CHAPTER 4(a)

DISCUSSION

a) Biological
A. BIOLOGICAL PARAMETERS

The present investigation was undertaken on diatoms as pollution indicators of two freshwater lakes of Kashmir. The two lakes viz; the Anchar and the Dal lake are drainage type of lakes with perennial inflow and outflow channels. The two lakes are connected through a channel called Nallah Amir Khan and being situated close to Srinagar, are exposed to typical urban environmental conditions.

The present study aims at the elucidation of the various ecological aspects of the diatom community viz.-a-viz. water chemistry. Diatom abundance and species composition was assessed in the planktonic, epiphytic and epipelic material in the two lakes. It was observed that the diatom populations colonising different substrates within the same lake bore many similarities in their taxonomic composition but differed in their numerical values and the dominant taxa. This quantitative variation can be related to the specificity of
the substratum and the micro-environment prevailing on each substrate.

The investigation describes the freshwater diatom collections representing 100 taxa from 34 genera. Of these, 4 species belonged to centric and 96 forms to pennate diatoms. The centric diatoms represented two families namely Discoideae and Biddulphioidae, while the pennate forms were distributed among seven families namely Fragilarioideae, Eunotioideae, Achnanthioideae, Naviculoideae, Epithemioideae, Nitzschiioideae and Surirelloideae (Table: 10).

A i. Planktonic diatoms:

The total number of planktonic diatom species recorded in the two investigated lakes was 91. Eighty six species each were recorded in the Dal lake and the Anchar lake with eighty one species being common to the investigated lakes.

The predominant planktonic diatom species worked out on the basis of importance value of the species are Synedra ulna (Nitz.) Ehr., Fragilaria capucina Desmaz., Nitzschia acicularis W. Sm., Fragilaria construens (Ehr.) Grun., F. crotonensis (Ed.) Kitt. and Navicula spp. Bory. The importance values of different diatom species clearly demonstrate that Synedra ulna (Nitz.) Ehr. is by far the most dominant planktonic diatom with Fragilaria capucina Desmaz. close behind. The high importance values reflect the wide range of tolerance of these two diatoms which transcend the microecological barriers in the two lakes and dominate the diatomaceous flora of the phytoplankters. Nitzschia acicularis W. Sm., Fragilaria construens
Table 10: List of the diatoms species recorded on all the three substrates viz; Planktonic, Epiphytic and Epipelic.

Division: BACILLARIOPHYTA.

A. CENTRALES

I. Discoidae.
   
   *Cyclotella* sp. Kutz.

   *Melosira granulata* (Ehr.) Ralfs.

   *Coscinodiscus* sp. Ehr.

   ii. Biddulphiodeae.

   *Chaetoceros* sp. Ehr.

B. PENNALES

I. ARAPHIDEAE

   a. Fragilarioideae

   *Asterionella formosa* Hassall.

   *Ceratoneis arcus* (Ehr.) Kutz.

   *Diatoma elongatum* Agardh.

   *Diatoma hiemale* (Lyngb.) Heib.

   *Diatoma vulgare* Bory.

   *Diatomella* sp. Grev.

   *Fragilaria arcus*

   *F. capucina* Desmaz.

   *F. construens* (Ehr.) Grun.
F. vaucheriae (Kutz.) Peterson.

Meridion sp. (Gruv.) Ag.

Synedra sp. Ehr.

S. acus (Kutz.) Grun.

S. capitata Ehr.

S. ulna (Nitz.) Ehr.

Tabellaria fenestrata (Lyng.)

II RAPHIDIOIDEAE

b. Eunotioideae

Eunotia sp. Ehr.

E. diodon Ehr.

E. faba (Ehr.) Grun.

E. gracilis (Ehr.) Rab.

E. lunaris (Ehr.) Grun.

E. pectinalis (Kutz.) Raben.

III MONORAPHIDEAE

c. Achnanthioideae

Achnanthes sp. Bory.

Cocconeis sp. (Ehr.) Grun

C. placentula Ehr.

C. thumensis (A.M. Mayer)
d. Naviculioideae

Amphora sp. Ehr.

A. bitumida Prowse

A. normanii Donk

A. ocellata Donk.

A. ovalis Kutz.

A. proteus Greg.

Anomoeoneis sp. Pfitzer.

Caloneis sp. Cleve.

Cymbella sp. Ag.

C. affinis Kutz.

C. cistula Hempr.

C. ehrenbergii Kutz.

C. gauroides Kutz.

C. lanceolata Ehr.

C. prostrata (Berk) Cl.

C. tumida Breb.

C. turgida (Greg.)

C. ventricosa Kutz.

Diploneis sp. Ehr.

Frustulia rhomboïdes (Ehr.) Detoni.

Gomphonema sp. Ag.

G. accuminatum Ehr.
G. a. var. coronatum (Ehr.) W. Sm.

G. augur Ehr.

G. constrictum Ehr.

G. geminatum (Lyngb.) Ag.

G. gracile Ehr.

G. intricatum Kutz.

G. lanceolatum Kutz.

G. olivaceum Kutz.

G. parvulum Kutz.

G. subtile Ehr.

Gomphoneis herculeanum (Ehr.) Cl.

Gyrosigma sp. Hassall.

Navicula sp. Bory.

N. cuspidata Kutz.

N. elegantoides Hustedt.

N. irides Ehr.

N. lanceolata Kutz.

N. radiosa Kutz.

N. rhyncocephala Kutz.

Pinnularia sp. Ehr.

P. gibba (Ehr.) Q. Mull.

P. legumens Ehr.

Pleurosigma sp. W.Sm.
Stauroneis sp. Ehr.
S. anceps Ehr.
S. phoenicenteron Ehr.

e. Epithemioideae

Epithemia sp. Breb.
E. argus Kutz.
E. sorex Kutz.
E. turgida (Ehr.) Kutz.
E. zebra (Ehr) Kutz.

Rhopalodia sp. O. Mull.
R. gibba (Ehr.) O. Mull.

f. Nitzchioideae

Nitzschia sp. (Hassall : W.Sm.) Grun.
N. acicularis W.Sm.
N. apiculata ( Greg ) Grun.
N. longissima ( Breb ) Ralfs.
N. linearis (Ag.) W.Sm.
N. obtusa W.Sm.
N. plana W.Sm.
N. sigmoidea ( Ehr.) W.Sm.

Hantzschia amphioxys ( Ehr.) Grun.
g. *Surirellioideae*

*Cymatopleura solea* (Breb) W.Sm.

*Surirella* sp. Turpin

*S. linearis* W.Sm.

*S. ovalis* Kutz.

*S. robusta* Ehr.
(Ehr.) Grun. and F. crotonensis (Ed.) Kitt. also show higher dominance as compared to other diatoms whose importance values are far less than the above mentioned dominant species. The observations are in consonance with those of Mir and Kachroo (1982) and Sarwar et al. (1996) who also reported the dominance of diatoms in the Valley lakes. The presence of above dominant species is indicative of the enriched status of the water body. Their presence in the lake waters is indicative of the fact that both the water bodies are organically polluted as they are planked with a number of floating gardens, paddy fields, orchards, drains from the catchment area and are also beset with other systems where organic matter is utilised / decomposed which finally finds its way into the aquatic system through leaching. Shetty et al. (1961), Singh (1961), Chaturvedi (1985), Prasad et al. (1988), Valecha and Bhatnagar (1988), Rushforth and Brock (1991), Varghese and Naik (1992) in their investigations have also impressed upon the utility of these species as the potential indicators of pollution and eutrophy.

The population density of diatoms, being four times higher in the Anchar lake than the Dal lake reflects the enriched status of the system and is indicative of its higher trophic status.

The seasonal peaks attained by the planktonic diatoms reflect their affinity for the cold to warm temperatures. The sites A, B and E showed diatom peak in spring, C and F in autumn and site D was unique in showing peak during winter. The sites A, B and E, being low to moderately exposed to
pollution, showed an early peak and affinity for moderate spring temperatures. The sites C and F, receiving huge quantities of pollutants, showed peak in autumn reflecting an affinity for moderate temperature. The site D, being an open water area, exhibited diatom peak during winter with extremely low temperatures. According to Lund (1965), abundance of diatom population in cold months is probably due to the fact that they are able to grow under the conditions of weak light and low temperature, both of which are less suitable for other algae. Zafar (1967) observed that cold months are more favourable for multiplication of planktonic diatoms in freshwater bodies. He contends that the preference of diatoms to the colder waters is partly due to the fact that their heavier bodies are better supported by denser (colder) water. Patrick (1948) has also emphasized the importance of temperature for the development of diatoms. In the present investigation also positive correlation of temperature with diatoms was observed. Decrease in temperature was accompanied with increase in the number of diatoms at the investigated sites of both the lakes. Similar observations have also been made by Sarwar et al. (1994) on planktonic diatom flora of a lacustrine habitat (Wular lake, Kashmir).

A ii. Epiphytic diatoms:

A total of 88 species of epiphytic diatoms were recorded from the two investigated macrophytes viz: Potamogeton lucens and P. crispus from the two lakes. 68 species were common to both the macrophytes with almost identical representation of 85 (P. crispus) and 82 (P. lucens).

On the basis of importance values, the predominant epiphytic
The enriched nutrient status of the two lakes is reflected in high abundance of the epiphytic diatoms. Sarwar (1991a) related the nutrient enrichment of the Dal lake to the dominance of the forms which were also reported in the present investigation viz., Achnanthes, Cocconeis, Cymbella, Fragilaria, and Navicula sp. Similar observations have also been made by Kawoosa (1985) in Ahansar, Gilsar, and Khushalsar lakes which are all moderate to highly eutrophic lakes of the valley.

Significant variations were observed in population densities of epiphyton that colonised Potamogeton crispus and P. lucens within the same lake. On Potamogeton crispus, the peak development of diatoms was
January, 94 (Anchar) and December, 93 (Dal) while on *P. lucens*, the highest diatom population density was recorded in April, 94 in both the lakes. This may be due to the conditions in the microhabitat of the substrate which determines the dominance and abundance of the flora.

The dissimilarities in the population density colonising different substrates of the same lake points to the fact that the influence of the substrate cannot be completely ruled out. Young (1945) also observed that the substrate does influence the community structure and population density of epiphyton. This suggests that the nature of the substrate definitely has an influence on epiphyton community size and composition.

The seasonal population density values on the two macrophytes also showed variations. *Potamogeton crispus* showed highest population density during winter and lowest in summer while *P. lucens* registered seasonal peak development during spring and lowest in summer and autumn. The variation on seasonal basis can be attributed to the fluctuations in the microclimate of each substrate. The peak development of epiphyton during winter/spring is due to the preference of diatoms for low to moderate temperatures as they are sensitive to high summer temperature. The abundance of diatoms during low temperature can also be related to the possible release of metabolites from the macrophytes at the time of senescence and when decay sets in. The results are compatible with those of woosa (1985) who also reported highest epiphyton densities on decaying macrophytes in spring and winter. With increase in light intensity and
temperature and peak growing season of macrophytes, the densities start decreasing as has been observed during the present investigation when low densities were recorded in May, 93 for both macrophytes in the investigated lakes.

Sarwar (1985) also reported high diatom population density during winter and spring on different natural and artificial substrates in the Dal, Anchar and Waskur lakes and related its dominance to low temperature and weak light intensity prevailing during this period in Kashmir. The relationship between growth cycle of macrophytes and temperature and low light intensities has also been recorded by Sarwar (1987) in his investigations on the epiphytic algae flora of Ceratophyllum demersum. Mir (1995) also recorded higher population density values of epiphyton during winter when the substrate was in the decayed condition.

Roy (1955), Lund et al. (1963) and Vass et al. (1978) also reported the dominance of diatoms in the periphyton communities and related their peak development to the low temperature.

A iii. Epipelic diatoms:

A total of 92 epipelic diatom species were recorded from the two lakes (89 species from the Anchar and 82 from the Dal lake) with striking resemblance in species structure. The study revealed a diatom dominated epipelic community with a high standing crop of $2595 \times 10^3 \, \text{I / mg. d.wt.}$ in the Anchar lake and $2101 \times 10^3 \, \text{I /mg. d.wt.}$ in the Dal lake. The two lakes
are moderate to highly eutrophic and the physico-chemical nature of water and sediment has played a role in the determination of epipelon. This is again in consonance with works of Round (1985) who concluded that the composition of the epipelic flora is determined by the complex of factors of which the chemical composition of water is dominant, which interacts with the chemical and physical nature of the sediment.

Similar observation has been made by Moore (1974) in the epipelon of ponds of Canadian arctic diatoms which contributed 63% of the total species and at times could be 60-100% by cell numbers with a high standing crop.

The dominant epipelic forms in both the lakes (on the basis of importance values) were represented by *Syne*dra *ulna* (Nitz.) Ehr. followed subsequently by *Cymbella cistula* Hempr., *Fragilaria crotonensis* (Ed.) Kitt., *Nitzschia acicularis* W. Sm., *Navicula* spp. Bory and *N. rhyncocephala* Kutz.

The present investigation on epipelon also bring into focus almost the same dominant species as the planktonic and epiphytic diatom communities. Among these *Syne*dra, *Cymbella*, *Fragilaria*, *Nitzschia*, *Navicula* and *Cocconeis* are important as they have been observed as dominant forms for both the lakes and for all types of habitats. It is interesting to note that these forms have been found within both the lakes, particularly at regions which show nutrient enrichment, thus depicting their high preference for eutrophic waters. Similar observations has been made by Lund (1942), Round (1953) and Moore (1981).
Seasonally, peaks for epipelic diatoms were attained in winter in both the investigated lakes and lowest values were recorded during summer (Anchar) and autumn (Dal) with values of $723 \times 10^3$ l / mg. d.wt. and $593 \times 10^3$ l / mg. d.wt. respectively. The epipelic diatoms like the planktonic and epiphytic forms depicted an affinity for low temperature and very low light intensity at the bottom and more so for a sediment which was enriched by accumulation of a lot of decaying macrophytes during winter months. With increase in temperature and light intensity and decrease in decaying macrophytes viz. - a - viz. macrophytes dominance towards summer and autumn, there was concurrent decrease in diatoms in epipelon.

Counts of the diatoms in the sediment of the investigated lakes showed that most of the species which occurred in the overlying water column at sometime during the sampling period were alive in relatively large numbers in the bottom muds. Therefore, it is the diatom on the sediment which accounted for sudden increases in the numbers of different species in the water column. The study of diatoms on all the three assemblages thus revealed that the distribution of diatom flora recorded was not uniform which may be either due to difference in their dispersion ability or due to their differential tolerance limit to the pollution.

The most dominant diatom species on the basis of importance value was *Synedra ulna* (Nitz.) Ehr. which showed perennial existence in all the three habitats. The distribution pattern of *Synedra ulna* (Nitz.) Ehr. in the
three habitats, is the reflection of it having a wide adaptability and that it is highly tolerant to eutrophication. It is important that the species is found constantly as dominant form and as such can be regarded as a potent pollution indicator for both the lakes Lowe (1972) and Dickman (1975) also regarded Synedra ulna as pollution indicator.

Fragilaria capucina Desmaz., Nitzschia acicularis W. Sm., Fragilaria construens (Ehr.) Grun., Fragilaria crotonensis (Ed.) Kitt., Navicula spp. Bory and Amphora ovalis Kutz. were the predominant forms among planktonic forms while species like Navicula rhyncocephala Kutz., Cocconeis placentula Ehr., Achnanthes sp. Bory, Navicula spp. Bory and Cymbella ventricosa Kutz., as predominant epiphytic forms. The dominant epipelic forms were represented by Cymbella cistula Hempr., Fragilaria crotonensis (Ed.) Kitt., Nitzschia acicularis W. Sm., Navicula spp. Bory and N. rhyncocephala Kutz. All of these are known to inhabit eutrophic waters (Rawson, 1956; Round, 1964; Richardson, 1968; Lowe, 1974 and Hickman, 1976). Nitzschia sp. W.Sm. with its dominance at site A (Entry of Sind) where in input of lot of organic and inorganic segments brought in is reflected as characteristic of organically rich water by Richardson (1968) while Sommerfeld et al. (1975) considered it to be a typical eutrophic form.

Fragilaria capucina Desmaz. highest contribution to total planktonic diatom population was 57% (site A), 68.7% (site B), 54.7% (site C), 42.2% (site D), 68.6% (site E) and 30.8% (site F). The species showed better
representation at site A, B, D and E where moderate values of sodium, potassium, silicate, nitrate, ammonium and phosphorus were recorded while its least representation at the highly nutrient enriched sites (C and F) indicates that this species is an indicator of moderate to low pollution level and it shows poor representation at highly polluted areas (site C and F).

The species of *Navicula* mainly *Navicula rhyncocephala* Kutz., and *Navicula* spp. Bory were represented by larger numbers in epiphytic and epipelic flora. *N. rhyncocephala* Kutz., comprised about 35% of the total epiphyton on *Potamogeton crispus* in the Anchar lake. *Navicula* spp. showed luxuriant growth at site F where waters are hard and calcium rich. It may be concluded that the species has an affinity for calcium. Higher values of the species for the Anchar lake can be attributed to high macrophytes growth resulting in lower light intensity. Its presence at site F, an entry point of domestic sewage from the houseboat area and hotel Heemal, also reflect the pollution tolerance of the species.

*Fragilaria crotonensis* (Ed.) Kitt., when present, indicates a trend towards eutrophication or even pollution (Conner, 1977; Cassie, 1979). The species highest contribution was in planktonic diatom flora contributing 44% at site E which is flanked by human settlements and is exposed to open lavatories with discharge of sewage directly into the water at the site. The species has been regarded as an indicator of sewage pollution by Williams (1969), Stockner and Benson (1967) and Vollenweider (1968).
considered it as an indicative of eutrophy. The species contribution was 25% to the total epipellic flora in the Anchar lake during colder months indicating the species having an affinity for weak light and cold temperature and high nutrient enrichment as is reflected by highest values of conductivity, calcium and orthophosphate during winter.

*Cocconeis placentula* Ehr. dominated the epiphyton during summer and contributed about 88.7% (*Potamogeton crispus*) and 32.6% (*Potamogeton lucens*) in the Anchar and the Dal lakes respectively. The species has been described as summer encrusting communities (Butcher, 1932) which is in consonance with the present investigation as it dominated both the macrophytes during summer. Godward (1937) also observed the epiphyton community to be dominated by *Cocconeis placentula* Ehr. on the upper side of *Potamogeton* and *Elodea* leaves.

*Nitzschia acicularis* W. Sm. was the third dominant species in the planktonic flora and fourth in the epipellic diatom flora of the Anchar lake. This is attributed to its tolerance to high level of nutrient enrichment as the Anchar lake has an high electrolyte content. The species was ranked sixth tolerant in the list of 60 pollution tolerant genera given by Palmer (1969), Fjerdingated (1950) regarded it as saprophilus, occurring most generally in polluted waters.

The three diatom communities namely planktonic, epiphytic and epipellic were similar in terms of overall species composition excepting few species like (*Synedra* sp. Turpin,*) restricted to planktonic diatom flora,
Navicula irides Ehr. to epiphyton while Cymbella sp. Kutz., C. turgida Gerg., Epithemia argus Kutz., Diatoma hiemale (Lyngb.) Heib., and Navicula lanceolata Kutz. to epipelic flora, but the quantitative richest abundances of species occurred in the epiphyton ($39991 \times 10^3 \text{l}/10\text{mg.d.wt.}$) and epipelon ($2595 \times 10^3 \text{l}/250\text{mg.d.wt.}$). The quantitative variation can be related to the specificity of the substrate. The effect of the nature of the substrate on the diatom growth had little effect in qualitative terms while quantitatively there appears to be some effect which is in conformity with the finding of Hodgkiss and Tai (1976). Stevenson and Hashim (1989) also found stream to stream differences in species composition greatest for epilithon and epiphyton and least for plankton.

Shannon's diversity was highest in the Dal lake both in case of plankton (3.204) as well as epiphyton (3.766). Higher diversities may have resulted from reduced competition among organisms. The index was found to be greater than 2.5 for each lake. Therefore, water is best suited for the aquatic organisms on which most of the culturable fishes subsist as their food during various developmental stages. Gaur and Khan (1993) also arrived at the same conclusion while carrying out investigation on the biomonitoring of leachate reservoir receiving effluents from a thermal power plant.

William and Dorriss (1966) considered species diversity index values between 1 - 3 as indicator of moderate pollution. Applying this approach, then sites A and B of the Anchar lake and site E of the Dal lake are moderate polluted. Since, the values exceeded (>3) at site C and F, hence
these are designated as heavily polluted sites. Applying the approach of William and Dorriss, to the overall species diversity values of the Anchar and the Dal lake, then both the lakes fall under moderate pollution category as the diversity values are within 3.

Community co-efficient, used to determine the extent of similarity of diatom population among different habitats and lakes revealed that the communities were heterogeneous even if sampling was taken on monthly basis and the seasonal changes manifest themselves as differences in the population of species which is in consonance with the findings of Neushall (1967), Dayton (1970) and Tenore (1974) who also observed the seasonal differences as difference in the population of annual species or as changes in the abundances of perennials. The coefficient values were highest during winter on all the three substrates being 11.3%, 67.2%, 58.3% (Dal) and 16.8%, 75.7%, 58.3% (Anchar) in planktonic, epiphytic and epipelic diatom communities respectively and lowest during summer. The community thus exhibited seasonal changes but usually showed minor variations as they remained relatively more uniform.
b) Physico-chemical
B. PHYSICO - CHEMICAL PARAMETERS

The bio-physico-chemical factors around the lake change the water quality to a greater extent which ultimately affect the biological phenomenon. Besides, applying biological or ecological indicator method for interpreting the trophic status of aquatic ecosystem, direct interpretation can also be drawn by working out the physico-chemical features.

The climate of Kashmir shows four seasonal changes and has been classified as submediterranean type. Temperature is one of the important parameter in controlling both the total quantity and specific composition of the flora. The average water temperature values for the investigated lakes were more or less similar with maximum recorded during summer and minimum during winter. The peak growth of diatoms during the present study was in the temperature range of 2.5°C to 33°C which is in conformity with Patrick (1971) who gave the temperature tolerance range of diatoms from
Lower population density values of diatoms were observed during summer months which is in conformity with Zafar (1967) who also observed that the decreased diatom population in summer months is due to inhibitory influence of higher temperature. Lin (1972) also attributed the decline in the diatom population to rise in temperature. Water temperature thus had a discernible influence on the diatom assemblage and structure in comparison to water chemistry and it is for this reason that it can be called a quasi-seasonal response.

The two lakes differ in their morphometric features to an appreciable extent. The Dal lake has the maximum area while the Anchar lake has the minimum. The Dal lake is slightly deeper ($\bar{x} = 1.96 \text{ m}$) than the Anchar lake ($\bar{x} = 1.03 \text{ m}$). The ratio of the mean and the maximum depth was highest for Dal lake (0.63) and lowest for the Anchar lake (0.35) indicating the gentle slope of the lake basin.

Since the two lakes are shallow basined with gentle slopes, hence these fit in the eutrophic category of Naumann (1919) and Thieneman (1925) who distinguished two types of lake basins, deep and steep basins for oligotrophic lakes and shallow basins with gentle slope for eutrophic lakes.

Transparency may not always help in assessing the change in trophic status of the lake but this factor can nevertheless, be used as one more aid for such an evaluation. The fluctuations in the transparency values in the Dal lake were highest ranging from a minimum of 0.01 m to the maximum of 2.50 m ($\bar{x} = 1.27 \text{ m}$). In the Anchar lake, the values were lower, fluctuating.
between 0.01m to 1.60 m ($\bar{x} = 0.40$ m). Comparing, the average values of both the lakes, light penetration in the Anchar lake extends up to a lesser extent which may be partly due to the presence of suspended silt particles brought in by the feeding channels of river Sind and partly due to dense macrophytic growth. Lower values of transparency during autumn and winter coincided with the peak development of diatoms during the period which is in consonance with the finding of Jindal and Ghezta (1991) who attributed the plankton maxima to low penetration of light and to inflow of silt along with surface run-off water.

The average transparency value for the Anchar lake ($\bar{x} = 0.40$ m) was 1/3rd of the value recorded for the Dal lake. The investigated lakes are showing signs of rapid eutrophication. According to Yoshimura (1933), the lakes showing transparency values of 1.50 cm or less exhibit a tendency towards higher trophic levels. The values recorded for transparency in the investigated lakes indicate their eutrophic nature.

The investigation identified Hydrogen -ion concentration, specific conductivity, total hardness, calcium, phosphate and silicate as the most important factors influencing the distribution of diatom assemblages with nitrates, iron and magnesium having the second most important influence.

The Hydrogen -ion concentration of the investigated lakes remained on the alkaline range throughout the present study. The lake waters were well buffered with no sudden shifts in pH values. The diatom population in the present study preferred water with pH values > 7. Thus, on the basis of
Hustedt (1938 - 39) classification of diatoms based on the pH values, the diatoms grouped as alkaliibiontic forms - diatoms that prefer water with pH value >7. Peak development of diatoms during colder months coincided with lower pH values recorded during autumn (sites A, B & C) and winter (sites D, E & F). Low pH values during colder months is possibly due to low photosynthetic activity coupled with decomposition.

The specific conductivity can be utilized as one of the indications for assessing the trophic level of the lake. The conductivity values evinced a definite seasonal trend being higher during winter / spring and lower in summer. The higher average annual values of conductivity were recorded at site C ($\bar{x} = 488 \mu S$ at 25 °C) in comparison to other sites (site A ; $\bar{x} = 292$; site B ; 276 $\mu S$ at 25 °C) of the Anchar lake while in the Dal lake, the highest average annual values were registered at the site F ($\bar{x} = 229 \mu S$ at 25°C) in contrast to site D ($\bar{x} = 168 \mu S$ at 25 °C) and site F ($\bar{x} = 179 \mu S$ at 25 °C). Applying the system of classification based on conductivity values as given by Olsen (1950), various sites of the investigated lakes are grouped into:

a. Oligo - mesotrophic type with conductivity of 200 $\mu S$
   (sites D and E).

b. β - mesotrophic with conductivity of 200 - 500 $\mu S$
   (sites A, B, C and F)

Comparing, the average values of conductivity of both the lakes, it is evident that the Anchar lake has an high electrolyte content ($\bar{x} = 352 \mu S$ at 25 °C) than Dal lake ($\bar{x} = 192 \mu S$ at 25 °C) Consequently, the Anchar lake falls
under β-mesotrophic type and the Dal lake under Oligo-mesotrophic category of Olsen. Highest conductivity values during autumn and winter coincided with the peak development of diatoms during the period indicating positive relationship between the two. On the whole, the increased conductivity values in the Anchar lake is indicative of its tendency towards higher levels of eutrophication.

Dissolved oxygen is one of the important pollution parameters which measures the extent of organic as well as biological pollution load of the aquatic systems. Higher average dissolved oxygen values in the Anchar lake ($\bar{x} = 10.9 \text{ mg/l}$) and the Dal lake ($\bar{x} = 11.5 \text{ mg/l}$) indicate the degree of pollution. Higher values in both the lakes lead to increase consumers complaints especially regarding taste, odour and colour of the water. The maximum average dissolved oxygen concentration was observed in winter at sites B, C, D, E and F when water was cooler and decompositional processes within the water body and the activities of micro-organisms were lowered. However, at site A the maximum dissolved oxygen concentration was observed in summer, possibly due to the fact that site A being a feeding channel brings in a lot of siltload nutrients, sediments and animal wastes which increased microbial activity during the period. Anoxic condition recorded during autumn at the site C as a result of direct sewage dumping from various outlets at the site resulting in increased microbial activity during the period. Further, reduction in the oxygen content of Kashmir lake waters due to Salvinia cover has been reported by Zutshi and Vass (1971). Since Salvinia was
abundant at the site and the growth was so dense that it was difficult to make passage for the boat. Thus, the *Salvinia* cover was also one of the important factors responsible for low oxygen concentration at the site during autumn.

Average chloride contents of the Anchar (37 mg/L) and the Dal (30 mg/L) lakes were more or less similar. High concentrations of chloride show that lakes are receiving pollutants mainly in the form of excretes. Human and animal excretes contain on an average 5 grams chloride per litre. The average chloride contents was highest at site C of the Anchar lake (52 mg/L) which is attributed to washing down of the faecal matter, organic wastes and other hospital wastes directly into the lake at this site. High chloride contents of waters due to organic pollution and/or human/animal excretion have also been reported by Thresh et al. (1944) and Cole (1975).

On the basis of classification of lakes based on alkalinity values proposed by Moyle (1945), the Anchar lake falls under hard type with alkalinity values over 90 mg/L and the Dal lake in a medium hard category \( (\bar{x} = 90 \text{ mg/L}) \). Accordingly, the sites A, B, C and F are ‘hard type’ and site D and E as ‘medium hard type’. The investigated lakes fall under nutrient rich category as the average bicarbonate alkalinity is more than 60 mg/L at all the selected sites as per the classification of Spence (1964).

Hardness is an important indicator for classifying the domestic sewage. The values of hardness were almost double in the Anchar lake (181 mg/L) as compared to the Dal lake (98 mg/L). Highest average values
of hardness were recorded for site C (\( \bar{x} = 217 \text{ mg/L} \)) and site F (\( x = 117 \text{ mg/L} \)) of the Anchar and the Dal lake respectively. Both these sites are exposed to all sorts of sewage and other wastes from the institute, Heemal hotel and the houseboat area located in the vicinity of site F.

Among the elements responsible for hardness, calcium is the most dominant cation in the lakes which is in conformity with the findings of Zutshi et al. (1980) for other valley lakes. According to Pearsall and Lind (1942) and Zafar (1964) calcium is one of the most important element influencing the distribution of diatoms in water bodies. The calcium contents at all the investigated sites of the Anchar lake varied between 5.3 mg/L to 112.5 mg/L while in the Dal lake the values ranged from 11.3 mg/L to 77.4 mg/L. Highest calcium contents during winter in both the lakes may be attributed to the prevailing low temperature during the period which increased the calcium solubility in water. Low temperature and abundant calcium supply during the period seems to be favourable for the peak development of diatoms. As per the classification of Ohle (1934), the waters of the Anchar and the Dal lake are calcium rich as the average calcium values at all the selected sites exceed 28 mg/L and they harbour rich diatom growth.

Magnesium, as represented in total hardness though behaved sympatric with calcium, smaller range of its variations suggest that little magnesium is precipitated in photosynthesis and its salts are more soluble than
their calcium counterparts presents in the ratio of 7:1 and 5:1 in the Dal and the Anchar lake respectively. These findings are in conformity with Sharma (1989), Zutshi and Khan (1977), Sarwar (1982) and Khan (1982). The low concentration of magnesium during summer and spring is due to its uptake by plants in the formation of chlorophyll magnesium porphyrin metal complex and its enzymatic transformation (Wetzel, 1975).

Highest average seasonal calcium and magnesium contents of the investigated lakes were registered during autumn/winter which also accounted for the peak development of diatoms during these seasons. Similar conclusions were also drawn by Munawar and Nauwerck (1974) who attributed the luxuriant growth of diatoms to higher calcium and magnesium concentrations.

Average sodium and potassium contents for the site C (78mg/l) of the Anchar lake were highest in comparison to the other investigated sites. Seasonal values were highest during autumn/winter. Fluctuations in the monthly values of the sodium contents at site C are attributed to the direct disposal of varied types of organic and inorganic wastes into the water. Since these are highly mobile elements and as such are taken up during growth but due to their loose attachment are easily leached.

The ratio of sodium and potassium/calcium and magnesium known as basic ratio used as one of the parameters to access the nutrients enrichment of waters, was found as low as 0.94 and 0.85 for the Anchar lake and the Dal lake respectively which is in conformity with
findings of Zafar (1964) who observed that the diatom population was influenced by low basic ratio of \( \text{Na}^+ \text{K}^+/\text{Ca}^{2+} \text{Mg}^{2+} \).

The equivalency order of the cations at all the selected sites was \( \text{Ca}^{2+} > \text{Na}^+ > \text{K}^+ > \text{Mg}^{2+} \) which represents a marked shift from the earlier observation of Zutshi et al. (1980) and Trisal (1977) who reported the cationic order as \( \text{Ca}^{2+} > \text{Mg}^{2+} > \text{Na}^+ > \text{K}^+ \). This change in ionic concentration of the water body is the result of direct disposal of sewage, animal wastes and other degradable effluents into the water. The order of anions at all the investigated sites was \( \text{HCO}_3^- > \text{Cl}^- > \text{SiO}_3^- \) which is in accordance with the earlier observations of Trisal (1977) and Zutshi et al. (1980).

Higher iron contents in the Anchar lake \( (\bar{x} = 589 \ \mu\text{g} / \text{L}) \), which is almost double the value in the Dal lake \( (\bar{x} = 288 \ \mu\text{g} / \text{L}) \) reflects the increased amount of leaching from the catchment. The iron enrichment in the Anchar lake takes place in varied ways; firstly from the effluents drains opening directly from the Institute of Medical science; secondly, by the disposal of sewage directly into the lakes by human settlements and thirdly due to the input of huge wastes brought in by its feeding channel - River Sind. Leaching of iron from the catchment area into the waters have also been reported by Sarwar and Wazir (1988).

The importance of phosphorous, nitrate and silica in the distribution of diatoms has been stressed by Pearsall (1932) in the British lakes. The silicon is most important element which aids in the development of diatom frustules. The average values of silicate in the Anchar lake are higher by
3.9 mg / L in comparison to the average value of this anion in the Dal lake. Welch (1952) held that since diatoms require silicon for the manufacture of their shell, large population of diatoms affect the silicon concentration producing variations in the surface waters. Abundance of silicate favours multiplication of diatoms. Positive correlation between increase in the number of diatoms and decrease in amount of silica in waters was observed at all the investigated sites of both the lakes (Table: 11). Similar results have also been recorded by Stockner (1975), Wood and Carter (1978), and Parker et al. (1978). Kilham (1971) drew a strong correlation between the dominance of some specific diatoms and silica content in water, suggesting further the possibilities of utilization of some measure of "Silica demand" as an index of environmental enrichment or eutrophication. During the present study, the silica content in general was found to be relatively high during or after the dominance of diatoms establishing a positive relationship between this mineral and the diatom periodicity. The reduction in the silicate contents may be attributed to its uptake by the diatoms and the bottom vegetation and in the reformation of the humate complex. (Ahl, 1966)

The primary factor for enrichment of waters are phosphorus and nitrogen (Ohle, 1955). Whipple and Parker (1902), Pearsall (1923) and Lund (1938) suggested the nitrate as being the mean factor in controlling the periodicity of diatoms. The average \( \text{NO}_3 - N \) contents was higher in the Anchar lake (640 \( \mu \text{g} / \text{L} \)) in comparison to the Dal lake (504 \( \mu \text{g} / \text{L} \)).
<table>
<thead>
<tr>
<th>Parameter</th>
<th>Lakes</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Anchar</td>
</tr>
<tr>
<td>Silicate</td>
<td>+ 0.297</td>
</tr>
<tr>
<td>Nitrate</td>
<td>+ 0.302</td>
</tr>
<tr>
<td>Ammonium</td>
<td>+ 0.397</td>
</tr>
<tr>
<td>Phosphate</td>
<td>- 0.397</td>
</tr>
</tbody>
</table>

*Table: 11  Correlation of diatoms with some chemical parameters*
nitrate - nitrogen at all the sites in both the lakes depicted irregular concentrations during the investigation period as the lakes usually receive their nitrate supply from agricultural runoff, sewage effluents and decomposed organic matter. Dunst (1974), Lee (1970) and Garrell et al. (1977) have also found such irregularities in the nitrate - nitrogen contents in their studies. Positive correlation was established between the nitrate - nitrogen contents and diatom population diversity in all the three habitats. According to Patrick (1948) the nitrate form of nitrogen is mostly utilized by diatoms. Munawar (1970) also opined that the nitrate control the development of diatoms to a greater extent in freshwater.

The values of average ammonical - nitrogen concentrations were fairly high for the Anchar lake \( (\bar{x} = 352 \ \mu g / L) \) than the Dal lake \( 21 \ \mu g / L \) to 742 \( \mu g / L \) \( (\bar{x} = 203 \ \mu g / L) \). According to Eliss et al. (1946) the concentration of ammonia and ammonium compounds in unmodified natural waters is very small \( (< 0.1 \ mg / L) \) while quantities more than 0.1 \( \ mg / L \) are indicative of organic pollution. On the basis of average annual values of ammonical nitrogen the highest values were recorded at the site C of the Anchar lake \( (664 \ \mu g / L) \) which is five times higher than the other sites of the lake while in the Dal lake the highest average ammonical nitrogen was registered at site F \( (\bar{x} = 298 \ \mu g / L) \). The degree of pollution is highest at site C in comparison to other sites where ammonical nitrogen concentration also exceeded 0.1 \( \ mg / L \). All the investigated sites showed abundant diatom population together with increased ammonical - nitrogen concentration. A
positive relationship was recorded at all the sites of the investigated lakes between the ammonical-nitrogen concentration and the diatom population densities at different habitats.

Phosphorus is ecologically the most important element for living organisms. Average phosphate-phosphorus values were slightly higher (189 µg/L) in the Anchar lake than in the Dal lake (140 µg/L). The phosphate phosphorus values ranged from 3 mg/L to 1099 µg/L in the Anchar lake while the values varied between 6 µg/L to 847 mg/L in the Dal lake. On seasonal basis, the average values for PO$_4^-$ P and total phosphorus were maximum during winter and autumn and the minimum values were recorded during spring and summer except at site D and E where lower average seasonal values were recorded during winter. The reduction in phosphate peak shows its utilization by this community. Welch et al. (1970) opined that phosphate plays an important role in phytoplankton growth. Since in our water bodies diatoms form an important and dominant component of phytoplankton hence the utilization of phosphate by diatoms during peak development is quite understandable. Negative correlation was established between the total diatom population and the total phosphorus concentration of both the lakes. The U. S. Deptt. of Interior Division of Technical support (1969) reported that in order to prevent biological nuisance, the total phosphorus concentration in the lake should not exceed 50 µg/L. Total phosphorus concentration in the Anchar lake ranged from a low value of 30 µg/L to a higher value of 8667 µg/L and from
106 µg / L to 3939 µg / L in the Dal lake with an average values of 1364 µg / L and 989 µg / L respectively. The lakes under investigation show total phosphorus above the threshold limits and hence has real nuisance value for the lake. Higher total phosphorus values are largely due to the addition of phosphorus both directly (through the amount dissolved in it) and indirectly through the runoff entering the lake which carried it from sediments, human and animal excreta and fertilizers used in the adjoining agricultural fields.

It is well known that the trace quantities of some elements exert a positive or negative influence on plant, animal and human life. When present in low concentration can retard or induce abnormal growth. But when their concentration exceeds the permissible limits, these elements become higher toxic and can endanger even human life (Kaul, 1984). The concentration of trace elements viz., Zn, Cu, Co, Pb and Mn in the investigated lakes were within the permissible limits as provided by WHO (1979) and USEPA(1975). Comparison of the recorded results with WHO standards are given as under:

<table>
<thead>
<tr>
<th>Metal</th>
<th>Anchar</th>
<th>Dal</th>
<th>WHO Standard</th>
</tr>
</thead>
<tbody>
<tr>
<td>Zn</td>
<td>2.32</td>
<td>2.31</td>
<td>5.0</td>
</tr>
<tr>
<td>Cu</td>
<td>0.17</td>
<td>0.13</td>
<td>0.15</td>
</tr>
<tr>
<td>Co</td>
<td>0.08</td>
<td>0.05</td>
<td>0.05</td>
</tr>
<tr>
<td>Pb</td>
<td>0.08</td>
<td>0.02</td>
<td>0.10</td>
</tr>
<tr>
<td>Mn</td>
<td>Traces</td>
<td>Traces</td>
<td>0.01</td>
</tr>
</tbody>
</table>
Higher values of conductivity, alkalinity, calcium, nitrate, ammonia, sodium, potassium and phosphate together with the increased population densities of diatom in all the assemblages in the Anchar and the Dal lake are largely due to input of human and animal excreta, sewage, surface runoff and domestic pollution to which the waters are exposed. In the investigated urban lakes, changes in water quality are rapid and large because of the nature of flow, which in turn varied in terms of quantity, chemistry and unabated and unpredictable biotic pressures in the catchment. This accounted for the observed variations in the diatom assemblages at the selected sites but the present study has shown that the diatom population appears to exploit their habitats most efficiently. The relative proportions of individuals species varied in response to the changing water chemistry and the flora was able to re-establish itself within a few days after the drastic alteration in the water chemistry.

Consideration of the various biological and physico-chemical parameters studied, the lakes under investigation are definitely ahead in regard to their trophic status. The parameters indicating the eutrophic nature of the investigated lakes are:

i. Increased specific conductance values

ii. Increased alkalinity, chloride, silicate, iron and calcium contents

iii. Higher concentration of nitrate and phosphate

iv. Dominance of diatoms

v. Abundance of indicator species lake *Synedra ulna* (Nitz.) Ehr.
Navicula spp. Bory, Fragilaria crotonensis (Ed.) Kitt., Nitzschia acicularis (Kutz.) which are regarded as important indicators of pollution and eutrophy.

The chief causative factor for a change towards eutrophication in these lakes is the rapid cultural development of their catchment areas, direct disposal of leachates from the catchment and illegal reclamation. Diatoms by their nature are quite sensitive to trophic changes in the water body and hence good biological indicators.

From the results of the investigation it can be concluded that these culturally eutrophic lakes of Kashmir need proper attention for their conservation and management. The water chemistry and the diatom wealth of these lakes are certainly high and the pollution indicating species are present in reasonably alarming proportions. The point and diffused sources of pollution like the nutrient loaded inflows, sewage, domestic wastes, municipal wastes, large drains from the Medical Institute and various hotels and houseboats, agricultural run-off and leachates from the catchment areas should be checked. The harvesting of Potamogeton natans, P. crispus and Ceratophyllum demersum in the Anchar and Nymphaea sp., Myriophyllum spicatum and Ceratophyllum demersum in the Dal lake may be regarded as possible measures of reducing the nutrient pollution as they retain higher percentage of bound nutrients and plankters. This would reduce nutrient and plankton concentration in the sediment - a major source of supply to the macrophytes and water of the lakes.