2. REVIEW OF LITERATURE

Water is like religion and ideology, which acts as power to more millions of people. Since the very birth of human civilization, people have moved to settle close to it. People move when there is too little of it. People move when there is too much of it. People journey down it. People write, sing and dance about it, everywhere and every day they need it.

Environment is the interaction of air, land, water and energy in relation to life system. Among them water is one of the most important commodities which is exploited by man than any other resources for the sustenance of life. According to Odum (1971), pollution is misplaced by energy and matter. In polluted water, excessive energy/matter is introduced into the aquatic system that in turn proves to be harmful to living organisms.

There is a great variation among living organisms found on the earth since they differ in structure, habit, habitat, mode of nutrition and physiology. Such a diversity among organisms is called biodiversity.

A review of previous works presented here in by design restricted to recent studies on freshwater microalgae with special reference to physico-chemical parameters of water, morphology, distribution, richness, specimens, nutrient analysis and mineral distribution in
microalgae, since a complete review is impossible. Occurrence of freshwater microalgae in lentic type of water bodies at different parts of Tamil Nadu was studied by several workers.

Studies on freshwater bodies of India extend back to later half of the 19th century and were initially in the nature of mentioning species list and the description of taxa new to the Indian sub-continent (Muchael, 1980).

The inland freshwater bodies of India were classified on the basis of location and time duration of the water body Ganapathi (1960). Philippose (1960) classified them on the basis of total alkalinity. According to Sreenivasan (1979), temple tanks constitute a very peculiar ecosystem in India. Most of these are hyper-trophic, though they are not directly polluted by sewage, indicated by a dense bloom of blue green algae, especially *Microcystis aeruginosa*. According to Gulathi and Schutz (1980) the number of lakes and reservoirs in India is very low considering the size of the country. The number of ponds and tanks is undoubtedly larger than those of lakes and reservoirs. Studies on smaller water bodies are far more important when compared to those on lakes and reservoirs.

The studies on water quality of lakes in Kashmir has been carried out by Zutshi *et al.* (1980); Zutshi and Vass (1982); Mir and Kachroo (1982). In Madhya Pradesh, Adholia *et al.* (1991) studied on
the abundance, distribution and total population of phytoplankton in relation with limno-chemical parameters of Manasarowar reservoir in Bhopal. Rao and Choudary (1990) studied some aspects of phytoplankton dynamics in relation to hydrological parameters and explained their relation with status of primary production in Gandhisagar reservoir. In Uttar Pradesh, diurnal variation in physico-chemical factors of Rihand reservoir was studied by Singh et al. (1980). Singh (1983) and Srivastava et al. (1999) have studied in the G.B. Plant Sagar reservoir in the South Mizapur district of Eastern Uttar Pradesh in terms of its water quality, phytoplankton abundance and primary production.

The Indian sub-continent enjoys a great variety of topographical and climatic conditions and as result of this the freshwater algae are rich both in variety and abundance. These freshwater habitats ranging from large deep perennial lakes to the small shallow static ponds and pools are dispersed all over the country. The Indian freshwater systems offers a wide variety of habitats providing subtropical to fully tropical conditions for rich phytoplankton association.

Filamentous cyanobacteria (blue-green algae, cyanoprokaryotes) include some of the most widely recognized and important freshwater algae in the world, many of which produce surface blooms, fix atmospheric nitrogen and are important components of global carbon fixation (Whitton and Potts, 2000). Basic information on the biology and ecology of the unique morphology and biology of filamentous blue-
greens has been obtained from literature collection. The system that has been used for several decades for distinguishing genera of filamentous cyanobacteria is based on phenotypic characters which has further been supported by ultrastructural and molecular data in many instances (Rippka et al., 1979; Anagonstidis and Komarek, 1988). Current molecular analyses support the separation of non-heterocystous and heterocystous genera; however, we can expect further changes on both the generic and the species levels for many of these organisms through recent biotechnology (Castenholz, 1992; Rudi et al. 1998).

Since the earlier days very impressive progress has been made in the field freshwater biology and the comprehensive books on Limnology by Hutchinson (1967, 1975a,b) and Wetzel (1975) are the very valuable source of literature.

The algal problems peculiar to the tropics, with special reference to those of India, were highlighted by comparing the tropical and temperate climates, Iyengar (1939). Thineman (1954) concluded that the impact of environmental factors was much weaker in water than on land. He further reported the tropical waters are characterized by greater phytoplankton biomass, phytoplankton productivity and higher rates of bacterial decomposition in the bottom sediments, which are all attributed to the low angles of incident radiations, longer day lengths, greater intensity of illumination and uniform high temperature.

In Andhra Pradesh, Venkitawarlu and Manikya Reddy (1985) worked a number of rivers for different physico-chemical and physiological angles. Johnson (1991) worked on total nitrogen and phosphate content of two freshwater lakes of Hyderabad. In Karnataka, Hedge and Bharati, (1985) compared the biomass of plankton in four water bodies of Dharwar. Ayyappan and Gupta (1985) while studying a perennial pond of coastal Karnataka traced out a significant correlation between physical and chemical parameters and plankton.

In Tamil Nadu, Iyengar (1939), Chacko and Krishnamurthy (1954); Zafar (1959); George (1961; 1966); Sreenivasan (1964; 1965; 2002); Munawar (1972) worked on pond ecosystem. Palaniappan (1989) made ecological studies on pools of Salem district. Anand (1998) made survey on fresh water micro algae of India. Jeeji Bai and Lakshmi (1999) made studies on few temple tanks. However, the literature pertaining
to the occurrence and distribution of freshwater microalgae in the Perumal lake at Cuddalore district and Kolavoy lake, Kanchipuram district in Tamil Nadu, in our country is found meager.

Limnological studies on seasonal variation and human activities causing changes in nutrient availability and creating unfavourable conditions for other aquatic life, especially phytoplankton are limited. Phytoplankton abundance and composition in aquatic ecosystems are regulated by abiotic factors such as, nutrients related to physico-chemical variability and biotic, trophic interactions (Sin et al., 1999 and Lewis, 2000). The growth of phytoplankton in tropical regions depends on ambient nutrient levels more than other environmental factors (Mooris, 1980 and Al-Jassabi and Khalil, 2006). However the relationships between phytoplankton dynamics and environmental change are still poorly understood in many regions of the world (Miretzky et al., 2002).

Information on algal diversity is important for the study of primary productivity, to understand the factors influencing rise, fall and change in algal populations, interactions of algae with other organisms and to study the effect of anthropogenic pressure upon aquatic habitats (Goldman and Home, 1983; Kumar, 1990). Some algal forms can used as indicators on which major water management practices and water quality analysis can be keyed (Palmer, 1969; Schubert, 1984). The importance of algal dynamics, particularly cyanobacteria as the enormous potential organisms for the pollution free environment.
Cyanobacteria, also known as blue green algae, are a group of extraordinary diverse gram-negative prokaryotes that originated 3.5 billion years ago. The diversity ranges from unicellular to multicellular cocoid to branched filaments, nearly colourless to intensely pigmented, autotrophic, heterotrophic psychrophilic to thermophilic, acidophilic to basophilic, planktonic to benthic, freshwater to marine including hypersaline. Cyanobacteria were originally considered as algae because of their microscopic morphology, pigmentation and oxygen evolving photosynthesis in which photosystems, PSII and PSI are connected in series. Cyanobacteria are known to occur even in anoxic environments (Thajuddin and Subramanain, 2005).

During the recent past, studies on cyanobacteria have emphasized their important role in ecosystems. They grow at any place and in any environment where moisture and sunlight are available. However, specific algae grown in specific environment and therefore the distribution pattern, ecology, periodicity, quality and quantitative occurrence differ widely.

Besides their ecological significance, as a great potential tools as an organisms for the biotechnological interest such as mariculture, food, fuel, fertilizer, medicine and combating pollution (De, 1939; Venkataraman, 1981; Venkataramanan, 1983; Kannaiyan, 1985; Borowitzka, 1988; Prabaharan and Subramanian, 1995; Subramanian and Uma, 1996).
Diatoms have been focused as powerful indicators of environmental change (Dixit et al., 1992). They have been used extensively in recent studies related to ecological aspects e.g. indicator value for water quality (Van Dam et al., 1994), acidification of water systems (Battarbee, 1994) and trophic index for monitoring eutrophication (Kelly and Whitton, 1995).

It was found during the present investigation that *Cyclotella meneghiniana* occurred in lakes and was the most prominent indicator of organic pollution. Anthropogenic pollution were indicated by diatom such as *Synedra ulna* which occurred in all the lakes. Other species were represented by *Amphora ovalis, Pinnularia gibba, Cymbella tumida, Gomphonema olivaceum, Synedra acus, Nitzschia gracilis, Navicula rhynocepalata, Cocconies pedicules* and *Navicula amphiceropsis* which were all indicators of anthropogenic activity in the lakes. Therefore diatoms serve as powerful indicators of organic as well as anthropogenic pollution. The habitat of all the diatoms recorded were tochoplanktonic to euplanktonic and the tolerance status ranged from sensitive to most tolerant.

However, due to the advantage of habit and sampling of epilithon (usually epihlithic diatoms), the colonization and/or establishment of the epilithic algal community both structure and composition was studied in a lentic and lotic water system (Blinn et al., 1980). The establishment of epilithic algae on newly exposed stream bedrock
(Stock and Ward, 1989), the colonization of the periphytic microalgae on artificial substrates such as wood, acryl plate and marble stone (Cho, 1994), the colonization dynamics of algal communities on wood and tiles (Sabater et al., 1998) and the establishment of epilithic algae on glass slides (Lee et al., 1998; Lam and Lei, 1999). But recently Cattaneo et al. (1997) pointed out the importance of substratum rather than the biomass of periphyton distribution and abundance. On fine sediments, (sand and fine gravel) most algae were loosely attached to the substratum and colonial blue greens and motile diatoms were important but in contrast on coarser substrata algae were strongly attached. However the relationship between the colonizers and the substratum were uncertain.

Analysis of physico-chemical parameters of water is essential, to assess the quality of water for the best usage like irrigation, drinking, bathing, fishing, industrial processing and so on. Water quality deals with physical, chemical and biological characteristics in relation to all other hydrological properties. In India large number of studies on limnology of lentic water bodies have been carried out in past 30 yeas (Lakshminarayana, 1963; Shardendu and Ambasht, 1988; Pathak and Bhatt, 1990; Pandey et al., 1993; Lohar and Patel, 1998; Shashtri et al., 1999; Prapurna and Shashikant, 2002; Shaikh, 2004; Madhuri and Minakshi, 2008).
Nutrient stimulation of algal growth made algae part of the problem in the eutrophication of lakes such as trophic status of lakes was also characterized by the amount of algae (Vollenweider, 1976; Carlson, 1977). In North America, Ruth Patrick and Mervin Palmer were pioneers in the development of large monitoring programs to assess the ecological health of rivers and nuisance algal growths (Patrick, 1949; Patrick et al., 1954; Palmer, 1969). More recently, the sensitivity of many algal taxa to pH, combined with preservation of certain algal cell wall components (e.g. diatom frustules and chrysophyte scales) in sediments, has been employed to assess problems with acid deposition and to determine if rates of lakes acidification have been enhanced by human contributions to acid deposition (Smol, 1995; Battarbee et al., 1999).

Richness and evenness of taxa abundance are two basic elements of diversity (Shannon, 1948; Simpson, 1949; Hurlbert, 1971) of biological assemblages. Richness and evenness are hypothesized to decrease with increasing human disturbance of habitats; however, evenness of species abundances may increase if toxic stresses retard the growth of dominant taxa more than rare taxa (Patrick, 1973). Two problems develop with use of diversity measures in environmental assessment: standard counting procedures may not accurately assess diversity (Patrick et al., 1954; Stevenson and Lowe, 1986) and
diversity may not change monotonically across the gradient of human disturbance (Stevenson, 1984; Juttner et al., 1996; Stevenson and Pan, 1999). Species diversity and evenness are highly correlated with standard 300-600 cell counts (Archibald, 1972). In these counts many species have usually not been identified, so richness is more a function of evenness than evenness is a function of richness (Patrick et al., 1954; Stevenson and Lowe, 1986). As shown by standard counting procedures, nonmonotonic (showing both positive and negative changes as the independent variable increases) response of algal diversity to some environmental gradients seem to be related to maximum evenness of tolerant and sensitive taxa at midpoints along the environmental optima, to fewer species being adapted to environmental extremes at both ends of environmental gradients, and to subsidy-stress perturbation gradients (Odum et al., 1971). Despite these difficulties, species richness and evenness may respond monotonically (having only positive or negative changes, but not necessarily linear changes, as the independent variable increases, sensitively, and precisely to gradients of human disturbance in some settings and should be tested for use as metrics.

The chemical composition of algal assemblages can be used to assess the trophic status of water bodies (Carlson, 1977), such as total phosphorus (TP) and nitrogen (TN) concentration of water and periphyton (Dodds et al., 1998; Biggs, 1995). TN:TP ratios are widely
used to infer, which nutrient regulates algal growth (Healey and Hendzel, 1980; Biggs, 1995). In many of these assessments, most of the total P and N are particulate and much of the particulate matter is algae. Thus, measurements of TP or TN per unit volume or area of habitat largely reflect the amount of algae in the habitat. Of course, the most widespread use of tropic assessments with TP and TN is phytoplankton in lakes (Carlson, 1977) and in streams, rivers, and wetlands (Dodds et al., 1998; McCormick and Stevenson, 1998). TP and TN per unit biomass in benthic algae have also been positively correlated to benthic algal biomass in streams; however, negative density-dependent effects may reduce biomass-specific concentration of benthic algal TP and TN and confound estimates of P and N availability to cells (Humphrey and Stevenson, 1992). Volume-specific, area-specific and biomass-specific estimates of TP and TN do increase monotonically and may be good metrics for trophic status in streams, rivers and wetlands as well as lakes.

Chemical assessments are also valuable for monitoring heavy metal contamination in rivers, lakes and estuaries (Briand et al., 1978; Whitton et al., 1989; Say et al., 1990). Many algae accumulate heavy metals when exposed to them in natural environments (Whitton, 1984). While toxicity of heavy metals in algae, other reasons include bioaccumulation and metal removal from waste streams and movement of heavy metals into the food web (Whitton and Shehata, 1982; Vymazal, 1984; Radwin et al., 1990).
Metabolism of algal assemblages is highly sensitive to environmental conditions and is important to the assessment of ecosystem function and many ecosystem service. Estimates of photosynthesis (gross primary productivity), respiration, net primary productivity, nutrient uptake and cycling and phosphate activity are common functions measured in ecological studies (Bott et al., 1978; Healey and Hendzel, 1979; Wetzel and Likens, 1991; Marzolf et al., 1994; Hill et al., 1997; Whitton et al., 1998). These techniques are rarely incorporated into routine monitoring and survey work because they require more field time than typical water, phytoplankton and periphyton sampling. However, they can be valuable additions to bioassessment projects. Biggs (1990) describes that algal growth rates can be used to assess stream enrichment. Metabolism can be based on an area-specific, or biomass-specific basis. The most direct measurement of cellular performance is biomass-specific rates of metabolism; however area-specific and volume-specific measurements directly relate to community performance and ecosystem services. Caution in the accurate use of these attributes must be exercised. Area and volume-specific measurements of productivity and respiration increase with biomass in the habitat, irrespective of human influence of biomass-specific rates of productivity and nutrient uptake decrease substantially with increasing biomass in the habitat, presumably because of shading and impairment of nutrient mixing through the microbial matrix (Stevenson and Glover, 1993).
Many ultrastructural features of euglenoids indicate that a significantly greater diversity exists within this group than previously recognized from light microscopic studies (Triemer and Farmer, 1991a,b). A revision of evolutionary lineages of euglenoids has been proposed based on ultrastructure and nutritional modes (Dawson and Walne, 1994). Ultrastructural studies have focused on the feeding apparatus, basal body complex, and pellicular complex (Moestrup, 1982, Kivic and Walne, 1984, Triemer and Farmer, 1991a,b). Four different types of feeding apparatus have been reported in euglenoids (Triemer and Farmer, 1991a). The diverse feeding apparatus serve as a basis for interpreting phylogenetic relationships among euglenoids and kinetoplastids (Kivic and Walne, 1984, Willey and Wibel, 1985a,b, Willey et al., 1988, Triemer and Farmer, 1991a,b). A striated fiber occurs in the feeding apparatus of the phagotrophic euglenoids (Mignot, 1966, Triemer and Fritz, 1987) but there are, no reports on the presence of such a striated fiber in the photosynthetic members.

Two basal bodies and three asymmetric microtubular roots of the flagellar apparatus are seen in euglenoids. In addition to these structures, euglenoids have either a large connective fiber or smaller reduced fibers (Solomon et al., 1987; Farmer and Triemer, 1988). The fibers are suggested to have been gradually reduced in size and complexity after the acquisition of chloroplasts (Triemer and Lewandowski, 1994).
The pellicular complexes and its associated microtubules have been used to infer phylogenetic relationships of euglenoids (Leedale and Hibberd, 1974; Kivic and Walne, 1984). The pellicular microtubules are continuous with microtubules of the reservoir base and considered to give the body its shape, elasticity and rigidity (Willey et al., 1988). Although ultrastructural information on the cytoskeleton is available for green algae (West et al., 1980; Willey and Wibel, 1985a, 1987, Surek and Melkonian, 1986, Owens et al., 1988; Triemer and Lewandowski, 1994; Shin et al., 2000) and colorless euglenoids (Leedale and Hibberd, 1974) still many taxa are in need of detailed observations of microtubule arrangement from the basal body complex to the pellicular ridges.

*Phacus dujardin* is photographed with small chloroplasts, slightly to markedly compressed and free swimming (Leedale, 1967). Despite being one of the largest euglenoid genera, *P. pleuronectes* (O.F. Muller), *dujardin* is the only species studied by transmission electron microscopy (Dynesius and Walne, 1975). To enhance our understanding of the phylogenetic relationships of *Phacus* in the euglenoids, we present detailed observations on the feeding apparatus of basal body complex, and microtubule arrangement from the basal body to pellicle of *P. trypanon*. The morphology of *P. trypanon* in light and scanning electron microscopy has been studied by Kim et al. (2000a,b). This species differs from *P. pleuronectes* in two ways; it has a helically arranged pellicle and it occurs commonly throughout the world (Pochmann, 1942).
The genus *Phacus dujardin* consists of free-swimming phototrophic taxa commonly bearing small discoid chloroplasts, having a slightly to markedly compressed rigid body with helically or longitudinally arranged pellicular strips (Leedale, 1967). Recent light and electron microscopic studies of the genus focused on the general morphological features (Dynesius and Walne, 1975; Kim *et al.*, 2000a,b, Shin and Boo, 2001). However, the ultrastructure of the flagellar apparatus and microtubule-reinforced (MTR) pocket has not been described for any *Phacus* species having longitudinally arranged pellicle strips and a markedly compressed cell body. Both the key features have been used in the taxonomy of the genus. On the basis of morphological characters, Leedale (1967, 1978) placed the genus *Phacus* near the top of his phylogenetic scheme, a hypothesis later supported by Dawson and Walne (1994). However, recent data now suggest that the genus *Phacus* is polyphyletic (Leander and Farmer, 2001a) and more basal (Linton *et al.*, 1999; 2000). Earlier investigators hypothesized that the euglenoid species with basal body connective fibers and pocket-like feeding apparatus (type I of Triemer and Farmer, 1991a) arose early on in the euglenoid lineage (Triemer and Farner 1991a,b, Montegut-Felkne and Triemer, 1997). This reasoning was based on the generalization that most phagotrophic euglenoids, the postulated progenitors of the phototrophs, have a striated fiber in the basal body region and Boo (2001) suggested that the genus *Phacus* should be
considered to be at the base of the euglenales disvering early in the history of the photosynthetic euglenoids. The only ultrastructural study (Dyneius and Walne, 1975) on *P. pleuronectes* before this description examined some features of the reservoir region and flagella and described a “multitubular structure” that they suspected was part of the flagellar root system. This multitubular structure probably represents a portion of what is now known as the MTR pocket complex. In this study, we present the absolute configuration of the region of the cell from the level of the basal body complex to the level of the reservoir canal transition and phylogenetic relationships between photosynthetic euglenoids and colorless euglenoids based on similarities in the striated fibers of the flagellar apparatus and MTR pocket complex is discussed.