was filtered through the planktonic net and sample was collected inside the collection tube. The sample was then transferred in sterilized tubes of 250 ml capacity and preserved in 4%formaldehyde solution (APHA, 1998; Trivedi and Goel, 1986). The phytoplanktons were made identified following Alfred et al. (1973); Randhawa (1959); Vollen winds (1969) and Peat (1974). Phytoplankton data was also analyzed by statistical approaches like standard deviation (SD) and Pearson correlation coefficient (r).

## Results and Discussion

### Physico-chemical parameters

Monthly fluctuations in the values of different physico-chemical parameters in Asan wetland have been given in table -1.

**Table1: Monthly variation in physico-chemical parameters of Asan wetland from 2011-2012**

| Month / Parameters | Aug | Sept | Oct | Nov | Dec | Jan | Feb | Mar | April | May | June | July | Avg.±S.D |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Temperature (ºC)** | 21.0 | 20.0 | 19.0 | 18.0 | 17.0 | 15.0 | 17.0 | 19.0 | 21.0 | 22.0 | 22.0 | 20.0 | **19.25±2.17** |
| **Velocity (m/s)** | 0.57 | 0.53 | 0.49 | 0.38 | 0.35 | 0.33 | 0.36 | 0.34 | 0.36 | 0.43 | 0.55 | 0.48 | **0.43±0.08** |
| **Conductivity (µmhocm$^{-1}$)** | 0.125 | 0.137 | 0.132 | 0.128 | 0.138 | 0.141 | 0.137 | 0.139 | 0.155 | 0.162 | 0.149 | 0.135 | **0.139±0.01** |
| **TDS (mg/l)** | 500 | 300 | 200 | 200 | 200 | 100 | 200 | 200 | 300 | 300 | 200 | 400 | **258.33±108.36** |
| **pH** | 8.2 | 8.3 | 8.1 | 8.4 | 8.2 | 8.0 | 8.2 | 8.1 | 8.3 | 8.1 | 8.2 | 8.3 | **8.2±0.11** |
| **Total alkalinity (mg/l)** | 196.0 | 165.0 | 173.0 | 192.0 | 166.0 | 153.0 | 162.0 | 159.0 | 147.0 | 158.0 | 173.0 | 182.0 | **168.33±15.05** |
| **Total Hardness (mg/l)** | 92.0 | 95.0 | 110.0 | 105.0 | 94.0 | 85.0 | 92.0 | 84.0 | 93.0 | 105.0 | 98.0 | 115.0 | **97.33±9.59** |
| **Chloride (mg/l)** | 34.25 | 32.44 | 28.68 | 35.21 | 29.87 | 27.55 | 31.47 | 34.21 | 37.38 | 35.77 | 48.29 | 42.65 | **34.81±5.90** |
| **D.O (mg/l)** | 10.67 | 10.72 | 10.92 | 11.25 | 11.43 | 11.56 | 10.74 | 10.33 | 11.23 | 10.67 | 10.36 | 10.47 | **10.86±0.41** |
| **B.O.D (mg/l)** | 2.87 | 2.68 | 2.64 | 2.36 | 2.41 | 2.25 | 2.64 | 2.57 | 3.29 | 3.38 | 3.57 | 3.71 | **2.86±0.49** |
| **Phosphates (mg/l)** | 0.922 | 0.734 | 0.582 | 0.563 | 0.572 | 0.563 | 0.628 | 0.657 | 0.735 | 0.752 | 0.648 | 0.629 | **0.66±0.10** |
| **Nitrates (mg/l)** | 0.75 | 0.83 | 0.92 | 1.21 | 1.33 | 1.25 | 1.32 | 1.29 | 1.38 | 1.44 | 1.63 | 1.57 | **1.243±0.277** |

***± S.D = Standard Deviation***

During the present investigation temperature was recorded maximum in the months of May and June and minimum in the month of January. The average temperature recorded in Asan wetland was 19.25±2.17 $^{0}$C.The velocity was low throughout the year with average value of 0.43±0.08 m/s. Temperature, flow and standing water levels are the important environmental factors of marked variations that affect all the other environmental characteristics of freshwater ecosystems. Conductivity is an important physical quality parameter, which explains the ionic status of all waters and its measurement. This is mostly influenced by dissolved salts such as sodium chloride and potassium chloride. Relatively lower values of conductivity were recorded throughout the study period with an average value of 0.139±0.01 (µmhocm$^{-1}$). This was because of dilution effect of freshwater which the wetland received from river Yamuna. TDS of the wetland followed the similar trend as that of conductivity. These were maximum in months of summer and minimum in winter with an average value of 258.33±108.36 mg/l. This pattern of fluctuations in TDS is in conformity with those of Gurumayum et al. (2002). However, Rajurkar et al. (2003) have reported minimum values of TDS during post monsoon. However appreciable TDS values were observed during all the months indicating the mixing of pollutants from anthropogenic activities in and around the lake. The pH of water in Asan Lake in general showed an alkaline tendency during all the months with an average value of 8.2±0.11.Talling and Talling (1965) have reported that the pH value in lake water increased with increasing alkalinity. Alkalinity is a measure of buffering capacity of water and is important for aquatic life in a freshwater system because it equilibrates the pH changes that occur naturally as a result of photosynthetic activity of phytoplankton (Kaushik and Saksena, 1989).The total alkalinity of the Asan wetland was high throughout the study period. Maximum alkalinity was reported in the month of August and minimum total alkalinity was recorded in the month of April with an annual average of 168.33±15.05 mg/l. Monthly variations were quite significant. The increase in total alkalinity was the sign of anthropogenic impact on the Asan Lake. The higher total alkalinity may be also due to the decomposition of organic matter settled at the bottom.

The total hardness is defined as the sum of Ca and Mg concentrations, both expressed as $CaCO_3$ in mgL$^{-1}$. Carbonates and bicarbonates of Ca and Mg cause temporary hardness. Sulphates and chlorides cause permanent hardness. Hardness has got no adverse effect on human health. Water with hardness above 200 mg/l may cause scale deposition in the water distribution system and more soap consumption. During the present study total hardness of Asan wetland was low with an average value of 97.33±9.59 mg/l. Chloride in the natural waters occurs due to the pollution from sewage. The value of chloride in the present study indicated that the Asan wetland free from sewage as the concentration of chloride was low with an annual average value of 34.81±5.90 mg/l. The relatively low concentration of chloride in Asan wetland may be due to dilution effect of River Yamuna. The values of chloride observed in this study are not significant when compared to tolerable values posted by USEPA though chloride contents in water are not harmful.

Dissolved Oxygen (DO) is essential to all forms of aquatic life including the organisms that break down man-made pollutants. Oxygen is soluble in water and the oxygen that is dissolved in water will equilibrate with the oxygen in atmosphere. Oxygen tends to be less soluble as temperature increases (Kannel et al. 2007). DO of Asan wetland was recorded maximum in the month of January and minimum in the month of March with mean value of 10.86±0.41 mg/l. There is no defined trend in variation of maximum value of DO in all the months. This indicated that the turbulences of water in Asan wetland, which may be beneficial for dissolved solid breakdown through self-pollution regulating mechanisms of fresh water system was found here (Hassan et al. 2009). The quality of the water in terms of DO content is always of primary importance, because at the waste discharge points, the DO is required for aerobic oxidation of the wastes. Also, Zeb et al., (2011) explained that DO levels are important in the natural self-purification capacity of fresh water ecosystems. A good level of DO indicated a high re-aeration rate and rapid aerobic oxidation of biological substances. The values obtained are well above the values recommended by USEPA, which indicate low level of anthropogenic activities within the study area. Other indirect laboratory test for assessing the DO is the Biological Oxygen Demand (BOD) which is the amount of oxygen required to biologically break down a contaminant. It is often used as a measurement of pollutants in natural and waste waters and to assess the strength of waste, such as sewage and industrial effluent waters (Zeb et al., 2011). BOD therefore is an important parameter of water indicating the health scenario of fresh water bodies (Bhatti and Latif, 2011). In the present study, BOD varied from 2.25 to 3.71 mg/l with the mean value of 2.86±0.49 mg/l. The lower BOD concentration confirmed non existence of point source pollution. Phosphate is the nutrient considered to be the critical limiting nutrient, causing eutrophication of fresh water systems (Rabalais, 2002). It is major nutrients that triggers eutrophication and required by algae in small quantities (Bandela, et al, 1999).P additions to landscape enter water via waste water effluents and soil erosions, and also from detergents. Therefore, Phosphate in large quantities in water is an indication of pollution through sewage and industrial waste. Higher Phosphate in bottom water may result from decomposition of organic matter and its release from sediments under the anoxic conditions. It also limits the growth of all the algal forms most often and hence, the Phosphate nutrient assessment of waters is crucial to the monitoring investigations of natural freshwater bodies. In instances where phosphate is a growth limiting nutrient, the change in its concentration can cause the stimulation or inhibition in the growth of photosynthetic aquatic micro and macro organisms such as phytoplankton and green bacteria (Droop, 1983 and APHA, 1998). In the present study the concentration of phosphate was consistently low with an average value of 0.66±0.10 mg/l. Nitrate levels over 10 mg/l in natural waters normally indicate man made pollution, but the measured values in this study were within the limit range. Man made sources of include, fertilizers, livestock, urban runoff, septic tanks and waste water discharges. As more land is converted into agricultural land and as urban areas expand, nitrate monitoring is an important tool in accessing locating and mitigating manmade sources of nitrate. Man made sources of phosphate in the environment include domestic and industrial discharges, agricultural runoff where fertilizers are used and changes in land use in areas where phosphorous is naturally abundant in the soil. In general, phosphates are not very toxic to people or other living organisms. The values measured in this study were under limits with an average value of 1.243±0.277 mg/l. Nitrate and phosphate are important parameters of showing the pollution status and anthropogenic load in river water (Khan and Khan,1997).

## Correlation between physico-chemical parameters

The Pearson correlation coefficient (r) calculated between physico-chemical parameters of Asan wetland are presented in table-2.

**Table -2 Pearson correlation coefficient (r) between physico-chemical parameters of Asan wetland**

| | Temperature | Velocity | Conductivity | T.D.S | pH | Total Alkalinity | Total Hardness | Chloride | D.O | B.O.D | Phosphate | Nitrate |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Temperature (ºC)** | 1 | | | | | | | | | | | |
| **Velocity (m/s)** | 0.656* | 1 | | | | | | | | | | |
| **Conductivity (μmhocm$^{-1}$)** | 0.402** | -0.203** | 1 | | | | | | | | | |
| **TDS (mg/l)** | 0.626* | 0.608* | -0.160** | 1 | | | | | | | | |
| **pH** | 0.259** | 0.190** | -0.240** | 0.372** | 1 | | | | | | | |
| **Total alkalinity (mg/l)** | 0.165** | 0.569** | -0.720* | 0.486** | 0.439** | 1 | | | | | | |
| **Total Hardness (mg/l)** | 0.348** | 0.398** | -0.050** | 0.286** | 0.370** | 0.449** | 1 | | | | | |
| **Chloride (mg/l)** | 0.693* | 0.440** | 0.308** | 0.318** | 0.398** | 0.233** | 0.336** | 1 | | | | |
| **D.O (mg/l)** | -0.640* | -0.545** | -0.050** | -0.410** | -0.020** | -0.222** | -0.183** | -0.593** | 1 | | | |
| **B.O.D (mg/l)** | 0.798* | 0.476** | 0.500** | 0.520** | 0.212** | 0.035** | 0.484** | 0.836* | -0.579** | 1 | | |
| **Phosphates (mg/l)** | 0.658* | 0.535** | 0.082** | 0.814* | 0.082** | 0.183** | -0.159** | 0.181** | -0.388** | 0.358** | 1 | |
| **Nitrates (mg/l)** | 0.095* | -0.339** | 0.591** | -0.280** | 0.015** | -0.315** | 0.163** | 0.598** | -0.133** | 0.525** | -0.399** | 1 |

***Significant at P <0.001* and P <0.05****

The temperature showed positive correlation with all parameters whereas showed negative significant relation with dissolved oxygen ($r = -0.640, p < 0.001$). Velocity showed a negative correlation with conductivity, D.O and nitrates and positive correlation with all other parameters. Conductivity showed negative correlation with total alkalinity ($r = -0.720, p < 0.001$). TDS showed significant positive relation with phosphate ($r = 0.814, p > 0.001$). pH was positively correlated with all the parameters except D.O ($r = -0.020, p < 0.05$). Chloride showed positive correlation with BOD ($r = 0.836, p > 0.001$). DO was negatively correlated with BOD, phosphate and nitrate where as BOD showed positive correlation with phosphate and nitrate.

## Phytoplankton growth and dynamics

The most important and remarkable aspect of the present study was the phytoplankton growth and dynamics of Asan wetland and the results are presented in table-3.

**Table-3 Monthly spatial qualitative and quantitative distribution of phytoplankton (Unit/l) in Asan wetland from 2011- 2012**

| Month / Phytoplankton | Aug | Sep | Oct | Nov | Dec | Jan | Feb | Mar | Apr | May | June | July | Avg.± S.D |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ***Chlorophyceae*** | | | | | | | | | | | | | |
| *Volvox* | 8 | 10 | 14 | 17 | 21 | 17 | 12 | 8 | 11 | 15 | 13 | 10 | **13.00±3.97** |
| *Chlaymydomonas* | 12 | 16 | 13 | 16 | 22 | 18 | 12 | 6 | 14 | 24 | 18 | 15 | **15.50±4.77** |
| *Spirogyra* | 12 | 14 | 21 | 25 | 33 | 47 | 27 | 13 | 26 | 13 | 11 | 16 | **21.50±10.77** |
| *Ulothrix* | 5 | 15 | 24 | 27 | 35 | 52 | 33 | 27 | 34 | 42 | 28 | 17 | **28.25±12.49** |
| *Hydrodictyon* | 11 | 8 | 6 | 13 | 17 | 25 | 18 | 10 | 16 | 19 | 14 | 11 | **14.00±5.30** |
| *Cladophore* | 2 | 8 | 12 | 14 | 11 | 18 | 23 | 17 | 25 | 18 | 13 | 10 | **14.25±6.41** |
| *Cosmarium* | 7 | 5 | 13 | 11 | 16 | 23 | 11 | 8 | 6 | 12 | 7 | 3 | **10.16±5.49** |
| *Chlorococcum* | 4 | 7 | 13 | 16 | 12 | 27 | 18 | 4 | 12 | 18 | 13 | 8 | **12.66±6.59** |
| *Oedogonium* | 9 | 11 | 10 | 13 | 15 | 24 | 15 | 9 | 23 | 19 | 22 | 16 | **15.50±5.43** |
| *Microspora* | 10 | 13 | 17 | 21 | 22 | 25 | 13 | 11 | 16 | 23 | 15 | 9 | **16.25±5.39** |
| *Desmidium* | 18 | 21 | 25 | 19 | 20 | 38 | 32 | 21 | 35 | 27 | 16 | 12 | **23.66±7.93** |
| *Chara* | 11 | 9 | 12 | 15 | 21 | 18 | 13 | 6 | 14 | 11 | 10 | 7 | **12.25±4.33** |
| *Zygenema* | 9 | 13 | 16 | 22 | 25 | 32 | 25 | 12 | 26 | 18 | 11 | 10 | **18.25±7.58** |
| *Syndesmus* | 10 | 16 | 21 | 16 | 24 | 38 | 22 | 14 | 27 | 15 | 22 | 14 | **19.91±7.54** |
| *Chlorella* | 23 | 16 | 13 | 11 | 10 | 17 | 12 | 7 | 12 | 19 | 21 | 13 | **14.50±4.75** |
| **Total** | **151** | **182** | **230** | **256** | **304** | **419** | **286** | **173** | **297** | **293** | **234** | **171** | **249.66±76.34** |
| ***Bacillariophyceae*** | | | | | | | | | | | | | |
| *Ceratoneis* | 13 | 15 | 12 | 17 | 22 | 28 | 18 | 12 | 19 | 21 | 16 | 13 | **17.16±4.80** |
| *Amphora* | 13 | 10 | 8 | 21 | 26 | 33 | 23 | 15 | 24 | 17 | 22 | 16 | **19.00±7.17** |
| *Caloneis* | 8 | 12 | 15 | 18 | 23 | 38 | 24 | 12 | 27 | 18 | 21 | 12 | **19.00±8.29** |
| *Fragilaria* | 96 | 120 | 156 | 234 | 252 | 266 | 231 | 173 | 156 | 183 | 144 | 125 | **178.0±55.78** |
| *Navicula* | 76 | 125 | 138 | 153 | 115 | 184 | 132 | 126 | 135 | 127 | 114 | 85 | **125.83±28.28** |
| *Synedra* | 14 | 17 | 23 | 26 | 29 | 45 | 23 | 19 | 24 | 33 | 17 | 10 | **23.33±9.37** |
| *Diatoms* | 75 | 58 | 84 | 123 | 154 | 172 | 94 | 75 | 69 | 57 | 44 | 39 | **87.00±42.18** |
| *Gomphonema* | 24 | 33 | 37 | 45 | 51 | 66 | 43 | 28 | 36 | 47 | 32 | 17 | **38.25±13.17** |
| *Pinnularia* | 10 | 13 | 17 | 23 | 27 | 35 | 24 | 10 | 15 | 22 | 19 | 17 | **19.33±7.32** |
| *Melosira* | 9 | 15 | 22 | 14 | 26 | 22 | 16 | 8 | 14 | 18 | 12 | 7 | **15.25±5.94** |
| *Tabellaria* | 14 | 25 | 34 | 37 | 32 | 45 | 28 | 14 | 24 | 17 | 22 | 10 | **25.16±10.54** |
| *Denticula* | 13 | 17 | 24 | 26 | 31 | 37 | 23 | 8 | 19 | 15 | 25 | 16 | **21.16±8.11** |
| *Cymbella* | 14 | 21 | 25 | 32 | 26 | 38 | 26 | 15 | 11 | 16 | 16 | 12 | **21.00±8.48** |
| *Cyclotella* | 16 | 24 | 26 | 21 | 24 | 28 | 14 | 6 | 8 | 13 | 25 | 11 | **18.00±7.57** |
| **Total** | **395** | **505** | **621** | **790** | **838** | **1037** | **719** | **521** | **581** | **604** | **529** | **390** | **627.50±189.74** |
| ***Myxophyceae*** | | | | | | | | | | | | | |
| *Nostoc* | 8 | 13 | 24 | 22 | 27 | 33 | 23 | 14 | 24 | 16 | 11 | 10 | **18.75±7.80** |
| *Anabaena* | 9 | 11 | 16 | 24 | 28 | 35 | 24 | 9 | 0 | 13 | 16 | 0 | **15.41±10.75** |
| *Oscillatoria* | 10 | 13 | 16 | 21 | 11 | 17 | 11 | 7 | 13 | 19 | 23 | 12 | **14.41±4.81** |
| *Rivularia* | 16 | 23 | 22 | 19 | 20 | 27 | 15 | 10 | 26 | 17 | 14 | 12 | **18.41±5.38** |
| *Coccochloris* | 7 | 13 | 15 | 19 | 23 | 26 | 12 | 5 | 18 | 23 | 11 | 15 | **15.58±6.48** |
| *Phormidium* | 6 | 10 | 21 | 26 | 24 | 32 | 16 | 7 | 6 | 17 | 13 | 10 | **15.66±8.56** |
| **Total** | **56** | **83** | **114** | **131** | **133** | **170** | **101** | **52** | **87** | **105** | **88** | **59** | **98.25±35.23** |

***± S.D = Standard Deviation***

Phytoplankton community structure and species type indicate some of the crucial environmental developments in aquatic systems. Pollution may be measured by either chemical or biological means but the role of a bio-indicator has been well established in aquatic ecosystems. The phytoplankton on which whole of aquatic life depends directly or indirectly are governed by a number of physical, chemical and biological conditions, their interactions, and tolerance of organisms to variations of these conditions (Cronberg, 1999). During the present study monthly results, annual average of the total density of different families of phytoplankton and density of all the species of phytoplankton in Asan wetland was derived. The fluctuations in phytoplankton density were significant during the pre-monsoon, monsoon and post monsoon. The phytoplankton density and diversity was recorded maximum in winter, moderate in summer and minimum in monsoon period. Venkateshwarlu and Menon, (1979) recorded maximum values of phytoplankton in winter and minimum during rainy season. Three families of phytoplankton which include *Chlorophyceae, Bacillariophyceae* and *Myxophyceae*were observed during the study period. Among three families the number of individuals were found maximum in family Bacillariophyceae (627.50±189.74 Unit/L) followed by Chlorophyceae (249.66±76.34 Unit/L) and minimum in Myxophyceae (98.25±35.23 Unit/L).The family Bacillariophyceae was reported with maximum density at and was dominating among the three different families following the trend *Bacillariophyceae*>*Chlorophyceae*>*Myxophyceae*. The population dynamics of the phytoplankton is influenced by the climatic conditions as well as the physico-chemical characteristics. A marked difference in the composition and in the abundance of various algal groups was observed during the present study.

The Phytoplankton diversity observed in Asan wetland comprised of 35 genera out of which Chlorophyceae constitute (15 genera), Bacillariophyceae (14 genera) and Myxophyceae (6 genera) (table 3). The qualitative study of phytoplankton revealed that the family Chlorophyceae was represented by *Chlorella, Chlaymydomonas, Spirogyra, Ulothrix, Hydrodictyon, Cladophora, Cosmarium, Chlorococcum, Oedogonium, Microspora, Desmidium, Chara, Zygenema, Syndesmus, and Volvox.* The family Bacillariophyceae was represented by *Ceratoneis, Amphora, Caloneis, Fragilaria, Navicula, Synedra, Diatoms, Gomphonema, Pinnularia, Melosira, Tabellaria, Denticula, Cymbella, and Cyclotella.* The family Myxophyceae was represented by *Nostoc, Anabaena, Oscillatoria, Rivularia, Coccochloris and Phormidium.* Monthly and seasonal were quite evident in phytoplankton species during the study period. The fluctuations in diversity of species may be attributed to climatic and seasonal changes and month wise fluctuations give much more explanation of the ecological tendencies of phytoplankton community in the wetland. The results also revealed that in case of family Chlorophyceae *Ulothrix* was found with maximum number(28.25±12.49 Unit/L)and Cosmarium was found minimum in number (10.16±5.49 Unit/L).Whereas in case of family Bacillariophyceae *Fragilaria* was dominating with maximum number (178.0±55.78 Unit/L) and *Ceratoneis*was recorded with the minimum number (17.16±4.80 Unit/L). The family Myxophyceae was mostly dominated by *Nostoc* (18.75±7.80 Unit/L) and *Oscillatoria* was reported with lowest number (14.41±4.81 Unit/L). It is well known that a combination of physical, chemical and biological factors determine the distribution of the Bacillariophyceae in Rivers (Fabricus, et al., 2003, Fouzia Ishaq and Amir Khan, 2013). Diversity of phytoplankton is an indication of purity and the use of community structure to assess pollution is conditioned by four assumptions: the natural community will evolve towards greater species complexity which eventually stabilizes; this process increases the functional complexity of the system; complex communities are more stable than simple communities, and pollution stress simplifies a complex community by eliminating the more sensitive species (Cairns, 1974).

Physico-chemical parameters played a major significant role in phytoplankton density. During the present study (table 4) temperature, velocity, TDS, pH, total alkalinity, total hardness, chloride, BOD and phosphate registered negative correlation with total phytoplankton density and conductivity DO and nitrate showed highly significant positive correlation with phytoplankton density.

**Table -4 Pearson correlation coefficient (r) between physico-chemical parameters and phytoplankton density of Asan wetland**

| | Temperature | Velocity | Conductivity | T.D.S | pH | Total Alkalinity | Total Hardness | Chloride | D.O | B.O.D | Phosphate | Nitrate |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ***Chlorophyceae*** | -0.563 | -0.645 | 0.411 | -0.659 | -0.393 | -0.577 | -0.277 | -0.383 | 0.754 | -0.326 | -0.473 | 0.305 |
| ***Bacillariophyceae*** | -0.811 | -0.692 | 0.038 | -0.785 | -0.324 | -0.351 | -0.318 | -0.573 | 0.814 | -0.672 | -0.65 | 0.101 |
| ***Myxophyceae*** | -0.671 | -0.48 | 0.068 | -0.707 | -0.274 | -0.249 | -0.077 | -0.51 | 0.827 | -0.55 | -0.622 | 0.051 |

Development and persistence of dense algal blooms in a wide range of water bodies pose serious problems for water quality management. For the restoration and management of water bodies, it is crucial to identify the factors that ultimately control the algal growth (On derka 2007). Seasonal growth of phytoplankton is strongly influenced by environmental factors and nutritional status of water bodies where these factors show distinct variation with seasons (Paerl et al., 2001). In this study, a close analysis of the physico-chemical parameters indicated relatively decreased availability of phosphate which might be the reason for less algal blooms in the wetland affecting the process of cell division resulting in reduced population. Small amount of nitrate recorded throughout the sampling period indicated that the water body was less influenced by pollution. High concentration of nitrate is usually considered a criterion of pollution (Fernández-Argüelles et al., 2004). It is produced predominantly by bacterial reduction and partly by oxidation of ammonium. Chloride is an indicator of poor water quality. Its concentration in water body increases with imperviousness of surrounding surfaces (surfaces that prohibit the movement of water from the land surface into the underlying soil). During urbanization, a lot of porous natural lands are being converted into buildings, pavements, roads, parking lots, drive ways, sidewalks, etc. Hindrance in the water's ability to penetrate into the underlying ground increases surface run off, which carry road salts into the receiving water body. Inorganic chloride salts are toxic, and high levels adversely affect the quality of receiving waters as well as stress aquatic organisms (Amirsalari and Li 2007). Almost nothing is known about the impact of chloride on phytoplankton growth and development.

Physical factors such as water temperature and pH indirectly affect the availability of various nutrient sand dynamics of phytoplankton composition (Paerl et al., 2001). Fluctuations in pH affect the availability of carbon. An increase in pH raises carbonate concentration in water, while molecular $CO_2$ and bicarbonate decrease. At high pH, $CO_2$ becomes limiting, and species tolerant to low $CO_2$ thrive (Goldman and Shapiro 1973; Chen and Durbin 1994). High temperature (>20°C) and alkalinity favors algal blooms, whereas low temperature and acidic pH supports the growth of eukaryotic algae (Paerl et al.2001).Temperature of the wetland ranged between 15 to 22 °C. Seasonal fluctuation in water temperature affects N2 fixation, nitrification, solubility of oxygen and carbonate, and availability of light, as a consequence productivity and community dynamics. In the present study, water temperature appeared to be relatively less important. This is probably due to the climatic location of the sampling area where variation in water temperature is small compared to that of temperate freshwater bodies. Algal blooms, generally absent during winter months in temperate regions, are dominant in tropical water bodies and persist throughout the year (Oliver and Gnaf 2000).In eutrophic water bodies, besides nutrients, factors such as irradiance, water column stability, structure of phycosphere, and interaction with macro flora and fauna regulate the development, proliferation, and maintenance of the blooms. Microbial associations occur during all stages of the bloom development. Intensity and specificity of microbial epiphytism may vary dramatically during a seasonal bloom cycle (Oliver and Gnaf 2000; Paerl et al. 2001). With less nutrient concentration and high DO concentration Asan wetland is an oligo trophic fresh water wetland. In such systems, interaction among nutrients and environmental factors is key feature in regulating the growth and development of algal blooms (Fouzia Ishaq and Amir Khan, 2013). In oligo trophic waters, availability of inorganic nutrients in utilizable form ($PO_4$, $NH_4^+$, $NO_3^-$*etc.*) is more important than that of aged water systems, where dissolved organic forms and their recycling by microbes hold the key. Cabrican and Valiela (1999) reported that timing and magnitude of bloom varied between close locations and even within the same location.

## Conclusion

Several genera with no seasonal impact on their abundance and variation were most prevalent during the research period. The temporal and spatial patterns shown in some of these dominant species were linked to variations in important environmental factors like temperature, flow, pH, dissolved oxygen, and nutrient concentrations.

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## Disclaimer Statement

Authors declare that no competing interest exists. The products used for this research are commonly used products in research. There is no conflict of interest between authors and producers of the products.

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