CHAPTER-8

DISCUSSION

Several forms of algae and their variability have been observed in relation to pollution load of effluent and water of different sampling stations of Tunia river. The result of present investigation indicate that several algal species showed interesting pattern of distribution in relation to pollution load due to the impact of Bongaigaon Refinery and Petrochemical effluent.

8.1 ALGAE AS IN THE EFFLUENT OF BRPL

The effluent exhibited characteristics algal flora. It was mainly comprised of Cyanophyceae, Bacillariophyceae, Chlorophyceae and Euglenophyceae. Our findings are closely similar to many earlier studies demonstrating abundance of diatoms, green and blue-green algae and flagellates in the effluent of oil refinery (Sherman and Phinney, 1971; Kumar et al., 1974; Gaur and Kumar, 1985). The Cyanophyceae, particularly members of the family Oscillatoriaceae was found to be the most dominant groups in the effluent consisting 54.65% of the total collected samples. Our findings were in accord with some earlier investigations demonstrating luxuriant growth of Cyanophyceae in the
effluent with mostly oil spills (Miller et al., 1978a; Gaur, 1981) and also in habitats polluted by oils and oilywastes (Konig, 1968; Baker, 1971, 1973; Reish, 1971). Among the different members of Cyanophyceae Oscillatoria chlorina, O. tenuis, Phormidium tenue, Phormidium sp. and Lyngbia limnentica were most dominant species in effluent. Some other workers (Kumar et al., 1974; Cooper and Wilhm, 1975; Gaur and Kumar, 1985) have also observed the genus like Oscillatoria in oil refinery effluent or streams receiving oil refinery effluent (McCauley, 1966; Kumar et al., 1974) and in presence of oil constituents (Snow and Scott, 1975; Schultz and Tebo, 1975; Gaur, 1981). Kumar et al. (1974) concluded that the occurrence of certain Cyanophytes in refinery effluents is indicative of their capacity to tolerate heavy loads of organic pollution and they can utilize phenolic compounds, hydrocarbon or oily substances present in the effluents. Among other forms like Nitzschia palea, Navicula sp. under Bacillariophyceae, Chlamydomonas sp., Chlorella vulgaris, Scenedesmus quadricauda and Ankistrodesmus falcatus under Chlorophyceae and Euglena acus under Euglenophyceae were also found in dominating state in the effluent of present study. Gaur (1981) also observed the occurrence of different species like Nitzschia linearis, N. hugarica, N. amphibia, Gomphonema parvulum, Synedra ulna, Pinnularia sp., Cymbella sp., Closterium acerosum, Scenedesmus dimorphus and Cosmarium sp. in the effluents of five different oil refineries of India. Contrary to his observation the species like Pinnularia sp., Cymbella sp. and Cosmarium sp. were not observed in the effluent of BRPL. Palmer (1969) reports that some species belonging to Ankistrodesmus, Chlamydomonas, Scenedesmus, Oscillatoria, Lyngbia and Euglena are
indicators of oily waste. Present findings is in accordance with his observation.

8.2 ALGAE AS IN TUNIA RIVER

The algal communities in Tunia river were mainly composed of Cyanophyceae, Bacillariophyceae and Euglenophyceae except for a sudden appearance of Batracospermum, a numbers of Rhodophyceae at sampling station S-4. Our findings agree closely with the investigation of Venkateswarlu (1981) demonstrating Cyanophyceae, Bacillariophyceae and Euglanophyceae, which constitute the algal flora of polluted river. Horizontal variations of algal flora under different classes were observed at different sampling station of Tunia river depending upon the high or low load of pollution due to the discharge of BRPL effluents. The high pollution load at S-1 sampling station did not permit large number of algal species to thrive and only a few species were encountered which obviously had profound tolerance to oil pollution. Similar findings was observed by Gaur (1981) during the investigation of five different oil refineries of India. Our findings also support the observations of Patrik (1949) with regard to mark reduction in species number under pollutional stress.

Accompanying with the decrease in total number of species there was a pronounced increase in number of individuals per species under severe oil pollution. There was gradual increase in number of species towards downstream with decreasing load of pollution due to microbial
decomposition of the effluents as well as the self-purification of river water. It is based on the observation of Tarzwell and Gaufin (1953) demonstrating the decomposition of organic wastes by the bacteria in the septic zones and recovery zone help in the gradual building up of the Phytoplankton populations.

On the basis of our results it was apparent that changes in algal population can be attributed to (i) Seasonal variation (ii) High load of different pollutants and (iii) the relative adaptability or resistance of algal forms to pollutants. The growth of several forms was influenced by various pollutants. Cyanophyceae was represented by highest number of species as well as the largest number of individual at sampling station S-1 consisting 46.79% of all total collected population. However, their dominance slightly declined at sampling station S-2 (44.35%) and at S-3 (29.78%) by the members of other groups (Fig. 4.16). All these three stations exhibited low values of DO and high values of BOD, COD, Sulphate, Chloride, pH, Alkalinity, Conductivity and OAG. Our findings are similar to the observation of Kaushik et al. (1991) demonstrating the values of pH, Alkalinity, Conductivity, Phosphate and Chloride favoured the growth of Cyanophyceae. However, Kaushik et al. (1991) did not take OAG into consideration in their study. Similarly, Prescott (1938) reported that low oxygen content in water accelerate the growth of blue green algae. Venkateswarlu (1969), Sampath Kumar (1977) and Bharati and Krishnamurthy (1991) reported that blue greens grow profusely in highly polluted habitats. Jampani et al. (1985) reported that blue-green algae are more tolerable to any type of pollution than that of green algae. Our findings agree with the earlier
claim. On the other hand the remaining three stations (S-4, S-5, S-6) of Tunia river the average annual percentage of Cynophyceae were reduced drastically to 10.74%, 12.63% and 8.74% respectively (Fig. 4.16). This was due to higher amount of DO with low values of other parameters including OAG. Among different members of Cynophyceae, Oscillatoria chlorina, Lyngbya limnetica, Arthospira sp. and Anacystis sp. were dominant at sampling station S-1. This station exhibited higher amount of OAG along with other parameters responsible for pollution. Other members of this station were O. curviceps, O. tenuis, O. princeps, O. rubescens, Phormidium sp., P. tenue, Haplosiphon sp., Microchaete sp., Anabaena variabilis, Anacystis cyanea, Chlorococcus sp. and Merismopedia sp. Kumar et al. (1974) also observed the species like Phormidium tenue and Oscillatoria curviceps at the outfall of Barauni oil refinery. He also concluded that these Cynophyceae may fix nitrogen under the anaerobic conditions that prevail in oil refinery effluent. Palmar (1969) considered the genus Oscillatoria as highly resistant to organic pollution and has been placed in the second position in listing of algae most tolerant to organic pollution. Marathe and Nandkar (1976) used this genus as an indicator of the α-mesosaprobic zone of polluted waters. Fjerdingstad (1950) considered the species like O. tenuis and O. chlorina, found in river Mollena to be polysaprobic. Palmer (1980) demonstrated that presence of species of Oscillatoria, Arthospira, Merismopedia and Phormidium which are reportedly pollution tolerant ones, coupled with absence of many fresh water forms substantiate its highly polluted nature. Another species of Cyanophyceae like Anabaena constricta which starts to appear from S-3, was more
predominant than clean water stations. So, they were \( \beta \)-mesosaprobic. Their dominance particularly in S-3 sampling station was due to the moderate amount of DO and appreciable amount of sulphate. Absence of large number of blue-green algae is an indication of clean water (Rafter, 1900). In the present investigation the lower percentage of Cyanophyceae specially in S-4, S-5 and S-6 sampling station correspond to clean water habitat. The species like Calothrix, Cylindropermum, Lyngbya, Nostoc, and Anabaena azollae were recorded from these clean water stations. So, they are oligosaprobic forms. Paramasivam and Sreenivasan (1981) considered some species of Phormidium and Lyngbya to be oligosaprobic. Mittal et al. (1991) concluded that Nostoc sp. was favoured by moderate oxygen content. Palmer (1980), Kolkwitz and Marsson (1908) also report that few species of Calothrix is an indicator of clean water. Our findings is in conformity with above observations.

Bacillariophyceae were represented by 10 to 20 species in different sampling stations of R Tunia depending upon the high or low pollution load. The sampling stations S-4, S-5 and S-6 supported large number of diatom population i.e. 18, 19 and 20 species consisting 53.11%, 59.11% and 64.68% respectively of the total algae recorded at that sampling stations. These stations exhibited higher concentration of DO coupled with lower values of BOD, COD, Phosphorus and negligible amount of OAG. On the other hand sampling stations S-1 and S-2 recorded low percentage (16.82% and 18.65% respectively) of diatoms. This was due to lower amount of DO coupled with higher values of other parameters including OAG. While the station S-3 exhibited intermediate percentage
(27.49%) of Bacillariophyceae due to moderate values of DO, Phosphate, Choride and OAG. Similar findings also observed by Bharati and Krishnamurthy (1991) during the ecological study of river Kali. Rice (1938), Venkateswarlu (1969), Sampathkumar (1977) and Manikya Reddy (1984) found that organic matter adversely affected the growth of diatoms in river water. In the present findings also organic load appeared to regulate their distribution at different sampling stations of Tunia river.

A healthy portion of a stream reportedly contained mostly many species of diatoms with mere presence of green algae (Patrick, 1965). In the present studies the higher percentage of diatoms specially correspond to clean water stations. Neidium sp., Cocconeis sp., Melosira sp., Asterionella sp., Rhopalodia gibba, Amphora ovalis, Pinnularia sp., Achnanthes minutissima, Hutzschia amphioxys, Eunotia sp. and Calonesis sp. constituted the bulk of diatom plankton in these clean water stations. So, they were oligosaprobic forms. Our findings is more or less in conformity with the findings of Palmer (1969), Paramasivum and Sreenivasan (1982) and Vankateswarlu (1983) and contrary to that of Paramasivum and Sreenivasan (1981) who found the Amphora ovalis as more pronounced in mildly polluted zones than in clean water. Among other pollution tolerant forms of Bacillariophyceae Nitzschia palea was found to be dominant at station S-1 due to high amount of OAG along with other parameters. Other important members present in this station were N. linearis, N. hungarica, N. amphibia, Gomphonema parvulum, G. olivaceum, Navicula sp. and Syndra ulna. Similar findings was also observed by Gaur (1981). Contrary to his observation, in the present
study *Pinnularia sp.* and *Achnanthes minutissima* were observed in clear water while *Cymbella sp.* in medium polluted station (S-3). Kumar et al. (1974) also observed the species like *Nitzschia* and *Navicula* at the outfall of Barauni oil refinery and few meters downstream. Sengar et al. (1985) concluded that high amount of dissolved solids, Hardness, Sulphate, Phosphate, Ammoniacal nitrogen favoured the better growth of diatoms while Chloride and Calcium have been reported to affect the diatom communities. Contrary to his observation Paramasivam and Sreenivasan (1982) observed more diatoms in the downstream where chloride and the total hardness value increase with the intensity of pollution along its course. Somashekar (1984) showed distinct zonation with respect to chloride concentration in the river water. In the present investigation too the abundance of these pollution tolerant forms specially at sampling station S-1 was also favoured by above factors coupled with OAG. Paramasivam and Sreenivasan (1982) observed *N. palea* predominantly in polluted zones and considered as poly to beta-mesosaprobic form. He also concluded that the group *Nitzschia* seems to be more important in the self-purification of the river. In our present findings the abundance of this group particularly at S-1 proved that they were utilizing organic nitrogenous compound enhancing self-purification system of the river as observed by Paramasivam and Sreenivasan (1982). The sp. like *Navicula, Synedra ulna, Fragilaria* and *Cyclotella meneghiniana* which were present throughout the sampling stations were more predominant in S-3 sampling stations. So, they were oligo to β-mesosaprobic forms.
Chlorophyceae were represented by 9 to 15 species in different stations of Tunia river. The sampling station S-3 supported high percentage of Chlorophyceae population i.e. 15 species consisting 31.47% of total algae recorded at that station. It was significant to note that the Chlorophyceae become dominant over Cyanophyceae in this sampling station. The station showed slight improvement in certain physico-chemical characters as a result of which both pollution tolerant and pollution preferred forms become dominant. This findings is in conformity with the observation of Palmar (1969) demonstrating the general tendency is for the green algae to be predominant in the final stage of active decomposition β-mesosaprobic. Spirogyra sp. was the most dominant sp. in this station. This was due to the influence of hardness and sulphate as observed by Mittal et.al. (1991). According to Nygaard (1949) Spirogyra sp. is also one of the pollution tolerant form. Other important mesosaprobic forms in this station were Actinostrum hantzchii, Scenedesmus obliquus, Closterium sp., Cosmarium sp., Ulothrix sp. and Tetradon muticum. Palmer (1969) also considered all these sp. as pollution tolerant forms. Paramasivum and Sreenivasan (1981) observed both the sp. of Cosmarium and Closterium as more pronounced in polluted zones while Ulothrix sp. in clean water zone. Contrary to his observation Kolkwitz & Marsoon (1908) observation the sp. Ulothrix as mesosaprobic form. Our data more or less agree with all the above earlier claim. Mittal et.al. (1991) concluded that the growth of Cosmarium sp. was enhanced by appreciable amount of hardness and moderate quantity of dissolved solids. The growth of Cosmarium specially at S-3 sampling station is in conformity with the above factors.
Several sp. of Chlorophyceae showed interesting pattern of distribution in different sampling station of Tunia river. Among different pollution tolerant forms *Chlamydomonas* sp., *Chlorella vulgaris*, *Stigeoclonium tenue*, *Schizomeris leibleinii*, *S. quadricauda*, *S. quadricauda var bicaudatus*, *S. dimorphus*, *Closterium acerosum* and *Ankistrodesmus falcatus* were in most dominant sp. at sampling station S-1. This was due to high amount of OAG including other parameters responsible for pollution. Similar findings also observed by Gaur (1981) excepting *S. quadricauda var bicaudatus* and *S. leibleinii*. Yadaya and Pandey (1980) observed *S. leibleinii* specially at polluted habitate and treated as a indicator of water pollution. The occurrence of large number of Chlorococcales (three genera) at this sampling station was due to high temperature, high level of dissolved solids, sulphate, calcium, magnesium (Sengar and Sharma, 1986) and low turbidity value (Philipose, 1960). The sp. like *Hydrodiction*, *Desmidium*, *Cladophora* started to appear from the sampling station S-4. This station showed marked improvement in all the physico-chemical characters resulting the reappearance of all these fresh water forms. So, they were oligosaprobic forms. Blum (1957) pointed out that the *Cladophora* sp. reappear in the recovery zone of a polluted water. Venkateswarlu (1981) recorded low temperature, high DO and very low organic matter to be the most suitable for *Hydrodicton* sp. The species like *Euastrum*, *E. spinulosum*, *Kirchneriella obesa*, *Staurastrum*, exclusively were recorded at sampling station S-6. This was due to the high DO and low organic matter. Venkateswarlu (1981) also observed a similar state of appearance. He pointed out that among the greens, desmids are very sensitive to...
pollution. The lower number of desmids indicated high level of eutrophication in river (Shaji, 1991) and absence or low number itself indicates the polluted nature of water (Rana and Palria, 1988). In our present findings large number of desmids indicate the clean water habitat. So, they were oligosaprobiac forms. Sengar et al. (1985) observed Kirchneriella sp. in clean water habitat and treated as pollution sensitive form.

Another interesting point is the existance of Batracospermum moniliforme, a member of the class Rhodophyceae specially in the sampling station S-4 indicate the clean water habitat. The member of Rhodophyceae were completely absent at S-1, S-2 and S-3 due to high amount of OAG. Our findings closely similar with the observation of Gaur (1981) demonstrating the filamentous red algae are most severely affected by oils and emulsifiers possibly due to susceptibility of phycoerythrin to oils. This was also supported by Manwell and Baker, (1967).

Members of Euglanophyceae were present only at S-1, S-2 and S-3 sampling stations where there was high organic enrichment, low level of DO and slightly higher temperature. Our findings are more or less similar with the observation of few earlier workers demonstrating the temperature, organic matter (Chakrabarty et al., 1959) and lower concentration of DO (Hosmani and Bharati, 1975) favoured the growth of Euglanophyceae. Kumar et al. (1974) observed that the blue-green algae and Euglenoid flagellates were mostly associated with organically rich effluents containing less dissolved oxygen. Bharati and
Krishnamurthy (1991) observed the members of Euglanophyceae were present only at polluted stations. Rai and Kumar (1977) reported that Euglenoids thrived well with low oxygen and high organic matter. Palmer (1969) also considered the *Euglena* sp. as an indicator of oil pollution. Tunia river too reflects such situation especially in S-1, S-2 and S-3 sampling stations. Among different members of Euglanophyceae *E. acus* was predominant at S-1 whereas *P. longicauda* and *P. pleuronectes* were in S-3 sampling station which in addition to refinery effluents also receives sewage from New Bongaigaon Railway colony. This was in conformity with the observation of Khan and Sarma (1991) demonstrating sewage contamination are favourable for the growth of Euglanophyceae. Patrick (1965), Sladecek (1973) and Kolkwiitz and Marsoon (1908) classified *Euglena* sp. and *Phacus* sp. as alphameso to polysaprobic. Our findings also indicate the same characteristics.

8.3 PHYSICO-CHEMICAL PARAMETERS AND POLLUTION

To support the algal indicators of pollution, the physico-chemical parameters were also studied and taken into consideration. In fact both physico-chemical and biological information are essential to determine the pollution status (Trivedy and Goel, 1986).

Temperature is basically important for its effect on certain chemical and biological reaction taking place in the organisms inhabiting aquatic media. It depends upon the season, time of the sampling and also upon the temperature of the effluents which are being added in the river (Mishra and Saksena, 1991). Temperature is very important parameter
which affects the self-purification capacity of water and influences the aesthetic and sanitary qualities of water (Kakati, 1991). At temperature above normal, Oxygen solubility in water will be appreciably less leading to total oxygen depletion and obnoxious septic conditions (Velz, 1970). The lower temperature, on the other hand, affects the water treatment processes. Water temperature and oxidizable organic matter go hand in hand are inversely proportional to the dissolved oxygen (Iyengar and Venkataraman, 1951; Venkateswarlu, 1969) and all the three seem to form an ecological complex, where a change in one necessarily influences the others (Venkateswarlu, 1969).

The temperature of Indian oil corporation drain, Noonmati ranged from 17°C to 32°C (Sarma, 1996). In contrast to this the temperature of the effluents of BRPL outlet (E) varied from 24.0°C to 35.5°C. The present investigation also revealed slightly higher temperature at station S-1 and S-2 while temperature of remaining stations (S-3, S-4, S-5 and S-6) did not exhibit much fluctuation. The higher temperature at E and sampling stations S-1 and S-2 may be attributed to the various chemical reactions among the pollutants (Srivastava et al., 1994) present in the BRPL effluent. Moreover, the temperature of the stations E and S-1 were significantly correlated (r=0.985375).

Turbidity in water and in waste water is caused by the substances which are not present in the form of true solution. Prasad and Singh (1980) observed high turbidity due to the contamination of sewage. The turbidity of water is found to be less during summer, intermediate in winter and maximum in monsoon (Matowani et al., 1956;
Lakshminarayana, 1965; Bilgrarrri and Dutta munshi, 1979; Prasad and singh, 1980). In the present study, it has been observed that the turbidity values were considerable in the effluents and as well as in all the sampling stations of Tunia river. In these effluents, this parameter showed its annual mean maximum values as 11.68 NTU ranging from 7.5 to 15.0 NTU while in R Tunia maximum values as 41.0 NTU at sampling station S-6 ranging from 15.0 to 66.50 NTU. The stations S-3 (23.19 NTU) and S-5 (34.41 NTU) also showed slightly higher turbidity values during monsoon and retreating monsoon. The higher turbidity values in the Tunia river particularly at station S-3, S-5 and S-6 during monsoon and retreating monsoon was not due to the influence of BRPL effluents alone but also due to the stormwater (Lal and Bhattacharya, 1989; Kakati, 1991 and Sarma, 1996), total solids, partly or fully decomposed organic matter and turbulence caused by anthropogenic activities and domestic animals (Mishra and Saksena, 1991).

Conductivity is the measure of capacity of a substance or solution to conduct electrical current. It’s measurement allows to have a rough estimate of the degree of mineralization of the water samples. In the present investigation the conductivity showed its mean maximum values 851.25 Mmhos/cm at effluent ranging from 600.0 to 1295.0 Mmhos/cm while minimum (79.05 Mmhos/cm) at S-6 ranging from 71.0 to 100.0 Mmhos/cm. The high values of conductivity at E indicating the presence of large amount of ionic substances (Lal and Bhattacharya 1989; Kakati, 1991). However, lower levels of conductivity recorded at S-6 possibly due to dilution effect. The seasonal variations in conductivity at S-1
followed the pattern of effluent conductivity variation exhibiting a highly significant correlation between the two \( r = 0.941072 \).

Total dissolved solid data again show highest for the station E \( (678.11 \text{ mg.L}^{-1}) \) and S-1 \( (337.73 \text{ mg.L}^{-1}) \) while lowest for S-6 \( (50.05 \text{ mg.L}^{-1}) \) in conformity with the observed conductance values. Similar relation was also observed by Lal and Bhattacharya (1989) in the R Bharulu. The high level of TDS specially at S-1 indicating the input of Ionic substances along with the BRPL effluent as evident from their significant \( (r=0.941072) \) correlation obtained between E and S-1 for tills Parameter.

For water and waste water, pH is an important criterion because it determines the degree of toxicity of many pollutants and solubility of metals from bottom sediments or suspended matter (Delfino and Lee, 1971). It also gives an idea in the type and intensity of pollution (Verma et al., 1984). In Barauni Oil Refinery pH of effluent was generally ranged from 6.8-7.4 at guard basin and from 7.1 to 7.6 at out fall (Kumar et al., 1974). In Caltx oil Refinery the pH of effluent as 7.5 was observed by Reddy et al. (1983). Gaur (1981) observed the alkaline pH of effluent (before treatment) in five different oil refineries of India (Viz. Barauni, Guwahati, Gujrat, Cochin and Madras) but after treatment the pH of effluent dropped down to 7.1 to 7.6. The pH of BRPL effluent was found to be always alkaline during the study period, ranging from 8.1 to 9.2 with a mean maximum value of 8.53 indicating the enrichment of chemicals which are alkaline in nature (Shrivastava
et. al., 1994). Though the minimum pH value recorded was well above the lower pH tolerance limit of 5.5 fixed by ISI, the maximum pH value recorded was not below the upper tolerance limit of 9.0 fixed by the same institute. Ellis (1937) and Klein (1973) have pointed out that the pH value between 6.7 and 8.4 are suitable while the pH values below 5.0 and above 8.8 are detrimental. In the present findings the maximum pH value (9.2) during the period of premonsoon indicates the pollution nature of the effluents. Similarly, the S-1 also under the influence of effluent which is exhibited by their significant correlation (r=0.997525) with respect to their pH values. The S-2 also showed slightly higher level of pH. This was due to the stirring of the bed sediment at the point of mixing of effluent with water of Tunia river (Shaw et. al., 1991). The mean pH values of rest of the stations were quite constant and were not much different from season to season as well as from station to station. This is reflected in the small values of SD and CV (Table 5.5).

Dissolved oxygen is one of the important parameter in assessment of water and waste water quality. It has been suggested that low values of DO are usually associated with high concentration of organic pollutants (Prasad and Singh, 1980). Non-polluted surface waters remain normally saturated with DO. The low levels of DO were recorded by few earlier workers in different oil refinery effluent and in the stream receiving oil refinery effluent (Kumar et. al., 1974; Reddy et. al., 1983; Gaur and Kumar, 1985). In present study, the DO in the effluent was not satisfactory. The minimum mean value was recorded as 1.1 mg.L⁻¹ ranging from 0.2 to 2.0 mg.L⁻¹ indicating presence of various oxygen demanding matter (Lal and Bhattacharya, 1989) in the effluent. In the
The entire stretch of the Tunia river oxygen depletion was noted at sampling stations S-1 and S-2. These findings clearly indicate that there was an influx of heavy organic load from BRPL effluents. Our findings are closely similar with earlier claims. The variations in DO at S-1 followed the pattern of the effluent DO variation, exhibiting a highly significant correlation ($r = 0.784396$) between the two. The S-3 showed slightly better condition of DO level and ranging from 1.6 to 4.97 mg.L$^{-1}$. Self-purification of stream, may be responsible for this phenomenon (Sarma, 1996). The rest of the downstream stations of Tunia river were closely related to each other in terms of DO level, exhibiting suitable condition of DO to support diverse form of aquatic life including algae.

The Biological oxygen demand (BOD) and Chemical oxygen demand (COD) represent the biologically and chemically oxidizable organic matters present in water and waste water respectively. These two parameters are interrelated and show inverse correlation with DO (Banerjee and Motwani, 1960; Verma and Delela, 1973). Generally, the BOD values are 50 to 70% of the COD values depending upon the organic matters in the water (Kakati, 1991). Kumar et al. (1974) have reported COD from 500.0 to 700.0 mg.L$^{-1}$ at guard basin while from 180.0 to 350.0 mg.L$^{-1}$ at outfall of Barauni Oil Refinery effluent. But Gaur (1981) has determined BOD from 5.0 to 500.0 mg.L$^{-1}$ and 6.0 to 264.0 mg.L$^{-1}$ and COD from 10.0 to 750.0 mg.L$^{-1}$ and 60.0 to 572.0 mg.L$^{-1}$ from the effluents of Cochin and Madras Oil Refinery respectively. In the present study the highest annual mean values of BOD and COD were noted at E (20.6 and 84.25 mg.L$^{-1}$ respectively) and at station S-1 (18.28 and 74.75 mg.L$^{-1}$ respectively) than the other downstream stations.
The higher values of BOD and COD indicate the presence of considerable amount of bio-oxidizable organic matter and chemically oxidizable matter (Lal and Bhattacharya, 1989; Shaw et al., 1991) in the effluent as well as in the water of the S-1 sampling station. Both the stations were significantly correlated (r=0.938574, r=0.978754 respectively) with respect to the BOD and COD levels. Further gradual reduction of BOD and COD values towards downstream was probably due to microbio-degradation of effluents responsible for pollution (Srivastava et al., 1994) as they were not in easy reach of effluent water (Shaw et al., 1991).

Martin (1970) considered waterbody with BOD level exceeding 8.0 mg.L\(^{-1}\) to be moderately polluted. Prati et al. (1971) classified waterbodies into five classes depending upon the BOD, COD and other values. He puts that waterbody with BOD and COD respectively of above 12.0 mg.L\(^{-1}\) and 80.0 mg.L\(^{-1}\) into class V, of 12.0 mg.L\(^{-1}\) and 80.0 mg.L\(^{-1}\) into class V, of 12.0 mg.L\(^{-1}\) and 80.0 mg.L\(^{-1}\) into class V, of 12.0 mg.L\(^{-1}\) and 80.0 mg.L\(^{-1}\) into class IV, of 6.0 mg.L\(^{-1}\) and 40.0 mg.L\(^{-1}\) into class III, of 3.0 mg.L\(^{-1}\) and 20.0 mg.L\(^{-1}\) into class II and of 1.5 mg.L\(^{-1}\) and 10.0 mg.L\(^{-1}\) into class I. Referring to this classification, the Tunia river system mostly falls under class II, III and IV respectively.

The most objectionable pollutants of oil refineries are oils and grease (OAG) and phenol and for this reason, pollution control technologies are based on measures for removal of these pollutants (Gaur, 1981). The OAG and phenol content in the Barauni oil Refinery effluent fluctuated between 9.0 and 11.0 mg.L\(^{-1}\) and 0.0 and 1.0 mg.L\(^{-1}\) respectively. While Gaur (1981) reported oil upto 6.0 mg.L\(^{-1}\), 5.0 mg.L\(^{-1}\),
4.6 mg.L⁻¹, 4.0 mg.L⁻¹ and 10.0 mg.L⁻¹ and phenol upto 1.0 mg.L⁻¹, 6.0 mg.L⁻¹, 2.5 mg.L⁻¹, 1.0 mg.L⁻¹ and 2.0 mg.L⁻¹ in the effluents of Barauni Guwahati, Gujrat, Cochin and Madras Refinery respectively. In present investigation also the BRPL effluents had appreciable amount of OAG while having no detectable amount of phenol. The maximum mean value of OAG was 7.72 mg.L⁻¹ at effluent while it ranged from 7.00 to 8.20 mg.L⁻¹. This was due to high amount of OAG in the effluent (Gaur, 1981) discharged by the BRPL. In whole of the Tunia river highest amount of OAG was recorded as 7.29 mg.L⁻¹ at S-1 ranging from 5.60 - 8.10 mg.L⁻¹ while the lowest amount as 0.14 mg.L⁻¹ at the last sampling station (S-6). The higher amount of OAG at S-1 in comparison to other stations of Tunia river, suggests a direct influence of the effluents as revealed by their significant correlation (r= 0.853039). The gradual low values of OAG towards the downstream station (Table 5.19) was due to bio-degradation (Gaur and Kumar, 1985), dilution and partly adhesion to the surrounding area.

Major sources of nitrate nitrogen, ammoniacal nitrogen and phosphate phosphorus are domestic sewage, agricultural and industrial waste water. The high concentration of nitrate nitrogen (Agarwal et al., 1976), ammoniacal nitrogen (WPCF, 1985) and phosphate phosphorus (Mishra and Saksena, 1991) are indicative of pollution accelerating eutrophication of waterbodies (Kakati, 1991). Gaur (1981) observed slightly higher level of nitrogen and phosphorus in the effluents of five different oil refineries of India due to mixing of effluents with domestic sewage. In the present study the annual mean concentration of nitrate nitrogen (1.23 mg.L⁻¹) ammoniacal nitrogen (3.11 mg.L⁻¹) and
phosphate phosphorous (1.03 mg.L\(^{-1}\)) were found to be little higher in the effluent in comparison to R Tunia. However, station S-1 was found to be largely under the influence of the effluent with respect to nitrate nitrogen, ammoniacal nitrogen and phosphate phosphorous levels as revealed by significant correlation (r = 0.984707, 0.839969 and 0.879816 respectively) obtained between stations S-1 and E. The higher level of all these nutrients specially at E are due to mixing of refinery effluent with domestic sewage from BRPL township complex (Gaur, 1981) and regular dosing of nitrogen and phosphorus for maintenance of microorganisms in biofilter at WWTP. Interestingly the level of phosphate was found to be slightly higher (0.93 mg.L\(^{-1}\)) at sampling station S-4 than all the sampling stations of Tunia river. This was perhaps due to influx of rain water containing phosphate enriching substances (Sarma, 1996), partly or fully decomposed organic matter (Baker et al., 1992).

Major sources of sulphate in waste water are domestic water, commercial and industrial waste water (Kakati, 1991) including oil refinery. Kumar et al. (1974) have reported the concentration of sulphate 300.0 mg.L\(^{-1}\) as maximum and 130.0 mg.L\(^{-1}\) as minimum at the effluent of Baruani Oil Refinery out fall. In contrast to the present study the annual mean value of sulphate at effluent was 27.50 mg.L\(^{-1}\) while it ranged from 13.5 to 75.0 mg.L\(^{-1}\). With respect to the sulphate levels also S-1 was largely under the influence of the effluent as reveled by the positive correlation (r = 0.769964) obtained for the E Vs S-1 sulphate concentration. In remaining station of Tunia river the levels of sulphate concentration were minimum (Table 5.19) excepting the station S-3 (13.09 mg.L\(^{-1}\)). This slightly higher level of sulphate was due to
influence of rain water containing sulphate enriching substances (Sarma, 1996) from the area of New-Bongaigaon Railway colony.

Chloride is one of the major inorganic constituents of water and waste water. Although Chloride is not classified as a harmful constituent, excessive chloride concentration of more than 250.0 mg/L may be harmful (Dey, 1987). High chloride content along with low pH indicates industrial waste containing hydrochloric acid (Kakati, 1991). Thresh et.al. (1944) reported that chloride content is expressed as an index of organic pollution of animal origin. Chloride content also increases with the degree of eutrophication (Goel et al., 1980). Chlorides of Baruni Refinery effluent at outfall ranged between 35-70 mg/L (Kumar et al., 1974). Reddy et.al. (1983) found maximum value of chlorides as 14715.0 ppm in the effluent of Caltex oil refinery. In the present study, the concentration of chloride were found to be maximum at the effluent in comparison to different sampling stations of Tunia river. The maximum mean value was 35.62 mg/L while it ranged from 24.0 to 42.0 mg/L. In the entire stretch of the Tunia river the maximum chloride content was recorded as 29.87 mg/L at S-1 and the minimum was recorded as 4.5 mg/L at S-6. But in other remaining stations the values were in intermediate range. Similar to sulphate, the levels of chloride at S-1 was largely under the influence of the effluent of BRPL as it is evident from the significant correlation (r = 0.92998) obtained between S-1 and E for this parameter.

Calcium and magnesium salts seems to be responsible for the hardness of water and waste water (Khan and Sarma, 1991). The
increased values of hardness are found to be directly related to sewage contamination of the river water (Prasad and Singh, 1980). Again the hardness of water is not a pollutional parameter, but indicates water quality mainly in terms of Ca$^{2+}$ and Mg$^{2+}$ (Baruah et al., 1993; Sarma, 1996). Reddy et al. (1983) recorded hardness upto 2.31 mg.L$^{-1}$ in the effluent of Caltex oil refinery. Hardness of IOC refinery drain, Noonmati varied from 18.15 to 25.01 mg.L$^{-1}$ (Lal and Bhattacharya, 1989), from 55.0 to 84.1 mg.L$^{-1}$ (Sarma, 1996). In present study, the mean value of hardness at effluent were 68.37 mg.L$^{-1}$ and it ranged from 46.0 to 90.0 mg.L$^{-1}$ indicating the presence of large amount of calcium and magnesium ion at the effluent. The hardness values at S-1 was also higher than the rest of the stations of Tuniya river. Both the stations (E and S-1) are significantly correlated ($r=0.979568$) exhibited by their correlation obtained between effluent and S-1 for this parameters. The S-2 also under the influence of effluent and showed the high values of hardness (52.1 mg.L$^{-1}$) next to the value of S-1. The minimum value of hardness (27.12 mg.L$^{-1}$) was recorded at S-5 followed by S-6 (29.30 mg.L$^{-1}$), S-4 (31.75 mg.L$^{-1}$) and S-3 (40.75 mg.L$^{-1}$). The high value of hardness (46.75 mg.L$^{-1}$) at S-3 than S-4, S-5 and S-6 was not only due to the influence of BRPL effluents but also due to sewage concentration (Prasad and Singh, 1980). It is also interesting to note that the hardness values are always lower than the values of alkalinity at all the sampling station. Similar findings were also observed by Lal and Bhattacharya (1989).

Alkalinity of both natural and waste water is an important parameter because its value determines the amount of chemicals needed
to the added in water treatment. It is the sum total of constituent of water that are responsible for raising the pH of water. It has direct effect on organisms and on toxicity of certain pollutants. Natural alkalinity helps to buffer pH changes and is thus important for aquatic organism (Kakati, 1991). In the effluent of Barauni oil Refinery, Kumar et al. (1974) observed the alkalinity in the range of 180.0 to 250.0 mg.L\(^{-1}\). Reddy et al. (1983) observed the alkalinity as 121.0 ppm in the effluent to Caltex oil Refinery. In the present investigation the highest alkalinity (218.75 mg.L\(^{-1}\)) was observed at effluent (E) and it ranged from 160.0 to 250.0 mg.L\(^{-1}\). Our findings are closely similar with the observation of Kumar et al. (1974). Similarly, the higher alkalinity was also observed at S-1 (207.29 mg.L\(^{-1}\)) while lower at S-6 (39.0 mg.L\(^{-1}\)) of whole of the Tunia river. The S-1 is also under the influence of E as exhibited by their positive correlation (\(r = 0.62512\)) with respect of these two parameters. On the basis of total alkalinity, waste water are classified as low (40 to 50 ppm), moderately high (50 to 100 ppm), high (100 to 200 ppm) and toxic (200 ppm and above) in productivity (Philipose, 1959). Considering to this classification the stations E and S-1 fall under toxic, S-2 under high, S-3 and S-4 under moderately high and S-5 and S-6 under low with respect to their alkalinity levels.

Agricultural, industrial and domestic wastes containing metals bring about major changes in aquatic ecosystem (Konar, 1975). Metals in water and waste water may have beneficial or toxic effects depending upon concentration (Kakati, 1991). Calcium and magnesium both contribute to the total hardness of water (Prasad and Singh, 1980). A range of fluctuation between 85.0-100.0 mg.L\(^{-1}\) in Calcium and 53.0-60.0
mg.L⁻¹ magnesium contents were recorded by Kumar et al. (1974) in the effluent of Barauni oil refinery. Reddy et al. (1983) reported calcium upto 294.0 ppm and magnesium upto 954.0 ppm in the effluent of Caltex oil refinery.

In the present investigation, calcium content of effluent was 24.82 mg.L⁻¹ and it ranged from 20.0 to 28.0 mg.L⁻¹ while magnesium was 11.68 mg.L⁻¹ and ranged from 6.0 to 18.6 mg.L⁻¹. This findings is contrary to that of Kumar et al. (1974) and Reddy et al. (1983). Similarly in the Tunia river both the values of calcium and magnesium were found to be higher (16.58 mg.L⁻¹ and 5.21 mg.L⁻¹ respectively) at S-1 than the other stations of Tunia river, suggesting a direct influence of the effluent. The levels of calcium was minimum (6.16 mg.L⁻¹) at S-5, followed by S-6 (9.13 mg.L⁻¹), S-4 (9.8 mg.L⁻¹), S-3 (14.63 mg.L⁻¹) and S-2 (14.8 mg.L⁻¹), while magnesium values minimum at S-5 (2.73 mg.L⁻¹) followed by S-6 (3.25 mg.L⁻¹), S-4 (3.36 mg.L⁻¹), S-3 (3.40 mg.L⁻¹) and S-2 (4.6 mg.L⁻¹). Slightly higher levels of calcium and magnesium at the last sampling station i.e. S-6 than S-5 indicate the additional sources at the river Champamati. It is also conformity with slightly higher level of hardness values at this station. Again high values of these metal specially at S-2 and S-3 sampling stations were due to the direct influence of effluent while at S-3 in addition of this, there is also due to influence of sewage contamination (Prasad and Singh, 1980) at New Bongaigaon Railway Colony.
8.4 ASSESSMENT, EVALUATION AND ABATEMENT OF POLLUTION LOAD

The use of algae for biomonitoring of pollution is at present qualitatively stressed. Several investigators (Whitton, 1975; Palmer, 1980) have pointed out the use of indicator species to certify the water quality. Rana and Palria (1988) have stressed upon the use of algae for assessment, evaluation and abatement of organically polluted rivers. Compared to the other species the indicator species were seen growing and multiplying profusely in polluted habitat. Their high representation indicates their capacity to thrive in this type of man made habitat. In the present investigation the occurrence of algae commonly sharing Palmer’s (1969) list of pollution tolerant genera and species in order of decreasing emphasis in effluent and water at different sampling stations of Tunia river also reflects the polluted nature. In comparison to downstream stations, algae of effluent and upstream stations are exposed to different environmental stress due to oil pollution and a study on the algal characters of such water bodies certainly paves the way for future waste water treatment programmes, using the indicator species.

The algal flora of effluent and all the six sampling stations were subjected to Palmer’s pollution index (Palmer, 1969) for rating the pollution status. All these results (Fig 6.1 and 6.2) revealed that the E and S-1, S-2 and S-3 sampling stations were highly polluted with a score (both generic and species) more than 20 points reflecting a high organic pollution. This findings again is in conformity with the observed physico-chemical and
phycological characters of their corresponding sampling stations. Thus, physico-chemical characters together with biological monitoring and indices exhibited converging lines of evidences for evaluation of polluted habitats in our studies as also reported by earlier workers (Cairns and Dickson, 1971 and Rana and Palia, 1988).

Further algal assays were carried out to observe the toxic nature of the effluents using five different pollution tolerant algae under laboratory condition. The test algae isolated from Tunia river, carrying the effluents of BRPL, were found to be tolerant to various concentration of BRPL effluents. This was due to physiological and/or biochemical or genetical peculiarities as they had a chronic experience of refinery effluents before they were isolated and purified for the experimentation (Gaur, 1981). Gaur (1981) also observed *Chlorella vulgaris* and *Oocystis sp.* isolated from waters contaminated with oily wastes were more tolerant to test oils than that the laboratory-grown culture of *Anacystis nidulans* and *Scenedesmus capricornutum*. The effect of effluents on the test algae were highly species-specific. The Blue-green algae can tolerate higher percentage of BRPL effluents even 100 percent in comparison to the green algae. The enhanced growth of Blue-green algae in effluents also explains the results of field observation that the abundance of Blue-green at E and S-1, S-2 S-3 sampling stations compared to their downstream stations. Growth inhibition of algae by oils is attributed to the presence of hydrocarbons, napthalenes, nitrogen and sulphur compounds (Rosini, 1960) and degraded products of oils (Soto *et al.*, 1975b) which bring about the permeability of cell, inhibition of enzyme system, photosynthesis and respiration, biochemical products (*O’ Brein and Dixon, 1976; Karydis,*
The growth inhibition of green algae in our present study was probably due to the presence of oils and its degraded products, high concentration of dissolved solids and other toxic materials (used in refinery process) present in the effluents as reported by Reddy et al. (1983). The lower concentration of effluents stimulate the algal growth was probably due to the presence of growth stimulating substances in the effluents as reported by Gordon and Prouse (1973); Gaur and Kumar (1981); Reddy et al. (1983).

Palmer (1980) state that by adapting particular strains of algae it may be possible to reduce toxicity of industrial waste. The algae that are isolated from the Tunia river could be later grown on large scale in controlled waste stabilization ponds and thus pollution is taken care of to certain extent. Many of the studies conducted in various laboratories have also shown that under defined conditions indicator species actively take part in the degradation of organic matter. Hence, the indicator species are of immense value for the future pollution abatement programmes. In the present investigation the *O. chlorina* was used to test its capacity to reduce the levels of COD (Fig. 7.6). It was found that the test alga could significantly reduce the levels of COD of BRPL effluents. Our findings agree closely with the observation of Rana and Palria, (1991) demonstrating the luxuriant growth of *O. chlorina* in organically polluted habitats and it has a capacity to reduce the levels of phosphate, nitrate and COD from polluted water. These studies exhibit that algae can be used for assessment, evaluation and abatement of polluted river.