


1. **GENERAL INTRODUCTION**
1.1. Introduction

Water is an indispensable natural resource on earth. All life including human being depends on water. We have enormous resources on the earth amounting to about 13,481,96000 Km$^3$ of water. In India 77% of water is used for agriculture sector (Goyal, 1996). Out of the total water reserves of the world about 97% is salty water and only 3% is freshwater. Even this small fraction of freshwater is not available to us as most of it is locked up in polar ice caps and just 0.003% is readily available in the form of ground water and surface water (Kaushik and Kaushik, 2006).

1.2. Freshwater and its importance

Freshwater habitats occupy a relatively small portion of the earth’s surface as compared to marine and terrestrial habitats, but their importance to man is far greater than these areas. Freshwater is the most suitable and cheapest source of water used for domestic and industrial needs and they provide convenient waste disposal systems (Kamble et al., 2008). The increased demand for water as a consequence of population growth, agricultural and industrial development has forced environmentalists to determine the chemical, physical and biological characteristics of natural water resources (Regina and Nabi, 2003).

A freshwater environment is subject to several external factors such as temperature, dissolved oxygen, light penetration, turbidity, density, etc. These factors are responsible for the distribution of organisms in different freshwater habitats according to their adaptations, which allow them to survive in that specific habitat (Jaffries and Mills, 1990).

In India, the freshwater constitutes rivers, streams, lakes, ponds and reservoirs. These freshwater bodies directly help in the growth of human civilization. Fresh water
resources are being polluted day by day at faster rate, so the water quality is now in a global problem. There is an extensive literature, which stresses the deterioration of water quality (Venkatesh et al., 2009). Among the freshwater ecosystem, pond ecosystem remains as a significant one.

A pond is referred to as a man made or natural water body which is between 1 m$^2$ and 2 ha (~ 5 acres cr 20,000 m$^2$) in area, which holds water for atleast four months of the year or more. The component of water includes dissolved oxygen, hardness, turbidity, alkalinity, nutrients, temperature, etc. conversely, other parameters like biological oxygen demand and chemical oxygen demand indicate pollution level of a given water body. In most water bodies various chemical parameters occur in low concentrations (Ehiagbonare and Ogunrinde, 2010).

Temporary ponds are found throughout the world. Though there are considerable regional differences in their type and method of formation, many physical-chemical and biological properties are quite similar. The worldwide distribution of water body leads to a large variety of temporary pond type due to climatic and geological differences (Solanki et al., 2007).

Stagnant water bodies have more complexes and fragile ecosystems in comparison to running water bodies as they lack self cleaning ability and hence, readily accumulate greater quantities of pollutants. Increased anthropogenic activities in and around the water bodies damage the aquatic systems and ultimately the physico-chemical properties of water (Upadhyah et al., 2010). Aquatic ecosystems are dynamic systems, in which several biotic and abiotic variables change in space and time due to different processes. The realization of the causal changes in time of these complex systems are very restricted (Kobbia et al., 1991).
1.3. Temple Ponds

In India natural ponds are estimated to have an area of about 0.72 million ha, most of which are found in the vicinity of villages, places of religious worship and other human inhabitations (Isaiarasu and Mohandoss, 1998; Kamat and Sima, 2000). Temples are centers of worship for Hindus and Sikhs. Most of the Hindu temples in India have ponds which are holy and called temple ponds. Ponds are found inside or outside the temples. Temple management imposes restrictions over misuse of these holy ponds and therefore they remain comparatively clean. Temple devotees use the holy dip into the water, people believe that it can wash all their sins away. However, temple ponds located outside the temples are used by the people for bathing and even washing clothes. Literature review showed that only a few studies (Anithakumari and Aziz, 1989; Maya et al., 2000 and 2001) were available on temple ponds. In most of the districts certain sacred groves were recorded and they also provided with ponds named as sacred grove ponds. Their physico-chemical characters of water and sediment vary. The algal diversity was different and reported with pollution indicating algae (Kavitha and Balasingh, 2007).

1.4. Water Qualities

Water quality provides current information about the concentration of various solutes at a given place and time, and the parameters provide the basis for judging the suitability of water for its designated uses and to improve existing conditions. For optimum development and management for the beneficial uses, current information is needed which is provided by water quality programmes (Lloyd, 1992). Unequal distribution of water on the surface of the earth and fast declining availability of useable freshwater are the major concerns in terms of water quantity and quality (Boyd an
Tucker, 1998). Factors like pH, temperature, alkalinity, turbidity and dissolved solids along with the nutrient concentrations are related to the functioning of the biological system of the pond (Mohar and Beena, 2010). Chemical analysis of water provides a good indication of the chemical quality of aquatic systems, but do not integrate ecological factors such as altered riparian vegetation or altered flow regime and therefore, do not necessarily reflect the ecological state of system (Karr et al., 2000). Biological assessment is a useful alternative for assessing the ecological quality of aquatic ecosystems. Biological communities integrate the environmental effects of water chemistry, in addition to the physical and geomorphologic characteristics of rivers and lakes (Stevenson and Pan, 1999). Phytoplankton encountered in the water body reflects the average ecological condition and therefore, they may be used as indicator of water quality (Bhatt et al., 1999; Saha et al., 2000; Bhuiyan and Gupta, 2007).

Algae are frequently found in all types of water and due to their behavior they are generally useful to determine the quality of water. These are very suitable organisms for the determination of the impact of toxic substances in the aquatic environment because they affect the level of the food chain (Jaiswal, 1983). They are used for assessing the degree of pollution or as indicator of water pollution of different water bodies (Trivedy, 1986; Sudhaker et al., 1994; Dwivedi and Pandey, 2002). A number of studies have been carried out on ecological conditions of freshwater bodies in various parts of India (Sinha and Islami, 2002; Bianchi et al., 2003; Hoch et al., 2008)

1.5. Productivity and its importance

The physico-chemical parameters and nutrient status of water body plays an important role in governing the production of plankton which is the natural food of many species of fishes, especially diatoms constitutes important food source of many carnivorous fishes and also support the necessary amount of protein for the rapid growth
of larval carps (Rahman and Hussain, 2008). Diatoms are used extensively in environmental assessment and monitoring because they have ranges and tolerances for environmental variables like pH, nutrient concentrations, suspended sediment, flow regime, elevation and different types of human disturbances (Lascar and Gupta, 2009). Phytoplankton primary productivity in association with limno-chemical qualities could be fruitfully utilized as indices of trophic status of water bodies (Ahmed and Alfasane, 2004). Several authors reported the relationship between algal population, physico-chemical parameters and primary productivity (Wang et al., 2002; Umavathi and Logankumar, 2008). Productivity mainly depends upon organic carbon, pH, nutrients and temperature (Ali et al., 2005). Phosphate and nitrate concentrations play a key role in the productivity phenomenon (Das, 2000).

Primary productivity is an important biological phenomenon in nature on which the entire diverse array of life depends directly or indirectly. The importance of primary productivity in aquatic ecosystem is well realized for estimating the productive capacity. It shows the nature of ecosystem, its trophic level and availability of energy for secondary producers. In India, some man-made water bodies have already been assessed for their primary productivity (Pathak, 1979; Sreenivassan, 1996; Singh, 1998; and Sahib, 2002).

1.6. Sediments

Most of the nutrients settle at the bottom of the aquatic ecosystem as sediments, which possess various physical and chemical characters (Rainey et al., 2003; Pekey, 2006). Sediment particles often consist of sand, gravel, silt, mud and loess below 2000 micrometers in diameter (George et al., 2010). They play a significant role in nutrient cycle and its breakdown produces nutrients that are absorbed by the planktonic and benthic organisms (Krom, 1991; Sundback and Snoeijis, 1991). Sediment analysis is
important in evaluating the qualities of aquatic ecosystem (Adeyemo et al., 2008). Both suspended and predicated substances stored in the bottom form a reservoir for many pollutants and trace substance of low solubility and low degree of degradability (Barbour et al., 1998 and 1999).

1.7. Heavy metals in aquatic ecosystem

Heavy metals are ecologically relevant because of their toxicity and non-biodegradable characters (Forstner et al., 1990). Sediment acts as sinks for trace elements, thus they become more or less a permanent part of the entity. Remobilization processes reintroduce them into the ecosystem in bio-available form (Cietzze, 1993). Metals can be released into the water phase when conditions such as pH, redox potential, ionic strength and the concentration agents are appropriate, therefore sediments also act as sources of metals (Dhakate and Singh, 2008).

Rapid industrial development, as well as the use of metals in production processes has led to the increased discharges of heavy metals into the aquatic environment (Koli et al., 1977). According to Forstner and Prosi (1979) the harmful effects of heavy metal as pollutants result from incomplete biological degradation. Therefore, these metals tend to accumulate in the aquatic environment. Since heavy metals are non-biodegradable, they can be bio-accumulated by the biological organisms, either directly from the surrounding water or by the uptake of nutrients (Patrick and Loutit, 1978; Kumar and Mathur, 1991).

The most important heavy metals from the point of view of water pollution are zinc, copper, lead, cadmium, mercury, nickel, cobalt and chromium. Some of these metals like Cu, Zn, Co are essential trace elements for living organisms, but become toxic at higher concentrations. Other metal pollutants (Pb, Hg, Cd) are non essential and toxic even at relatively low concentrations. Much work has been performed on heavy metal
pollution in river and lake sediments (Unlu and Gumgum, 1993; Gulmini et al., 1994; Gumgum et al., 1994; Leonard et al., 1996; Minissi et al., 1998; Liu et al., 1999; Mahar et al., 2000).

1.7.1. Pollution problems of aquatic ecosystem

Pollution is one of the major problems in developing countries like India. In our country all the water sources are subject to various forms of pollution with regular declining water quality as well as level of underground water (Ramesh and Saradhamani, 2009). Stagnant water bodies have more complex and fragile ecosystem in comparison to running water bodies as they lack self cleaning ability and hence readily accumulate greater quantities of pollutants. Increased anthropogenic activities in and around the water bodies damage the aquatic systems and ultimately the physico-chemical properties of water (Sawant and Telave, 2009).

Human history has often been shaped by water bodies. The overuse or abuse of water has already started affecting the water cycle in such a way that, in combination with other environmental factors such as climatic changes, droughts, flooding, desertification, acid rains etc, causes water pollution. Quality of water is of significant consideration, because provision of reliable and clean water supply is an essential element in improving the quality of life. Barbas (1986) has estimated that 10 million deaths resulted from 25 million new cases of water related diseases reported annually and that half the world population suffers from infection caused by polluted water. According to WHO (1995) nearly 80% of pollution is caused by untreated sewage entry into the freshwater ecosystems (Jameel, 1998). Many studies have been carried out earlier in the polluted and unpolluted ecosystem (Sharma and Sarang, 2004; Kavitha et al., 2005).
The quality of urban water bodies in India is deteriorating rapidly due to the increase in population and industrialization. A great pressure has been put on the existing water resources due to lack of sanitary facilities and improper waste water treatment. About 80% of urban water supply finds its way back into the drainage system as domestic and industrial waste (Gautam, 1990).

1.7.2. Importance of Algae in Aquatic Ecosystem

Algae constitute a major part of primary producers in aquatic ecosystem and are ubiquitous component of the biosphere (Raj et al., 1981). They occur in a wide variety of habitats and play an important role in nature. Several reports are available throughout India about pond ecosystem (Sastri and Pendse, 2001). The phytoplankton diversity and seasonal oscillations were also reported earlier (Das 2000; Sedamkar and Angadi, 2003).

Fresh water algae which occur abundantly in ponds, lakes, slow flowing streams, wetlands etc. in various habitats significantly influence the ecosystem and also support secondary productivity (Rout and Borah, 2009). Algae are classified into several groups as blue-green, green, brown, red etc depending upon their pigment, biochemical and physiological constituents (Round, 1971).

Phytoplankton forms a vital link as primary producers and its density assesses the quality of ponds. The diversity in a community is composed mainly of two components, i.e., species richness and evenness of suitability of a given species by their relative abundance, both denoting single term heterogenicity (Lloyd and Gheraldi, 1964). These components are mainly dependent on the physico-chemical characteristics of the aquatic system (Kalff and Knoechel, 1978).

In India algal diversity of freshwater has been studied by Kartha and Rao (1992); Pandey (1993); Veereshkumar and Hosmani (2006); Senthilkumar and Das (2008). There
are yet a large number of aquatic systems that have to be explored. The use of density and diversity of phytoplankton and their associations as biological indicators in the assessment of water quality or trophic status have been made by several researchers (Chaturvedi et al., 1999; Sengar et al., 2009).

The diversity and variety of indigenous fresh water biota depend upon the habitat. Biodiversity in this context means the full expression of the natural components of the ecosystem that were present before widespread habitat modification, harvest of native species, whether by accidental or intentional means. Species richness, generic diversity and unmodified indigenous communities are all components of biodiversity. Algae are microscopically small, unicellular organisms. Few form colonies and are visible to naked eye as minute green particles. The organisms are finely dispersed throughout the water and may cause considerable turbidity showing the maximum algal bloom. The freshwater ecosystem is of lotic and lentic types, lotic include streams, canals, waterfalls, rivers and rivulets. The lentic system includes the pools, puddles, ponds, reservoirs, lakes and fields. The freshwater ecosystem includes various types of plankton (free floating), benthons (attached to sediments), epiphytic algae (on stones, sand, mud and rock of reservoir and lakes). Depending on the seasons the algae appear and disappear. In most of the temple ponds algae belong to Cyanophyta (Blue-green algae), Chlorophyta (Green algae), Bacillariophyta (Diatoms), Xanthophyta (Yellow orange algae), Cryosophyta and Euglenophyta.

Considerable work has been carried out throughout India in the systematic position, periodicity, seasonal distribution and diversity (Mohan et al., 2003). Most of the members are economically useful as food, feed, bio-fertilizer, vitamin yielders and in medicines. Members like Chlorella, Spirulina, Scenedesmus are cultured in enormous
quantities to meet the human needs (Srivastava, 2010). Algae like *Nostoc, Anabaena, Scytonema, Rivularia* and *Oscillatoria* are the main nitrogen fixers. Still several species of *Phormidium* act as an excellent source of phycocyanin and species of *Synechococcus* show the ability of binding heavy metals (Prasanna *et al.*, 2008) and cause deoxygenating of water (Whitton and Patt, 2000). Diatoms like *Skeletonema, Thalassiosira, Amphora, Navicula* and *Nitzchia* are utilized in the field of aquaculture as feed to several thousands of flagellates (Brown *et al.*, 1994). Many euglenophytes like *Euglena, Trachelomonas* and *Phacus* are reported as indicators of pollution. Diversity indices are often used to monitor the impact of pollutants on aquatic biological communities. The dynamics of phytoplankton growth and community structures are closely related (Ashfaque, 2004).

### 1.8. Eutrophication and is significance

Eutrophication of water bodies rapidly increase in quality and quantity discharge of sewages which in turn enhance the algal proliferation in the aquatic ecosystem. Eutrophication of most freshwater including wetland is dependent upon the supplies of nutrients like nitrogen and phosphorus (Vollenweider, 1968). As a result of increased nutrient loading, detrimental effects have been observed on the health of aquatic ecosystems leading to excess accumulation of phytoplankton biomass resulting noxious algal blooms and depletion of dissolved oxygen. Phosphorus is an important nutrient governing the overall algal growth (Ryther and Dunstan, 1971; Hecky and Kilham, 1998). Enriched nutrient sources of water from external sources and sediment encourage the luxurious growth of selected species of algae. This may cause the death of fishes, unpleasant smell to water and create untolerate situation (Kumar, 1985). Species like *Microcystis aeruginosa, Oscillatoria princeps, Chroococcus minutus, Scenedesmus armatus* and few species of diatoms showed blooms in several aquatic ecosystems.
Blooms indicating the tropical status of the water body have been reported by several researchers (Rao, 1977; Johnson et al., 2003; Shamal and Balasingh, 2007).

1.9. Description of the experimental ponds

The study area, Kanyakumari district is situated in the extreme southern tip of the Indian peninsula, smallest in the state with an area of 1689 Km$^2$ and lies between 77.0$^0$ area 77.36$^0$ of the eastern longitude and 8.08$^0$ and 8.35$^0$ of the northern latitude having the best tropical climate (Fig. 1). To the north and northeast the district is bounded by Kerala state, to the southwest Arabian Sea, to the south Indian Ocean, in the southeast the Bay of Bengal (Aiya, 1906). The Western Ghats that starts from the river Tapthi ends in the district. This hilly region in spite of exploitation still retains its pristine nature (Nair and Daniel, 1986). Annual rainfall differs and the district receives both southwest and northeast monsoon and there are few summer showers too. Moreover, the district is blessed with five river basins, namely Thambraparani, Valliyar, Pazhayar, Bomfoori and Ponnivaikal. The channels from these basins feed the various ponds of the district. According to Padmanaban (1997), a total of 2633 freshwater ponds were recorded which includes 52 temple ponds. All the temple ponds were under the control of Hindu Religious and Charitable Endowments Department, Suchindrum, Kanyakumari District. The temple ponds have unique characteristic features in their physico-chemical parameters, sediment analysis, primary productivity and phytoplankton diversity. Few researchers have reported the diversity and biological characters of the freshwater environments of the district (Ida, 2004; Kavitha, 2006; Shamal, 2011 and Joseph, 2012). The diversity studies on phytoplankton of temple pond remains as an empty space. In order to study the significance of physico-chemical parameters of water, sediment, productivity nature and diversity (Fig. 2), eight temple ponds were chosen from the four
taluks, two from each taluk and named as $V_1$ and $V_2$ (Vilavancode taluk), $K_1$ and $K_2$ (Kalkulam taluk), $T_1$ and $T_2$ (Thovalai taluk), $A_1$ and $A_2$ (Agastheeswaram taluk) and are shown in Plate 1 to 4.

1.9.1. Pond 1 - $V_1$

It is designated as $V_1$ and named as Sree Mahadevar temple pond. This pond is situated in Vilavancode taluk near Munchirai village and extends up to an area below one acre. The average depth of the pond ranged from 6 meters in the margin and more than 20 meters in the center. Due to the large extended area human activities like bathing, washing clothes and cleaning cattles were the common activities (Plate 1).

1.9.2. Pond 2 - $V_2$

This pond is named as Sree Shankara Narayana Temple pond. It is situated in Nattalam village of Vilavancode taluk and 11 kilometers away from Munchirai temple pond. The pond extends upto 1.5 acres with the average depth of 10 to 15 meters in the center. This pond looks always dark green in colour and $Microcystis$ blooms were observed during the study period. When the water level becomes low it was filled from Pechiparai reservoir. It is surrounded by paddy fields and banana plantations and fulfills the water demand of the villagers. Mainly the pond water is used for bathing and washing purposes (Plate 1).

1.9.3. Pond 3 - $K_1$

The pond $K_1$ is named as Sree Nayinar Neelakandaswamy Tirukovil temple pond which is situated near Padmanathapuram Palace of the Kalkulam taluk, which occupies an area of about 2 acres with a depth of 18 meters in the margin and 25 meters in the center. Aquatic weed were not available during the study period. The overflow water is
used for irrigation and the pond is fed by Pechiparai dam. Water from the temple pond is
commonly used for domestic purposes like washing, bathing etc. Several stone racks were
constructed all around the pond for washing purposes (Plate 2).

1.9.4. Pond 4 - K₂

This pond is named as Sree Krishnancoil temple pond. It is situated in
Kaniaankulam village of Kalkulam taluk along the Nagercoil Trivandrum main road and
extends to an area of 1 acre with a depth of 25 to 30 meters in the center. This pond water
is used for domestic purposes, bathing cattles and during festivals the water is used for
washing the idols (Plate 2).

1.9.5. Pond 5 - T₁

This pond is named as Boothalingaswamy thirukoil temple pond. It is situated in
Boothapandi village of Thovalai taluk which occupies an area of 1 acre with 25 to 30
meters depth and fed by natural spring. This pond is used for fish culture and domestic
purposes (Plate 3).

1.9.6. Pond 6 - T₂

The pond T₂ is named as Sree Thiruvazhmarphan thirukovil temple
pond in Thirupathaissaram village of Thovalai taluk. Although it receives water
from Mukkadal dam the water level gets reduced during summer. It extends upto
an area of 2 acre with the average depth of 40 to 45 meters. The water is not
used for domestic purposes and the water remains transparent in most of the
season (Plate 3).

1.9.7. Pond 7 - A₁
The pond $A_1$ is named as Sree Subramaniaswamy thirukovil temple pond in Marungoor village of Agastheeswaram taluk. The pond occupies an area below half an acre and the depth varies from 23 to 27 feet in the center. The water is used for domestic purposes and fed by Pachiparai dam (Plate 4). No aquatic weed was recorded during the study periods.

### 1.9.8. Pond 8 - $A_2$

The pond $A_2$ is named as Arulmigu Thanumalayaswamy thirukovil temple pond. It is situated in Suchindrum village of Agastheeswaram taluk. Among the experimental ponds the pond $A_2$ extends maximum of 4 acres with depth of 40 to 47 meters in center. The pond is fed by Pachiparai dam and the water is mainly used for fish culture. The water looks dark green almost in all the season because of the blooms produced by Microcystis (Plate 4).

**Objectives of the study**

1. To analyse the monthly, seasonal and annual variation of physico-chemical parameters of the water and sediment from the eight temple ponds for a period of two years (February 2009 to January 2011).

2. To study the productivity status of the experimental ponds.

3. To assess the phytoplankton diversity with reference to species diversity, species richness, species evenness, dominance index and percentage frequency.

### 2. REVIEW OF LITERATURE