CHAPTER-I

Introduction

In all its forms, water shapes and nourishes life on earth. Two third of earth surface is covered by water (Clarke, 1994) which is about 365,656,200 km^2 of the globe. The world's unique biodiversity and human communities both depend upon quality and availability of water. About 35% of the world's primary productivity comes from aquatic plants including phytoplankton (Alexander, 1999). Depending upon the concentration of dissolved solutes, aquatic ecosystems of earth are broadly divided into two types -marine and fresh water. Marine ecosystems cover approximately 71% of the Earth's surface and contain approximately 97% of the planet's water which include oceans, salt marshes, intertidal zones, estuaries, lagoons, mangroves, coral reefs, the deep sea and the seas floor.

Fresh water ecosystems contain only a small fraction (0.01%) of the earth's water (Gleick, 1996). Fresh water systems are replenished by water that enters into the terrestrial environment as precipitation and flows both above and below ground towards the sea. These systems encompass a wide range of habitats, including rivers, lakes, wetlands, ponds and the riparian zones associated with them. Their boundaries are constantly changing with the seasonality of the hydrological cycles. Though fresh water ecosystems contain negligible portion of earth's water and occupy less than one percent of the earth surface, they are performing major ecological roles in the biosphere (Lieth and Whittaker, 1975). The different forms of freshwater ecosystems provide a broad variety of valuable goods and services for nature and environment, some of which are irreplaceable (Covich *et al.*, 2004). They are profitably used by humans for different purposes like drinking, cleaning, fishery, agriculture, navigation, industrial production, hydropower generation, recreational activities etc. Freshwater ecosystems provide several important ecosystem services to nature like maintenance of global hydrological cycles, nutrient cycles, harbouring biodiversity, treating and detoxifying pollutants, storing of excess water as a sink etc (Anonymous, 2005).

Freshwater ecosystems are the home to an extraordinarily high level of biodiversity. Freshwater biodiversity constitutes a vitally important component of the planet with a species richness that is relatively higher as compared to both terrestrial and marine ecosystems (Gleick, 1996). About 29,000 species have been reported in freshwater ecosystems which include about 12,000 species of fish with 17,000 other species from diverse groups such as microbes, algae, nematodes, rotifers, insects, crustaceans, annelids, and molluscs (Abell *et al.*, 2000; Moyle and Cech, 1996 and Palmer *et al.*, 2000). Global freshwater biodiversity is under threat due to combined and interacting influences of overexploitation, water pollution, flow modification, destruction or degradation of habitat and invasion by exotic species (Dudgeon *et al.*, 2006). Recent population explosion, consequent urbanization and industrialization exert serious environmental pressures on fresh water ecosystems and have affected them in such a way that their benefits and services have found to be declined significantly (Ramachandra, 2005). The losses of biodiversity in freshwater ecosystems are far greater than that of terrestrial ecosystems (Sala *et al.*, 2000).

Algae are photosynthetic organisms possessing chlorophylls and simple reproductive structures but lacking true root, stems and leaves. They are widely distributed in different forms of aquatic habitats extending from saline sea water to fresh water lakes/ponds and hot sulphur springs to ice capped mountains. Algae (derived from Latin word “alga” meaning seaweed) are heterogeneous group of traditional thallophyta (Round, 1981). The scientific history of algal research was days back to 7th September, 1674, as on that very day great inventor, Antone van Leeuwenhoek observed and reported a number of algae and unicellular flagellates. Later, the great scientist Linnaeus, in his artificial system of classification for plant kingdom kept a comparatively simple group of autotrophic plants as a distinct group and named as 'algae'. Smith (1955) described algae as simple plants having autotrophic mode of nutrition, whereas, Prescott (1969) defined that algae are chlorophyll bearing organisms and placed along with their colourless relatives (fungi) in the group thalloid i.e. they have no true roots, stems and leaves or leaf like organs. The most acceptable definition of algae till date was put forth by Fritsch (1935). According to him, “Unless purely artificial limits are drawn, the designation algae must include all holophytic organisms (as well as their numerous colourless derivatives) that fail to reach the differentiation characteristic of archegoniate plants”. The study of algae is called as “phycology” in contemporary science. It comes from the Greek term “phykos” means algae. Now a days, phycology is an important branch of plant science as because of its contribution towards the welfare of mankind and conservation of nature.

Being the autotrophic organism, algae make substantial contribution towards the primary productivity in aquatic ecosystems (Ganapati, 1972) and the base level in energy transfer within such natural bodies (Mishra and Tripathi, 2000). They are the most important photosynthesizing organisms on earth as they can produce more amount of oxygen by photosynthesis than that was produced by all other higher plants together (Round, 1981; Acharya, 2008). Being a producer in a waterbody, they are the prime source of energy for water dwelling animals (Sharma, 2003). The algae play an important role in solving some of the environmental problems (Kurano and Miyachi, 2004; Chu *et al*., 2009) besides having vast industrial and economic potential (Rai *et al*., 2000) as valuable sources for pharmaceuticals, health foods, carotenoids (Harun *et al.*, 2010*)*, restriction endonucleases (Saravanan *et al*., 2003) and in the bioremediation of industrial effluent (Muthukumaran *et al*., 2005; Kamaleswari and Sivasubramanian, 2011). Algae are also used as biological indicators of water pollution (Palmer, 1969; Prasad and Singh, 1982).

Structurally algae show a great diversity that ranges from simple unicellular non motile to motile, filamentous and ultimately to giant thalloid branched complex marine kelps (Sharma, 2003). As per mode of nutrition, algae range from autotrophic to heterotrophic through symbiosis and true parasites (Round, 1981). Due to all these contradictory characters and diversities, a definite and proper classification of algae became a tough job. But still a number of classification schemes are introduced by many workers from time to time. Some of them are not at all proper and some others are near about appropriate and thus classification has been changing from time to time (Sharma, 2003).

Algae occur in different habitats extending from saline sea water to fresh water lakes/ponds and hot sulphur springs to ice capped mountains. Algae are thus, ubiquitous (Round, 1981). Basically algae are true hydrophytes, but aerial / sub aerial and even some crustose forms are also familiar and found to occur in various environments. But most profoundly algae prefer to grow on wet conditions. The algae are almost invariably being found in all fresh water bodies. They exhibit a wide spread distribution in terms of latitudes. Different ecotypes may occur in different geographical regions (Sharma, 2003). The distribution and growth of algae is greatly influenced by the environmental factors like light, oxygen, carbon-dioxide, temperature, physico chemical parameters of water like pH, alkalinity, salinity, turbidity, DO, free CO_2, BOD, COD, dissolved nutrient like nitrate, phosphate and different kinds of mineral salts in water. Growth of algae suffers adversely due to inadequate or excess of nutrient supply in their habitats (Dixit *et al.*, 1991; Hall and Smol, 1992; Leland and Porter, 2000).

Rapid urbanization, industrial development and fluctuation in monsoonal rains have severely affected the physicochemical and biological constituents of natural water bodies like rivers, streams, lakes and ponds in India as a whole and North East India in particular. These changes in habitat conditions could influence natural process of algal seasonality. Thus it is very important to understand the interrelationship of seasonal variations in algal communities in relation to changed physico-chemical characteristics of the aquatic bodies for formulating management action plan in conserving these ecosystems.

Algae can tolerate stressed physical and chemical environmental conditions such as extremes of temperature; altitude; hypo and hyper salinity; high or low pH; domestic, municipal, industrial effluent and can grow in varied light intensity (Lackey, 1966). The algae that requires or that lives in such a extreme environment are known as "extremophilic". The extremophilic algae are very unique and maintain some unusual physiological and biochemical properties. A thorough understanding of particular adaptations of extremophillic algae may provide solutions to several environment related issues of the present world.

Algae are the indicators of pollution in aquatic ecosystems. They use to grow quickly and are very sensitive to any kind of changes in environmental quality. Algae are among the first organisms to respond to environmental changes and nutrient fluctuation. (Frempong, 1981; Sudhakar *et al.*1981, Tilman *et al.*1982). For the first time Kolkwitz and Marsson (1908, 1909) reported some pollution indicating algae. They described the pollution oriented changes in species composition and behaviour of algal communities in rivers. Palmer (1969) was one of the pioneer workers who made an attempt to identify the algal species that are highly tolerant to organic pollution and prepared a list of algae with 80 species under 60 genera tolerant to organic pollution. Khan, (1991); Biswas and Konar, (2000) also reported some algae as indicator of water pollution and eutrophication of water bodies. The profuse growth of Cyanophycean algae indicates disturbance of the biological equilibrium in water bodies in stagnant conditions (Fay, 1983). BGA under certain favourable conditions, grow enormous in number and subsequently form water blooms (Fitzerald, 1971). Cyanobacterial bloom usually appears in summer or autumn after a period of long warm season, followed by heavy rain. They are also associated with eutrophication. Algal blooms are harmful as they suppress the growth of other aquatic flora and fauna where they occur and also, retard the growth of other species of algae. Common algal species that cause algal blooms are *Microcystis aeruginosa; M. flos-aquae, Anabaena circinalis, A. flos-aquae, Euglena sp, Oscillatoria sp, Lyngbya sp* etc. (Rahman and Jewel, 2008). Algal bloom induce unpleasant odour and taste in aquatic systems thus making them unfit for consumption (Bordoloi, 1977; Bairagi and Goswami, 1992). Diatoms are also used in pollution studies because of their relatively more selective nature and it is easy to study their associations and communities for different environmental conditions (Werner, 1977). Desmids are one of the indicators of good quality of water (Prescott, 1938). They mainly occur in soft and slightly acidic habitat with rich organic and low calcium content. The ratio of desmids to other selected algal groups can be used as a measure of eutrophication in freshwater bodies **(**Shivalingaiah *et al*. 2009). Some of the Algal genera *viz. Euglena, Oscillatoria, Scenedesmus, Navicula, Nitzschia and Microcystis* are found basically in organically polluted waters. Moreover, epilethic and epiphytic algae is excellent indicator of water pollution (Round, 1965). *Microcystis aeruginosa* is regarded as the best single indicator of pollution and it is associated with highest degree of civic pollution. Some blue green algae (*Anabaena flos-aquae, Microcystis, aeruginosa, Aphanizomenon flos-aquae*) produce some metabolically active toxic substances due to their decay that cause severe ailment to human and other living bodies.

The crude oil industry is truely global, operating in every corner of the world, in all type of habitats from Arctic to desert, from tropical rain forest to temperate woodlands, from onshore to offshore. The global human community is entirely depended upon supply of oil and gas for day to day activities. Being the primary source of energy, crude oil render 36% of total global energy source (Anonymous, 2001).

Crude oil is a colloidal mixture of huge number of hydrocarbon and non-hydrocarbon (Cadwellaer, 1993). It is the source material for nearly all petroleum products like gasoline, diesel, wax, naptha etc. Hydrocarbons form 90% of crude oil are grouped according to their chemical structures such as saturated, unsaturated and aromatics. The remaining 10% non-hydrocarbon components of crude oil are known as heteroatom compounds. They include oxygen, carbon and sulphur along with some metals related porphyrin oxygen containing compounds e.g. naphthenic acid, carboxylic acid, esters, ketones, phenols etc (Odu, 1981).

India's history of oil exploration is 161 years old since 1854 when an Austrian entrepreneur, Wagentreiber get the lease and monopolistic rights over a tract of land between Bappapoong and Namchik in Assam by then British Government (Biswas, 2012). It is estimated that about 55 % of the local geographical area of Assam is made up of sedimentaries and can be considered as potentially oil bearing (Anonymous, 2009). Presently oil exploration and production in Assam have been carried out by two national public sector companies namely Oil India Limited (OIL) and Oil and Natural Gas Corporation (ONGC). Assam produces 4709 thousand metric tons of crude oil in 2013-14 which is about 12.5 percent of the total crude oil production in the country (Anonymous, 2014).

From exploration to production operations of crude oil, a huge amount of aqueous wastes rich in inorganic salts, heavy metals, solids, hydrocarbons, polycyclic aromatic hydrocarbons (PAHs), and naturally occurring radioactive materials are generated which causing adverse affects on aquatic systems (Kemmer, 1988). Oil contamination has been found to be toxic to wide array of aquatic organisms including algae. Oil affects algae in both direct and indirect way. Oil contamination affects algae on community level or species level depend upon type and volume of oil (Taş *et al.* 2010), time and prevailing weather condition, environmental and physical condition and algal composition and density of the area of oil contamination (O'Brien and Dixon, 1976). High concentration of soluble fraction of oil in water (WSF) inhibit algal growth significantly also decrease cell density (Huang *et al.* 2011). The decrease of DO and free CO_2 in water due to oil toxicity inhibit both respiration and photosynthesis of algal population (Tkalich *et al.* 1999). However, in some cases it was observed that low concentration of oil in water may promote the growth of certain species of algae (Jiang *et al.* 2010). Some tolerant species of algae can use oil hydrocarbons as additional source of carbon and accumulate them as their biomass (Tkalich *et al*,1999).Generally oil contamination reduces algal density but some groups may actually increase in relative abundance, resulting in a change in community structure. (Gilde and Pinckney 2012). Naturally algae show distinct seasonal change in species composition in aquatic systems. But in case of oil contamination tolerant groups become gradually dominant over less tolerant species, which may be dominant species in that area, decrease even vanish them, thus causing abnormal succession (Huang *et al.*, 2011; Jiang *et al*,. 2010).

In 1867, crude oil was first successfully explored in present day Tinsukia district. Since the day of discovery the aquatic life of this area was contaminated from natural and artificial seepage. The contaminated oil fields are surprisingly rich in biodiversity in terms of species and habitat (Baruah *et al*. 2006). Being situated amidst humid sub-tropical forest patches having high rainfall of more than 1800 mm per annum, the area harbors a good number of algal species both in the aquatic and terrestrial environment (Singh and Gaur, 1989; Bordoloi and Baruah, 2015a, 2015b). The freshwater algae of this area regularly exposed to crude oil contamination due to exploration, production, transportation and storage processes of oil industry. As these algal genera are growing in such an extreme habitat, they may acquire tolerance to oil contamination. Hence, a few thus could be identified as indicator of oil contamination.

The unique algal flora of the oil fields which is supposed to be one of the most potential sources in these subtropical crude oil contaminated environment of the world for phycoremediation, is yet to be explored for the purpose. The success in phycoremediation and future development of its scientific package and practice is entirely dependent upon identification and selection of appropriate algal strain, which is commonly available in the area with having high tolerance level to the exposed crude oil contamination and showing the most desirable and exploitable growth characteristics. For which ecological study of crude oil contaminated water bodies of oil fields is important to enumerate diversity, distribution and seasonality of fresh water algae along the gradient of crude oil contamination.

The present endeavour was therefore, aimed to develop a fresh water algal database of Tinsukia district (Assam) in relation to crude oil contamination with the following objectives:

1. To enumerate the diversity of fresh water algae in different polluted and non polluted water bodies of Tinsukia district.
2. To study the distribution pattern, periodicity and seasonal dynamics of algal population in the water bodies.
3. To study the physico-chemical properties of the water bodies.
4. To identify the crude oil tolerant fresh water algae.