CHAPTER I
INTRODUCTION

The Blue-green algae (BGA), also known as Cyanobacteria, are the pioneer oxygenic phototrophs on earth whose distribution around the world is surpassed only by bacteria. Cyanobacteria and similar organisms produced most of the oxygen found in Earth's atmosphere, which implies that early photosynthetic organisms would have lived in an atmosphere that was rich in CO₂ and poor O₂ (David et al., 2005). It was shown that three common cyanobacterial species can grow under conditions that resemble those thought to have existed on early Earth: very high pCO₂ and low pO₂. Fossil evidence points to their presence in geographically diverse regions during the Precambrian (2 or more than 3.5 billion years ago). They are a large and morphologically diverse group of phototrophic prokaryotes, which occur in almost every habitat on earth. This versatility may explain the remarkable lack of morphological (and presumably physiological) change seen in 3.5- billion-year-old fossilized BGA and their modern day counterparts (Adams, 2000). Their long evolutionary history has been marked by key geochemical and biotic transitions, including the creation of oxygenic photosynthesis (Holland, 1977), a prerequisite for the development and proliferation of metabolically complex microbial and higher eukaryotic life forms. Indeed, plastids of higher plants and other photosynthetic eukaryotes are thought to have possibly arisen from a single common ancestor, which is a result of an endosymbiosis between a phagotrophic host and a blue green alga (Loffelhandt and Bohnert, 1977). The gliding photosynthetic bacterium Chloroflexis is a
reasonable candidate as a for runner of the blue green algae (Pierson and Castenholz, 1971)

BGA are microscopic in morphology; they show pigmentation and oxygen evolving photosynthesis in which photosystems, PS II and PS I are connected in series. The genome size of blue green algae, representative of all major taxonomic groups, lies in the range, $1.6 \times 10^9$ to $8.6 \times 10^9$ Da which is comparable to that of other bacteria ($1.0$ to $3.6 \times 10^9$ Da) (Herdman, Janvier, Rippka and Stanier, 1979).

BGA are known to occur in oxic and anoxic environments. Several species can switch to the typical bacterial anoxygenic photosynthesis using sulphide as electron donor; other species assimilate sugars and organic compounds in presence of light (Rippka, 1972). In dark, blue green algae gain energy by respiring endogenous carbohydrates, which are accumulated in the light. However, under anoxic conditions some species maintain this requirement by fermentation whereas in a few cases chemo-organotrophy is found. Blue green algae can grow under very low water potential; such species can resist desiccation and grow in arid environments (Deserts) and/ or can tolerate high salinity to grow in hypersaline ponds (Thajuddin and Subramanian, 1992).

The survival of terrestrial blue green algae with respect to environmental stress condition have been studied by Gupta and Agrawal in 2006. They observed that Scytonema millei, Phormidium bohneri and Lyngbya mesotricha survived to 100 percent at atmospheric temperature of 5- 35°C and relative humidity 55-100 percent in rainy, winter and spring season but the survival was 15-25 percent in summer when temperature reached 48°C and relative humidity was ≤ 23 percent. Microcoleus chthonoplastes maximum survival was ≈ 80 percent in rainy season followed by a decrease to ≈ ½ and ¼ levels in winter and spring, respectively; it
disappeared in summer but a few cells and/or trichomes enclosed within sheath may be surviving sticking to soil, not evident microscopically, since the population reappeared at the same place with the onset of rain.

In many environments, BGA are the primary producers at the base of the food web of the ecosystem, viz. marine waters; hypersaline, brackish waters, soda lakes, freshwater, paddy field soils, deserts, cave walls, hot springs, polar regions and other extreme environments (Thajuddin and Subramanian, 2005).

BGA are basically microscopic, although large colonies or mats are quite conspicuous (Geitler, 1932; Desikachary, 1959). Coccid species occur as single cells, colonies or masses of various shapes wherein cells are arranged in rows resulting in a flat plate or are arranged radially in spherical colonies. Cell numbers may range from few to many. Colonies may be loosely attached to the substrata without polarity or remain firmly attached with a distinct base and apex. However, these are enclosed in a gelatinous sheath that varies in consistency and thickness. Filamentous forms produce a row of cells, referred to as trichome. Trichomes may be simple, straight as aggregated bundles, and or permanently spirally coiled. The trichome with the enclosing sheath is referred to as a filament; in some forms, trichomes may be enclosed by a common sheath. Some filamentous species are characterized by true cell differentiation and form heterocysts which unlike vegetative cells, lack an oxygenic photosystem, possess extraordinarily thick cell wall, and lack biliprotein pigments and carboxysomes. These cells are considered as the sites of nitrogen fixation, provide vegetative cells with combined nitrogen and are not viable when disconnected from the trichome. Many heterocystous BGA also form a second cell type, an akinete, which can germinate when conditions are suitable for growth. Akinetes are common among freshwater forms
but uncommon in marine habitat, probably because of the stability of the marine environment. Desiccated akinetes in soil samples have survived for 70 years (Bristol-Roach, 1920). The filaments are either unbranched or may be branched with uniseriate or multiseriate arrangement of cells. Besides presence of true branching, false branches may occur in some forms. The cells, filaments or colonies of most of the BGA are covered with distinct sheaths. The cell wall, which lies internal to the sheath is typically four layered. The four layers, L I to IV lie outside the plasmalemma in most blue green algae. The L- IV layer has a globular structure which contrasts with the fibrous or non-globular nature of the innermost layer of the sheath (Santra, 1993). An additional fibrous layer, called F-layer external to the L- IV is present in the members of Pleurocapsales (Waterburry and Stainer, 1978).

Pigmentation constitutes one of the primary characteristics of BGA. There is Chlorophyll-a, Phycocyanin-r, Phycocyanin-c, Phycoerythrin-c, B-Carotene and as many as eight Xanthophylls. The variations in the relative abundance of these pigments in various combinations result in many hues- olive-green, grey green, yellow brown or purplish. The same species when grown in different wavelength shows significant variation in pigment composition. This type adaptation is known as Gaidukov phenomenon (Krik, 1994)

BGA form symbiosis with major plant and animal groups- such as Fungi (lichens), Bryophytes, Pteridophytes, Gymnosperms, Angiosperms and animals (Rai, 1990; Playfair, 1921). The most common BGA found in symbiosis with plants belong to the filamentous genus *Nostoc* (Dodds and Gudder, 1927). Usually the proportion of heterocyst to vegetative cells in higher in symbiotic forms compared to free living BGA and this is determined by the nitrogen status of the
environment. A number of BGA live endophytically in other algae. The small filamentous BGA *Richilia intracellularis* lives endophytically in cells of the marine diatom *Rhizosolenia* sp., whereas *Nostoc symbioticum* occurs in *Geosiphon pyriformis*, a siphonous green alga. Species of Calothrix, Cyanodictyon, Lyngbya and Phormidium have been reported from the mucilage of other algae. Rhopelodia is fresh water centric diatom in which unicellular cyanosymbiont appears intracellularly as inclusion bodies (Pazinsky, 1997).

Lichens are symbiosis of fungi with green algae or BGA. The most common BGA found in lichens are species of *Calothryx, Fischerella, Gloeothecae, Nostoc* and *Scytonema* (Hitch and Millbank, 1975). Of the total of 18,000 species of lichens, about 8 percent are composed of nitrogen-fixing BGA (Cyanolichens).

A number of Bryophyte taxa are known to harbour symbiotic BGA which usually live intercellularly and belong to the genus *Nostoc* (Rodgers and Stewart, 1977). The cyanobionts, *N. calcicola* and *N. sphaericum* occupy mucilage filled cavities on the ventral side of the gametophyte of the bryophytes, *Aneura, Anthoceros, Blasia, Cavicularia, Diplolaena, Notothylus, Pellia, Riccardia, Riccia* and *Sphagnum*.

As many as 150 species in nine genera belonging to the family Cycadaceae of Gymnosperms, which produce coralloid roots, contain nodule-like structures that are inhabited by heterocystous BGA belonging to Anabaena or *Nostoc* (Grilli, 1980).

In angiosperms, the best-known symbiotic BGA association is formed between *Gunnera* sp. and *N. punctiforme*, where the BGA is located intracellularly in special stem nodules (Nilsson, Bergman and Rasmussen, 2000). Other less intensively studied angiosperm-BGA associations that are located in
root nodules are reported from *Trifolium alexandrinum* and *N. punctiforme* and from *Lemna triscula* that harbour BGA of different taxa (Nilsson, Bergman and Rasmussen, 2000; Bhaskaran and Venkataraman, 1958).

Symbiotic BGA have been reported in a large variety of sponges in which the unicellular BGA, *Aphanocapsa* sp. situated both intercellularly and intracellularly in host vacuoles (Wilkinson, 1979); marine echiuroid worms such as *Bonellia fuliginosa* and *Ikedogonium oogonia* and *Codium bursa*, different species of filamentous BGA have been reported (Fogg, Stewart, Fay and Walsby, 1968). Several blue green algal species have been studied as algae-moss association on barks of selected tree species in Arunachal Pradesh. A total 17 different species have been observed by them which are growing in association with epixylic bryophytes on trees of Rono Hills of Arunachal Pradesh. They suggest that algae bryophyte association can be used as an effective biological indicator to monitor any abrupt change in the environmental factors especially the pollution load in the environment (Mikter et al, 2006).

**Importance of Blue Green Algae:**

Some species of *Anabaena* and *Nostoc* are consumed as human food in Chile, Mexico, Peru and Philippines. *Nostoc commune* with high amount of fiber and moderate protein is of potential use as a new dietary fiber source and can play an important physiological and nutritional role in human diet (Subramanian *et al* 1996). *Spirulina* is used as food supplement because of its excellent nutrient composition and digestibility. It has high Protein content (60-70 percentage), 20 percentage Carbohydrate, 5 percentage Lipids, 7 percentage Minerals and 6 percentage moisture. It is also rich source of β-carotene, α-tocopherol, thiamine and riboflavin and is one of the richest sources of vitamin B₁₂. It is now
commercially available in the market in the form of powder, granules or flakes and as tablets and capsules (Thajuddin and Subramanian, 2005).

A large number of marine nitrogen fixing BGA has been tested for their nutritional value with the hybrid *Tilapia* fish fry; majorities were acceptable as single ingredient feeds. Very little growth rate of *Tilapia* fish using marine BGA with in-door and out-door cultures have been reported (Mitsui, Enternmann and Gill, 1983). In the laboratory of National Facility for Marine Cyanobacteriology, Bharathidasan University, Tiruchirapalli, the marine BGA *Phormidium valderianum BDU 30501* was shown to serve as a complete aquaculture feed source, based on the nutritional qualities and non-toxic nature with animal model experiments (Thajuddin and Subramanian, 2005).

A number of BGA are rich in vitamins and many can excrete them into the surrounding environment. Some marine BGA are potential source for large scale production of vitamins of commercial interest such as vitamins of the B-complex group and vitamin-E (Borowitzka, 1995). These are also considered as valuable sources of carotinoids which are mostly used as natural food colour, as additive for animal feed which results in enriching the colours of egg yolk, poultry and fish meat. The commercially used carotinoids include β- carotene, leutine, Zeaxanthin, astaxanthin, lycopene and bixin (Becker, 1990). β- Carotene offer immense scope because of its higher demand as it is an analogue of Vit- A and has the potential of forming two molecules of Vit- A. The vitamin content of the alga depends on the genotype, growth phase, nutritional status, growth conditions (light intensity, temperature, etc.) and other factors that affect growth and metabolism (Odintsova *et al.*, Nishijima *et al.*, 1991; Shigeoka *et al.*, 1995).
Different BGA that have been investigated for the production of vitamins include: *Anabaena cylindrical*, *A. flos-aquae*, *A. variabilis*, *Calothrix parietina*, *Chlorogloea fritschi*, *Diplocystis aeruginosa*, *Gleocapsa sp.*, *Nostoc muscorum*, *Plectonema nostocorum*, *Spirulina maxima*, *S. platensis*, *Phormidium bijugatum*, etc. Most of the water soluble vitamins are excreted in the supernatant and the proportion of the vitamin produced that is excreted in the medium may be quite high.

BGA being photoautotrophs have the ability to photosynthetically transform simple, labeled compounds such as $^{14}$CO$_2$, $^{13}$CO$_2$, $^3$H$_2$O and $^{15}$NO$_3$ into complex organic compounds. Isotopically labeled BGA metabolites such as sugars, lipids and amino acids are commercially available (Patterson, 1996).

BGA secretes enzymes that can be exploited commercially. In the laboratory of National Facility for Marine Cyanobacteriology, Bharathidasan University, Tiruchirapalli, the marine BGA have been used in large scale production of enzymes such as beta lectamase, protease and lipase (Prabaharan, Sumathi and Subramanian, 1994). Several common and unique sequence- specific endonucleases are known from *Anabaena cylindrical* (Acy I), *Anabaena flos-aquae* (Afl I & Afl III), *Anabaena variabilis* (AvaI & AvaII), *Anabaena variabilis* UW (AvrII), *Microcoleus sp.* UFFX 2220 (MstII), *Nostoc sp.* PCC 7524 (Nsp C I), which can be marketed at low cost since relative biomass production of BGA is much less expensive than that of bacteria (Elhai and Wolk, 1988). Enzymes such as chitinase, L- asparaginase, L- glutaminase, amylase,
protease, lipase, cellulose, urease and superoxide dismutase have been reported from BGA (Wikstrom, Szwajeer, Brodelius, Nilsson and Mosbach, 1997).

The antioxidant activity of C-phycocyanin isolated from three cyanobacterial species *Lyngbya* (marine), *Phormedium* (marine) and *Spirulina* (fresh water) was studied in vitro (Patel et al., 2006). The results demonstrate that C-phycocyanin from these three algae is able to scavenge peroxyl radicals with relative rate constant ratio 3.13, 1.89 and 1.8 respectively.

Analysis of extracellular growth-promoting substances liberated by *Nostoc muscorum* and *Haplosiphon fontinalis* was found to contain amino acids like serine, arginine, glucine, aspartic acid, threonine, lysine, histidine and iso-leucine (Misra and Kaushik, 1989a, 1989b). In addition, BGA are rich sources of several polyols, polysaccharides, lipids, fatty acids, halogenated compounds, etc. with properties employable as flocculants, surfactants and others (Becker, 1983).

Many BGA have been reported to produce antibiotics and other agents having antitumour or anticancer properties. Acrylic acid produced by BGA inhibits both G-ve and G+ve bacteria. *Lyngbya spiralis* has been shown to possess anti-parasitic activity against *Trichomonas sp.* (Davidson, 1995). A study carried out at National Cancer Institute, US observed that active agents, consisting of sulfolipids with different fatty acid esters isolated from *Lyngbya lagerheimii* and *Phormidium tenui* were remarkably active against the AIDS virus. Other BGA that produced extracts having inhibitory properties were *Phoemidium cebennse*, *Oscillatoria raciborskii*, *Scytonema burmanicum*, *Calothrix sp.* and *Anabaena variabilies* (Becker & Venkataraman, 1984). Phycocyanin, a blue pigment produced by BGA, orally extracted from *Spirulina*, when given orally to
laboratory mice infected with liver tumor cells, increased their survival rate (Iijima et al., 1999). Phycobilins have been used as antitumour agents and also for treatment of ulcers and haemorrhoidal bleeding (Anonymous, 1983). β-carotene extracted from *Spirulina* causes inhibition of experimental carcinogenesis (Schwartz et al., 1986)

Recently another compound named curacin A has been isolated from *Lyngbya majuscule* with antiproliferative activity (Dale et al., 1995). Another freshwater BGA, *Microcystis aeruginosa* has been shown to be a rich source of a number of unique peptides like microcystins, aeruginopeptins, microcystilide A, cyanopeptolins, micropeptins, microginin and aeruginosin 298- A which are basically protease inhibitors. Other trypsin inhibitors isolated from the same organism recently have been designated as aeruginosins 98- A and B (2) (Okino et al., 1995).

BGA produces a range of carbohydrates and fatty acids as storage products, as osmotic effectors, as metabolites and as sources of energy. And there are certain algal strains that produce a few important long chain saturated fatty acids. Under stress conditions lipid synthesis occurs as a result of decrease in photosynthetic activity. Although most of the oils produced by micro algae have fatty acid constitutions similar to common vegetable oils, there are several high value unusual fatty acids that can be synthesized exclusively by a number of algae (Becker, 1983). In BGA, total lipid content (% of dry weight) ranges from 2-23% and contains all different classes of lipids like neutral lipid, glycolipids and phospholipids. The major parts of non-polar lipids are triglycerides and free fatty acids, whereas the polar lipids are essentially glycerides. Algal lipids are typically
composed of glycerol, sugars or bases esterified to fatty acids with carbon chain length ranging from $C_{12}-C_{22}$ having straight chain molecules with an even number of carbon atoms as a result of their biosynthesis from acetate by $\alpha$- addition (Becker, 1983).

Hydrocarbon content is generally less in BGA but there are few species that contain relatively large amounts. These consist of normal alkanes, alkenes and methyl-branched alkanes with major components in the $C_{15}$ to $C_{18}$ range with traces of pristane and phytane in most species (Fehler and Light, 1970; Gelpi et al., 1968, 1970; Han and Calvin, 1970, Winters et al., 1969). The total hydrocarbon content in BGA is generally less than 1% and ranges from 0.05 to 0.6%. Another important group of compounds having commercial uses produced by algae including BGA are sterols. These act as substrates for synthesis of steroid hormones and related compounds. *Spirulina* produces clionasterol (Paoletti et al., 1976). The algal fats, oils and hydrocarbons have been commercially exploited with a wide range of applications like liquid fuels, waxes, biosurfactants, phospholipids and lecithins, essential fatty acids and prostaglandins. A number of lipids produced by these algae have surface active properties and can be potentially used in different industrial processes like flocculation and emulsification. These surfactants are particularly attractive as these are biodegradable. A large range of surfactants produced by BGA include phosphatidyl glycerol, phosphatidyl choline, phosphatidyl ethanolamine and a range of glucosyl diglycerides.

BGA have the ability to fix nitrogen of the atmosphere (biological nitrogen fixation). In this process the molecular nitrogen is reduced to ammonia by the
enzyme nitrogenase. Nitrogen fixation by BGA was first reported in 1889. The existence of an agronomic potentiality of blue green algae was recognized by De (1936), Singh (1942) who attributed the natural fertility of tropical rice fields to biological nitrogen fixation. Each year biological nitrogen fixation adds about 139 million tones of nitrogen to the land surface of the earth, chemical nitrogen fertilizer contributes about 36 million tones (Svensson et al, 1991). There are more than 100 species that have been shown to be capable of fixing N\textsubscript{2} symbiotically or non-symbiotically (Santra, 1993). Heterocystous forms belonging to Anabaena, Nostoc, Cylindrospermum etc. and some non-heterocystous forms like Plectonema, Gleocapsa and Trichodesmium can fix nitrogen of the atmosphere non-symbiotically. Only the Nostoc and Anabaena can fix nitrogen symbiotically. Non-symbiotic or free living BGA constitute a major group of N\textsubscript{2}-fixing microorganisms in rice-fields. These groups of BGA along with symbiotic form Anabaena azollae associated with the leaf of Azolla sp. have been held responsible for the spontaneous fertility in rice-field soils. The symbiotic nitrogen fixing relation between Azolla and Anabaena azollae is most active in flooded soils where it can fix as much as 4 kg of atmospheric nitrogen per hectare per day (Singh and Singh, 1987). Azolla supplies 150-300 tons per hectare per year of green manure, which supports growth of soil microorganisms including heterotrophic nitrogen fixers. The daily N\textsubscript{2}-fixing rate is as high as 7 kg N/ha in optimum condition for Azolla filiculoides and 3 kg for A. pinnata (Watanabe, 1984). Under favourable conditions certain species of BGA can fix as much as 80 kg nitrogen per hectare per crop depending upon the ecological condition (Roger and Watanabe, 1986). Nitrogen accumulated through this symbiosis is released in to the soil and made available to rice plants. Because of its high nitrogen fixing
activity and unique property of being able to retain a significant amount of nitrogenase activity in the presence of combined nitrogen, making the system compatible with inorganic nitrogen fertilization (Ray et al., 1979). In tropical rice fields, biological nitrogen fixation is essentially a blue green algal process (Singh, 1961; Subrahmanyan et al., 1964; Venkataraman, 1967; Singh, 1985; 1992). The beneficial effect of algal inoculation on the grain yield of many rice varieties has been demonstrated in different parts of the world. In general, these trials indicate that 10-15% increase in grain yield could be obtained through algal inoculation. On an average, there is contribution of 20-30 kg N/ha/season which means that chemical nitrogen fertilizer could be saved to that extent. This is especially more relevant to small and marginal farmers who are unable to invest on chemical nitrogen fertilizer. It is also observed that continuous application of algae for 4-5 consecutive season’s results in an appreciable population build up. The algal effect could be seen in subsequent years without any further inoculation. An inexpensive, rural oriented ‘Algal Biofertilizer Technology for Rice’ has been developed for the well being of small and marginal farmers in the country. This involves mass production of a mixture of BGA mainly constituting nitrogen fixing Anabaena, Tolypothrix and Westellopsis in an open air system along with a carrier (soil) in kucha pits (polythene lined) or permanent cemented tanks and then drying the mixed culture in sun. The dried flakes are collected and used to inoculate rice field. The advantage of this technology is that farmers can produce the algal biofertilizer at their own fields and according to their requirements with bare minimum inputs (Venkataraman, 1975, 1981). Beneficial effects of BGA inoculation have also been reported on a number of other crops such barley, oats, tomato, radish, cotton, sugarcane, maize, chilli and lettuce. And their residual
effects on any crop that follows rice because of their role in improving soil health (Kaushik and Venkataraman, 1979; Dadhick, Verma and Venkataraman, 1969). Most of the benefits derived by soil from this biofertilizer are either due to influence of their metabolic products or due to mechanical binding of the soil particles (Pabbi and Singh, 2004). A major role of BGA comprises organic matter accumulation in soil which becomes available to the subsequent crops. Organic matter acts as a storehouse of nutrients like nitrogen, phosphorus micronutrients, increases the exchange capacity of soils, releases CO$_2$, increases water holding capacity of soil, buffers the soil against rapid changes in pH, etc. Under field conditions 5-32 percent increase in soil organic carbon has been observed as a result of algal inoculations (Singh and Bisoyi, 1987, 1988). BGA also contribute in improving soil health, producing humus on soil surface after death and dissolve certain soil minerals, maintaining a reservoir of element in a semi available form for higher plants. 50-70 percent increases in soil aggregation capacity due to algal inoculation have been observed. This is attributed to the action of polysaccharides released by the algae and presence of interwoven filamentous BGA on the soil (Pabbi and Singh, 2004).

Reclamation of saline, saline-sodic and sodic soils with BGA has been advocated (Singh, 1961; Thomas, 1984; Kaushik, 1981). Alkaline and / or saline soils are extensively distributed in India. This unproductive soils characterized by impermeability and the presence of undesirable salts make soil surface extremely hard. The pH is usually high throughout the soil profile. The use of BGA has several advantages over chemical amendments by enriching the soil with organic carbon, nitrogen and increased availability of phosphorus. BGA respond to salt stress by releasing certain cellular constituents on coming in contact with salt
affected soils like salt stress proteins and amino acids. BGA also colonize the calcareous (CaCO$_3$) nodules that are richly present in saline soils. During the dissolution process, the Ca$^{+}$ ions are released which replace Na$^{+}$ on soil complex and thus reducing Na: Ca ratio in soil. Application of selected strains of BGA (Nostoc punctiformis, Tolyphothrix ceylonica, westiellopsis prolifica and Calothrix sp.) followed with incubation and irrigation has brought about reclamation of these soils (Kaushik, 1987).

There have also been claims that BGA can benefit rice plants by producing Plant Growth Regulators (PGR). The PGR effects the BGA cultures were likened to those of Vit.B$_{12}$, gibberellins and amino acids.

**Diversity of Blue Green Algae:**

BGA are widespread and abundant in most marine habitats. Of the total estimated area of 150 million sq. km of the earth, about 70.68 percent is occupied by oceans. However, of all the total photosynthetic productivity of 555.2 billion tons of dry weight/year on earth, only 34.4 percent is contributed by the oceans (Bassham, 1973). India has vast coastline of over 7500 km; in addition it has many lakes, ponds, puddles, backwater areas and a tropical climate that results in abundance of natural population of varied organisms. BGA have the ability to grow in sea water is presumably related to a preference for alkaline conditions and the ability to tolerate high salt concentrations. The resistance, which many species show towards osmotic shock, extremes of temperature and reducing conditions, suits their existence in a variety of intertidal habitats (Thajuddin and Subramanian, 2005. About 20 percent of all known BGA occur in saline conditions and majority of them are truly marine (Desikachary, 1959).
The upper millimeter of dry soil often appears crusty in nature due to growth of microorganisms comprising cyanobacteria, algae and/or lichens. Species of filamentous, sheath-forming cyanobacteria were the major component in the blakish-brown crusts on the upper milliletre of soils in different regions of India (Tirkey and Adhikary, 2005). BGA are available in the rocky shores covering the intertidal area showing benthic habit. They are apparently always present as epiliths, chasmolith and endoliths including sometimes as discrete well-developed cryptoendolith layer at a depth of 6mm inside the rock (Moul, 1975). On sandy shores, the BGA shows poor growth due to rough tides, absence of substratum, and poor nutrient content of water (Thajuddin and Subramanian, 1992). In some areas, the stagnant sea water ponds and puddles showed rich populations blue green algae in the form of thick mats, because these habitats remained undisturbed for relatively long periods (Thajuddin and Subramanian, 2005).

Backwater and mangrove forests are common along many shores in the tropics and subtropics, particularly where they are protected from severe wave action and major rivers enter the sea. Benthic BGA are abundant in mangrove environments. This is on account in mangrove substratum, relatively stagnant shallow water conditions, sheltered nature and optimum salinity conditions (15-30 ppt.) (Thajuddin and Subramanian, 2005). There are as many as 58 species of BGA belonging to 22 genera in backwaters and mangrove habitats of the southern east coast of India have been reported. BGA are reported from salt pans with salinity over 50 ppt. Non heterocystous forms in general and the species belonging to the family Oscillatoriaceae in particular were dominant; and some could grow at even 340 ppt. salinity (Thajuddin and Subramanian, 1992). Hof and Fremy,
who studied the flora of salt waters, divided algae in two physiological groups, halotolerant and halophilic. Halotolerant species are not able to grow at NaCl concentration above 3 M (175.5 ppt.), e.g. *Calothrix scopularum*; other examples include salt-water forms such as *Microcoleus chthonoplastes* and *Lyngbya aestuarii*. Halophilic species such as *Spirulina subsala* can grow at salt concentrations above 3 M and therefore occur commonly in salt pans (Hof and Fremy, 1993).

BGA, belonging to the order Chroococcales, and families Oscillatoriaceae and Nostocaceae occur ordinarily as planktonic forms. Several species grow in abundance and colour the entire body of water, forming the so-called waterblooms. Huber-Pestalozzi (cited by Desikachary, 1959) lists as many as 42 genera of 251 species of BGA that occur as freshwater planktons. *Microcystis* is one of the dominant organisms that associated with almost permanent blooms in tropical freshwater that are exposed to constant sunshine, warmth and nutrient like phosphate, silicate, nitrate, CO$_2$ and lime (Frankelin, 1972). Formation of BGA blooms in fresh water bodies is essentially due to the buoyant nature of these organisms. Buoyancy is imported by the gas vacuoles and the rate of surface accumulation of these organisms is dependent upon the number of gas vacuoles within their cells. Gas vacuole containing BGA form dense growth on the water surface in ponds, reservoirs and lakes and cause serious nuisance because of visual appearance, production of toxins and unpleasant odour produced by substances such as geosmin (Carmichael, 1985; Juttner, 1995).

BGA have been reported from sea level to high altitudes. They are abundant in temple tanks, ponds in the hill ranges and water lakes. They occupy a
variety of terrestrial environments. Soil is one of the most potential habitats for algal growth particularly in moist or waterlogged conditions. Various workers have studied the Indian rice field for BGA during the past half century. Waterlogged rice field is an ideal habitat for these BGA which are capable of N\textsubscript{2} fixation. Summarizing past studies of BGA distribution in rice fields of tropical and temperate countries, it can be concluded that BGA constitute about 15 percent of the total algal flora in the tropics and about 2 percent in the temperate climate.

BGA have been reported from thermal waters all over the world. Setchell (1903) suggested that the upper limit of BGA as 65°C to 68°C and describes it as 69°C. *Mastigocoleus laminosus, Phormidium tenue* and *Synechococcus elongates var. amphigranulatus* are more common species in hot springs (Lemmermann, 1970).

BGA can also tolerate low temperatures; *Phoemidium* sp. has been reported from extensive ice layers in the Antarctic lakes. (Taylor, 1954) reported *Calothrix* and *Rivularia* as common BGA inhabiting marine Arctic areas while *Gleocapsa* and *Nostoc* were abundant in freshwaters. A recent amount estimated that 700 taxa of nonmarine algae are present in Antarctica (Broady, Garrick and Anderson, 1996). Many extremophiles have evolved to grow best at extremes of pH. BGA are indeed present in acid lakes (pH 4.1-5) and have even found to dominate at low pH (Kwiatkowski, 1976).

BGA are often exposed to heavy metal pollution due to the disposal of industrial and domestic wastes into waterways. BGA growing in metal-polluted environments display the ability to tolerate high concentration of toxic metals, Cu, Cd, and Zn (Mallick and Rai, 1990).
The above mentioned work shows that blue green algae is an important organism which require lot of attention for exploration, identification and documentation of each and every district of India. In this regard Bongaigaon is one of the biodiversitically rich districts of Assam where no such works have been done till now. Bongaigaon is selected for the present survey work. The BGA of this district was not explored earlier and most of the areas are still lying virgin. Therefore knowledge of the occurrence, distribution, and morphology of BGA in the district is considered to be of paramount importance. The study was undertaken to survey, collection and identification of BGA of different habitats of the study area.