RESULTS
RESULTS

Physico-chemical characteristics

The river Disang carries loads of fertilizer effluent, industrial and domestic wastes along its course. To study the water quality, pollution level and ecological status of Disang River, physico-chemical and certain biological characteristics of river water samples were analyzed from different pollution source points along the course of the river and also in the ground water samples. The results are presented in Tables, Figures and Appendices.

Temperature (°C):

The temperature of the surface river water showed marked variation (14 – 30°C) during (2004-2006) the study period (Table 1a). However, mean annual temperature recorded among the study sites remained more or less the same. Among the study sites, 5th and 6th recorded lower temperature (14 – 28°C) compared to others (14 – 30°C). (Table 1a) Mean summer (March – June) season temperature varied from 21 to 22.5°C; in rainy season (July – October) it varied from 26 to 28°C while, in winter (November – February) it varied from 14 to 15°C (Fig 3a).

pH:

The pH of the surface water in all the study sites was in the range of 6.6 to 8.9. They were higher in 2nd 3rd and 4th site ranging from 7.7 to 8.9, while it ranged from 6.6 – 7.9 in other study sites (Table 1a). There was no seasonal fluctuation in pH values during the study period (Fig. 3a).

The pH of the ground water samples was comparatively lower than the corresponding site's surface water samples. In all the study sites pH of the
ground water was in the range of 6.5 to 7.4 during the study period. They were higher in 2nd 3rd and 4th site ranging from 6.9 to 7.4, while, it ranged from 6.6 to 6.9 in other study sites (Table 4a).

Dissolved Oxygen (mg/l):

Average dissolved Oxygen (DO) in the surface water was found to be highest at source in site 1 (9.5 - 9.6) during the study period, while sites 5 and 6 also showed similar result (9.6 - 9.7) in the second year of study only (2005-2006). Dissolved oxygen values were comparatively lower in 2, 3 and 4th sites respectively during the study period (Table 1a). There was no seasonal variation found in DO during the study period (Fig. 3a).

Bio-Chemical Oxygen Demand (mg/l):

Average values of Bio-Chemical Oxygen Demand (BOD) in the surface water were in the range of 2.9 to 5.7. There is significant variation in mean annual BOD values in site 2 and site 4 during second year (5.1 and 5.7 respectively) compared to the first year of study (3.9 and 4.1 respectively). While, no significant variation was recorded in other study sites during the study period. Comparatively lower mean BOD values were recorded in 5th (3.1 and 2.9) and 6th (3.3 and 3.8) study sites during the study period (Table 1b). No seasonal variation was observed (Fig 3b).

Total Alkalinity (mg/l):

Maximum values (195.4 in 2004-2005; 243 in 2005-2006) of total alkalinity were recorded in site 2 followed by site 3 and 4. Comparatively lower total alkalinity values were recorded in site 1, 6 and 5 respectively (Table 1b). There was no seasonal variation in total alkalinity was found during the study period (Fig 3b).
The total alkalinity values of the ground water samples were comparatively lower than the corresponding site’s surface water samples during the study period. Total alkalinity values of the ground water were in the range of 29.2 to 33.7 during the year 2004 – 2005, while comparatively, they were higher (36.3 to 48.6) during 2005 - 2006 (Table 4a).

**Conductivity (µ S cm⁻¹):**

Annual mean conductivity values ranged from 109 to 133 in 2004-2005 among the six study sites, while it ranged from 108 to 243 in 2005-2006. However, the conductivity values were much higher in 2nd, followed by 3rd and 4th study sites respectively. There was no significant variation in mean annual conductivity values during the study period except in site 2, where significantly higher values were recorded during the year 2005-2006 (Table 1b). Rainy season showed lower conductivity values compared to other seasons, while in summer conductivity values were higher during the year 2004 -2005. However in the 2nd year (2005-2006) conductivity values were higher in winter season except in site 2 and 3 (Fig.3b).

The conductivity of the ground water samples was comparatively lower than the corresponding site’s surface water samples during 2005 – 2006 while conductivity remained almost at the similar level during 2004 – 2005. In all the study sites conductivity of the ground water was in the range of 84 to 160 during the study period in all the study sites (Table 4a).

**Turbidity (NTU):**

Turbidity showed higher values in the order of 2nd 4th and 3rd sites respectively ranging from 234 to 408. However, Site 2 recorded highest mean annual turbidity values during the study period (404 to 408). 5th, 6th and 1st site showed comparatively lower values ranging from 47 – 84 during the study period.
period. However, lowest values were recorded in site 1 (48-52) during the study period (Table 1c). During winter season in both the years, site 1, 5 and 6 showed lower turbidity values compared to other two seasons. In site 2, 3 and 4 recorded lower turbidity values during rainy season compared to other two seasons during the study period (Fig.3c).

The turbidity values of the ground water samples was comparatively higher than the corresponding site's surface water samples except sites 2 and 3 in during 2004 – 2005 (ranged 184 and 217 respectively) and sites 2 and 4 during 2005 – 2006 (200 for both the sites) where it shows lower values. In all the study sites conductivity of the ground water was in the range of 135 to 487 study sites during the study period in the corresponding study sites (Table 4a).

**Total Solids (mg/l):**

Total Solids showed higher values in the order of 2nd 4th and 3rd sites respectively ranging from 115 to 162. However, Site 2 recorded highest mean annual (Total Solids) values during the study period (126 to 162). 5th, 6th and 1st site showed comparatively lower values ranging from 95.7 – 152 during the study period. However, lowest values were recorded in site 1 (95.7 - 102) during the study period (Table 1c). During the rainy season in both the years recorded lower values of total solids compared to other two seasons (Fig.3c).

The total solid of the ground water samples was comparatively almost similar in the corresponding site's surface water samples. In all the study sites total solids of the ground water was in the range of 76 to 134 during the study period in all the study sites. The annual variation was recorded to be comparatively higher during 2004 – 2005 than 2005 – 2006 in the range 95-121 (Table 4a).
Total hardness (mg/l):

Annual mean total hardness values ranged from 46.4 to 69.4 in 2004-2005 among the six study sites, while it ranged from 48.5 to 58.9 in 2005-2006. Lowest total hardness values were recorded in site 1 (46.4 to 48.5) while, the highest in site 5 from 58.9 to 69.5 (Table 1c). Winter season recorded greater total hardness values compared to others two seasons in the study sites during the study period (Fig.3c).

The total hardness of the ground water samples was comparatively similar in the corresponding site’s surface water samples during 2005 – 2006 while conductivity level was higher during 2004 – 2005 ranged 61 to 90. In all the study sites total hardness of the ground water was in the range of 45 to 90 during the study period in all the study sites. However, site 1 recorded to be low (Table 4a).

Carbonate (mg/l):

Maximum carbonate was detected in S 2 ranging from 2.25 to 7.5 in 2004-2005, while in 2005-2006 it ranged from 5.3 to 6.35. Carbonate was below detectable levels in the surface water samples in study site 1 and 6 in 2004-2005, while in 2005-2006 1, 6 and 3. However, it was negligible in 3, 4, and 5 in 2004-2005, while in 2005-2006 it was 4 and 5 (Table 2a). No seasonal trend was found during the study period in all the study sites (Fig.4a).

The carbonate of the ground water samples was below the detection level in the corresponding site’s surface water samples (Table 4a).

Bicarbonate (mg/l):

Annual mean Bicarbonate values ranged from 15.2 to 33.2 in 2004-2005 among the six study sites, while it ranged from 13.8 to 36.3 in 2005-
2006. Bicarbonate was more in site 6, 5 and 1 compared to 2,3 and 4 during the study period. There is no significant mean annual variation was found in bicarbonate content during the study period (Table 2a). No seasonal variation was observed during the study period (Fig.4a).

The Bicarbonate values of the ground water samples were comparatively higher than the corresponding site’s surface water samples. In all the study sites Bicarbonate values of the ground water was in the range of 28.9 to 48.7 during the study period. They were higher during 2005 – 2006 ranged from 35.7 – 48.7 (Table 4a).

Ammonical Nitrogen (mg/l):

The average Ammonical Nitrogen in the surface water samples in site 1 was found to be very low and or below the detection level while, in Site 2 it ranged from 8-9 in both the years and its levels gradually declined from site 3 onwards and reached to its minimum level in site 6. There is no significant mean annual variation was found in Ammonical Nitrogen content during the study period (Table 2a). In 2004-2005 Ammonical Nitrogen content was comparatively higher in rainy season, while in the second year no clear cut variation was found (Fig.4a).

The Ammonical Nitrogen of the ground water samples was comparatively lower than the corresponding site’s surface water samples. In all the study sites Ammonical Nitrogen of the ground water was in the range of 0 to 4.5 during the study period. They were higher in site 2 (ranged 5 – 7) followed by 3rd and 4th site ranging from 1.5 to 4.5, while it ranged from 0 to 1 in other study sites (Table 4a).
Chloride (mg/l):

The average chloride levels in the surface water samples in site 1, 5 and 6 were found to be comparatively low and no significant variation in mean annual chloride levels were found in site 1 during the study period (6.7-6.9). However, this not true in case of site 5 and 6, where in 2004-2005 it ranged from 7.5- 4.8 while, in 2005-2006 it ranged from 8.2 -5.03. In site 2 mean annual chloride levels were comparatively high in both the years, while they gradually declined from site 3 and 4 and reached to its minimum level in site 6 (Table 2b). No clear cut seasonal variation was found among the study sites (Fig. 4b).

Chloride level in the ground water was in the range of 7.8 to 10 (Table 4a).

Phosphate (mg/l):

The average Phosphate levels in the surface water samples were markedly higher in sites 2 (34.9-31), 3 (29.5-26) and 4 (39.2-37.7) during 2004-2005 and 2005-2006 respectively, while they did not show much variation in mean annual Phosphate levels during the study period. However, mean annual Phosphate values remain more or less similar in the case of 1, 5 and 6 ranging from 14 to 18.2 during the study period (Table 2b). No clear cut seasonal variation was found during the study period among the study sites (Fig. 4b).

The Phosphate levels of the ground water samples were comparatively lower than the corresponding site's surface water samples. In all the study sites Phosphate levels of the ground water was in the range of 1 to 2.5 during the study period. They were higher in site 2 (2.5) followed by other sites (Table 4a).
Sulphate (mg/l):

Sulphate levels sowed similar trend as that of Phosphate during the study period. The average Sulphate levels in the surface water samples in site 1, 5 and 6 were found to be comparatively low and no significant variation in mean annual Sulphate levels were found in these sites; the values ranged from 3.6 to 5.3 during the study period. In sites 2, 3 and 4 mean annual Sulphate levels were comparatively high in both the years and there is significant variation in mean annual Sulphate levels was found during the study period. However, in 2004-2005 they ranged from 10.7-16.2 while, in 2005-2006 they ranged from 15.8 to 21.7. Though, in site 2 mean annual Sulphate levels were found to be high in both the years compared to site 3 and 4 (Table 2b). No pronounced seasonal variation was found among the study sites (Fig. 4b).

The Sulphate levels of the ground water samples were comparatively lower than the corresponding site's surface water samples. In all the study sites Sulphate levels of the ground water was in the range of 2.3 to 6.3 during the study period. They were higher in site 1 followed by other sites (Table 4a).

Calcium (mg/l):

The average Calcium levels in the surface water samples in the study sites 1-4 showed more or less similar amount (14.3 – 15.8 respectively) while in site 5 and 6 they were in the range of 10.8- 11.8 respectively during the study period. There was no mean annual variation in Calcium levels during the study period among the sites except in sites 5 and 6 (where its level varies from 10.8 to 11.8) during 2004-2005 (Table 2c). No pronounced seasonal variations were recorded during the study period (Fig 4c.).
The Calcium levels of the ground water samples were comparatively more or less similar to the corresponding site’s surface water samples during the study period. They were higher in site 2 followed by other sites (Table 4a).

**Magnesium (mg/l):**

The average Magnesium levels in the surface water samples in the study sites 1 to 4 showed more or less similar amount of Magnesium content (2.6-3.6 in 2004-2005; 2.3 – 3-1) during the study period. No mean annual variation in Magnesium levels were recorded during the study period in the study sites. The average Magnesium levels were found to be slightly higher in the study sites, 5 and 6 ranging from 4.4 and 5.3 respectively during 2004-2005 than 2005-2006 where it ranged from 4.2 and 3.7 respectively (Table 2c). Magnesium content was comparatively higher in winter season than others during the study period, while during summer and winter its level was remained more or less same (Fig. 4c).

The Magnesium levels of the ground water samples were comparatively lower to the corresponding site’s surface water samples during the study period in the range 1 to 1.9. They were higher in sites 1 and 2 followed by other sites (Table 4a). The annual variation in Magnesium level recorded did not follow any specific pattern.

**Sodium (mg/l):**

The average Sodium levels in the surface water samples ranged between 4.6 to 6.6 in the year 2004-2005, while the same was 4.5 -6.6 in 2005-2006 . Minimum values of Sodium were recorded in site 1 (4.5 in 2004-2005; 4.6 in 2005-2006) and the maximum in site 2 (6.6), while other study sites recorded lower values than the study site 2 during the study period. No mean annual variation was recorded among the study sites during the study
period (Table 2c). The trend in seasonal variation was not prominent among the study sites except in site 5 and 6 during the rainy season in 2005 – 2006, compared to other seasons (Fig. 4c).

The Sodium levels of the ground water samples were comparatively higher to the corresponding site’s surface water samples during the study period. They were in the range 5.5 to 15.6 in all the study sites. The annual variation recorded to be higher during 2004 – 2005 ranging from 10.6 to 15.6 and during 2005 – 2006 it ranged between 5.5 to 6.5 (Table 4a).

Potassium (mg/l):

The average Potassium levels in the surface water ranged between 0.9 and 1.2 among the study sites during the study period and no mean annual variation in Potassium levels were recorded during the study period (Table 2c). The seasonal variation did not follow any specific trend among the study sites during the study period (Fig. 4c).

The Potassium levels of the ground water samples were also comparatively higher to the corresponding site’s surface water samples during the study period. They were in the range of 0.93 to 2.35 in all the study sites (Table 4a).

HEAVY METALS:

In the present investigation the heavy metals such as, Mn, Cr, Zn, As, Cd, Pb, Fe, Cu and Ni were analyzed. However, only Fe, Zn, Cu, Pb, Cr, Ni were detected and Mn, As, Cd were absent in the surface water samples of the river Disang. In ground water, Fe, Zn, Cu, Ni were detected others were absent along the course of river Disang. The results are presented in Tables and Figures.
Iron (mg/l):

The average iron levels in the surface water samples ranged from 0.22 to 0.83 among the study sites during the study period. Comparatively higher average iron levels were recorded in sites 2 followed by site 3 and 4 respectively and then gradually declined and recorded close in minimum in site 6 and the least values were recorded in site 1 (0.22 in 2004 -2005 and 0.26 in 2005 - 2006). The mean annual variation was comparatively higher during 2004 – 2005 (0.22 to 0.83) than in 2005-2006 (Table 3a). The average iron levels were comparatively higher during winter during the study period, while in 2004 – 2005 rainy season also followed similar trend in sites 2, 3 and 4 compared to summer (Fig. 5a).

The levels of iron in the ground water samples were also comparatively higher to the corresponding site's surface water samples during the study period. They were in the range of 1.2 to 1.6 in all the study sites though in 2005 – 2006 it was much lower compared to 2004 - 2005 (Table 4b).

Zinc (mg/l):

The average zinc levels in the surface water ranged from 0.03 to 0.285 in 2004 – 2005 and 0.008 to 0.25 in 2005 – 2006 among the study sites. Average zinc levels were comparatively higher in sites 2 (0.21 and 0.13), 3 (0.29 and 0.16) and 4 (0.21 and 0.25) in 2004-2005 and 2005-2006 respectively. The average zinc levels were lower in site 1, 5 and 6 ranging from 0.008 to 0.065. No significant mean annual variation was recorded during the study period (Table 3a). The seasonal variation was comparatively very less during 2005 – 2006 however in 2004 – 2005 the season variation did not follow any specific trend though it was recorded to be, higher in summer during 2004 – 2005 and winter, during 2005 – 2006 (Fig.5a).
The levels of Zinc in the ground water samples were also comparatively higher to the corresponding site's surface water samples during the study period. They were in the range of 0.27 to 0.41 though in 2005 – 2006 it was much lower compared to 2004 – 2005 (Table 4b).

Copper (mg/l):

The average Copper levels were found to be generally either very low or below the detection level in sites 1, 2 and 6, while in sites 3, 4 and 5 they were low but consistent throughout the study period (Table 3a). Average Copper levels in site 1 were very low during rainy season (June-August) while, rest of the year they were below the detection level in both the years (Fig. 5a).

The levels of Copper in the ground water samples were also comparatively higher to the corresponding site's surface water samples during the study period. They were in the range of 0.03 to 0.10 in all the study sites, though in 2005 – 2006 it was much lower compared to 2004 – 2005 (Table 4b).

Nickel (mg/l):

The average Nickel levels were found to be generally either very low or below the detection level among the study sites throughout the study period. The average Nickel levels were below the detection level in both the years (Table 3b, Fig. 5b).

The levels of Nickel in the ground water samples were also comparatively higher to the corresponding site's surface water samples during the study period. They were in the range of 0.2 to 0.47 in all the study sites. However it was detected only during 2004 – 2005 (Table 4b).
Chromium (mg/l):

The average Chromium levels were below the detection level in site 1 in both the years. Its concentration was high in sites 2, followed by other study sites and the minimum average Chromium values was recorded in site 6. The mean annual variation was recorded to be higher in 2005 – 2006 (Table 3b). The seasonal variation was recorded to be higher during winter in 2005 – 2006 (Fig. 5b).

Lead (mg/l):

The average level of Lead was found to be very low or below the detection level in site 1 while in site 2, 3 and 4 level of lead could be detected at lower level ranging between 0.0002 and 0.0005. However, it was more pronounced in down stream i.e. at site 5 and 6 ranging between 0.002 and 0.019. The mean annual variation was higher during 2004 – 2005 (Table 3b). Seasonal variation did not follow any specific trend though during rainy and winter it was recorded to be higher whenever Lead level was detected during the study period (Fig. 5b).

Assessment:

Both surface and ground water quality of Disang river found to be as per the norms laid down by BIS (1991: 10500) and WHO (1993) for drinking water. However, turbidity exceeded the limit for both surface and ground water (Table 7a, 7b)

TOTAL DENSITY, DISTRIBUTION AND SEASONAL VARIATION OF PLANKTON:

In the present study total density (no./ml), distribution and seasonal variation of planktons in the surface river water samples along the course of
Disang river in Namrup Sibsagar District of Assam during the years 2004-2005. The results are presented in Tables and Figures.

**Phytoplankton density (No/ml):**

Total and mean annual densities (no. /ml) of phytoplankton were markedly higher (276 - 3392) in 2005-2006 compared to 2004-2005 (175-1787) except in site 2 where no significant variation (47 in 2004-2005 and 54 in 2005-2006) was recorded. Least total and mean densities (3.91 to 4.5 respectively) were found in site 2 during the study period. However, maximum phytoplankton densities were recorded in site 5 (1613 in 2004-2005 and 3098 in 2005-2006) and site 6 (1787 in 2004-2005 and 3392 in 2005-2006) during the study period (Table 5a).

**Phytoplankton distribution:**

It is found that among the total phytoplankton Chlorophyceae, Xanthophyceae, Bacillariophyceae, Myxophyceae and Englenophyceae family members were recorded. Total phytoplankton was markedly higher in 6 and 5 compared to other study sites. However the values were in decreasing order in 4, 3 and 2. Least number of algal groups recorded in Site 2 (Table 5a, 5b). Occurrence of total phytoplankton was comparatively low during winter while it was higher and or similar during summer and rainy season (Fig.7a & 7b)

**Chlorophyceae:**

In the present study Chlorophyceae was dominant in all the sites except in site 2. The species recorded was Trentepohlia, Chactophora, Colechacte, Odogonium, Spirogyra, Closterium, Cosmarium and Nitella. The Trentepohlia, Spirogyra and Odogonium were comparatively more in number. Among the study sites, abundance of Chlorophyceae was highest in S6
followed by 5 and 1. While, the least was in site 2 followed by 3 and 4. (Table-5b). Chlorophyceae was highest in number during summer and closely followed by rainy season, while it was least in winter months (Fig.7a). Mean annual density of Chlorophyceae was greater in 2005-2006 compared to 2004-2005 (Table-5b).

Bacillariophyceae:

In Bacillariophyceae, only *Navicula* was recorded. Among the study sites, abundance of Bacillariophyceae was highest in S6 followed by 5 and 1. While, the least was in site 2 then it gradually increased in site 3 followed by site 4 (Table-5b). Bacillariophyceae was highest in number during winter and closely followed by summer season (Fig.7a), while it was least in rainy season. Mean annual density of Bacillariophyceae was greater in 2005-2006 compared to 2004-2005 (Table-5b).

Xanthophyceae:

In the present study *Vaucheria* is the only species of Xanthophyceae was recorded. Abundance was found to be more in sites 5 and 6 followed by site 1. In sites 3 and 4 its abundance was found to be much lower compared to other study sites. However in site 2, Xanthophyceae was not found in the surface water samples (Table-5b). Xanthophyceae followed similar seasonal trend as that of Chlorophyceae (Fig.7a).

Myxophyceae:

In the present study *Oscillatoria* is the only species of Myxophyceae was recorded. Abundance of Myxophyceae was more in sites 6 followed 1 and 5 respectively (3.5 to 8.1; 42 to 97). It was rare in the sites 3 and 4 while it was absent in site 2. Mean annual density of Myxophyceae was more or less similar during the study period (2004-2006). (Table-5b) Myxophyceae was
highest in density during summer season and closely followed by rainy season, while it was least in winter months (Fig. 7b).

**Euglenophyceae:**

- In the present study *Euglena* is the only species of Euglenophyceae was recorded. Abundance of Euglenophyceae was more in sites 5 and 6 followed by site 1 (2.08 to 3.33; 25 to 40). It was rare in the sites 3 and 4 while it was absent in site 2. Mean annual density of Euglenophyceae was greater in 2004-2005 compared to 2005-2006 (Table-5b). Euglenophyceae was highest in density during rainy season and closely followed by summer, while it was least in winter months (Fig.7b).

**Distribution of plankton within the study sites:**

Distribution of plankton within the study site 1, indicates that Chlorophyceae was the dominant family followed by Myxophyceae, Xanthophyceae, Bacillariophyceae and the least was Euglenophyceae. Higher zooplankton density was recorded during the year 2005-2006 compared to 2004-2005. In the study site 2, only two phytoplankton families were recorded. However, 52% of them was Bacillariophyceae and the rest was Chlorophyceae. In the study site 3, besides Chlorophyceae the other co-dominant plankton was Bacillariophyceae 13.3% followed by Xanthophyceae, Myxophyceae and Euglenophyceae respectively. The study site 4 also followed similar trend as that of site 3, but the percentage of Bacillariophyceae declined to about 7%. In site 5 and 6 about 90% of the plankton was Chlorophyceae while 5% represented by Xanthophyceae, and the rest were Myxophyceae and Euglenophyceae (Table 5c – 5h, 6a; Fig.6a – 6c).
Zooplankton:

During the study period total plankton recorded in all the study sites were 7231 in 2004 and 11697 in 2006 (no./ml). Out of these about 60% in 2004 and 26% in 2006 were phytoplankton and the rest was contributed by the zooplankton.

Average zooplankton density was comparatively lower and almost similar in site 1 (8) and 2 (7.6) but it increased markedly in sites 3 (31) and 4 (67). They get stabilized in site 5 (66) and 6 (56) during the year 2004 – 2005. However, 2005 – 2006 the marked increase in zooplankton density was recorded in site 5 (76). But, it get stabilized in site 6 (54). Average zooplankton density was 40 in site 1, while it was 29 in site 2 and 3 and declined in site 4 (24). Zooplankton was recorded more in 4, 5 and 6th study sites, while the least was in 1 and 2. Zooplankton was comparatively lower during summer in 4, 5 and 6 while just opposite trend was observed in 1, 2 and 3 study sites (Table 6a, 6b).

However algal density a in both the years study site 2 showed the least algal density while in other study site the trend in seasonal variation was similar except total algal density where 2005 – 2006 recorded double the values compared to 2004-2005.

PHYSICO-CHEMICAL PARAMETERS AND PHYTOPLANKTON

Correlation and Multiple Regression analysis was performed between various physico-chemical parameters and phytoplankton. The results are presented in Appendices I and II.
At different seasons: (Appendix I A – O)

Chlorophyceae:

Correlation studies revealed negative relationship between Chlorophyceae and factors such as turbidity and temperature, while conductivity and total solids showed weak but positive relationship. Multiple regression analysis results also showed weak but positive relationship between Chlorophyceae and the parameters studied i.e. temperature, turbidity, total solid and conductivity. The $R^2$ values (vig.0.885 in pre-monsoon, 0.830 in monsoon, 0.699 in post-monsoon, 2004 and 0.924 in pre-monsoon, 0.839 in monsoon and 0.865 in post-monsoon, 2005) indicate strong relationship for Chlorophyceae on one side and pH, Acidity, carbonate, bicarbonate, phosphate, Ammonial nitrogen, chloride etc. on other side for all the seasons in both the years 2004 and 2005. A strong positive relationship was found between Chlorophyceae and the metals in all the seasons of 2004. This is evidenced by high $R^2$ values viz. 0.853 in pre-monsoon, 0.795 in monsoon and 0.820 in post-monsoon, 2004 but weak for the year 2005.

Bacillariophyceae:

Positive correlation was found between Bacillariophyceae and the chemical parameters. ($R^2$-values ; 0.767 in pre-monsoon, 0.982 in monsoon, 0.775 in post-monsoon2004 and 0.929,in pre-monsoon, 0.836 in monsoon and 0.816 in post-monsoon, 2005. Similarly a moderate to strong relationship between Bacillariophyceae on one side and the metals on the other side.($ R^2$ values; 0.772 in pre-monsoon, 0.784in monsoon and 0752 in post-monsoon 2004 and 0.534 in pre-monsoon 0.528 in monsoon and 0.50 in post-monsoon, 2005)
Xanthophyceae:

The correlation coefficients of Xanthophyceae with conductivity, total solid, turbidity and temperature in pre-monsoon and post-monsoon in the year 2004 are found to be negative, but in monsoon season all the parameters showed positive correlation. Considering the regression results we have seen that there exists a strong relationship between Xanthophyceae on one side and the chemical parameters on the other side (R²-values viz. 0.827 in pre-monsoon, 0.981 in monsoon, 0.579 in post-monsoon, 2004 and 0.878 in pre-monsoon 0.791 in monsoon and 0.819 in post-monsoon, 2005). The regression results revealed that only for monsoon, 2004 post-monsoon, 2004 and pre-monsoon, 2005 have strong relationship between Xanthophyceae on one side and metals on the other side.

Myxophyceae:

Negative correlations were found for Myxophyceae in response to conductivity, turbidity, total solid and temperature for pre-monsoon and monsoon 2004 and for post-monsoon in the year 2005 and in others it indicated weak but positive relationship. From the regression results it was found a strong relationship between Myxophyceae on one side and the chemical parameters on the other side (R² values viz.0.717 in pre-monsoon, 0.980 in monsoon, 0.858 in post-monsoon, 2004 and 0.871 in pre-monsoon, 0.665 in monsoon and 0.920 in post-monsoon, 2005). Moderate to weak relationship was found between Myxophyceae and metals.

Euglenophyceae:

In the present study Euglenophyceae was found in S-5 and S-6. In S2, it was nil and in S3 and S4 only few were recorded in few months of the study
period. Therefore, the statistical analysis was done on the basis of S5 and S6 only.

At different study sites: (Appendix II A₁ – J₁)

Chlorophyceae

Study Site 1:

The high $R^2$ values in (viz. 0.989 in S3; 0.914 in S5; 0.859 in S4; 0.837 in S6 and 0.759 in S2) indicated strong relationship for Chlorophyceae on one side and physico-chemical parameters on the other side, while a weak but positive relationship in S1 was indicated. A group of seven highly positive factors viz. sodium, turbidity, total solid, pH, BOD, magnesium and phosphate are together responsible for 20.8% of algae variation. Among the above parameters phosphate is more significant as 1 unit change in its concentration change 31 unite in algae number. Multiple regression analysis (MRA) revealed that sodium alone contributes 3.1%, turbidity 3% and magnesium 1.4% of algae variation. Only Zn and Fe was found in the detection level, Cu was found only in five different months with a very low concentration, so only Fe and Zn were considered for statistical analysis in site1. The heavy metals Fe and Zn contributed to 2.8 % of algae variation. Fe showed the direct relationship but Zn showed the inverse relationship.

Site-2:

pH, Temp., carbonate, sulphate, ammonical-nitrogen, total hardness and sodium together contribute 18.5% of algae variation. Among the above parameters carbonate alone contributes 13.4% of algae variation and one unit change in its concentration will change 67 units of algae number. The parameters like total hardness, sodium and temperature had contributed less than 1% in algae variation. None of the heavy metals showed any marked
effect on Chlorophyceae growth except Ni. The results indicated a weak relationship between Chlorophyceae and heavy metals. Ni contributed to 2.4% in algae growth. It was also seen that Pb contributed to 0.1%; Cr contributed to 5.7%; Cu contributed to 0.1% and Fe contributed to 1.7% of variation in algae number.

Site-3:

Positively co-related parameters contributed only 21.9% of algae variation and dissolved oxygen contributed more among all. Regression analysis indicated that positively co-related parameters influence collectively on algae variation. In sta.-3, Cu, Pb and Zn were positively correlated. Low R² values (9.5) indicated weak relationship of Chlorophyceae on one side and heavy metals on other side. Cu, Pb and Zn individually contribute to 1.2%, 2.4% and 0.2% of variation.

Site-4:

Water, temperature, pH, sodium, ammonical-nitrogen, total alkalinity, sulphate and dissolved oxygen were related to the variation in Chlorophyceae number to the extent of 22%. pH, alone contributed 11.3% and ammonical-nitrogen contributed 8.2% .Heavy metals showed good correlation with Chlorophyceae than in S2 and S3. Pb, Cr, Ni, Cu, Zn and Fe collectively contributed to 19.7% of variation. Cu and Fe positively correlated while, Cu contributed to 9.17 %, Fe contributed to 0.1% variation on algae growth, which is evident by MRA result.

Site -5:

In the MRA, only conductivity, chloride, sulphate, dissolved oxygen, calcium and magnesium were found positively co-related and contributed to 36% of variation in Chlorophyceae. Conductivity and sulphate individually
contributed 12.5% and 11.1% respectively in Chlorophyceae variation. Among the above parameters conductivity is more significant as 1 unit change in its concentration may change 48 units in algae number. Similarly, Fe contributed to 7.2% and Cu contributed to 0.3% of variation in the Chlorophyceae density

**Site-6:**

Phosphate, total hardness, pH, potassium and sodium together contribute 75.5% of algae variation. Among the above parameters phosphate contributed 22.1% and one unite change in its concentration will change 18 units of algae numbers. Sodium contributed 27.8% and potassium contributes 10.8% of Chlorophyceae density. Heavy metals showed good correlation with Chlorophyceae like that of S4

**Bacillariophyceae**

**Site1:**

After step wise regression among the positively correlated parameters it is found that, variables together accounted for 21.6% of Bacillariophyceae variation. It was also found that except turbidity, dissolved oxygen and bio-chemical oxygen demand and other physico-chemicals factors found relatively less important in distribution of Bacillariophyceae as each of them contributed less than 1%. Less turbidity is an important factor for distribution of Bacillariophyceae as evidenced by 13.9% variation. Dissolved oxygen and bio-chemical oxygen demand account for 3.5% and 3.8% variation Calcium also accounted for 3.6% of algae variation. Fe and Zn are taken for MRA, as other heavy metals were present not in detectable concentration levels. Fe contributed to the extent of 6.6 % of variation and Zn contributed to 2.7 % variability but inversely correlated with Bacillariophyceae, while Fe contributed to 0.1 % variability but directly correlated.
Site-2:

In station-2, magnesium, dissolved oxygen, sulphate, bio-chemical oxygen demand, calcium, potassium, ammonical-nitrogen, turbidity and total solid account for 37.6% of Bacillariophyceae variation. Dissolved oxygen alone contributed to 9.1% of algae variation. Ammonical-nitrogen contributed to 9%. Total solids and turbidity contributed to 1.9% of algae variation. In correlation matrix Pb, Cu, Zn, Fe are negatively correlated and from the stepwise multiple regression analysis it is evident that, Pb, Cr, Ni, Cu, Zn and Fe influenced to the extent of 14 % variation in Bacillariophyceae. Pb contributed to 0.6 %; Cr contributed to 3.1 %; Cu contributed to 2.4 %. Zn contributed to 6.9 % and Fe contributed to 1.6% of variation.

Site-3:

Temperature, conductivity, turbidity, pH and dissolved oxygen were correlated to the variation of Bacillariophyceae to the extent of 20%. It is found that in group they influenced the growth of Bacillariophyceae. Conductivity contributed 6.2% and turbidity contributed to 4.5% of algae growth. Cr, Fe, Ni, Pb are negatively correlated and MRA revealed that Cr, Cu, Pb, Ni, Pb, Fe and Zn collectively contributed to 25 % of Bacillariophyceae variation. Fe alone contributed to 22.9 % of variation and Cu contributed to 1.3 % of variation. Ni contributed to 4.2 % of variation but negatively correlated.

Site-4:

Sodium, dissolved oxygen, total alkalinity, ammonical- nitrogen sulphate and total hardness influenced 33% of variation of algae number. Sodium accounted for 9.9% and ammonical-nitrogen contributed 20.8% of algae variation. Cu positively correlated and Pb, Cr, Ni, Zn and Fe were negatively correlated. The Pb, Cr, Ni, Cu, Zn, Fe together accounted for the
variation to the extent of 18.6 % Individually Zn positively correlated and one unit change in concentration will change 77 units of algal density as evident by stepwise regression analysis.

Site-5:

Total hardness, potassium, sodium, phosphate, total solid pH and sulphate were accounted the variation of Bacillariophyceae to the extent of 83.7% as evident from step wise regression analysis. Total hardness contributed to 6%, sodium contributed to 51% and potassium contributed 11.3% of algae growth. Similar results as that of S4 were found with heavy metals in this site.

Site-6:

Total hardness, potassium, sodium, phosphate, pH, total solid and sulphate contributed 62.3% of algae variation and sodium alone accounted for 20.4%, total solids 11.7% and total hardness 15.8% of algae growth. Here in this site also similar results of correlations analysis (as was found in S4 and S5) were found.

Thus, in present study, Bacillariophyceae prefered turbidity in S1and 3, dissolved oxygen in 2, ammonical-nitrogen in 4, and sodium in 5 and 6. Alkaline pH is also contributed in the growth of Bacillariophyceae.

Xanthophyceae:

Site-1:

A group of six highly positive factors, turbidity, sodium, total solids, magnesium, phosphate and pH are together responsible for 37.6% of algae variation. Among the above parameters sodium alone contributed 29.9% and magnesium contributed only 4% of algae variation. Phosphate contributed only 2.1% and others below 1% of algae variation as shown by regression
analysis. Zn and Fe contributed to the extent of 9.7 % of variation, and Zn, alone contributed to 9% of algae variation.

**Site-2:**

Xanthophyceae was not found.

**Site-3:**

Positively correlated bicarbonate, magnesium, sodium, sulphate, ammonical-nitrogen, BOD and pH contributed 24.8% of algae growth. Among the above parameters only ammonical-nitrogen contributed 11.2% and magnesium 10.9%. In the correlation matrix Cu and Zn were negatively correlated and Cr, Ni, Cu, Pb, Zn and Fe collectively contributed to 15.6 % of Xanthophyceae variation. Fe contributed to 2.2 % of variation and one unit change in concentration will change 52 units of algae number. Pb contributed to 0.1%; Cr contributed to 0.3%; Ni contributed to 7.3%; Cu contributed to 2% and Zn contributes to 5.5% of algae variation.

**Site-4:**

The positively correlated parameters such as pH, temperature, sodium, total hardness, sulphate, dissolved oxygen and turbidity contributed 14.3% of algae growth as suggested by regression result. Dissolved oxygen contributed 11.5% of algae growth. Pb, Cr, Cu, Zn, and Fe collectively contributed to 22.6% of Xanthophyceae variation, but individual contribution was very poor, as evident by the MRA.

**Site-5:**

Regression value was very low, among the positively correlated parameters viz. conductivity, dissolve oxygen and total solids contributed only 3.3% of algae growth.
Site-6:

Positively correlated factors such as pH, chloride, bicarbonate, temperature, sulphate, ammonical-nitrogen and dissolved oxygen contributed 17.8% of algae growth. Chloride contributed 6.9%; bicarbonate contributed 4% and ammonical-nitrogen contributed 2.3% of algae growth as suggested by regression value. In all the sites (S4 to S6) heavy metals collectively contributed to 22.6% of algae variation, as found in regression analysis.

From the foregoing account it is clear that at station-1, sodium, station-3 ammonical-nitrogen, and station 4, 5, 6, dissolved oxygen bring larger variation in the growth of Xantophyceae. Individually not a single metal showed significant correlation with Xantophyceae, but collectively they showed good correlation.

**Myxophyceae**

Site-1:

After step wise regression among the positive correlated parameters it is found that variable together account for 23.8% of Myxophyceae variation. It was also found that except pH, dissolved oxygen, phosphate and other physico-chemicals contributed less than 1%. pH, phosphate and dissolved oxygen accounted for 20.7%, 1.4% and 1% variation. Pb, Cr, Ni, Cu, Zn and Fe collectively contributed to 15.6% of variation in algae growth. Iron contributed to 2.27% of variation in algae growth and one unit change in concentration in iron will bring about 52 units of change in algae density. MRA revealed that Ni contributed to 7.3% in algae variation. Zn contributed to 5.5% and others contributed to below 1%.
Site-5:

Dissolved oxygen, total solids and conductivity were the positively correlated and accounted for only 4.8% of Myxophyceae variation. Cr, Ni and Cu were positively correlated. MAR revealed that Zn and Fe accounted for 2.1 % and 4.2 % of variation and others contributed to less than 1 %.

Site-6:

Total solids, total hardness, pH, bicarbonate, chloride, sulphate and BOD together contributed 35.5% of algae variation. Among the above parameters bicarbonate contributed 20.6% and one unit change in its concentration will change 22 units of algae numbers. Total solids contributed 5.6% and BOD contributed 1.6% of Myxophyceae variation. Hardness of water has a positively correlated with the growth of Myxophyceae. Cu is negatively correlated. MRA revealed that Fe and Pb individually contributed to 7.2 % of variation. Ni alone contributed to 49.5 % of variation and Cr contributed 3.3 % and Zn 1.9 %. Pb, Cr, Ni, Cu, Fe and Zn collectively contributed to 69.4 % of variation in Myxophyceae.

It is suggested that in S1, pH, dissolved oxygen in S5 and in S6 bicarbonate play an active role on the growth of Myxophyceae. The above statistical study indicated that, Fe, Cr, Zn and Ni influence the growth of Myxophyceae.

Englenophyceae

In the present study Englenophyceae was found in S-5 and S-6. In S2, it was absent and in S3 and S4 only few were recorded in few months of the study period. Therefore the statistical analysis was done on the basis of S5 and S6 only.
Site-5:

A group of six highly positive factors, pH, bicarbonate, ammonical-nitrogen, total hardness, conductivity and turbidity are together responsible for 8.5% of algae variation. Among the above parameters total hardness alone contributed to 3.5% and ammonical-nitrogen contributed only 1.8% of algae variation. One unit of change in concentration will change 51 units of Englenophyceae number. Contribution of pH is only 1.6% and others less than 1.6% of algae variation as suggested by regression. In S5, Pb, Cr, Ni, Cu, Zn and Fe collectively contributed to 15.5 % of Englenophyceae. Pb, Cr Cu were positively correlated; Pb contributed to 6.2 % of variation; Fe contributed to 6.5 % and Ni contributed to 1.3 % of variation in the growth of Englenophyceae in S5.

Site-6:

A group of nine positively correlated factors like, total alkalinity, bicarbonate, chloride, ammonical-nitrogen, dissolved oxygen, BOD, total hardness, calcium and magnesium were together responsible for 36.5% of algae variation. Among the above parameters bicarbonate alone contributed 12.1% and total hardness contributed 7.2% of algae variation. Calcium contributed to 0.9% and Magnesium 0.7% of algae variation. Except Pb and Zn other metals i.e. Cr, Ni, Cu, Fe are negatively correlated. Multiple regression analysis indicated good relationship with the better $R^2$ value i.e. 35.5 between heavy metal in one side and Euglenophyceae in other hand. Zn alone contributes to 22.1% of algae variation, Cu contributes to 10.5% of variation and Pb contributes to 2.1% of variation in the growth of Englenophyceae.
From the foregoing account it is clear that at S-5, total hardness and in S-6 bicarbonate brings larger variation in the growth of Englenophyceae. Lead and zinc played significant role in the growth of Englenophyceae.

It is evident that Fe, Cu and Zn influenced the growth of most of algal groups. Role of iron is significant in case of Chlorophyceae, Bacillariophyceae, Xanthophyceae and Myxophyceae.