The pond A₁ 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 - A₂

The pond A₂ is named as Arulmigu Thanumalayaswamy thirukovil temple pond. It is situated in Suchindrum village of Agastheeswaram taluk. Among the experimental ponds the pond A₂ 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
2.1. Introduction

Aquatic ecosystems are more productive ecosystems responsible for the regulation of biological cycles, balancing the water quality, nutrient concentrations in producing the primary producer, the phytoplankton (Mini et al., 2003). In general the freshwater bodies like ponds, lakes, streams, rivers, pools etc are exposed to pollution caused by pollutants. Contamination from several biotypes such as sewage disposal, municipal and solid waste, dumping of industrial and man-made activities drastically affect the quality of natural resource, the freshwater (Gupta and Deshpande, 2004; Hassan and Paul, 2007; Zuber and Sharma, 2007; Parray et al., 2010)

2.2. Water Quality Parameters

Physico-chemical parameters are essential in the assessment of water quality and the factor which causes deterioration of water quality need to be evaluated (Jawale and Patil, 2009). Much work has been carried out throughout the world on freshwater bodies. Lewis (1996) has reported the hydrobiological parameters of a tropical lake. Leghari et al. (2000) observed the limnological status of freshwater ponds in Pakistan. The monthly variation and physico-chemical parameters of a brackish water fish pond in Pakistan was highlighted by Ali et al., (2005) and Khan et al. (2007). Park and Hyun (2007) also studied the factors of water in a fish culture pond at Korea. Arimoro et al. (2007 and 2008) has observed the physico-chemical parameters of Warri river in Nigeria.

In India several researchers have determined the biological diversity of lakes, ponds, rivers streams etc. in assessing the health of the ecosystem (Srivastava et al., 2003 and Ramesh et al., 2007). Factors like turbidity, dissolved solids, temperature, alkalinity, nutrient composition are the major factors that determin the physico-chemical characters of water (Bhatt et al., 1999; Anand and Sharma, 2000; Jha and Barat, 2003;
Rajasulochana et al., 2008). Kaur et al. (2000) also reported the different factors in Kanjili wetland, Punjab. Ragavendra and Hosmani (2002) studied the different physico-chemical features of Mandakally lake and Prasad (2006) observed the monthly variation of water quality parameters of a perennial pond at Nepal. Diurnal variation in water quality of Ayyanakere lake of Karnataka state was reported by Thirumala et al. (2006). Rayaz and Zuber (2007) revealed the impact of earthquake on the ecology and economy of Kolakore hot spring water Rajouri, India. Lokhande et al. (2007) reviewed the water quality of Godrej Nellah and Bhandupeshwar lake near Mumbai. Tiwari and Shukla (2007) studied the status of water in some temporary freshwater bodies of Kanpur. A critical study on the limnology of a perennial water body was made by Hujare (2008a). Several researchers have pointed out the physico-chemical parameters of freshwater environment of Maharastra (Avinash and Prabhakar, 2009; Karne and Prabhakar, 2009; Ohol and Kamble, 2010; Karne, 2010). From Gujarat, reports on a urban pond were made by Kumar and Oommen (2009). The drinking water quality of Jaipur city was studied by Kumar et al. (2011). In the district of Chirang in Assam various parameters related to water quality was assessed by Baruah et al. (2011). The physico-chemical nature of Pakhal and Ramappa lake, Andra Pradesh was reported by Chinnaiah and Rao (2011). The seasonal distribution of nutrients, enviro-ecological status of freshwater system of North India was noted by several researchers (Hiware and Jadhav, 2001; Ramana and Reddy, 2004; Tiwari et al., 2004; Dhembare, 2007; Suthar et al., 2008; Razak et al., 2009; Latha and Mohan, 2010; Ajagekar et al., 2011).

A number of studies have been conducted in the water quality parameters from South India. Seasonal variation of different parameters in a rock pool of Kollam district was studied by Danielkutty and Shoba (2006). The potential source of pond water was
revealed by Reshma and Prakasam (2007). Senthilkumar and Sivakumar (2008) described the water quality parameters of Vereranam lake. Dhanalakshmi et al. (2008) made a study on the seasonal oscillations of different physico-chemical parameters of Sulur pond at Coimbatore. From a temple pond of Kanchipuram an assessment on water quality parameters was made by Murugan (2008). Sheeja and Narayan (2008) reported the seasonal dynamics of a temporary freshwater pond in Kaveri delta region. Sambathkumar and Ramakrishnan (2004) studied the characteristic features of a freshwater pond at Thiruvannamalai. Murugesan and Sivasubramanian (2005) and Rajkumar et al. (2006) have studied the different water quality parameters of Porur lake in Chennai and Kodaikanal lake. Water quality of Pulankurichi village in Sivagangai district was studied by Subramanian et al. (2007) and he observed the pond is away from industries and its water is good for drinking purposes. In the same district the physico-chemical characters of a bore well and a open pond was reported by Ramadevi et al. (2009) in the Ponnamaravathy area. In Madurai corporation water quality and bore well water qualities were compared and noticed by Pitchammal et al. (2009). Ramesh and Saradhamani (2009) studied the different parameters of water in the freshwater bodies in Nilgiris district, Tamilnadu. A special attention was made on water quality parameter of Kuruchi pond at Coimbatore by Kumari et al. (2009). In Ariyalur area the drinking water quality was reported by Vasanthy et al. (2009) and Prabhakaran et al. (2009) assessed the water quality of irrigation water in Villupuram district. Genotoxicity assay of three different surface water system of Madurai district, using Ames test was made by Nagendren (2010). From Kanyakumari district the hydro-geochemical characterization of Tambaraparani river Tamilnadu was critically analysed by Prakash (2011).

2.3. Sediment Studies
The undissolved substances which settle at the bottom of the freshwater ecosystem especially mixed with the decayed particles and function as sediment is a rich source of nutrient. By the rapid industrialization over the past century most of the nutrients with heavy metals have been discharged into the major rivers, streams, ponds etc (Tam and Wong, 2000; Cobelo-Garcia and Prego, 2003; Chen et al., 2004; Pekey, 2006). Sediments are used as indicators of environmental pollution because of their ability to trace contamination source (Sayadi et al., 2010). The metals can be either adsorbed by the sediments or get accumulated in the benthic organisms (Singh et al., 2005). Akhand et al. (2012) reviewed the pollution load of zinc, lead, chromium and cadmium in a sewage mixed Kuti River. Sediment has been regarded as a significant problem with several actual and potential risk to human health, contamination through non-point source of pollution including agricultural runoff (fertilizers and pathogens), storm water, urban runoff and atmospheric deposition of pollutants (Ritter et al., 2002). Much work has been carried out throughout India regarding the sediment nutrients (Meyer et al., 2005; Mishra et al., 2008; Rai, 2008). Several investigators have reported the sediment as indicators of pollutants (Singh et al., 1999; Baligar and Chavadi, 2005). Sediment concentrations have a great influence on the flora and fauna composition (Head et al., 1999). Freshwater ecosystems near the industrial areas have deposited more heavy metals in their sediments (Filipovic and Topalovic, 2002). Physical and chemical characteristics of sediment in a carp pond at Thailand were studied by Wudtisin and Boyd (2006). Sediment characters with special reference to heavy metal in the freshwater ecosystem of Nigeria were studied by Adefemi and Awokunmi (2010). Ansa and Francis (2007) reported the toxicity of nutrients in the sediments of Niger delta, Nigeria and George et al. (2010) studied the salient features of Okpoka Creek, Nigeria.
The characteristics of sediments in a shallow pond at Ujjain city Maharashtra was analysed by Singh et al. (2005). The sediment chemistry of river sediment was investigated by reporters (Singh, 1999 and Nicolan et al., 2006). The sediment qualities indirectly affect the biodiversity of phytoplankton and Zooplankton (Likamen et al., 2002). Nutrient dynamics of Madhurantakam lake, Tamilnadu was investigated by Moorthy et al., (2005). Abiding et al. (2009) described the sediment characters of Periyar river at Elloor Kerala State. Esakki (2006) studied sediment characters of Koondhankulam bird sanctuary pond at Tirunelveli district, Tamilnadu. Suneela et al. (2008) determined the water and sediment characters of Hussain Sagar lake at Hyderabad. Tharadevi and Santhakumari (2005) observed the concentration of different nutrients in the two freshwater ponds of Kanyakumari district.

2.4. Primary productivity and its significance

The primary productivity of an ecological system, community or any part thereof, is defined at the rate at which radiant energy is stored by photosynthetic and chemosynthetic activities of the producer organisms (Chiefly green plants) in the form of organic substances which can be used as food materials. Primary productivity thus denotes the rate of primary production i.e. the primary production per unit time and area. It refers to the quantity of organic matter produced by photosynthesis (Mandal et al., 2010) of phytoplankton which act as the primary producer and controlled by several physico-chemical parameters. Plankton diversity and distribution are closely linked to variables like physico-chemical and biological factors. Interactions of phytoplankton with physiological characteristic of the environmental variable result in primary productivity which in turn facilitates the zooplankton succession (Subha, 2002). The nutrient levels in relation to phytoplankton productivity and chlorophyll ‘a’ in lakes,
ponds and estuaries have been studied by Ketchum (1967); Williams (1972) and Santhosh (2002). Sobha et al. (2007) revealed the influence of returning activity on phytoplankton productivity of Kadinamkulam lake, Thiruvananthapuram, Kerala. In India some man-made reservoirs have been already assessed for their primary productivity (Singh, 1998 and Saha, 2004). From Maharashtra, primary productivity studies of some freshwater reservoirs of Sangli district were carried out Patil and Chavan (2010). Gowswami and Saha (2008) reported the spatial variation in primary productivity of river Damodar, West Bengal, India. A number of criteria have been employed for the evaluation of pollution and estimation of primary production (Nirmalkumar, 1991). Rajkumar (2004) reported the primary production of a polluted freshwater pond in Pollachi. Mali and Gajaria (2004) made an assessment on primary productivity and hydrobiological characterization of a fish culture pond at Gujarat. Kumar and Sharma (2005) studied the phytoplankton productivity of certain lentic ecosystems of Jharkhand, India. Among the several freshwater systems, ponds and lakes are the important sources of potential production in the world. Physical, chemical and biological aspects influence the primary productivity directly and the fish production indirectly. Chinnaiah and Madhu (2010) assessed the primary productivity of Darmasagar lake in Adilabad (A.P), India. In several reports factors like temperature, nutrient levels were noted as the main cause for increasing the productivity rates of freshwater environments (Vijayaraghavan, 1971; Arvola, 1983; Eloranta and Salminer, 1984; Varma and Mohanty, 1995). Kumar (1999) reported the effluents of coal mining on primary productivity rates.

Several researchers have studied lentic ecosystem in India with reference to physic-chemical status and primary productivity (Sharma and Durve, 1991; Kaur et al., 1996; Bais et al., 1997; Thomas and Abdul, 2000; Meena, 2001; Chisty, 2002; Rani et al.,
The primary productivity of lake Bari, Southern Rajasthan, India was studied by Muvanchiro and Durve, (1998). In a wetland system primary productivity of North Bihar was studied by Mandal et al. (1999). Rao et al. (1999) made a comparative report on primary productivity of three reservoirs in Visakhapatnam. The ecological status of a tropical water body with reference to primary productivity was pointed out by Sabrina et al. (2006) from Rajasthan. In a reservoir at Cuddalore, phytoplankton productions in terms of primary productivity with the environmental factors were observed by Sivakumar and Karuppasamy (2008). Primary productivity studies on Pusha lake region in Ajmar district, Rajasthan, India was studied by many researchers (Kar, 1986; Parvateesam and Mishra, 1993; Patni et al., 2006). Ida (2004) and Christi et al. (2011) made their studies on physico-chemical parameters and primary productivity of freshwater ponds in Kanyakumari district.

2.5. Phytoplankton diversity studies

Water quality i.e. the physico-chemical and biological characteristic of water bodies play a key role in plankton productivity as well as the biology of the cultural organisms determines the species in the aquatic ecosystem (Dhawan and Karu, 2002). Productivity functions as the backbone of the aquatic food chain (Ahmed and Singh, 1989). The plankton community is comprised of the primary producers or phytoplankton and zooplankton the secondary producer Battish (1992). The phytoplankton population represents the biological wealth of a water body, constituting a vital link in the food chain (Hossain et al., 2007) and zooplankton forms the principal source of food for fish within the water body (Prasad and Singh, 2003). Several researchers have stressed the importance of water quality which is used for the assessment of phytoplankton (Harikrishnan et al., 1999; Stevenson and Pan, 1999; Gaunker and Kerkar, 2004; Umavathi et al., 2007).
Several researchers have observed the diversity of phytoplankton from freshwater ponds other than India. Ali et al. (2000) and Leghari et al. (2001) made critical studies on physicochemical parameters and diversity of filamentous green algae from Sindh, Pakistan. In south Virginia region a comparative study on phytoplankton was made between the pond and lake in Virginia was reported by Burchardt and Marshall (2003). Seasonal observations on biodiversity changes were made by Ali et al. (2003) in a pond at Punjab, Pakistan. Rodríguez and Osuna (2003) analyzed the nutrient sources that produce algal blooms and their diversity were made from a shrimp culture pond of California. The toxic bloom of blue green algae in a reservoir of Brazil was described by Chellapa et al. (2004).

The communities of phytoplankton along with physico-chemical parameters of lake Nazer at Egypt was highlighted by El-otify et al. (2003). Gharib and Halim (2006) also reported the spatial variation of phytoplankton of lake Nazer. Park and Hyun (2007) made a study on the phytoplankton diversity of a freshwater pond at Korea. The ecological status and taxonomy of different algal groups were studied by Tas and Gonulol (2007). Different physico-chemical characteristic features along with the different population of phytoplankton from Nepal were noticed by Ranjan et al. (2007). The Bacillariophyceae members from eastern Nepal was studied by Misra et al. (2009a); Chellapa et al. (2009); Indabawa (2009) presented a detailed account of phytoplankton communities from freshwater ponds of Brazil and Nigeria. Akoma and Imoobe (2009) made a critical study on the diversity of algae in a freshwater pond at Ethiopia and Aliya et al. (2009) also made a survey on freshwater algae of Karachi, Pakistan. Janjua et al. (2009) studied the tropical status of freshwater ecosystem of Pakistan. Ali et al. (2010) made detailed studies on algal flora of Swat district, Pakistan.
In several aquatic ecosystems, the external environmental conditions and the internal nutrient concentrations play a significant role in the distribution pattern, species succession, and diversity of phytoplankton (Veereshkumar and Hosmani, 2006; Mohar et al., 2009). Much work has been carried out throughout India. Ashokkumar and Singh (2000) studied the diversity of phytoplankton in a pond at Deoghar with reference to physico-chemical parameters. Habib and Chaturvedi (2001) reported the diversity of desmids (green algae) in Kumaun, Himalayas. Singh et al. (2002) made a study on the hydrobiological study on two ponds at Satna, Madhya Pradesh. Limnological studies on Maralur pond at Tumkur, Karnataka, was observed by Puttaiah (2002). Algal diversity from polluted environments of Jodhpur, Rajasthan, was analysed by Vishnoi and Srivastava (2004). Dhakad and Chaudhay (2005) made a hydrobiological study of Natnagra pond in Dar district of MP. Tiwari and Chauhan (2006) found the diversity of phytoplankton and enumerated the chlorococcales order of chlorophyta in Agra. Deshmukh and Pingle (2006) studied the chlorophytae members from Ahmednagar district (MS) and Divekar and Deshmukh (2006) reported the phytoplankton diversity of polluted environments of Sangamner, Maharashtra. In Udaipur city of Rajasthan, a critical analysis was recorded by Rathore et al. (2006). The influence of environmental factors in accordance with phytoplankton flora was observed by Susheela and Toppo (2006) from Sikkim, India. Deshmukh and Gundale (2007) made a systematic study on chlorococcales with reference to their taxonomy from Ahmednagar district of Maharashtra. The distribution pattern and species succession of a freshwater pond at Mysore city was studied by Mruthunjaya et al. (2007). Studies were made on diversity, seasonal variation and species composition by several researchers (Tessy and Sreekumar, 2007; Kumar et al., 2008; Pandit et al., 2008; Dhande and Jawale, 2008). Kanolkar and Kerkar (2009) made a report on phytoplankton especially on green algae. Rout and Borah (2009) explained the algal diversity in Chatla
wetland of Assam. Much work has been carried out by several researchers on the diversity from north India (Sonaware et al., 2009; Jawale and Patil, 2009; Misra et al., 2009b). Diversity studies from a fish pond at Jharkhand were revealed by Jha (2010). From freshwater ponds and canals of Mohuda, Orissa Padhi et al. (2010) reported the algal flora and their importance. Mohar and Beena (2010) also pointed out the seasonal fluctuations of phytoplankton in a freshwater environment of Gwalior (M.P).

Physico-chemical parameters along with algal diversity in freshwater ecosystem was studied by Kumar et al. (2006) from Hunsur lake at Mysore and Ravikumar et al. (2006) reported the periodical relation to abiotic factors of Karnataka. Plankton communities with special reference to their seasonal distribution in Mysore were revealed by Thomas et al. (2007) and Sudeep et al. (2008). Algal diversity in relation to pH, temperature, light intensity along with micro nutrients of Sunumbu Kalathour lake at Rajasthan was studied by Rajasulochana et al. (2008). Similar studies were made by Bhagat et al. (2009) from Naukuchiyatal lake at Uttarakhand. Limnologicl studies were carried out by several researchers in relation to phytoplankton diversity (Bhosale et al., 2010a; Khare and Patil, 2011). In Mysore district algal diversity from fifteen lakes of Narasipur taluk was observed by Umamaheswari (2011) and freshwater diatoms of Mysore with reference to water quality was noticed by Basavarajappapa et al. (2011). Water quality evaluation and phytoplankton diversity of Hosahalli pond, Shvamogga, Karnataka was assessed by Sayeswara et al. (2011). Phycodiversity in irrigation tanks of Kheda and Anand district, Gujarat was reported by Brahmbhatt and Patel (2012).

Most of the freshwater algae belonged to Cyanophyta (blue-green algae), chlorophyta (green algae), Bacillariophyta (diatoms), Xanthophyta (yellow-green algae) and Euglenophyta. Several researchers took interest in the above groups. Cyanophycean
members in a freshwater tank at Karnataka were observed by Siddamallayya and Pratima (2006) from Porur lake at Chennai. Murugesan and Sivashubramanian (2005) investigated the blue green algal distribution in a fish culture pond at Chidambaram and from Cuddalore region the diversity was revealed by Sivakumar and Sundararaman (2006). Vijayakumar et al. (2007) and Muthukumar et al. (2007) reported the cyanobacterial diversity of Thanjavur in the area of industrial effluent. Several reports pointed out the diversity with special reference to the biotechnological application (Thajuddin and Subramanian, 2005; Kannan, 2006; Kasthuri, 2007). Joseph and Balasingh (2009b and 2010) also reported the biodiversity of freshwater cyanobacteria in the ponds of Kanyakumari district.

Many researchers have reported green algae and their diversity in the fresh water environment (Shetiya and Kerkar, 2004; More et al., 2005; Jena et al., 2006b; Vidyavathi, 2007; Dhande and Jawale, 2008). Systematic studies of green algae were reported by Perumal and Anand (2008). Prakash and Balasingh (2008) studied the green algae *Oedogonium echinospermum* as a biological filter in removing the toxic metals from water.

Diatoms of the freshwater environment were also highlighted by several researchers. Diatoms were used as indicators of water quality (Bate et al., 2002; Juttner et al., 2003 and Karthick et al., 2010). Freshwater diatoms from Kalkata with special reference to their taxonomy were studied by Bhattacharya et al. (2011).

2.6. Studies in Kanyakumari district

In Kanyakumari district few researchers have made critical studies on the physico-chemical parameter of freshwater environments. Limnology of selected perennial ponds was analyzed by Ida (2004) and Ida et al. (2004). Balasingh and Shamal (2007); Shamal

40
and Balasingh (2007) have studied the diversity with special reference to species richness. Joseph and Balasingh (2010) studied the diversity of a freshwater ecosystem of Kanyakumari and in the year 2009b they made a critical study on chroococcales of a freshwater pond. Manonmani (2010) studied the characteristic features of Narikulam tank, Perunchani, Kanyakumari District and seasonal abundance was also made by Balasingh (2010).

2.7. Reports on temple pond studies

Diversity studies on temple ponds are limited and few available reports on algal diversity were made by few researchers. Algal diversity in two temple ponds of Goa the Mangeshi and Nageshi ponds were studied by Gaunkar and Kerkar (2004) and Kanungo et al. (2005) in Rajpur, Chhattisgarch made a report on the diversity of blue green algae in the temple ponds. Murugan (2008) observed the dominant and sub-dominant groups of phytoplankton from the temple tanks of Kanchipuram. In Kanyakumari district, two temple ponds the Nagarajakovil at Nagercoil and Thanumalaya swamykovil at Suchindrum were studied by Kavitha et al. (2005). A sacred grove pond in of Kanyakumari District was studied in relation to the different algal groups by Kavitha and Balasingh (2007). Jemi and Balasingh (2011a and 2011b) have reported the physico-chemical and diversity studies of temple ponds in Padmanathapuram, Parvathipuram and Munchirai village of Kanyakumari District.
3. PHYSICO-CHEMICAL PARAMETERS OF WATER AND SEDIMENT

3.1. Introduction

Water is one of the abundantly available substances in nature, which man has exploited more than any other resources for the sustenance of life. Water of good quality is required for all living organisms. In India, freshwater constitutes rivers, streams, lakes, ponds, and reservoirs as the most important water resources (Mahadev et al., 2010). Unfortunately, ponds are being polluted by indiscriminate disposal of sewage, industrial waste and human activities. They became contaminated due to the incorporation of untreated solid and liquid waste. Nowadays due to increased human population and man-made activities the water quality becomes deteriorating everywhere (Jayabhaye et al., 2008) in a faster rate day by day (Mahananda et al., 2010).

Discharge of toxic chemicals, over pumping of aquifer and contamination of water bodies with substance that promote algal growth are some of today’s major causes for water quality degradation. Direct contamination of surface water with metals as discharges from minining, smelting and industrial manufacturing is a long standing phenomenon (Rani and Reddy, 2004). Soil receiving repeated applications of organic manures, fungicides and pesticides has exhibited high concentration of extractable heavy metals and thereby increase their concentration in run off (Moore et al., 2003), while falling as rain, water picks up small amount of gases, ions, dust and particulate matter from the atmosphere. These added substances may be classified as biological, chemical, physical and radiological impurities which include metals and acid salt, sediments, pesticides, herbicides, plant nutrients, decaying animal and plant matters and living microorganisms such as algae, bacteria and viruses (Vollenweider, 1976).
Water quality provides current information about the concentration of various solutes at a given place and time. Water quality parameters provide the basis for judging the stability 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 programs (Sheikh, 2004). Unequal distribution of water on the surface of earth and fast declining availability of usable freshwater are the major concerns in terms of water quality and quantity (Adarshkumar et al., 2006).

The physico-chemical characteristic of a lake or pond depends on size, shape, topography, climate biological community and anthropogenic activity. Lakes vary physically in terms of temperature, water current and transparency. Chemically they vary in major ions, minor ions, nutrients and contaminants (Adeyemi et al., 2009). The quantity of nutrients in water play a significant role in the distributional pattern and species composition of plankton in aquatic habitat, the penetration of light, temperature, salinity, pH, hardness, phosphate, nitrate and calcium are the important factors for all the aquatic organisms (Mahar et al., 2000). Excessive evaporation of water from the water bodies due to high temperature and low rainfall enhances the amount of salts, heavy metals and other pollutants which are essential factors for the poor quality of aquatic ecosystem (Arain et al., 2008). Among environmental pollutants, metals are of particular concern, due to their potential toxic effect and ability to bioaccumulation in aquatic ecosystems (Agbolada et al., 2010). The serious environmental problems have been faced in developing as well as developed countries. Dissolved constituents of water bodies are often determined as a major component for baseline limnological studies. The major ions Ca\(^{2+}\), Mg\(^{2+}\), Na\(^{+}\), K\(^{+}\), Cl\(^{-}\), SO\(_{4}\)\(^{2-}\), HCO\(_3^{-}\) and CO\(_3^{2-}\) are essential constitute of water and responsible for ionic salinity as compared to other ions (Wetzel, 1983). The supply of safe water has a significant impact on the anticipation of water transmissible diseases.
The abundance of organic compounds, nitrites and nitrates in water may cause unfavorable effects on human health, especially cancer, other human body malfunctions and chronic illness. Every factor of the aquatic ecosystems interlinked with the living organism and temperature is an important abiotic factor. It not only affects the abundant availability and distribution of fishes (Ibe, 1985) but also influences their activities such as breathing, growth and reproduction (Francis et al., 2007).

The studies of different water parameters are very important for understanding the metabolic events of the aquatic ecosystem. Therefore, it has become obligatory to analyse the important parameters when ecological studies on aquatic ecosystems are carried out (Shinde et al., 2011). In order to understand the suitability for multipurpose usage viz. drinking, domestic, recreational, irrigation, livestock, fisheries and industrial studies the water quality of ponds were performed by several researchers (Fisher et al., 2000; Froreman et al., 2001; Zuo et al., 2004; Papastergindou et al., 2007; Shellenberger et al., 2008; Doraipandian and Thangasamy, 2010).

Similar to water quality and sediment characters are also important as sediments have enormous quantities of nutrients, heavy metals, organic and inorganic matters. Its heterogeneous nature provides good ecological informations (Gunkel, 2000). Sediments have been widely used as indicators of environmental pollution because of their ability to trace contamination sources (Sayadi et al., 2010 and Akhand et al., 2012). Harikrishna (2008) has pointed out the deposition of clay, silt, gravel and soil texture of the sediment. The textural composition was determined by lithogenic, minerological and anthropogenic substances (Adhikari, 2003). Sediments get contaminated by the mixing of polluted waters and several aquatic weeds were involved in the accumulation of heavy metals (Kumar et al., 2008). Sediment studies are essential to assess the biodiversity as the
different particles and composition determine the floral constituents of the aquatic ecosystem (Garg et al., 2006a).

The temple ponds are restricted in avoiding the human activities and other domestic utilization. Every temple of this district, even the sacred grooves are provided with ponds and the studies on physic-chemical parameters remain unknown. Hence the present study was undertaken in assessing the important parameters and its effect on the floral diversity of the ponds.

3.2. Materials and Methods

3.2.1. Water Analysis

Surface water samples were collected from the eight selected temple ponds at monthly intervals for a period of two years from February 2009 to January 2011. The collections were made between 6 am to 8 am by using clean sample bottles. Parameters like nitrate and phosphate were estimated by photometric method. Sodium, potassium, calcium, magnesium, chloride, total alkalinity and TDS were analysed by standard method of APHA (1998). Rainfall data was collected in the statistical department, Nagercoil.

3.2.1.1. Laboratory Studies

1. Temperature - Determined by 0°C thermometer
2. pH - Using pH meter (Elico – model – 21)
3. Dissolved oxygen - Wrinkler’s Iodometric method
4. Biological oxygen demand - Five days of incubation at 20°C and Wrinkler’s Iodometric Method was adopted.
5. Total dissolved solids - Gravimetric method
6. Carbon dioxide - Titrimetric method using 0.05N NaOH and phenolphthalein indicator
7. Total Alkalinity - Titrimetric method
8. Chloride - Argentometric Method
9. Calcium - Ethylene diamine tetracetic acid method (EDTA)
10. Magnesium - Ethylene diamine tetracetic acid method (EDTA)
11. Sodium - Flame photometry method
12. Potassium - Flame photometry method
13. Sulphate - Gravimetric method
14. Nitrate - Phenodisulphonic acid method (Colorimetric estimation)
15. Phosphate - Ascorbic acid method (Colorimetric estimation)

Descriptive statistics for evaluating physico-chemical properties of water were used for each sample taken from different study ponds. Replicates were averaged to determine the mean values and utilized for data analysis with two way ANOVA and correlation (Zar, 1996). The significance level was observed at P<0.05.

3.2.2. Sediment Analysis

From the eight selected temple ponds, sediment samples were collected by using bottom grab sampler and shade dried separately. pH and electrical conductivity was measured before drying the sediment samples following the method of APHA (1998). Organic carbon, phosphorus, potassium and nitrogen were analysed by the method of Clarson (2002).

For heavy metals (Zn, Fe, Cu and Mn) one gram of each of the fine powered samples of the sediment was taken separately and digested following the method of Smith and Windom, (1992). To each sample 10 ml of concentrated HCl and 5 ml of
Concentrated HNO₃ were added and heated for about two hours of low heat till the organic matter was completely decomposed. 10 ml of perchloric acid was added to it and the sample was heated to dense white fuming. The sample was further digested with 5 ml of concentrated HCl and 20 ml of double distilled water for 30 minutes at low heat. The solution was cooled and the final volume was made up to 50 ml.

The elemental analysis was carried out in a Parkin Elmer 2380 Atomic Adsorption Spectrophotometer. Analyses were done in triplicate for all the samples provided and the average values were interpreted.

The collected data were subjected to mean, standard deviation, two way ANOVA and correlation (Zar, 1974).

**3.3. Result**

**3.3.1. Water Analysis**

**3.3.1.1. Rainfall (mm)**

The data collected on monthly variations of rainfall in the four taluks of Kanyakumari district during the year 2009 – 2010 is shown in Figure 3. In the first year maximum rainfall of 288.0 mm (November) was reported from Agastheeswaram taluk against the absence of rain in the remaining taluks during February.

In the following year (2010 – 2011), Kalkulam taluk recorded maximum of 529.03 mm of rainfall during November against the absence of rain in February of the remaining taluks (Fig. 4).

**3.3.1.2. Temperature (°C)**

The variation of surface water temperature recorded from different ponds in the first year of study period is shown in Figure 5, in which a maximum of 30.3 °C (May)
was reported in $A_2$ against the minimum of $21.6 \, ^\circ C$ (September) in $T_1$. Seasonal variations in the surface water temperature showed the lowest of $24.98 \pm 0.62 \, ^\circ C$ in $V_1$ during southwest monsoon and the highest of $29.40 \pm 0.46 \, ^\circ C$ in $T_2$ during non-monsoon (Table 1). The annual mean temperature of different temple ponds indicated the highest temperature ($28.1 \pm 1.70 \, ^\circ C$) in $A_2$ and the lowest ($26.5 \pm 1.42 \, ^\circ C$) in $V_2$ (Table 3).

Statistical analysis of two way ANOVA (Table 5) reported that the temperature was significantly influenced by the seasons and ponds ($F = 68.40; 2.90; P < 0.05$). The correlation studies between temperature and water quality parameters showed a significant positive correlation at 5% level with pH, BOD, TDS, CO$_2$, chloride, calcium, nitrate and negative correlation with dissolved oxygen and alkalinity.

In the following year (2010 – 2011) the minimum temperature reported was $24.2 \, ^\circ C$ ($A_1$) in September against the high temperature of $30.7 \, ^\circ C$ ($A_2$) during May (Fig. 6). Seasonal observation reported a minimum of $25.70 \pm 0.53 \, ^\circ C$ in $V_1$ (Southwest monsoon) against a maximum of $29.98 \pm 0.58 \, ^\circ C$ (Non-monsoon) in $T_1$ (Table 2). The annual mean values on temperature are given in (Table 4). The lowest mean value of $26.93 \pm 1.36 \, ^\circ C$ was observed in $V_2$ against the highest of $28.03 \pm 1.04 \, ^\circ C$ in $K_1$.

Statistical analysis of two way ANOVA reported that a significant variation in seasons ($F = 93.13; P<0.05$) and a non significant influence ($P>0.05$) between ponds were observed (Table 5). The correlation between temperature and water parameters showed a positive significant observation with pH, BOD, TDS, CO$_2$, chloride, calcium, magnesium, sodium, potassium, nitrate, phosphate and negative correlation with dissolved oxygen and alkalinity in most of the ponds.
3.3.1.3. pH

The results obtained in the variation of pH recorded from different ponds (2009 – 2010) are shown in Figure 7, in which a minimum of 6.27 was reported in A₁ (September) against the maximum of 8.35 (May) in A₂. Seasonal observation of water pH showed a lowest value of 6.76 ± 0.43 in K₂ during southwest monsoon and the highest of 8.22 ± 0.13 in A₂ during non-monsoon (Table 1). The annual mean pH (Table 3) of different ponds indicated the highest pH (7.79 ± 0.39) was obtained in A₂ and lowest (7.11 ± 0.51) in V₁ pond.

Statistical analysis of two way ANOVA revealed that there was a significant variation (Table 6) between seasons (F = 165.05; P<0.05) and ponds (F = 18.17; P<0.05). Correlation analysis of pH values showed a significant positive influence with BOD, CO₂, chloride, calcium, nitrate and negative correlation with DO and alkalinity.

In the following year (2010 -2011), the reported pH values are shown in Figure 8. Among the eight temple ponds, K₁ showed a lowest value of pH (6.11) in September and a highest value of 8.47 in May (A₂). The seasonal mean pH values are given in (Table 2). During non-monsoon months the maximum pH of 8.25 ± 0.16 was observed in A₂ and the minimum mean pH was 6.60 ± 0.71 in K₁ during southwest monsoon. The annual mean of 7.59 ± 0.63 was the maximum pH value obtained from A₂ against the minimum of 7.17 ± 0.66 in K₁ (Table 4).

Two way ANOVA test revealed that a significant influence of seasons (F = 56.04; P<0.05) and a non significant (P > 0.05) influence between ponds (Table 6). Correction analysis of pH showed a positively significant relationship with BOD, TDS, chloride, calcium, sulphate, nitrate and negative significant correlation with DO and alkalinity at 5% level.
3.3.1.4. Dissolved Oxygen (DO mg/L)

The monthly variation of dissolved oxygen content observed during the first year of the study period is shown in Figure 9. In the first year (2009 – 2010), dissolved oxygen content reached its peak value in September as 12 mg/L in T\textsubscript{2} and low value of 4.0 mg/L in A\textsubscript{2} during the month of May. The seasonal mean values of dissolved oxygen content are represented in Table 1. The maximum dissolved oxygen content was 10.47 ± 1.70 mg/L during southwest monsoon in T\textsubscript{2} and minimum of 4.65 ± 0.52 mg/L during non-monsoon in A\textsubscript{2} was observed. The resulted annual mean values are shown in Table 3. High mean values were recorded in T\textsubscript{2} (8.42 ± 2.13 mg/L) against the low value of 6.03 ± 1.14 mg/L in A\textsubscript{2}.

Statistical analysis on two way ANOVA revealed that the variation (Table 7) between the seasons and ponds were significant (F = 81.56; 8.79; P<0.05). Dissolved oxygen content showed a significant positive correlation with alkalinity and negative correlation with BOD, TDS, CO\textsubscript{2}, chloride, calcium and nitrate at 5% level.

During the year 2010 - 2011 the DO content reached its peak value in November as 12.7 mg/L (T\textsubscript{2}) and low value (3.2 mg/L) during May in A\textsubscript{2} (Figure 10). The seasonal variation of dissolved oxygen content observed from the ponds showed high values (9.98 ± 2.29 mg/L) during northeast monsoon in T\textsubscript{2} and low values (3.90 ± 0.64 mg/L) in A\textsubscript{2} during non-monsoon season (Table 2). The annual mean value was low as 4.90 ± 1.09 mg/L in A\textsubscript{2} and high as 7.41 ± 2.47 mg/L in T\textsubscript{2} (Table 4).

Two way ANOVA test revealed that the variation between seasons were significant (F = 17.32; P<0.05) and ponds were non-significant (Table 7). Dissolved oxygen values showed a significant positive correlation with alkalinity, sulphate and negative correlation with BOD, TDS, CO\textsubscript{2}, chloride, calcium, magnesium, potassium and nitrate in the respective ponds at 5% level.
3.3.1.5. Biological Oxygen Demand (BOD mg/L)

The results on biological oxygen demand recorded in the temple ponds during the first year of the study period (2009 – 2010) are illustrated in Figure 11. The maximum amount of BOD level was (3.26 mg/L) resulted in A2 (January) whereas a minimum of 0.72 mg/L was reported in T2 during June. Seasonal observation reported that 7.14 ± 0.75 mg/L of BOD were the highest value in A2 during non-monsoon season against the lowest value of 1.03 ± 0.33 mg/L in T2 during southwest monsoon (Table 1). The resulted annual mean values of BOD levels in the experimental ponds are shown in Table 3, in which V2 showed highest (4.56 ± 1.41 mg/L) mean value and T2 showed lowest mean value (1.38 ± 0.45 mg/L).

Statistical analysis (two way ANOVA) revealed that a significant variation of BOD resulted between (Table 8) seasons (F = 33.39; P<.05) and ponds (F = 29 .12; P<0. 05). It also showed a significant positive correlation with temperature, TDS, CO2, chloride, calcium, sodium, nitrate, phosphate and negative correlation with alkalinity in selected ponds at 5% level.

In the following year (2010 -2011), the biological oxygen demand resulted in the experimental ponds are illustrated in figure 12. The highest (6.55 mg/L) value was reported in V2 in the month of May and the lowest value was resulted (0.83 mg/L) in T2 during September. Seasonal observation showed 5.97 ± 0.52 mg/L as the highest value of BOD in V2 during non-monsoon against the lowest of 1.27 ± 0.33 mg/L in V1 during southwest monsoon (Table 2). The annual mean values recorded from the experimental ponds are shown in Table 4, and it was minimum of 1.57 ± 0.52 mg/L in V1 against the maximum of 4.59 ± 1.27 mg/L in V2.

Analysis of two way ANOVA indicated a significant influence on seasons and stations (F= 50.66; 46.37; P<0.05) in the level of biological oxygen demand (Table 8). It
also showed a significant positive correlation with TDS, CO$_2$ chloride, calcium, magnesium, sodium, potassium, nitrate, phosphate at 5% level in the experimental ponds.

3.3.1.6. Total dissolved solids (TDS mg/L)

The results on the monthly variation of total dissolved solids (TDS) collected from the experimental ponds are shown in Figure 13. During the first year (2009 – 2010) the TDS contents were higher in A$_2$ (108 mg/L) in the month of April and lower in A$_1$ (29 mg/L) in November. The seasonal variation of the pond A$_2$ showed a maximum mean value of 96.75 ± 10.59 mg/L during non-monsoon and A$_1$ showed a minimum of 35.0 ± 5.35mg/L during northeast monsoon (Table 1). The data on annual mean values indicated a highest value of 77.2 ± 19.82 in A$_2$ and a lowest value of 48.1 ± 14.41 in K$_1$ (Table 3).

Statistical analysis of data (two way ANOVA) revealed that, the variation in TDS content between seasons and ponds were statistically significant (F = 130.16; 25.70; P<0.05) during the study period (Table 9). It also showed a positive correction with temperature, BOD, magnesium, sodium, potassium, nitrate and phosphate in the study ponds at 5% level.

During the second year, in the month of May a maximum value of TDS was (111mg/L) in A$_2$ and a minimum value of 28 mg/L (K$_1$) in the month of September was registered (Fig. 14). A low seasonal mean value of 38.50 ± 10.14 mg/L in K$_1$ during southwest monsoon and a high value of 99.25 ± 10.46 mg/L in A$_2$ during non-monsoon month was noticed (Table 2). A high annual mean value of 81.25 ± 18.10 mg/L in A$_2$ and a low mean value of 53.42 ± 14.77 in K$_1$ was noticed (Table 4).

Data on two way ANOVA revealed that a significant variation (Table 9) exists between seasons (F = 34.37; P<0.05) and ponds (F = 5.06; P<0.05). TDS showed a
positive correlation with CO₂, chloride, calcium, magnesium, nitrate, phosphate and negatively significant with alkalinity and sulphate.

3.3.1.7. Carbon dioxide (CO₂ mg/L)

The monthly variation of CO₂ concentration observed during the study periods are shown in Figure 15. The peak value of 7.30 mg/L was registered in the month of April (T₁) against a very low value of 2.90 mg/L in October (A₁). The seasonal variations of CO₂ level reported are shown in (Table 1). Seasonal mean value of CO₂ concentration was high during non-monsoon (7.13 ± 0.17 mg/L) in V₁ and low during southwest monsoon (3.75 ± 0.72 mg/L) in T₂. The reported annual mean value was high in V₁ (6.06 ± 1.05 mg/L) and low (4.53 ± 0.95) in A₁ (Table 3).

Data on two way analysis of variance revealed that the variation in CO₂ concentration was significantly influenced by seasons (Table 10) and ponds (F = 89.63; 15.82; P<0.05). Correlation coefficient of CO₂ showed a significant positive relationship with parameters like temperature, pH, BOD, chloride, calcium, nitrate and negative correction with alkalinity in the experimental ponds at 5% level.

In the second year of study period (2010 – 2011), V₁ showed maximum value of 7.40 mg/L in May and a minimum value of 3.50 mg/L (November) in A₁ was registered (Fig. 16). Data on seasonal variation of CO₂ during the second year of study showed higher value of 7.38 ± 0.2 mg/L during non-monsoon season (V₁) and lower value of 4.33 ± 0.67mg/L in A₂ during northeast monsoon season (Table 2). The annual mean values were varied from 5.05 ± 0.90 mg/L (A₁) to 6.55 ± 0.82 mg/L in V₁ (Table 4).

Data on statistical analysis of variance (Table 10) revealed that the variation in CO₂ was significantly influenced only by the seasons (F=12.63; P<0.05). The correlation
between CO₂ and water parameters showed a significant positive correlation with calcium, magnesium, sodium, potassium, nitrate, phosphate and negative correlation with DO, alkalinity and sulphate in the experimental ponds at 5% level.

3.3.1.8. Total Alkalinity (TA mg/L)

The result on the monthly variation of total alkalinity content observed during the study period (2009 – 2010) is shown in Figure 17. The peak value of 174 mg/L was registered in the month of September in T₂ and in March the values remained very low (33 mg/L) in A₂. Seasonal mean values were high (139.75 mg/L) during southwest monsoon season in V₁ and K₁. Low value (47.25 ± 4.03 mg/L) was registered during non-monsoon in A₂ (Table 1). The annual mean value was high in T₂ (119.4 ±30.36 mg/L) and low value (71.8 ± 23.68 mg/L) in A₂ (Table 3) was observed.

Data on two way ANOVA revealed (Table 11) that a significant variation exists between seasons and pond (F=69.79; 12.76; P<0.05). Correlation coefficient of total alkalinity in the experimental temple ponds showed a significant positive correlation with DO and negative correlation with chloride and calcium at 5% level.

In the following year of the study period, T₂ showed a maximum value of 183 mg/L in November and a minimum value of 43 mg/L in A₁ during May (Fig. 18). The seasonal variation of total alkalinity values ranged from 54.0 ± 10.36 mg/L (A₂) to 145.0 ± 31.20 mg/L (V₁) during non-monsoon and northeast monsoon seasons (Table 2). The annual mean value was high (122.17 ± 36.74 mg/L) in T₂ and low (78.42 ± 23.94 mg/L) in V₂ (Table 4).

Statistical analysis (two way ANOVA) indicated that, there was a significant variation (Table 11) between seasons and ponds (F= 37.17; 5.73; P<0.05). Correlation coefficient of total alkalinity showed a significant positive variation with DO and
negative variation with BOD, TDS, chloride, calcium, sodium, potassium, nitrate and phosphate at 5% level in the selected ponds.

3.3.1.9. Chloride (Cl mg/L)

The results on the monthly variations of chloride content recorded from the eight experimental ponds are shown in Figure 19. During the year 2009–2010, in the month of March a maximum of 53 mg/L was recorded in A2 against the minimum of 13 mg/L in V1 (September). Seasonal variation showed highest value of 54.50 ± 8.96 mg/L in A2 during non-monsoon and lowest value of 19.75 ± 4.79 mg/L in A1 during southwest monsoon season (Table 1). The observed annual mean value of chloride contents are shown in Table 3. It was high (44.58 ± 10.98 mg/L) in A2 and low values (23.75 ± 4.75 mg/L) in A1 in the year 2009-2010.

Statistical analysis of two way ANOVA revealed that the variation in chloride content was influenced significantly by seasons (F = 33.63; P<0.05) and ponds (F = 24.03; P<0.05) (Table 12). Correlation coefficient showed a significant correlation with calcium alone.

In the following year 2010–2011, the maximum amount of chloride content was observed (62 mg/L) in V1 during March and minimum (15 mg/L) in A2 during October (Fig. 20). The observed results on seasonal variation of chloride contents are shown in Table 2. A2 showed a higher concentration of 56 ± 4.96 mg/L during non-monsoon and V1 showed low concentration of 19.75 ± 5.25 chloride content during southwest monsoon. Annual mean value of chloride contents ranged from 24.08 ± 5.56 mg/L to 43.25 ± 11.13 mg/L in V1 and A2 (Table 4).

Statistical analysis of two way ANOVA revealed that significant variations (Table 12) exist between seasons and ponds (F = 53.87; 14.09; P<0.05). Correlation
coefficient also showed a significant correlation with calcium and sulphate at 5 % level in the selected ponds.

3.3.1.10. Calcium (Ca mg/L)

Data on the monthly variation of calcium content recorded in the experimental temple ponds during the first year (2009 – 2010) is illustrated in Figure 21. The peak value of 47 mg/L in V₁ was observed in April and low value of 7.8 mg/L was reported in the month of June (A₂). The observed seasonal variation of calcium contents are illustrated in the Table 1. During non-monsoon season seasonal mean value was high in V₁ (42.25 ± 3.30mg/L) and in southwest monsoon the value was low in K₂ (15 ± 3.74 mg/L). The annual mean values showed a maximum of 31.75 ±9.29 mg/L in V₁ and minimum of 18.83 ± 4.21 mg/L in V₂ (Table 3).

Statistical analysis of two way ANOVA revealed a significant deviation between seasons (Table 13) and ponds (F = 25.09; 5.65; P<0.05). Correction analysis between different parameters with calcium concentration showed a significant positive correlation with nitrate at 5 % level.

In the following year, the results obtained on the monthly variations of calcium content are illustrated in Figure 22. It shows higher value of 51 mg/L in V₁ (May) against the lower value of 10 mg/L in the month of October (T₁). The seasonal variation of calcium content was maximum of 40.75 ± 9.17 mg/L in V₁ (non-monsoon) and minimum of 15.75 ± 2.98 mg/L in V₂ during northeast monsoon (Table 2). The annual mean value of 30.33 ± 11.27 mg/L was recorded in V₁ as maximum and 20.25 ± 5.42 mg/L as minimum in V₂ (Table 4).

Statistical analysis by two way ANOVA (Table 13) showed significant variation between seasons and ponds (F=67.73; 7.65; P<0.05). Correlation analysis between
different parameters with calcium concentration revealed significant positive variation with sodium, potassium, nitrate and phosphates at 5% level.

3.3.1.11. Magnesium (mg/L)

The monthly variations of magnesium contents resulted from different experimental ponds during the study period are shown in Figure 23. The highest magnesium content of 18.1 mg/L was recorded in April (T_2) and a lowest value of 4.1 mg/L in November (K_2). Seasonal studies showed the lowest of 5.38 ± 1.31 mg/L in K_2 during northeast monsoon and highest of 16.33 ± 2.59 mg/L in T_2 during non-monsoon (Table 1). A maximum annual mean value of 11.08 ± 5.13 mg/L was recorded in T_2 and the minimum of 8.08 ± 2.40 was recorded in V_2 (Table 3).

Statistical analysis by two way ANOVA showed that a significant variation exists between seasons alone (F=37.03; P<0.05) and a non-significant variation (P > 0.05) between ponds (Table 14). Correlation analysis revealed that magnesium shows significant positive correlation with sodium, potassium, nitrate and phosphate at 5% level.

During the second year of study (2010 – 2011), in February the magnesium content was maximum of 20.2 mg/L in T_2 and minimum of 6 mg/L in V_2 in October (Fig. 24). Observation on the seasonal variation of magnesium showed a lowest of 7.45 ± 0.83 mg/L in A_2 during northeast monsoon and highest of 17.18 ± 3.12 mg/L in T_2 during non-monsoon (Table 2). The annual mean value was maximum of 13.50 ± 3.48 mg/L (T_1) and 10.02 ± 2.82 mg/L (V_2) as minimum (Table 4).

Statistical analysis of two way ANOVA (Table 14) revealed that in the eight temple ponds the variation in magnesium content was influenced by both the variables (seasons and ponds) and is statistically significant (F=67.89; 4.24; P<0.05). Correlation
coefficient revealed a significant positive relationship with sodium, potassium, nitrate and phosphate at 5 \% level.

3.3.1.12. Sodium (Na mg/L)

The concentration of sodium content recorded from the experimental ponds during the study period is shown in Figure 25. During the first year of study a maximum value of 34 mg/L was recorded (A_1) in February and a minimum of 9 mg/L in T_1 (December). The seasonal variation of sodium content of the eight temple ponds during the study period is shown in (Table 1). A minimum value of 31.0 ± 2.58 mg/L in A_1 during non-monsoon and minimum of 12.75 ± 2.50 mg/L in V_2 during northeast monsoon was noticed. The annual mean value ranged from 14.58 ±2.27 mg/L to 22.92 ± 5.91 mg/L in K_2 and A_2 (Table 3) respectively.

Statistical analysis of two way ANOVA (Table 15) revealed that a significant deviation was observed between the seasons and ponds (F = 19.59; 3.54; P<0.05). Correlation analysis revealed a significant positive correlation with pH, BOD, TDS, potassium, nitrate and phosphate at 5\% level.

In the second year of the study period (2010 – 2011), the results on the monthly variation of sodium content is shown in Figure 26. The lowest value of sodium (8 mg/L) was registered during November in pond K_2 with the highest value of 36 mg/L during May (T_2). The observed seasonal values of sodium content are given in Table 2. The minimum value of 9.50 ±1.29 mg/L was recorded in K_2 during northeast monsoon and the maximum mean value of 30.75 ± 2.98 mg/L was noticed in T_1 during non-monsoon season. The annual mean value observed (Table 4) was high in T_2 (25.66 ± 6.87 mg/L) and low in K_2 (13.41 ± 4.10 mg/L).
Two way ANOVA revealed that the variation of sodium content (Table 15) was influenced significantly by the seasons and ponds (F= 44.53; 11.13; P<0.05). Correlation analysis revealed that sodium shows significant correlation with potassium, nitrate and phosphate at 5% level.

3.3.1.13. Potassium (K mg/L)

The result on potassium content of water samples from the eight experimental temple ponds under investigation during the first year (2009 – 2010) is given in Figure 27. The values ranged from a minimum of 1.41 mg/L in December (A1) to 5.17 mg/L in June (K1) as maximum. Seasonal variation from the ponds showed a minimum of 1.66 ± 0.22 mg/L in A1 during northeast monsoon and maximum of 4.42 ± 0.93 mg/L in K1 during southwest monsoon (Table 1). The minimum and maximum annual mean values of 2.37 ± 0.56 mg/L and 3.70 ± 1.13 mg/L (A2 and K1) were reported (Table 3).

Statistical analysis of two way ANOVA revealed that the variation in potassium content was significantly influenced (Table 16) by the seasons and ponds (F = 58.54; 11.37; P<0.05). It also showed a significant positive correlation with nitrate and phosphate at 5% level.

In the second year of the study period the monthly variation of potassium content observed from the experimental ponds are shown in Figure 28. The values were high (5.62 mg/L) in K1 and low (1.22 mg/L) in V2 during the month of May and December. Seasonal observation highlighted a peak value of 4.28 ± 1.05 mg/L during non-monsoon season in K1 and low value of 1.55 ± 0.20 mg/L in A2 during northeast monsoon (Table 2). Among the eight ponds K1 (3.51 ± 1.15 mg/L) was reported with maximum annual mean value (Table 4) and A2 was with minimum value (2.22 ± 0.62 mg/L).
Statistical analysis by two way ANOVA revealed that a significant variation (Table 16) exists between season and ponds ($F = 98.20; 6.95; P<0.05$). Correlation coefficient showed a significant positive relationship with nitrate and phosphate at 5% level.

### 3.3.1.14. Sulphate (SO$_4$ mg/L)

The results on the monthly variation of sulphate concentration obtained from the eight temple ponds in the year 2009 - 2010 is given in Figure 29. The values ranged from a minimum of 4.39 mg/L ($K_1$) in February to the maximum of 14.85mg/L ($A_2$) in November. Data on seasonal variation in sulphate concentration observed during the study period is shown in Table 1. When compared to the other ponds $V_1$ showed higher mean values ($13.28 \pm 1.68$ mg/L) during southwest monsoon season, whereas $V_2$ showed lowest mean values ($5.52 \pm 1.05$ mg/L) during non-monsoon season. The highest and lowest annual mean values were $10.34 \pm 3.10$ mg/L and $7.95 \pm 1.98$ mg/L in $V_1$ and $T_2$ (Table 3) respectively.

Statistical analysis of two way ANOVA revealed that the variations between seasons were significant ($F = 31.42; P<0.05$) and non-significant ($P > 0.05$) between ponds (Table 17). Correlation coefficient of sulphate content showed a negative significant correlation with temperature ($V_1$, $V_2$, $K_2$, $T_1$), pH ($V_1$, $V_2$ & $T_2$), BOD ($V_1$, $V_2$ & $K_2$) and positive correlation with DO ($V_1$, $V_2$, $K_2$ & $A_1$) and alkalinity ($V_1$, $V_2$ & $T_2$) at 5 % level.

In the second year of the study period, the recorded monthly variations of sulphate concentration in the experimental ponds are shown in Figure 30. A peak value of 17.13 mg/L was reported in July ($V_1$) and a low value of 4.82 mg/L in $A_2$ during May. Seasonal variation of sulphate concentration under study showed that the mean value were high
(16.0 ± 1.89 mg/L) in V during southwest monsoon, where as T showed low sulphate content (5.91 ± 1.30 mg/L) during non-monsoon (Table 2). The maximum and minimum annual mean values were 12.72 ± 3.22 mg/L and 7.98 ± 1.56 mg/L in V and T respectively (Table 4).

Statistical analysis of two way ANOVA revealed a significant variation between seasons (F = 13.99; P<0.05) and a non-significant variation (P > 0.05) between ponds (Table 17). Correlation coefficient of sulphate content showed a negative correlation with temperature, pH, BOD, TDS, CO and positive correlation with DO and alkalinity at 5% level.

3.3.1.15. Nitrate (NO₃ mg/L)

The nitrate content reported monthly from the different study ponds are shown in Figure 31. It reached maximum of 0.82 mg/L (A) in April against the minimum of 0.21 mg/L in December (A). The seasonal mean values were high (0.79 ± 0.03 mg/L) during non-monsoon in A against a low value of 0.27 ± 0.04 mg/L in A during northeast monsoon (Table 1). The annual mean value of nitrate content observed was high as 0.66 ± 0.11 mg/L in A and low as 0.41 ± 0.11 mg/L in A were observed (Table 3).

Statistical analysis by two way ANOVA reported a significant variation between seasons (Table 18) and ponds (F = 45.34; 7.62; P<0.05). Correlation coefficient of nitrate showed a significant positive correlation with phosphate at 5 % level.

During the study period 2010 – 2011, the results obtained on the monthly variations are shown in Figure 32. It reached a peak level of 0.87 mg/L in A during February and a low level of 0.25 mg/L in K during August. During non-monsoon season (V) the value was high as 0.66 ± 0.06 mg/L and low (K) as 0.32 ± 0.07 mg/L (Table 2).
The annual mean value was high in A₂ (0.59 ± 0.11 mg/L) and low (0.43 ± 0.09 mg/L) in A₁ (Table 4).

Two way ANOVA shows a significant variation (Table 18) between season (F = 22.58; P<0.05) and non-significant variation between ponds (P>0.05). The correlation analysis showed a significant positive correlation with temperature, pH, BOD, TDS, CO₂, calcium, magnesium, sodium, potassium, phosphate and a negative correlation with alkalinity at 5% level.

3.3.1.16. Phosphate (PO₄ mg/L)

In the year 2009 – 2010 the results on the monthly variations of phosphate content in the eight temple ponds are displayed in Figure 33. It shows maximum concentration of 1.10 mg/L in A₂ (May) and minimum of 0.41 mg/L in T₂ (November). Seasonal variation of phosphate content showed maximum of 0.97 ± 0.07 mg/L during non-monsoon season in T₁ against a minimum of 0.51 ±0.10 in T₂ during northeast monsoon in the first year of the study period (Table 1). The annual mean values of phosphate content in the ponds are shown in Table 3. A maximum of 0.82 ± 0.17 mg/L was reported in A₂ against a minimum value of 0.72 ± 0.18 mg/L in V₂.

Two way ANOVA (Table 19) revealed a significant variation between seasons alone (F = 147.31; P<0.05). Phosphate showed a significant positive correlation with TDS, magnesium, sodium, potassium and phosphate.

In the following year (2010 - 2011), the monthly variation of phosphate content reported from the ponds is illustrated in Figure 34. Among the eight ponds A₂ showed a high value of 1.20 mg/L in March and a very low value of 0.51 mg/L phosphate content in A₁ during December. During non-monsoon season a maximum of 1.11 ± 0.07 mg/L in A₂ and a minimum of 0.61 ± 0.09 mg/L in A₁ during northeast monsoon was observed.
(Table 2). The annual mean value registered was high (0.95 ± 0.13 mg/L) in T2 against a low value of 0.72 ± 0.14 in A1 (Table 4).

Analysis of two way ANOVA revealed a significant deviation between seasons (F = 66.44; 4.84; P<0.05) and ponds (Table 19). Phosphate showed a positive correlation with BOD and nitrate at 5% level.

3.3.2. Sediment Analysis

3.3.2.1. Sediment pH

The monthly observation of sediment pH from the experimental ponds during the year 2009 – 2010 is shown in Figure 35. The A2 pond showed a peak value in the month of April (8.39) meanwhile the least value was detected during December (5.73) in V2. The seasonal variation of pH in the experimental temple ponds showed a minimum mean value of 6.0 ± 0.21 (V1) during northeast monsoon, whereas a maximum of 8.51 ± 0.04 (T1) was observed in non-monsoon season (Table 20). The annual mean pH ranged from 6.43 ± 0.39 (V1) to 7.68 ± 0.71 (T1) respectively (Table 22).

Two way analysis of variance test (Table 23) revealed that, the sediment pH was significantly influenced by the seasons (F = 98.15; P<0.05) and ponds (F = 18.18; P<0.05). Correlation studies on pH showed a significant positive relationship with manganese (V1, V2, K1, T1 and T2) and significant negative relationship with EC, OC total nitrogen, iron and copper at 5% level.

During the second year of study period (2010 – 2011) the monthly variations of pH reported is shown in Figure 36. The pH values ranged from 5.64 (V2) to 8.60 (T1) during the month of September and February. The seasonal variation of pH in the experimental ponds showed a minimum mean value of 6.13 ± 0.10 (V1) during southwest
monsoon season and a maximum mean value of 8.46 ± 0.11 (T1) during non-monsoon season (Table 21). Observation of pH in the temple ponds revealed that the annual mean pH values ranged from 6.44 ± 0.39 (V1) to 7.97 ± 0.44 (T1) (Table 22).

Two way analysis of variance test (Table 23) revealed that, the sediment pH was influenced significantly by the seasons and ponds (F = 75.53; F = 29.32; P<0.05). The correlation matrix showed a positive correlation with manganese and negative correlation with EC, nitrogen, phosphorus, iron and zinc at 5% level.

### 3.3.2.2. Electrical conductivity (mhos/cm)

The monthly variation of EC values recorded from the eight temples ponds during the study period (2009 – 2010) is provided in Figure 37. A low value of 0.032 mhos/cm in T1 was noticed during April and high value of 0.78 mhos/cm in K2 during September was observed. The seasonal electrical conductivity recorded during the study period is given in Table 20. The maximum EC was recorded during southwest monsoon season and minimum during non-monsoon season. The highest mean value of 0.74 ± 0.06 mhos/cm from pond K2 and the lowest mean of 0.07 ± 0.03 mhos/cm in pond T1 were noticed. The observed annual mean value of EC recorded in the study pond is given in Table 22, and the values ranged from 0.21 ± 0.09 mhos/cm (K1) to 0.44 ± 0.27 mhos/cm (K2) respectively.

Statistical analysis of two way ANOVA (Table 24) revealed that EC showed a significant variation between season (F = 14.12; P<0.05) and a non significant variation between ponds (P>0.05). Correlation matrix showed a positive significant influence with organic carbon, nitrogen, phosphorus, potassium, iron, zinc and copper at 5% level.
In the succeeding year, (2010 – 2011) the monthly variation of EC recorded from the experimental ponds are shown in Figure 38. It ranged from 0.04 mhos/cm ($K_1$) to 0.81 mhos/cm ($K_2$) during the month of May and October. The seasonal observation on electrical conductivity showed a maximum of $0.65 \pm 0.15$ mhos/cm ($K_2$) during northeast monsoon and a minimum of $0.08 \pm 0.03$ mhos/cm ($K_1$) during non-monsoon season (Table 21). The annual mean values were minimum of $0.16 \pm 0.09$ mhos/cm in $K_1$ and maximum of $0.46 \pm 0.23$ mhos/cm in $K_2$ (Table 22).

The statistical analysis of two way ANOVA (Table 24) revealed a significant variation between seasons ($F = 16.42; P<0.05$) and ponds ($F = 4.42; P<0.05$). The correlation studies showed a significant positive deviation with organic carbon, nitrogen, phosphorus, potassium, iron, zinc and negative correlation with manganese at 5% level.

3.3.2.3. Organic carbon (mg/kg)

The monthly variation of organic carbon content in the experimental ponds during the first year of study (2009 – 2010) reported a peak value of $1.37$ mg/kg (December) in $T_1$ against the lowest value of $0.009$ mg/kg (March) in $A_1$ (Fig. 39). Seasonal observation of organic carbon content from the ponds showed a maximum value of $1.18 \pm 0.05$ mg/kg ($V_1$) during northeast monsoon season against the lowest value of $0.01 \pm 0.005$ mg/kg ($A_2$) during non-monsoon season (Table 20). The annual mean values of organic carbon in the experimental ponds ranged from $0.42 \pm 0.38$ mg/kg ($A_1$) to $1.03 \pm 0.15$ mg/kg in $V_1$ (Table 22).

Statistical analysis of two way ANOVA revealed that the variation in organic carbon concentration was significantly influenced by seasons and ponds ($F = 82.15; 8.96; P<0.05$) (Table 25). Correlation studies of organic carbon content with other parameters
showed a significant positive correlation with total nitrogen, phosphorus, potassium, iron and copper at 5% level.

During the second year of study (2010 – 2011) the organic carbon content reported a maximum of 1.43 mg/kg during November in T1 against the lowest value of 0.30 mg/kg during April in T2 (Fig. 40). Seasonal variation of organic carbon content reported a maximum mean value of 1.31 ± 0.09 mg/kg during northeast monsoon (T1) against the minimum of 0.36 ± 0.06 mg/kg (T2) during non-monsoon (Table 21). The annual mean values in the experimental ponds fluctuated between 0.65 ± 0.25 mg/kg (T2) and 1.08 ± 0.19 mg/kg in V1 (Table 22).

Statistical analysis of two way ANOVA (Table 25) revealed a significant variations between seasons and ponds (F = 101.39 and F = 11.54; P<0.05). Correlation of organic carbon content with other parameters showed a significant positive correlation with nitrogen, phosphorus, iron, copper and negative correlation with manganese at 5% level.

3.3.2.4. Nitrogen (mg/kg)

The monthly values of nitrogen content observed during the first year of the study period ranged from 1.11 mg/kg in V2 (April) to 11.80 mg/kg in T1 during the month of January (Fig. 41). The seasonal variations of nitrogen in the experimental ponds showed the highest mean values of 10.21 ± 0.47 mg/kg (V1) during northeast monsoon season against a low mean value of 1.44 ± 0.28 mg/kg (K1) during non-monsoon season (Table 20). The annual mean values reported in the experimental temple ponds varied from 4.81 ± 3.30 mg/kg (K1) to 8.89 ± 1.30 mg/kg (V1) during the first year of the study period (Table 22).
Statistical analysis of two way ANOVA (Table 26) revealed that, the variation in nitrogen was influenced significantly by both the seasons and ponds (F = 43.92; F = 4.80; P<0.05) Correlation analysis of nitrogen showed a significant positive result with phosphorus, potassium, iron and copper at 5% level.

In the following year (2010 – 2011) the observed monthly values of nitrogen are shown in Figure 42. It varied from 1.08 mg/kg in K1 (February) to 12.10 mg/kg in A2 (August). The values on seasonal variations of nitrogen showed the maximum of 10.43 ± 1.57 mg/kg (T1) during northeast monsoon season against the lowest value of 2.57 ± 1.60 mg/kg (K1) during non-monsoon season (Table 21). The annual mean values of total nitrogen ranged from 5.51 ± 2.43 mg/kg (A1) to 9.10 ± 1.32 mg/kg in V1 (Table 22).

Statistical analysis of two way ANOVA (Table 26) revealed that a significant deviation between seasons and ponds (F = 31.55; 5.35; P<0.05). Correlation analysis showed a positive correlation of total nitrogen with phosphorus, potassium, iron and negative correlation with manganese at 5% level.

3.3.2.5. Phosphorus (mg/kg)

The observed values on the monthly variation of phosphorus content recorded in the sediment samples during the first year of study under investigation ranged from 0.20 mg/kg (A1) to 1.84 mg/kg (K2) during the month of February and September (Fig. 43). The seasonal mean values of phosphorus content showed a maximum of 1.63 ± 0.22 mg/kg (K2) during southwest monsoon season and minimum of 0.24 ± 0.03 mg/kg (V1) during non-monsoon season (Table 20). The maximum annual mean of 1.42 ± 0.24 mg/kg in K2 was noticed against the minimum mean of 0.60 ± 0.32 mg/kg in A1 (Table 22).
Two way analysis of variance test revealed that, the variation of phosphorus content of sediment was significantly influenced by seasons (F = 61.17; P<0.05) and ponds (F = 14.38; P<0.05) (Table 27). Correlation analysis showed a significant positive correlation coefficient with nitrogen, potassium and iron at 5% level.

In the following study, period (2010 – 2011) the monthly variations of phosphorus content resulted is illustrated in Figure 44. It ranged from a maximum of 1.93 mg/kg in K2 during December and a minimum of 0.34 mg/kg in V1 during the month of March. The seasonal variation of phosphorus content was maximum in pond K2 (1.77 ± 0.13 mg/kg) during northeast monsoon and minimum in V1 (0.51 ± 0.12 mg/kg) during non-monsoon season (Table 21). The observed annual mean values were high in K2 and low in V1 (1.49 ± 0.25 and 0.81 ± 0.31 mg/kg) (Table 22).

Data on two way ANOVA (Table 27) showed a significant variation between seasons and ponds (F = 66.57; F = 22.55; P<0.05). Correlation analysis of phosphorus content showed a positive relationship with total nitrogen, iron and negative correlation with manganese at 5% level.

3.3.2.6. Potassium (mg/kg)

The resulted values on the monthly variations of potassium content during the study period attained a peak value of 43.6 mg/kg during the month of August in K2 and a low value of 11.24 mg/kg during April in V1 (Fig. 45). The seasonal mean values of potassium in the experimental ponds showed the highest value of 34.49 ± 0.63 mg/kg (K2) during northeast monsoon and lowest values of 12.65 ± 1.13 mg/kg (V1) during non-monsoon season (Table 20). The observed annual mean value of potassium content during the study period is shown in Table 22. The maximum mean value was registered
in the pond $K_1$ ($43.13 \pm 3.42$ mg/kg) and minimum value was registered in pond $V_1$ ($18.71 \pm 5.88$ mg/kg).

Statistical analysis of the data (Two way ANOVA) revealed that, the variations of sediment potassium in all the ponds were statistically significant between seasons ($F = 91.75; 43.39; P<0.05$) and ponds (Table 28). Correlation analysis of potassium revealed a significant positive relationship with total nitrogen, phosphorus and iron at 5% level.

In the following year (2010 – 2011) the minimum potassium content reported was 12.33 mg/kg in $V_2$ in the month of May against the maximum value of 46.20 mg/kg ($K_2$) in June (Fig. 46). Seasonal observation reported a minimum of $15.04 \pm 1.77$ mg/kg in $V_1$ (northeast monsoon) against a maximum of $42.44 \pm 3.39$ mg/kg (southwest monsoon) in $K_2$ (Table 21). The resulted annual mean potassium content of the sediment is given in Table 22. The lowest mean value of $20.40 \pm 5.67$ mg/kg was observed in $V_1$ against the highest of $31.85 \pm 5.78$ in $T_2$.

Statistical analysis on (Table 28) two way ANOVA reported a significant variation between seasons and ponds ($F = 13.32; F = 3.50; P<0.05$). Correlation coefficient of potassium with other parameters showed a positive relationship with nitrogen and zinc at 5% level.

3.3.2.7. Iron (mg/kg)

The monthly variation of iron content recorded from the experimental ponds in the first year (2009 – 2010) of the study period is shown in Figure 47, in which a maximum of 8.91 mg/kg was reported in $V_1$ (December) against a minimum of 1.73 mg/kg (June) in $T_1$. Seasonal variation of iron showed the lowest of $2.16 \pm 0.34$ mg/kg in $T_1$ during non-monsoon season and the highest of $9.34 \pm 0.38$ mg/kg in $A_1$ during northeast monsoon...
(Table 20). The annual mean values indicated a highest of $7.78 \pm 1.67$ mg/kg in $V_1$ and a lowest of $4.46 \pm 2.20$ mg/kg in $T_1$ (Table 22).

Statistical analysis of two way ANOVA revealed a significant deviation (Table 29) between seasons ($F = 120.17; P<0.05$) and ponds ($F = 24.50; P<0.05$). Correlation analysis of sediment iron showed a significant positive correlation with nitrogen, phosphorus, potassium and copper at 5% level.

In the following year (2010 – 2011), the reported values of iron content from the experimental ponds is shown in Figure 48. Among the eight temple ponds the iron content ranged from a low value of 1.18 ($A_1$) to a high value of 9.93 ($K_1$) mg/kg during the month of August and November. The reported seasonal mean values are given in Table 21. During non-monsoon months a minimum of $3.09 \pm 1.13$ mg/kg in $T_2$ and a maximum mean value of $8.64 \pm 1.25$ mg/kg were reported during southwest monsoon in $V_1$. The annual mean value of $6.80 \pm 1.67$ mg/kg was maximum in $V_2$, against the minimum of $4.98 \pm 1.93$ mg/kg in $A_2$ (Table 22).

Analysis of two way ANOVA (Table 29) revealed that a significant variation exists between seasons and ponds ($F = 52.82; F = 3.70; P<0.05$). Correlation analysis showed positive significant variation with electrical conductivity, organic carbon nitrogen, phosphorus, copper and negative correlation with pH and manganese at 5% level.

**3.3.2.8. Zinc (mg/kg)**

The monthly observations of zinc content from the experimental ponds are shown in Figure 49, which ranged from 0.004 mg/kg to 2.93 mg/kg during the month of February ($V_2$) and September ($V_1$). The highest ($2.65 \pm 0.42$ mg/kg) concentration was observed during southwest monsoon season in $V_1$ and lowest values ($0.01 \pm 0.003$ mg/kg)
during non-monsoon season in V2 (Table 20). The annual mean concentration of zinc in the study ponds during the first year of study period varied from 0.07 ± 0.06 mg/kg (V2) to 2.46 ± 0.31 mg/kg in V1 (Table 22).

Statistical analysis of data (two way ANOVA) in the study ponds revealed that, the variation of zinc was influenced significantly by the ponds (F = 113.1; P<0.05) and non-significantly by the seasons (P>0.05) (Table 30). Correlation analysis of zinc in the ponds showed a significant positive correlation with electrical conductivity alone at 5% level.

During the second year of study (2010 – 2011), the highest and lowest monthly values (Fig. 50) of zinc concentration observed from the study ponds were 0.02 mg/kg in V2 (May) and 2.85 mg/kg in V1 (October). The observed seasonal mean values varied from 0.01 ± 0.009 mg/kg (V2) to 2.69 ± 0.09 mg/kg (V1) during non-monsoon and southwest monsoon season (Table 21). A high annual mean value of 2.26 ± 0.44 mg/kg in V1 and 0.07 ± 0.05 mg/kg in V2 was reported as the low annual mean value (Table 22) of the experimental ponds.

Statistical analysis of two way ANOVA (Table 30) revealed that the variation in zinc concentration was influenced significantly by seasons (F = 5.50; P<0.05) and ponds (F = 39.49; P<0.05). Correlation coefficient studies showed a positive correlation with electrical conductivity and phosphorus at 5% level.

3.3.2.9. Copper (mg/kg)

During the period of investigation (2009 – 2010) the lowest and highest monthly values registered from the eight experimental temple ponds are displayed in (Fig. 51). It was 0.05 mg/kg (April) in K2 and 0.76 mg/kg (December) in T1 during the first year of study as higher and lower values. The seasonal variation of copper content in the study
ponds varied between 0.09 ± 0.03 mg/kg (non-monsoon) in K2 and 0.91 ± 0.04 mg/kg (northeast monsoon) in T1 (Table 20). The annual mean values of copper concentration recorded from the experimental ponds under investigation are given in Table 22. The annual mean values fluctuated from 0.28 ± 0.15 mg/kg (T2) to 0.74 ± 0.25 mg/kg (T1) in the first year of the study period.

The result of two way ANOVA (Table 31) indicated that, the variation of copper content in all the experimental ponds were significantly influenced by seasons and ponds (F =148.62; 46.04; P<0.05). The result on correlation for the relationship of copper with different parameters in the experimental ponds showed a positive significant correlation with electrical conductivity, organic carbon, nitrogen and iron at 5% level.

In the following year (2010 – 2011), the results obtained in the monthly variations of copper content are illustrated in Figure 52. It shows higher value of 0.99 mg/kg in T1 (November) against the lower value of 0.10 mg/kg in the month of June (A1). The seasonal variation of copper content was maximum of 0.73 ± 0.18 mg/kg in T1 (northeast monsoon) and minimum of 0.22 ± 0.08 mg/kg in A1 during southwest monsoon season (Table 21). The annual mean value of 0.48 ± 0.15 mg/kg was recorded in V2 as maximum and 0.34 ± 0.15 mg/kg as minimum in A1 (Table 22).

Statistical analysis of two way ANOVA (Table 31) revealed that, a significant variation exists between seasons and ponds (F = 46.59; F = 2.92; P<0.05) Correlation matrix between different parameters with copper concentration revealed a significant positive correlation with organic carbon, nitrogen, phosphorus and iron at 5% level.

3.3.2.10. Manganese (mg/kg)

The concentration of manganese recorded from the experimental ponds during the study period (2008 – 2009) is shown in Figure 53. During the study period the maximum of 10.20 mg/kg (A1) was recorded in February and a minimum of 0.38 mg/kg in V2
The observed seasonal variation in manganese content in the eight experimental temple ponds during study period is shown in Table 20. The maximum value of $6.94 \pm 0.40$ mg/kg in $A_1$ during southwest monsoon and minimum of $1.14 \pm 0.58$ mg/kg in $V_2$ during northeast monsoon season were reported. The annual mean value ranged from $2.18 \pm 1.36$ mg/kg to $5.51 \pm 2.75$ mg/kg in $V_2$ and $A_1$ (Table 22) of the study periods.

Statistical analysis of two ANOVA revealed a significant variation (Table 32) between seasons and ponds ($F = 96.09; F = 16.24; P<0.05$). Correlation matrix revealed that manganese content showed a significant negative correlation with organic carbon ($V_1$ and $T_2$), nitrogen ($V_1$ and $T_2$) iron ($V_1$, $K_1$, $K_2$, $T_2$ and $A_1$) at 5% level.

In the second year, of the study period the result on the monthly variations of manganese content observed is shown in Figure 54. The lowest value of $0.98$ mg/kg was registered during the month of January in pond $V_2$ and a highest value of $10.74$ mg/kg was noticed during April ($T_1$). The seasonal values of manganese content observed during the study period is given in Table 21, in which a minimum of $1.50 \pm 0.41$ mg/kg was recorded ($V_2$) during northeast monsoon and a maximum mean value of $8.67 \pm 1.85$ mg/kg was noticed in $A_1$ during non-monsoon season. The annual mean value (Table 22) was high in $A_2$ ($6.58 \pm 2.03$ mg/kg) and low in $V_2$ ($2.55 \pm 1.15$ mg/kg) during the study period.

Statistical analysis on two way ANOVA revealed that the variation of manganese content (Table 32) was influenced significant by the seasons and ponds ($F = 56.59; F = 16.08; P<0.05$). Correlation matrix revealed that manganese concentration revealed a significant negative correlation with organic carbon, nitrogen, phosphorus, iron and copper at 5% level.
3.4. Discussion

Water quality assessments are generally involved with the physico-chemical characteristics features of various factors of the aquatic ecosystem and it showed great variation in their nutrient concentrations and seasonal fluctuations with respect to the external environmental condition (Ghavzan et al., 2006). In the current study an assessment was made in the water quality of eight selected temple ponds from January 2009 to February 2011.

3.4.1. Physico-chemical parameters of Water

3.4.1.1. Water Temperature (°C)

Temperature is an important factor that regulates the biogeochemical activities of the aquatic environment (Pradeep et al., 2012). In general water temperature depends upon the season, geographical location and sampling time (Desai, 1995; Narayan et al., 2005). It influence aquatic weeds, algal blooms and surrounding air temperature (Pankit et al., 2002; Sivakumar and Karuppusamy, 2008) and it affects the metabolic rates of living organisms (Gupta et al., 2007).

In the present observation the temperature ranged from a minimum of 21.6°C (September in T₁) to 30.7°C (May in A₂) during the study periods. Seasonal variation reported a low mean value of 24.98±0.62°C during southwest monsoon and high mean value of 29.98 ± 0.58°C in the non-monsoon season (V₁ and T₁). Similar range of temperature was reported by Santhosh et al. (2006) in the brackish pond, Kavitha and Balasingh (2007) in a sacred grove pond, Rajagopal et al. (2006) in Chinnaperkoil pond at Virudhunagar, Sayeswara et al. (2010) in purple pond Karnataka and Upadhyah et al. (2010) in two tropical ponds at Varanasi.
Seasonal observation reported an increasing trend from monsoon to non-monsoon which was mainly caused by greater solar radiation, low water level of the experimental pond, clear atmosphere and also by the high atmospheric temperature, as pointed out by Kadiri (2000), Joshi and Singh (2001). As the temple pond T\textsubscript{1} (Boothapandi) is situated in the hilly region, it may influence the water temperature as evidenced by Verma \textit{et al}. (2011). Cole (1983) has pointed out that depth of the water body is another reason for increasing or decreasing the water temperature, as the two ponds of the present study remain not so deep. Temperature is very important, as it governs the solubility of oxygen, carbon dioxide and bicarbonate–carbonate equilibrium (Rajvaidya and Dilip, 2005).

Statistical analysis reported a significant influence of ponds and seasons on temperature at P<0.05 level. Correlation analysis showed significant positive correlation with pH (r = 0.946 and 0.734; BOD (r = 0.800 and 0.976); TDS (r = 0.679 and 0.937); CO\textsubscript{2} (0.699 and 0.843). Similar results were reported by Kumar and Oommen, (2009) in their studies on freshwater environment.

\textbf{3.4.1.2. Hydrogen non concentration (pH)}

pH is defined as the intensity of acidic or basic character of a solution at a given temperature. It is a factor that reflects as an index of pollution (Singh \textit{et al}., 2010), and also an important variable that is involved in all biological activities (Wang \textit{et al}., 2002). According to the Bureau of Indian Standards (BIS, 1991) the permissible limit of pH is 6.5 to 8.5 and all aquatic organisms are well adapted to the specific pH change (Sayeswara \textit{et al}., 2011).

In the present study the pH values ranged from a minimum of 6.11 in September (K\textsubscript{1}) to the maximum of 8.47 in May (A\textsubscript{2}). Seasonal observation reported high mean value (8.25 ± 0.16) during non-monsoon season with low value of 6.60 ± 0.71 in the monsoon season.
season of the study periods (Table 1 and 2). Similar findings were reported by Salam et al. (2000) and Moundiotya et al. (2004). It was also pointed out by Kavitha et al. (2005) in temple pond of Suchindrum and Nagercoil, Thirugnanamoorthy and Selvaraju (2009) in a temple pond of Chidambaram. Generally in India many small confined water bodies particularly reports the alkaline nature (Sharma et al., 2004 and Singh et al., 2005). The high pH values also indicate the high productive nature of the temple pond (Shanthi et al., 2002).

Seasonal observation of high mean pH during non-monsoon season in both the years were due to the high rate of photosynthesis by the phytoplankton of the ponds, resulting in high production of free carbon-dioxide shifting the equilibrium towards alkaline nature (Tiwari et al., 2004). Hujare (2008a) also reported such high pH values during non-monsoon season in their studies. A sharp decline in pH during monsoon season of the present study was mainly due to the mixing of fresh water influx, dilution effects by heavy rainfall, low temperature and decomposition of organic matter (Mistra et al., 2005; Kosygin and Haobijam, 2005). Moreover pH of water is directly related to temperature (Dhembare, 2007), and pH values below 5.0 reduces the productivity of the aquatic ecosystem (Santhosh, 2002).

3.4.1.3. Dissolved oxygen (DO mg/L)

The dissolved oxygen concentration of the aquatic ecosystem reflects the physical and biological character for the maintenance of a variety of organisms (Reetakumari and Rani, 2008). It is an essential factor that affects the solubility and availability of nutrients. It is removed from the water by respiration and decomposition of organic matters of the aquatic system (Solanki et al., 2007). Fluctuation in oxygen concentration is noticed in shallow lakes, ponds, streams and river systems (Varghese et al., 2005). It is
a critical factor of water that characterizing the health of an aquatic ecosystem and low concentration (< 3mg/L) indicates high pollution level (Yayintas et al., 2007).

During the study periods, the oxygen concentration of the temple ponds varied from a minimum of 3.2 mg/L during May (A₂) to the maximum of 12.7 mg/L in T₂ during November (Fig. 9 and 10). Seasonally the mean values were maximum (10.47 and 9.98 mg/L) in T₂ during monsoon than non-monsoon season of the study period (Table 1 and 2). Similar findings were made by Baruah et al. (2011) in the temple ponds of Madhava Pukhari in Kamrup district of Assam. Low content of DO is reported from the studies of Kavitha et al. (2005), Thirugnanamoorthy and Selvaraju (2009) in the temple ponds. Low concentration as a sign of organic pollution is also due to inorganic reductions like hydrogen sulphide, ammonia, nitrates, ferrous ion and other such oxidisable substances (Ara et al., 2003). Moreover the DO level remains low in A₂, may be due to the high water temperature, low flow rate and enhanced utilization of oxygen by microorganisms in the decomposition process and it reports the indication of microbial activity (Mir et al., 2005).

During monsoon the inflows of rain water entry into the temple pond direct diffusion from air, photosynthetic activity of autotrophs, increased the water level and DO concentrations. This is in agreement with the findings of Koshy and Vasudevan, 1999; Chaulya et al., 2002; Shastri et al., 2004 in the freshwater ponds. In general higher planktonic biomass also raised the level of DO (Venkatesh et al., 2009). Harsha and Mallaman (2004) reported that the higher DO was mainly due to moderate temperature. Khare et al. (2007) reported the relationship between dissolved oxygen and temperature when the solubility of oxygen decreases the temperature of the water increase (Ram et al., 2009) and in the present study DO shows inverse relationship with temperature. Similar
findings were observed by Agarwal and Thapliyal (2005). Statistical analysis on two way ANOVA pointed out a significant seasonal influence on dissolved oxygen at P<0.05 level (Table 7).

3.4.1.4. Biological oxygen demand (BOD mg/L)

BOD is an important parameter that indicates the magnitude of water pollution by oxidisable organic matter. The main sources of organic pollution include untreated sewage, agricultural runoff with residual fertilizers. The carbonaceous organic matter and nitrogenous compounds, on oxidation process enters into bio geochemical cycles (Shinde et al., 2010). In general BOD is a value of presence of organic materials in water which can support maximum microorganisms (Puri et al., 2010). The factors involved in the influence of BOD levels are, type of microbes, pH of the water, reduced mineral matters, density of plankton and temperature (Hosmani and Vasanthakumar, 1996). It is mentioned as the quantity of oxygen required for the metabolic process of microorganisms for five days at 20°C for the degradation of organic matters in the aquatic ecosystem (Harsha et al., 2006) and a measure to assess the water quality (Chaurasia and Pandey, 2007).

In the present observation BOD levels were minimum of 0.72 mg/L (June) to the maximum of 6.55 mg/L during May in T2 and V2 ponds (Fig. 11 and 12). Seasonal mean values of BOD were high during non-monsoon and low during monsoon (Table 1 and 2). Similar findings were previously pointed out by Bhatt et al. (1999) and Arimoro et al. (2007).

The higher BOD levels observed in the ponds A2 and V2 were mainly due to the bio degradation of organic materials which exerted oxygen tension in the water and thus increased the BOD (Kumar and Sharma, 2005; Arimoro et al., 2008). Moreover in this
temple pond human activities were more and it required more amount of oxygen for
decomposition and so the demand of oxygen increased. The lower level of BOD during
monsoon season was mainly attributed to the dilution effects of rain water and surface run
off into the ponds. Similar observations were made by (Mini et al., 2003).

Statistical analysis on two way ANOVA revealed a significant influence of
seasons at P<0.05 level in BOD levels. A significant positive correlation was observed
with temperature (r = 0.970), nitrates (r = 0.173), phosphates (r = 0.929) and TDS (r =
0.899). Similar findings were reported from the studies of Hepsibha (2012).

3.4.1.5. Total dissolved Solids (TDS mg/L)

Total dissolved solids are the infilterable solids that remain as residue upon
evaporation and subsequent drying at defined temperature. It gives the measure of ions
dissolved in the water (Ram et al., 2009). TDS indicate the general nature of water
quality and the permissible limit of TDS in drinking water is 500 mg/L according to BIS
(1991) and WHO (2008) standards. In the present investigation TDS ranged from a
minimum of 28 mg/L to 111mg/L during September and May months in the K₁ and A₂
ponds respectively. Seasonal studies reveal that high mean values were noticed during
non-monsoon and low during monsoon (Table 1 and 2). Similar observations were noted
by Tripathy and Pandey (1990); Kaur et al. (1997); Nagaraja et al. (2011). Its higher
concentration reduces the solubility of oxygen in the water.

The high concentration of TDS in the experimental ponds during non-monsoon
highlighted the contaminated nature that enriches the nutrient status of the pond thereby
resulting in eutrophication. The present observation coincides with the reports of
Swarnalatha and Rao (1998); Singh and Mathur (2005). Moreover during non-monsoon
higher decomposition and evaporatation occurs due to high water temperature and
decrease of TDS in monsoon could be due to the accumulation of dissolved solids by the runoff water (Sukhija, 2010). Present observation pointed out that the amount of TDS remains within the permissible limit of WHO (1995) which is less than 500 mg/L.

3.4.1.6. Carbon dioxide (CO$_2$ mg/L)

Carbon-dioxide is released by the decomposition of organic matter of plants and animals which produce carbonic acid that affect the hydrogen ion concentration of the water. It functions as a key factor in primary production (George and Koshy, 2008). According to the view of Sonaware et al. (2009) its concentration in water depends upon the water temperature, depth of the aquatic ecosystem, chemical nature of surface and bottom water and also by the respiration rates. It is a factor that is involved in the formation of carbonates and bicarbonates (Kataria et al., 2006).

In the present study the CO$_2$ concentration ranged from a minimum of 2.90 mg/L in A$_1$ during October to the maximum of 7.40 mg/L (V$_1$) during May (Fig. 15 and 16). Seasonal observation revealed increased mean values of 7.38 ± 0.25 mg/L during non-monsoon season in V$_1$ (Table 1 and 2). Similar results were previously reported by Narayan et al. (2007); Shiddamallayya and Pratima (2011) in the aquatic ecosystems.

The minimum concentration of CO$_2$ during monsoon was due to the influx of freshwater by rain, which increases the number of over grazing microorganisms (Sastri and Pendse, 2001). However it is an essential factor for respiratory metabolism of aquatic vegetation and phytoplankton. Its high level during non-monsoon season may be due to the uptake of CO$_2$ from the autotrophs, assimilation by algae and aerobic bacteria on decay (Sivakumar and Karuppasamy, 2008). Similar higher evolution of CO$_2$ during non-monsoon was also evidenced from the studies of Kaushik and Saxena (1999); Drusila et al. (2005); Karne and Prabhakar (2009).
Statistical analysis by two way ANOVA revealed seasonal influence of CO$_2$ in the experimental ponds at $P<0.05$ level. It also showed significant positive relationship with parameters like temperature ($r = 0.810$), pH ($r = 0.793$) and BOD ($r = 0.863$) at 5% level.

3.4.1.7. Total Alkalinity (TA mg/L)

Alkalinity of surface water is primarily a function of carbonate, hydroxide content and also includes the contribution from borate, phosphate, silicate and other bases. It is a measure of strong acid needed to lower the pH of a sample and a measure of capacity of water to neutralize a strong acid (Shinde et al., 2011). Water with high alkalinity is not always hard since the carbonates are brought into the water in the form of sodium or potassium carbonate. The desirable limit of total alkalinity is 200 mg/L (ICMR, 1975). It is not harmful, however its high quantity imparts bitter taste to water (Garg et al., 2008) and favours phytoplankton growth (Baskhar et al., 2009) Chemical parameters on total alkalinity revealed higher values (183 mg/L in $T_2$) during monsoon months and low value of 33.0 mg/L in $A_2$ during non-monsoon months (Fig. 17 and 18). Seasonal observation also noticed with high mean values on monsoon season (Table 1 and 2). Similar findings were observed from various freshwater ecosystems (Solanki and Pandit, 2006; Tiseer et al., 2008).

Higher values of total alkalinity during monsoon season depend upon the carbonate and bicarbonate ions of the water. The main source of high alkalinity was from the soaps and detergents used by the local residents for bathing and washing purposes in the experimental pond $T_2$. Some amount of them is used by the phytoplankton as carbon source (Ajagekar et al., 2011). The low values during non-monsoon season in the temple pond were mainly due to the low decomposition rates of organic matter. Similar findings were marked by Gupta and Bhadauraya, (2007) and Rajagopal et al., (2006) in the
Chinnaperkovil pond. Higher values of alkalinity also reported the productive nature of ponds (Shinde et al., 2011).

3.4.1.8. Chloride (Cl mg/L)

Chloride occurs naturally and produces salty taste to water (Mathivanan et al., 2005 and Harsha et al., 2006). In freshwater its concentration is involved in ion exchange and salinity balances. It is contributed mainly by rain water, salt deposits and from agriculture wastes (George and Koshy, 2008). High chloride content may affect a person who already suffers from diseases of kidney and heart (Shinde et al., 2010). Several researches reported that higher concentration of chloride in freshwater are indication of organic pollution (Trivedy and Raj, 1992; Tharsh et al., 1994).

In the present observation the chloride concentration of the experimental ponds ranged from a minimum of 13 mg/L September (V1) to the maximum of 62.0 mg/L in V1 (March) during the study periods (2009 – 2011). Seasonal mean values reported were high during non-monsoon and low during monsoon (Table 1 and 2). Similar results were pointed out by Subha (2002) in the Nellaiapper Gandhimathi temple tank at Tirunelveli, Narayana et al. (2008); Vasumathi et al. (2009) and Rajesh et al. (2011) in their studies.

The maximum values observed during non-monsoon was mainly due to higher rates of evaporation and similar findings were made by Kumar et al. (2005); Chouhan and Sharma (2007). The low chloride values during monsoon may be due to dilution effects as reported by Vyas and Sawant (2008); Srivastava et al. (2010). In the present investigation chloride content remained below the permissible limit of BIS (1991) and WHO (2008) as the recommended limit is 250 mg/L. Its concentration higher than 200 mg/L may cause unpleasant taste to water (Arain et al., 2008).
Statistical analysis revealed a significant influence of chloride content by the seasons (Table 12). Correlation studies reported a significant positive influence of calcium ($r = 0.713$) on chloride concentration of the pond at 5% level.

3.4.1.9. Calcium (Ca mg/L)

Calcium is one of the natural elements found in most of the freshwater in the form of calcium carbonate which is a prime factor for hardness (Kamaraj et al., 2008). Srisath et al. (2006) reported that calcium and magnesium are the principal cation that imports hardness. The main source is sedimentary rocks, seepage, leaching and run off from soil (Paul and Misra, 2004). Higher calcium concentration produces coma and death to human beings (Dasgupta and Purohit, 2001).

In the present investigation calcium concentration ranged from a minimum of 7.8 mg/L ($A_2$) during June to 51 mg/L ($V_1$) during May (Fig. 21 and 22). Seasonal mean values were high during non-monsoon season than monsoon season (Table 1 and 2) in all the study ponds. Similar findings were reported by several researchers like Verma et al. (2011) and Pradeep et al. (2012).

The higher concentration of calcium during non-monsoon season ($V_1$) was due to rapid oxidation/decomposition of organic matter (Angadi et al., 2005). Its higher concentrations restrict water use, while it is an important component in the exoskeleton of arthropods and shells in molluscans (Piska, 2000). Lower concentration of calcium ions during monsoon season ($K_2$) may be attributed to dilution effects and also due to the bioaccumulation by living organism. Similar observation was made by few researches (Gurumayum et al., 2000; Sivakumar and Karuppasamy, 2008). Statistical analysis by two way ANOVA showed a significant influence of season and ponds on calcium content of water at $P<0.05$ level.
3.4.1.10. Magnesium (Mg mg/L)

Magnesium is often associated with calcium in all kind of waters, but its concentration remains lower than calcium (Venkatasubramani et al., 2007). It is an essential element for the formation of chlorophyll and act as a limiting factor for the growth of phytoplankton (Dagankar and Saxena, 1992). According to WHO (1998) the permissible limit of Magnesium in freshwater is 150 mg/L. Rain water increases Magnesium concentration in freshwater and in excess it produces unpleasant taste (Narayan et al., 2007).

In both the years of observation (Fig. 23 and 24) Magnesium concentration remains low (4.1 mg/L and 6.0 mg/L) in November and October months in K2 and V2 ponds. Its concentration was high during April and February with 18.1 and 20.2 mg/L in T2 respectively. Seasonal observation reported higher values during non-monsoon (T2) and lower values in the monsoon season (K2) of the study periods (Table 1 and 2). Similar results were highlighted by Venkatasubramani and Meenambal (2007); Sawant and Telave (2009); Dutta et al. (2010).

The higher concentration during non-monsoon season may be due to low water level and high rate of decomposition and evaporation, thus concentrating the salts in the temple pond (Chatterjee et al., 2007). Magnesium content higher than 30 mg/L results in encrustation in water supply structure and poses adverse effects on domestic use (BIS, 1991). The amount of magnesium in all the experimental ponds remains within the permissible limit. Garg (2003) noticed that the higher hardness value in non-monsoon season was mainly attributed to raising temperature thereby increasing the solubility of calcium and magnesium salts.
3.4.1.11. Sodium (Na mg/L)

Sodium is a natural constituent of raw water but its concentration is increased by pollutional sources such as rock salt, precipitation run off, soap solution and detergent (Mishra and Saxena, 1991).

In the present observation sodium concentration ranged from a minimum of 8.0 mg/L in K₂ during November to the maximum of 36.0 mg/L in T₂ during May (Fig. 25 and 26) and higher mean values were observed during non-monsoon and lower values in the monsoon seasons (Table 1 and 2). Similar results were pointed out by Prakash and Somasekar, (2006), Baruah and Kakati, (2009), Krishnamoorthy and Selvakumar, (2010).

In the two years of observation higher values of sodium concentration was observed during non-monsoon season which was mainly due to the shrinkage of water volume in the experimental ponds as evidenced from the studies of Solanki (2001). According to Sathe (2000) the higher concentration of sodium was mainly due to the increased levels of pollution. The prescribed limit of sodium is 250 mg/L (WHO, 2008) and in the study ponds the reported values are within the permissible limits. The lower concentrations of sodium in the experimental ponds were mainly due to the increased level of water by the rain and inflow from the neighboring areas. In the experimental ponds addition of detergents and soap solution by the influence of human beings in T₂ pond may also increase the levels of carbonates and bicarbonates thereby sodium concentration was raised as supported by Mishra and Saxena (1991); Subhashini and Saradhamani (2005).

3.4.1.12. Potassium (K mg/L)

Potassium occurs as an important cation in natural water and closely related to sodium (Chapman, 1996). In pond water it occurs as a fourth ranking cation caused by
chemical corrosion, weathering process and anthropogenic inputs. It is a macronutrient and plays a vital role in the metabolism of fish (Ram et al., 2009).

In both the years of observation potassium concentration the values remained low (1.22 and 1.41 mg/L) in the month of December (V2 and A1) and high during June (5.17 mg/L) and May (5.62 mg/L) in K1 (Fig. 27 and 28). Seasonal mean value varied from high during southwest monsoon in the first year and non-monsoon season during the second year of the study period (Table 1 and 2). Similar observations were made by Kausik et al. (1991), Kumar and Hosmani (2006) in their studies on freshwater ecosystems.

Higher concentration during monsoon was mainly due to rain water (Shamal, 2011) and reduced water levels may increase the concentration of potassium as supported by Esakki (2006). Ahmad et al. (1996) pointed out that the raised levels of calcium and potassium in freshwater ponds was mainly due to lattice formation. According to ICMR (1975) the permissible limit of potassium is 10 mg/L and the present study the concentration of pond waters remains within the limit.

3.4.1.13. Sulphate (SO4 mg/L)

Sulphate is an ion that occurs naturally in waters. They contribute to the total solid and increase the concentration in the water body. Runoff water, mixing of minerals related to sulphur compounds in the agriculture fields contribute sulphate to water bodies. It occurs as H2SO4, free sulphur and HS-H2S (Singh, 1984). Maximum limit of SO4 in drinking water is 200 mg/L (WHO, 1998).

Present observation of sulphate content in the temple ponds, ranged from a minimum of 4.39 mg/L in February to the maximum of 17.13 mg/L during July in K1 and V1 ponds respectively (Fig. 29 and 30). In both the years of study maximum mean values
were observed during southwest monsoon (Table 1 and 2). Similar type of results were reported by Shanthi et al. (2006); Telkhade et al. (2008); Vasumathi et al. (2009).

The increased concentration of sulphate during monsoon season may be due to dilution effects and utilization by aquatic organisms. However during non-monsoon due to the biodegradation and low water level in the study ponds the sulphate concentration may be lesser in amount (Drusila et al., 2005; Umamaheswari and Saravanan, 2009). Its higher concentration causes gastro-intestinal problems in human beings (Ramadevi et al., 2009).

3.4.1.14. Nitrate (NO$_3$ mg/L)

Nitrate is the most highly oxidized form of nitrogen compounds commonly present in natural waters, because it is a product of aerobic decomposition of organic nitrogenous matter. Significant sources of nitrates are agricultural fertilizers, decayed vegetables and animal matter, industrial effluents and atmospheric washouts (Abulude et al., 2007; Sithik et al. 2009). Nitrate is a major ingredient of farm fertilizer and is necessary for crop production. It stimulates plankton growth and according to ICMR (1975) the permissible limit of nitrate is 50 mg/L. Nitrate concentration over 100 mg/L causes blue baby disease (Sooch et al., 2005).

In the study periods of observation nitrate concentration varied from 0.21 mg/L in $A_1$ during December to 0.87 mg/L ($A_2$) during February. During non-monsoon season maximum mean values (0.79 mg/L in $A_1$ and 0.66 mg/L in $V_2$) were observed (Table 1 and 2) and minimum concentration was reported during monsoon. Similar findings were noticed by Govindasamy et al. (2000) and Puri et al. (2010).

The lower concentration of nitrate in the experimental ponds during monsoon was mainly due to the insufficient mixing of organic waste and also due to the increased level
of water in the pond (A₂) during non-monsoon season. The higher amount of nitrate during non-monsoon was by the rain water mixing. During non-monsoon showers surface runoff and unpolluted water sources contain only minute quantities of nitrates, (Kannan, 1978 and Zuber, 2007). In the Thirumullavaram temple pond of Kollam municipality, Kerala the nitrate content was maximum (0.04 mg/L) during non-monsoon season (Sulabha and Prakasam, 2006) and the present investigation coincides with this report. Higher concentration of nitrates is an indication of organic pollution and eutrophication (Harikrishnan et al., 1999; Joseph and Tessy, 2010).

3.4.1.15. Phosphate (PO₄ mg/L)

Phosphorus is a nutrient for plant growth and a fundamental element in the metabolic reaction of plants and animals. It controls algal growth and primary productivity. It is considered as one of the limiting nutrients regulating plant production in aquatic ecosystem (Sonaware et al., 2009). In most natural waters the phosphate concentration was from 0.005 to 0.020 mg/L. Excess amount of phosphorus in water causes eutrophication which leads to algal blooms (Shinde et al., 2011) and helps in algal growth (Rajesh et al., 2011).

In the periods of observation phosphate concentration was maximum of 1.10 mg/L during May and 1.20 mg/L during March in A₂ with the minimum values observed during November (0.41 mg/L in T₂) and December (0.51 mg/L in A₁) months. Seasonal observation reported higher mean values during non-monsoon season (0.97 mg/L in T₁ and 1.11 mg/L in A₂) and minimum of 0.51 and 0.61 mg/L during northeast monsoon season of the study periods (Table 1 and 2). Similar results were noticed by Rajagopal et al. (2010b) in the Chinnaperkovil pond and Nallanchettipatti pond at Sattur, Tamil Nadu.
The higher concentration during non-monsoon season was mainly due to the presence of detergents used by the village people as the pond (A2) remains with high level of water during non-monsoon and similar findings were made by Khare et al. (2007); Soni and Bhatt, (2008); Kumar and Oommen, (2009). Phosphate functions as an important limiting factor for phytoplankton productivity and its concentration decreased by the utilization of plankton multiplication (Moss and Balls, 1989).

Statistical analysis by two way ANOVA reported that the phosphate concentration was significantly influenced by the seasons (F = 147.31 and 66.44; P<0.05) and correlation analysis showed a significant positive relationship with Magnesium (r = 0.668 and 0.670); Sodium (r = 0.980 and 0.953) and Potassium (r = 0.904 and 0.798) at 5% level. Similar findings were made by Prakash (2011) and Joseph (2012) in their studies on freshwater environments.

3.4.2. Sediment Discussion

In all aquatic ecosystems sediment conserves large quantity of minerals, heavy metals and different dissolved solids at the bottom region as a result of anthropogenic activities and mineralogical composition. The accumulated element in the bottom sediment influences the density, distribution, diversity, of micro and macro flora thereby influences the water quality (Suneela et al., 2008). A number of environmental factors such as EC, pH, OC and inorganic substances are involved in determining the sediment characters (Begam et al., 2009).

3.4.2.1. Sediment pH

The hydrogen ion concentration is an important parameter involved in the distribution of benthic organism and also in ion exchange process (Foth, 1990). It functions as a good indication of the chemical nature of sediment (Anand and Sharma,
In the present observation pH values ranged from a minimum value of 5.73 in December \((V_2)\) to the maximum of 8.39 \((A_2)\) in April during the first year and from a value of 5.64 to 8.60 during September \((V_2)\) and February \((T_1)\) of the second year \((\text{Fig. 35 and 36})\). Seasonal observation reported low values \((6.0 \text{ in } V_1)\) during monsoon and high values \((8.46 \text{ in } T_1)\) during non-monsoon season of the study periods \((\text{Table 20 and 21})\). Similar fluctuation in the pH was previously reported from the studies of Shanthi \textit{et al.} \(2002\) and Garg \(2003\).

The high pH during non-monsoon season in both the years of study indicates the release of acidic compounds by the decomposition of organic matters as reported by Saraladevi \textit{et al.} \(1992\). Moreover the precipitation of salts settled at the bottom region may also raise the value of pH \(\text{Forstner and Wittmann, 1983}\). The lower values observed in the experimental pond \((V_2)\) during monsoon months may be due to the oxidation process of FeSO\(_4\) and FeS to H\(_2\)SO\(_4\) \(\text{Holmer et al., 1994}\) and also by the breakdown of decayed matter in the lower region may reduce the pH as stated by Elewa and Ghallab \(2000\). Statistical analysis reported a significant influence of seasons and ponds in pH value at \(P<0.05\) level \((F = 31.42 \text{ and } 1.55; 75.53 \text{ and } 29.32)\) by two way ANOVA test \(\text{Table 23}\).

\subsection*{3.4.2.2. Electrical conductivity (EC mhos/cm)}

Conductivity measures the current carrying capacity which gives a clear idea of the salt present in the bottom region of the aquatic ecosystem \(\text{Prakash and Somasekar, 2006}\). It affects productivity, cation exchange capacity and subsoil characters \(\text{Sonaware \textit{et al., 2010}}\).
In the present study electrical conductivity values were high during monsoon months (September and October with 0.78 and 0.81 mhos/cm) in K₂. Similar findings of higher values were pointed out by Davies and Tiwari (2010); Singh et al. (2010) in their studies on freshwater ponds.

The high values of electrical conductance during monsoon season was mainly due to the conversion process of bicarbonates during photosynthetic activities, by rainfall and also by the pollution effect Subha (2002); Tiwari et al. (2004) and Shoba et al. (2009) of the water bodies.

3.4.2.3. Organic carbon (OC mg/kg)

The percentage contribution of organic carbon content is mainly derived from the primary production within the ecosystem and also from the terrestrial biota by the process of leaching. Its high contribution reported the level of organic pollution (Davies et al., 2009). Kumari et al. (2007) pointed out the level of nutrient regeneration can be noticed in view of analyzing the sediment organic carbon content.

In the present observation the organic carbon concentration reached maximum of 1.37 mg/kg (T₁) and 1.43 mg/kg (T₁) during December and November months (Fig. 39 and 40). Seasonal observation reported high mean values of 1.18 (V₁) and 1.31 mg/kg (T₁) respectively during the monsoon months in the first and second year of the study period (Table 20 and 21). Similar results were previously noted by Anilakumary (2001); Wudtistin and Boyd (2006) in the freshwater environments.

The higher contribution of Organic carbon during northeast monsoon season was mainly due to the entry of surface run off which carries terrigenous matter from the surrounds and the present finding is supported by Saraladevi et al. (1992) and Sonaware et al. (2010). The low content of OC during non-monsoon season in the ponds (A₁ and
T₂) may be due to the absence of rainfall and flow of surface water and similar findings were noticed by Retamani and Nayer (1996). Mandal et al. (2003) pointed out that the increased soil temperature also reduces low OC content.

Statistical investigation by two way ANOVA indicated that the OC levels were highly influenced by seasons (F = 82.15 and 101.39) and ponds (F = 8.96 and 11.54) at P<0.05 level (Table 25). Correlation analysis represents significant positive correlation with nutrients like nitrogen (r = 0.935) and Phosphorus (r = 0.918) at 5% level. Similar finding was made by Esakki (2006) and Prakash (2006).

3.4.2.4. Nitrogen (N mg/kg)

Nitrogen is one of the most important nutrients of the sediment which controls the production of phytoplankton and also controls the overlying waters in an aquatic system (Arunkumar and Joseph, 2007).

Present observation reported higher mean values of 11.8 mg/kg (T₁) and 12.10 mg/kg (A₂) nitrogen concentration during the months of January and August respectively (Fig. 41 and 42). Seasonal observation revealed higher mean values during northeast monsoon (10.21 and 10.43 mg/kg) in V₁ and T₁ in the first and second year of the study periods (Table 20 and 21). The present findings are in line with the reports of Chattopadhyay and Lahiri (2000) and Sharma et al. (2000) in their studies.

The higher nitrogen content of the present study in the V₁ and T₁ ponds of the district was mainly due to the entry of surface runoff, rainfall and also by the decomposition of organic matter, release of nitrogen by the phytoplankton and by the lack of oxygen in the bottom region of the soil as evidenced by Reddy and Hariharan (1986), Jenson et al. (1994), Koliyar and Vokade (2008) in their studies. Moreover the higher
nitrogen content of sediments are not good for the sustainability of aquatic life (Garg et al., 2006a).

Statistical studies reveal the significant effect of seasons on nitrate concentrations (F = 43.93 and 4.80; 31.55 and 5.35) at P<0.05 level which is similar to the earlier reports of Hepsibha (2012) on fresh water sediment studies.

3.4.2.5. Phosphorus (P mg/kg)

Another significant factor that influences the nutrient status of the aquatic ecosystem is phosphate concentration which also functions as a limiting factor (Adeyemo et al., 2008). In most of the aquatic systems sediment phosphate is deposited by the mixing of sewage but in temple ponds the concentration is mainly deposited by the decayed phytoplankton as pointed out by Trivedi and Gurudeep (2002).

In the present study the phosphorus content reached maximum of 1.84 mg/kg ($K_2$) and 1.93 mg/kg ($K_2$) in the months of September and December (Fig. 43 and 44). Seasonally the values were maximum of 1.6 and 1.77 mg/kg during monsoon in $K_2$ (Table 20 and 21). Similar observations were made by Bradly (2007) and Mini et al. (2008).

The higher concentration of phosphorus during monsoon season was mainly due to environmental factors such as depletion of oxygen in the bottom region, low pH level of the sediment and temperature as pointed out by Mc Comb et al. (1998). Use of detergents and mixing of rain water also increased the phosphate levels as reported by Ebenezer (2001). Leaching of phosphate based fertilizer may enter into the temple pond ($K_2$) as it is surrounded by paddy fields and the observation is supported by the evidences of Nasnolkar et al. (1996). Increased phosphate and nitrate concentrations favoured the growth of algae and causes eutrophication in several aquatic ecosystems (Murdoch et al.,
2001). The decreased levels of phosphate during non-monsoon season (0.20 to 0.34 A$_1$ and V$_1$) were mainly by the low value of pH and it is in agreement with the findings of Mishra and Dhar (2004). During the study period it was noticed that the influence of seasons on the phosphate concentration determines the fertility of soil (Pandey et al., 2002).

3.4.2.6. Potassium (K mg/kg)

Potassium is a naturally occurring element and an essential growth nutrient required by all the living aquatic organisms. It is mainly a source of weathering process and produced from agriculture sources (Krishnakumar et al., 2005).

Present finding revealed a low concentration of potassium in V$_1$ pond and higher concentration of 34.49 and 42.44 mg/kg during monsoon seasons in K$_2$ pond during the period of investigation (Table 20 and 21). The present results are in line with the findings of Vasantha (2009).

The higher concentration during monsoon season in the K$_2$ pond was mainly by the leaching process from the nearby agricultural lands of the surrounding areas of the temple pond and it is in line with the reports of Seralathan and Seetaramaswamy (1979).

3.4.2.7. Iron (Fe mg/kg)

Micronutrients or trace elements of the sediments are very essential and required in lesser quantities for the survival of organisms. Iron is one among the micronutrients and occurs naturally in the sediments of freshwater environment (Govindasamy et al., 2007). Padmalal and Seralathan (1995) have reported the occurrence of iron compound was partly in solution and partly in colloidal form.

In the present study iron concentration ranged from a minimum value of 1.73 mg/kg (T$_1$) in June (2009 – 2010) to the maximum of 9.93 mg/kg (K$_1$) in November
(2010 – 2011) and seasonally minimum (2.16 mg/kg in T1) iron concentration was noticed during non-monsoon season against a maximum mean value of 9.34 mg/kg (A1) during northeast monsoon season of the study periods respectively (Table 20 and 21). Similar findings were made in the freshwater sediments of ponds in Kanyakumari district (Tharadevi and Santhakumari, 2005).

The transportation of weathering process of the iron mixed particles may increase the concentration and settle in the sediment of the experimental pond as supported by Fernandez and Jones (1987).

3.4.2.8. Zinc (Zn mg/kg)

Zinc occur as an essential micronutrient and in high concentration, it acts as a weed killer (Abbasi et al., 1998). For all biological life the requirement of zinc is in lesser quantity (Sawant et al., 2005). In the present observation it occurs in minimum level 0.004 mg/kg in V2 during February and 0.002 mg/kg in V2 during May. Seasonal observation reported minimum amount during non-monsoon and maximum of 2.65 and 2.69 mg/kg of zinc content in V1 during southwest season of the study periods (Table 20 and 21). Similar findings were reported earlier by Ida (2004) and Akhand et al. (2012). The permissible limit is 5 ppm and in all the temple ponds the reported value remains within the limit. However zinc acts as a non-toxic element (Duruibe et al., 2007) and mixing of sewage is the main source. Since the temple ponds avoid the sewage mixing the amount of zinc remained very low and this maybe the reason for its occurrence. Xandong et al. (2001) has pointed out the presence of zinc occuring along with the oxides of iron and manganese. Statistical analysis on trace metals (Iron, Copper, Zinc and Manganese) revealed the significant influence of seasons (Table 29 to 32) on these metals at P<0.05 level.
3.4.2.9. Copper (Cu mg/kg)

Copper functions as a trace element and its distribution are in lesser quantities in all aquatic ecosystems and it reflects the status of the environment (Forstner and Williams (1981). Its mobility is increased by the dissolved organic matter (Asworth and Alloway 2004).

Present observation reported higher values during monsoon (0.91 and 0.73 mg/kg in T1) and lower (0.09 and 0.22 mg/kg in K2 and A1) values during non-monsoon and southeast monsoon season of the study periods (Table 20 and 21). Similar fluctuation in copper concentrations was observed by Shanthi et al. (2002). In the present finding spraying of fungicides to the banana field near the temple pond may contribute lesser quantities of copper by leaching process in to the aquatic environment and similar findings were highlighted by Prakash (2011) in his studies. Lie et al. (2000) has reported the sediments with clay materials were rich in trace elements.

3.4.2.10. Manganese (Mn mg/kg)

Another trace element detected from the sediment sample is manganese which also functions as an important micronutrient. Land runoff, fungicides and fertilizers used in the nearby agriculture field of the temple pond release manganese into the sediments. Its concentration decreases with the increase of pH and decreases with dissolved oxygen (Madu et al., 2007).

In the present observation manganese content was higher 6.94 mg/kg in A1 during southwest monsoon (2009 – 2010) and 8.67 mg/kg in A1 during non-monsoon season (2010 – 2011) of the study period (Table 20 and 21). Surface runoff water and fertilizers associated with manganese compounds may enter into the temple ponds by leaching process as supported by Ida (2004) in the freshwater sediments of Kanyakumari district.
In conclusion sediments have been widely used as indicators of environmental pollution because of their ability to trace contamination sources (Camusso et al., 2002 and Bermejo et al., 2003). In this district the temple ponds are provided with lower concentrations of trace elements because of the absence of well developed industries and sewage mixing.
4. PRODUCTIVITY ANALYSIS

4.1. Introduction

Primary productivity involves trapping of radiant energy and its transformation into high potential biochemical energy by photosynthesis using inorganic materials of low potential energy (Misra and Tirupathi, 2002). It is the most important biological phenomenon of nature on which the entire diverse array of life depends either directly or indirectly. In ponds, lakes, reservoirs and sea the primary production of organic matter is performed entirely by algae and the biomass of other autotrophic plants contributes a negligible quantity on a global scale. The dynamics of all aquatic ecosystems center around primary productivity for it supports to different food chain and food webs. Further it is of great interest to know the seasonal trend of primary production in tropical biotopes in view of climatic changes throughout the year. All biotic components of an ecosystem are interdependent and interrelated with each other through various kinds of trophic and non-trophic links. These close relationships with the environment constitute a balanced ecosystem. When the external influences like sewage inputs, pesticides and herbicides mixing, industrial effluents the aquatic environment becomes polluted (Danielkutty and Shobha, 2006).

Environmental pollution due to industrialization, urbanization and increasing human population is a modern evil affecting all types of ecosystems. A number of criteria have been employed for the evaluation of aquatic pollution and primary production (Nirmalkumar, 1991).

Primary productivity gives information relating to the amount of energy availed to support the bioavailability of the system and its estimations are adversely affected by anthropogenic activities (Vollenweider, 1969). It is a biological activity of aquatic
ecosystem in which phytoplankton act as the primary producer (Aravindkumar, 1997) and it is related to the physico-chemical parameters and nutrient concentrations of the water and sediment (Umavathi and Logankumar, 2008). Wetzel (1996) has reported that primary production of aquatic ecosystem is a reliable index of pollution of tropical and sub-tropical ecosystems of the world. Depending upon the primary production the level of primary productivity varies, may be high or low (Sreenivasan et al., 1973), and it is related to metrological, nutritional and biological characters (Das, 2000). During rainy season the primary productivity decreased to a minimum level, which may be due to the reduced nature of light intensity and low phytoplankton diversity. Odum (1960) stated that fish production in a pond has direct relation to its primary productivity and it depends upon the plankton biomass (Boney, 1975). Various researchers have studied different aspects of primary productivity for Indian waters (Kumar, 1999; Shukla and Pawar, 2001; Saha, 2004; Sobha et al., 2006 and Umavathi et al., 2007). In order to assess their role in aquatic ecosystem estimation of major nutrients like organic carbon, phosphorus and nitrate are important in limnological studies (Heizair et al., 1993).

Factors such as water pH, temperature, alkalinity and nutrients are involved in the phytoplankton production and thereby increase the productivity of aquatic ecosystem. Phosphate and nitrate concentrations influence the bloom formation and the primary productivity was increased (Ganai et al., 2010b). Phytoplankton peak resulted with increasing productivity. Nutrients from rain water, surface run off leaching of fertilizers from the neighboring agriculture fields may also be involved in the primary productivity increasing the load of nutrients and also through human activities (Conley, 2000). Several researchers have discussed the principles, mechanisms, techniques of measurement and limiting factors that involved in primary production (Gupta, 1982; Ahmed and Alfasane, 2004). Primary productivity studies are of paramount interest in
understanding the effect of pollution on systems efficiency. High rates of production both in natural and cultural ecosystems occur when physic-chemical factors are favourable (Koli and Ranga, 2011).

An understanding of primary productivity is essential in the evaluation capacity of freshwater ecosystem in this district. Hence the present study is conducted in eight temple ponds to find out the gross, net and community respiration for a period of two years (February 2009 to January 2011).

4.2. Materials and Methods

Primary productivity of the eight selected temple ponds were estimated by using Strickland and Parsons (1972) light and dark bottle method.

Water samples were collected in one set of BOD bottles (250 ml) from 10 – 15 cm below the surface of water and were immediately fixed with manganous sulphate and alkaline iodide. Then the oxygen content was measured by Winkler’s Iodometric method (APHA, 1985) and this was treated as initial oxygen concentration of water.

Another set of light and dark bottles were also filled with water, stoppered tightly and suspended using floats so as to maintain the bottles 10 – 15 cm below the water surface. Primary productivity study was carried out after 10.00 am. The time exposure (incubation period) in the present study was for a period of four hours. After the completion of the incubation period the bottles were removed from the float, and were immediately fixed with manganous sulphate and alkaline iodide. The bottles were then transferred to the laboratory for further analysis.

The different sets of light and dark bottles, which were transferred from the field were analysed for their oxygen content by modified Winkler’s method as stated earlier.
From the initial and final oxygen content i.e., before and after incubation in the light and dark bottles, the gross and net productivity and community respiration were estimated.

Gross primary productivity, g C/m$^3$/day = $\frac{D_l - D_i}{h} \times 0.375$

Net primary productivity, g C/m$^3$/day = $\frac{D_l - D_d}{h} \times 0.375$

Community Respiration, g C/m$^3$/day = $\frac{D_i - D_d}{h} \times 0.375$

Where,

- $D_i$ = Dissolved oxygen in the initial bottle in mg/L
- $D_l$ = Dissolved oxygen in the light bottle in mg/L
- $D_d$ = Dissolved oxygen in the dark bottle in mg/L
- $h$ = Duration of exposure in hours
- 0.375 = Respiratory quotient (to convert the value to carbon value)

4.3. Result

4.3.1. Gross Primary Productivity (GPP)

The monthly variations of gross primary productivity registered in the temple ponds during the year 2009 – 2010 are presented in Figure 55. The values ranged from 4.01 gC/m$^3$/day during December ($V_1$ and $K_1$) to 8.49 gC/m$^3$/day in $V_2$ during April. Seasonal observation reported that 8.03 $\pm$ 0.38 gC/m$^3$/day of gross primary productivity as the highest value in $A_2$ during non-monsoon season against the lowest value of 4.32 $\pm$ 0.25 gC/m$^3$/day ($K_1$) in the northeast monsoon (Table 33). The observed annual mean values of GPP levels in the experimental ponds are shown in Table 35, in which $V_2$ and $K_1$ showed highest (6.46 $\pm$ 1.42 gC/m$^3$/day) and lowest (5.20 $\pm$ 0.78 gC/m$^3$/day) mean values.
Statistical analysis (two way ANOVA) revealed that a significant variation of GPP resulted between (Table 36) seasons ($F = 37.10; P<0.05$) and ponds ($F = 3.22; P<0.05$). Gross primary productivity showed a significant positive correlation with phosphate, nitrate, cyanophyta, net primary productivity and community respiration at 5% level (Table 39).

In the following year (2010 – 2011), the GPP of the resulted experimental ponds are illustrated in Figure 56. The highest (8.73 gC/m$^3$/day) value was reported ($V_2$) in March and the lowest value (4.26 gC/m$^3$/day) in $K_1$ during November. Seasonal observation showed $8.39 \pm 0.25$ gC/m$^3$/day as the highest value of GPP in $V_2$ during non-monsoon against the lowest of $4.68 \pm 0.30$ gC/m$^3$/day in $K_1$ during northeast monsoon (Table 34). The annual mean values recorded from the experimental ponds are shown in Table 35 and it was minimum of $5.53 \pm 0.74$ gC/m$^3$/day in $K_1$ against the maximum of $7.50 \pm 0.75$ gC/m$^3$/day in $V_2$ respectively.

Results on two way ANOVA indicated a significant influence on seasons and ponds ($F = 100.87; F = 31.22; P<0.05$) in the level of gross primary productivity (Table 36). GPP showed a positive correlation with biological oxygen demand, phosphate, nitrate, net primary productivity, community respiration and cyanophyta at 5% level in the experimental ponds (Table 40).

4.3.2. Net Primary Productivity (NPP)

The monthly variations of net primary productivity (NPP) observed from the eight experimental temple ponds during the study period Feb. 2009 – Jan. 2010 are given in Figure 57. It showed minimum values during the month of December (2.12 gC/m$^3$/day in $A_1$) against the maximum value of 6.73 gC/m$^3$/day ($A_2$) in February. Seasonal mean value
was high (6.20 ± 0.38 gC/m$^3$/day) during non-monsoon in A$_2$ and low during northeast monsoon (2.46 ± 0.27 gC/m$^3$/day) in A$_1$ (Table 33). The annual mean value was high in T$_2$ (4.93 ± 0.78 gC/m$^3$/day) and low of 3.07 ± 0.54 gC/m$^3$/day in A$_1$ (Table 35).

Data on two way ANOVA revealed that significant variation exists (Table 37) between seasons and ponds (F = 77.81; 21.73; P<0.05). Correlation coefficient of net primary productivity in the experimental ponds showed a significant positive correlation with phosphate, nitrate, gross primary productivity, community respiration and cyanophyta at 5% level (Table 39).

In the succeeding year (2010 – 2011), the net productivity was maximum (6.87 gC/m$^3$/day) in A$_2$ during March and minimum of 2.01 gC/m$^3$/day in A$_1$ during October (Fig. 58). The seasonal variation of NPP values ranged from 2.64 ± 0.55 gC/m$^3$/day (A$_1$) to 6.32 ± 0.17 gC/m$^3$/day (K$_2$) during northeast and non-monsoon season respectively (Table 34). The annual mean value was high (5.28 ± 0.90 gC/m$^3$/day) in K$_2$ and low (3.08 ± 0.73 gC/m$^3$/day) in A$_1$ (Table 35).

Statistical analysis (two way ANOVA) indicated that, there was a significant variation between seasons (F = 78.94; 25.01; P<0.05) and ponds (Table 37). Correlation coefficient of NPP showed a significant positive variation with temperature, pH, BOD, phosphate, nitrate, GPP, community respiration, cyanophyta and negative correlation with DO and euglenophyta at 5% level (Table 40).

4.3.3. Community Respiration (CR)

The results on the monthly variations of community respiration recorded from the eight experimental ponds are shown in Figure 59. In the year 2009 – 2010 during February a maximum value of 5.13 gC/m$^3$/day was recorded in A$_2$ against the minimum
of 1.13 gC/m$^3$/day in T$_2$ (November). Seasonal variation showed highest value of 4.64 ± 0.41 gC/m$^3$/day in A$_2$ during non-monsoon and lowest value of 1.59 ± 0.26 gC/m$^3$/day in A$_1$ during northeast monsoon season (Table 33). The annual mean value obtained on community respiration is shown in Table 35. A high value of 3.74 ± 0.81 gC/m$^3$/day in A$_2$ and a low value of 2.11 ± 0.51 gC/m$^3$/day in A$_1$ were noticed.

Statistical analysis of two way ANOVA revealed that the variation of community respiration (Table 38) was influenced significantly by seasons (F = 132.85; P<0.05) and ponds (F = 27.77; P<0.05). Correlation coefficient showed a significant positive relationship with phosphate, nitrate, cyanophyta and negative correlation with chlorophyta at 5% level (Table 39).

During the following year 2010 – 2011 the maximum value of community respiration was observed (4.98 gC/m$^3$/day) in A$_2$ during March and minimum (1.41 gC/m$^3$/day) in K$_2$ and A$_1$ during October and November respectively (Fig. 60). Seasonal variation of the results is shown in Table 34. It showed higher value of 4.53 ± 0.33 gC/m$^3$/day during non-monsoon in A$_2$ and T$_2$ showed lower value of community respiration (1.92 ± 0.27 gC/m$^3$/day) during northeast monsoon. Annual mean value ranged from 2.27 ± 0.50 gC/m$^3$/day to 3.76 ± 0.67 gC/m$^3$/day in A$_1$ and A$_2$ respectively (Table 35).

Analysis of two way ANOVA revealed that a significant variation exists (Table 38) between seasons and ponds (F = 47.81; F = 12.99; P<0.05). Correlation coefficient also showed a significant positive correlation with temperature, pH, BOD, phosphate, nitrate, cyanophyta and negative correlation with dissolved oxygen at 5% level (Table 40).
4.4. Discussion

Photosynthetic fixation of carbon in the inland aquatic system occurs in various plant communities such as phytoplankton, periphytic algae, benthic algae and macrophytes. This has received much attention in limnological studies during the past decades and measured in various aquatic ecosystem of the world. Steeman – Nielsen (1952) discovered the $\text{C}^{14}$ method for regular analysis of photosynthetic rates of planktonic algae. Several modifications were made later in order to identify the causative agent for the increase or decrease in photosynthesis works on isolated chloroplast and the importance of pigments and algae were done by Fogg and Watt (1965). Productivity studies are limited and in this district though there are many temple ponds studies are meagre and the results on the eight temple ponds reported dynamic gross and net productivities with community respiration.

4.4.1. Gross Primary Productivity (GPP)

The results of the gross primary productivity in the eight temple ponds showed (Fig. 55 and 56) great variations and it ranged from a minimum of $4.01 \text{ gC/m}^3/\text{day}$ (December) to $8.49 \text{ gC/m}^3/\text{day}$ (April) and from $4.26 \text{ gC/m}^3$ (November) to $8.73 \text{ gC/m}^3/\text{day}$ (March) during the year 2009 – 11 (February – January). The fluctuations of productivity values in the experimental ponds in different months are well marked. Several researchers have pointed out low primary productivity values during monsoon months and higher rates during non-monsoon months, (Khan, 1980 and Singh, 1999). Prakasam and Joseph (2000) observed very low productivity values (0.31 to 0.99 gC/m$^3$/day) in the Sasthamcotta lake, Kerala. Acidic pH, low conductivity, poor nutrient contents and high transparency rates were reflected in the productivity of lake. He also pointed out that nitrate concentration of the pond water acts as the main limiting factor.
and poor productivity of the aquatic environment represents the oligotrophic nature of lake or pond (Hutchinson, 1957). Sobha et al., (2006 and 2007) made a report on Kadinamgalam Lake that during night and early morning hours the lake was noticed with low productivity rates, moreover the availability of nutrients and large standing crop of phytoplankton influences the primary productivity rates. The present observation coincides with the report of Goswami and Saha (2008) who found higher rates of GPP during non-monsoon and lower rates in the monsoon months. Sahib (2002) reported that the highest value of GPP and NPP were in the month of April at parapper reservoir at Kerala. Mandal et al. (2005) also obtained GPP and NPP during late non-monsoon in Karwar lake, Bihar and Hujare and Mule (2007) in the perennial lakes of Kolhapur district. Connell and Orias (1964) stated in their productivity hypothesis that greater production resulted in greater diversity. The present study supported this idea. The maximum diversity was found when the productivity (GPP) was the highest and diversity decreased in lower production is a major determinant of the species diversity of a community (Krebs, 1978). In the present observation phytoplankton population was maximum in non-monsoon season their reported maximum gross primary productivity it is similar to the results of Sulabha (2003) in her studies. Statistical analysis of two way ANOVA test also revealed the significant seasonal observation on gross primary productivity at P<0.05 level. A significant positive correlation was reported with phosphate and nitrate concentrations at 5% level.

4.4.2. Net primary productivity (NPP)

The results of the present investigation on eight selected temple ponds revealed higher rates of net primary productivity during non-monsoon months (February and March) and lower values in the months of December and October, during the study
In the first and second year (2009 – 11) the resulted values ranged from a minimum mean value of 2.12 to 6.20 gC/m$^3$/day and 2.01 to 6.87 gC/m$^3$/day (Table 33 and 34). Seasonal observation also indicated higher and lower values during non-monsoon and monsoon seasons. The present observations coincide with the results of Patil and Chavan (2010). Mandal et al., (2005), Hujare and Mule (2007) also pointed out similar observations in their studies on pond ecosystems. Thilaga et al., (2004) noticed that increase in temperature enhances the release of nutrients from sediments through bacterial decomposition which influences the net primary productivity of the aquatic environment. In both the years of study period analysis on two way ANOVA test and correlation studies revealed the significant influences of seasons, nitrate, phosphate, temperature, pH, BOD etc on net primary productivity.

4.4.3. Community respiration (CR)

The results of community respiration rates of the eight temple ponds showed lower values during monsoon months similar to the results of net and gross primary productivity rates. The values were high (5.13 and 4.98 gC/m$^3$/day) in the first and second year of the study period during non-monsoon months. Sahib, (2002) found higher rates of community respiration during non-monsoon months in Sasthamcotta lake, Kerala. It was also reported that in Darmasakar lake, Adilabad, a decrease in CR during monsoon months is in line with the present observation (Chinnaiah and Madhu, 2010). Sawant and Telave (2009) have reported low rates of gross, net and community respiration during monsoon months in the four freshwater ecosystems of Maharastra. Generally photosynthesis increases with the rising temperature upto maximum level and then diminishes rapidly with further rise of temperature. The pH, phosphate and nitrogen are important factors in controlling the productivity of ponds (Cabecadas and Brogueiva, 1987).
Among the eight ponds the annual mean values of gross primary productivity was high in V₂ and K₁, the net primary productivity rate was more in T₂ and K₂. The community respiration was maximum in V₂ and A₂ respectively during the two year study period. The reported ponds were utilized by the human beings for washing and bathing. The pond V₂ was used mainly for irrigation purpose. No aquatic weeds were observed and the ponds were never cleaned by the municipality or by any other organization or by the government. The rich settlement of nutrients in the sediment and water may influence the phytoplankton population mainly cyanophyta, diatoms and chlorophyta which increases the productivity of the freshwater temple ponds of the present study.
5. PHYTOPLANKTON ANALYSIS

5.1. Introduction

The word phytoplankton is derived from the Greek language (Phyto: Plant; plankton: wanderer). The phytoplankton and zooplankton are the principal components of the water bodies; the tolerance limits of these organisms to diverse stresses assume tremendous relevance from the ecological standpoint. The inter annual variability in phytoplankton dynamics is being controlled by several factors ranging from meteorological, climatic fluctuations (Arhonditsis et al., 2004), to quick recovery of nutrients by the system (Wang et al., 2006). Individually or in combination, all these factors affect the productivity of the phytoplankton population. According to Ramakrishnan et al., (2002), 97.8% of the variations in phytoplankton density of the freshwater ponds were influenced by physico-chemical factors. The phytoplankton population represents the biological wealth of a water body, constituting a vital link in the food chain (Hossain et al., 2007 and Onyema, 2008). Factors like water pH, turbidity, total dissolved solids, dissolved oxygen, alkalinity temperature, light penetration, sediment constituents and different nutrients of the aquatic ecosystem determines the succession, distribution and diversity of phytoplankton (Arimoro et al., 2008 and Kumari et al., 2009). The rich nutrient source favour the algal growth and several ponds, lakes and few selected areas of the river look dark green and develop bloom (Trivedy and Goel, 1984). Phytoplankton serves as good indicator of pollution and its stress reduces the number of species, but increases the number of individuals (Onyema, 2007). Pollution levels of aquatic ecosystem alter the functioning of the system and several andropogenic influences were involved in pollution (Simboura et al., 2005; Ekdahl et al., 2007). It was reported by many researchers, that several phytoplankton species function as pollution tolerant and indicators (Palmer, 1969).
Most of the aquatic ecosystems are provided with phytoplankton which belong to Chlorophyta (green algae), Bacillariophyta (diatoms), Cyanophyta (blue green algae), Xanthophyta (Yellow green algae) and Euglenophyta. The occurrence of these groups may be freshwater, marine, water, brakish water, terrestrial, subaerial, epiphytic, endozioic and thermophilic (Sharma, 1996). Chlorophyta forms the major constituent of the phytoplankton community and serves as efficient converters of solar energy, supplement as food source, bio-fuel agents, biological filters to remove toxic heavy metals and good antibiotic yielders. Genus like *Chlorella* and *Scenedesmus* are still used as single cell proteins (Lakshmi and Gunaseeli, 2009; Prakash and Balasingh, 2007).

Cyanophyta, a cosmopolitan group produces bluish green colour to the water and function as thermal algae. They are prokaryotes, simple in their structure causing water blooms and produce biotoxins (Bhagat *et al.*, 2009). Several of them are economically important as nitrogen fixers (Pingle *et al.*, 2005; Patil and Chaugule, 2006; Rode *et al.*, 2011), serve as single cell proteins (Kumar, 1990 and Becker, 2004) and as biofertilizer (Goyal, 2002).

The Bacillariophycean members are enormous in number in several aquatic ecosystem and well suited for water quality assessment (Stewart *et al.*, 1999 and Hill *et al.*, 2000a). They are taxonomically diverse, have short generation time, many species have a specific sensitivity to ecological characters (Stevenson *et al.*, 1984). Several of the diatoms are used as feed in the field of aquaculture (Muller-Feuga 2004).

The Euglenophytes are also represented in most of the freshwater ponds and represented by few genus. Euglenophyceae respond to higher temperature, carbon dioxide, nitrate, phosphate and oxidisable organic matter (Hosmani, 2008).

World wide aquatic ecosystem has been impacted by the excessive release of pollutants, leading to phytoplankton bloom and to the disruption of the structure and
function of these systems (Vasconcelos, 2001). It was also reported that several anthropogenic activities with rich source of phosphate and nitrates produces noxious blooms which altered the taste and colour of the water (Shamal and Balasingh, 2007). A good number of indices have also been used to determine the trophic level of freshwater ecosystem (Palmer, 1969).

Much information is available on the phytoplankton members with reference to their distribution (Reshmi, 2004; More et al., 2005; Deshmake and Pingle 2006; John and Francis, 2007). The inter-relationships of various nutrient analysis with chlorophycean members were traced out by Bhagat and Gupta (2005); Jawale and Patil (2009); Misra et al. (2009b). Limnological parameters with regard to phytoplankton diversity were pointed out by Ali et al. (2010), Mohar and Beena (2010) and Chakraborthy et al. (2010). Umamaheswari (2011) has studied the diversity of fifteen freshwater lakes in Mysore city.

Most of the temples of this district are well provided with a small or a big pond either infront or back or on either side of the temple. People utilize the pond water for domestic purposes and mixing of waste water is well prevented. There could be differences in species composition, diversity, richness and in their percentage frequency. The main aim is to observe the diversity changes with respect to their species composition and to find out the states of the temple ponds in this district.

5.2. Materials and Methods

5.2.1. Phytoplankton Collection

Phytoplankton was collected from the experimental ponds of chosen aquatic environment under study, for a period of two years from February 2009 to January 2011. Standard plankton net (No.25 aperture in micron) was used for the collection and the
sampling was done between 6 a.m to 8 a.m. About 100 liters of water was filtered through the net and the filtrate was collected in the collecting vessel. The sample was then concentrated to 25 ml and preserved in 1ml neutralized formaldehyde solution. Planktons count was done using Sedwick-Rafter counting chamber. From the collected and concentrated filtrate, 1 ml of sample was taken after shaking the concentrate, in order to get an even distribution of the planktonic organisms for analysis. The analysis was repeated 10 times with each sample and the average was computed and expressed in number per cubic meter. Subsequently samples were observed under microscope and microphotographs were taken using Nikon L-20 camera. A dichotomous key was prepared. Standard literatures were used for identifying the phytoplankton (Fritsch, 1945; Smith, 1950; Desikachary, 1959; Philipose, 1967; Round, 1971; Prescott, 1978; Anand, 1998; Krishnamurthy, 2000). Data were subjected to two way ANOVA to find out the variation between the seasons and ponds (Zar, 1974).

5.2.2. Species diversity

Shannon – Wiener Diversity index (Shannon and Wiener, 1949) was employed to determine species diversity (H’)

\[ H' = - \sum_{i=1}^{K} P_i \log P_i \]

Where,

\( P_i = \) Proportion of the observation of the total found in the category

\( K = \) Number of categories

5.2.3. Species Richness

Species richness index was calculated using the following formula (Gleason, 1922).

\[ SRI = \frac{[S - 1]}{\log N} \]
Where,

\[ S = \text{The number of species of the particular sample} \]
\[ N = \log_{\text{total number (H) of the individuals of all the species of the sample.}} \]

5.2.4. Dominance index

Dominance index (D1) of phytoplankton was calculated according to Ignatides and Mimicos (1977).

\[ C = \frac{n_1 + n_2}{N} \]

Where,

\[ C = \text{dominance index equal to the percentage of total crop contributed by the two most exuberant species.} \]
\[ n_1 \text{ and } n_2 = \text{percentage of total population contributed by the two most abundant species in the sample.} \]
\[ N = \text{concentration of standing crop in the same series of the sample.} \]

5.2.5. Species evenness

Species evenness was calculated using the following formula (Pielou, 1966).

\[ J' = \frac{H'}{H_{\text{max}}} \]

Where,

\[ H' = \text{Species diversity value} \]
\[ H_{\text{max}} = K \]
\[ K = \text{Total number of species} \]

5.2.6. Percentage Frequency

Percentage frequency of phytoplankton was calculated using the following formula (Trivedy and Goel, 1984).

\[ PF = \frac{\text{Number of individual species}}{\text{Total Number of all species}} \times 100 \]
5.2.7. Nygaard’s algal indices (1949)

To find out the trophic nature of the pond Nygaard’s algal indice were used

\[
\text{Compound Index} = \frac{\text{Centric diatom species} + \text{Euglenophycean species}}{\text{Desmideae species}}
\]

5.3. Result

5.3.1. Total phytoplankton population

The total phytoplankton population recorded from the temple ponds during the study period (2009 – 2011) are provided in Figure 61. Among the eight temple ponds, V1 pond showed maximum cell density of \(1477 \times 10^3\) cells/m\(^3\) during the year 2009 – 2010. In the following year T1 pond was reported with maximum of \(1621 \times 10^3\) cells/m\(^3\). The minimum contribution was produced by A1 and T2 ponds during the study periods. Seasonal fluctuations and nutrient concentration of the experimental ponds resulted in a dynamic change in their cell densities resulting in uni, bi and trimodel peaks in the monsoon and non-monsoon seasons.

5.3.1.1 Uni model peaks

In the ponds of Agastheeswaram taluk of Kanyakumari district, unimodel peak (Fig. 62b) was observed from A1 and A2 in the first year during July (\(197 \times 10^3\) cells/m\(^3\)) and April (\(259 \times 10^3\) cells/m\(^3\)) and in the second year A2 pond (Fig. 63b) alone showed a unimodel peak with a total cell density of \(250 \times 10^3\) cells/m\(^3\) (April).

5.3.1.2 Bimodel peaks

Bimodel peaks were reported from V1, V2, K1, K2 and T2 ponds respectively during the year 2009 – 2010. The ponds V1 and V2 showed primary peaks during February and April with maximum cell densities of \(196 \times 10^3\) cells/m\(^3\) and \(221 \times 10^3\) cells/m\(^3\).
cells/m$^3$ respectively along with the secondary peaks during November (279 x 10$^3$ cells/m$^3$) and August (218 x 10$^3$ cells/m$^3$) months. Likewise $K_1$ and $K_2$ showed maximum cell densities (197 x 10$^3$ cells/m$^3$ and 225 x 10$^3$ cells/m$^3$) during March and April with primary peaks. Meanwhile secondary peak densities were observed during August and October with 252 x 10$^3$ and 262 x 10$^3$ cells/m$^3$ cell densities (Fig. 62a and b). The pond $T_2$ was reported with a primary peak during May (181 x 10$^3$ cells/m$^3$) and secondary peak with the cell density of 205 x 10$^3$ cells/m$^3$ in the month of November.

In the following year 2010 – 2011 also bimodal peaks were reported from $V_2$, $K_1$, $K_2$ and $T_2$ ponds of the district. During April and November, maximum cell densities were observed from $V_2$ pond (244 x 10$^3$ and 230 x 10$^3$ cells/m$^3$). During non- monsoon month (April) maximum cell densities were observed showing primary peak (235 x 10$^3$ cells and 228 x 10$^3$ cells/m$^3$) by $K_2$ and $T_2$ pond, secondary peak period was also recorded during monsoon months (October and August) with cell densities of 252 x 10$^3$ and 219 x 10$^3$ cells/m$^3$ respectively (Fig. 63a and b).

5.3.1.3 Trimodel peak

In the first year of the study period (2009 – 2010) a trimodel peak was noticed from $T_1$ pond with a maximum cell density (201 x 10$^3$ cells/m$^3$) during February, July (215 x 10$^3$ cells/m$^3$) and (230 x 10$^3$ cells/m$^3$) December with primary, secondary and tertiary peaks of cell densities (Fig. 62b).

In the following year 2010 – 2011 trimodel peaks were reported from $V_1$, $T_1$, and $A_1$ ponds. A primary peak during April (190 x 10$^3$ cells/m$^3$), a secondary and tertiary peaks during August (256 x 10$^3$ cells/m$^3$) and November (265 x 10$^3$ cells/m$^3$) was noticed in the pond $V_1$. Similar trend was noticed during April, July and December with primary, secondary and tertiary peak cell densities (191 x 10$^3$ cells/m$^3$, 207 x 10$^3$ cells and 197 x
10^3 \text{ cells/m}^3) in T_1 \text{ pond. The pond } A_1 \text{ showed primary peak during April (191 x 10^3 cells/m}^3)\text{, a secondary and tertiary peaks during July (207 x 10^3 cells/m}^3)\text{ and December (197 x 10^3 cells/m}^3)\text{ months respectively (Fig.63a and b).}

**5.3.2. Percentage contribution of phytoplankton groups**

The phytoplankton population collected from the eight experimental temple ponds belonged to Chlorophyta (Green algae), Bacillariophyta (diatoms), Cyanophyta (blue green algae) and Euglenophyta. Each pond was noticed with variation in their percentage contribution.

**5.3.2.1. Chlorophyta**

In the first year of the study period (2009 – 2010) the pond V_1 showed 46.50% of chlorophycean members. The total cell density observed was 949 x 10^3 cells/m^3 with a maximum contribution during September (167 x 10^3 cells/m^3) and minimum during April (45 x 10^3 cells/m^3). V_2 pond contributed 43.62% of chlorophycean members with maximum of 53 x 10^3 cells/m^3 during October against a minimum of 20 x 10^3 cells/m^3 in March and the total cell density of 378 x 10^3 cells/m^3. The pond K_1 and K_2 showed 39.58 and 49.57% of chlorophycean members with maximum of 113 x 10^3 and 97 x 10^3 cells/m^3 during southwest (September and July) monsoon months. The minimum cell counts were observed during April in both the ponds. The ponds from Thovalai taluk (T_1 and T_2) showed 23.50 and 28.0% of chlorophycean members with higher cell densities during August (94 x 10^3 cells/m^3) and November (58 x 10^3 cells/m^3) months against the minimum contribution in February and June (Fig. 66). The ponds A_1 and A_2 showed 22.36 and 23.50% of chlorophycean members. The cell densities were more during September (85 x 10^3 cells/m^3) and December (52 x 10^3 cells/m^3) respectively against the minimum contribution of cell densities in the non monsoon months (March and May).
Among the eight ponds $V_1$ (46.50%), $V_2$ (43.62%), $K_1$ (39.58%) and $K_2$ (49.57%) were observed with maximum contribution of chlorophycean members (Fig. 64).

In the second year of the study period the pond $V_1$ and $V_2$ showed 45.78 and 23.74% of chlorophycean members. The cell densities of $175 \times 10^3$ cells/m$^3$ and $78 \times 10^3$ cells/m$^3$ were reported maximum during November and December against low cell densities during June and April respectively (Fig. 67). Meanwhile the ponds $K_1$ and $K_2$ donated maximum cell densities of chlorophycean members during August and November with the contribution of 29.39 and 31.30%. Similar to the previous year, the minimum cell densities were noticed during non monsoon months (February and May). The $T_1$ and $T_2$ ponds of Thovalai taluk was noted with maximum chlorophycean members during December ($151 \times 10^3$ cells/m$^3$) and January ($52 \times 10^3$ cells/m$^3$) with the percentage of 47.95 and 22.58 percentages. Likewise the ponds $A_1$ and $A_2$ showed higher densities of green algae during September ($110 \times 10^3$ cells) and July ($66 \times 10^3$ cells/m$^3$) with the percentage contribution for 44.02 and 24.49. During non monsoon month (February) the pond $A_1$ and $A_2$ was observed with less number of chlorophycean members. The highest contribution was produced by $V_1$ (45.78%), $T_1$ (47.95%) and $A_1$ (44.02%) ponds (Fig. 65).

Seasonal observation of chlorophycean members form the eight experimental ponds showed great variation (Table 41). In the year 2009 – 2010 the ponds $V_2$, $K_2$, $A_1$ and $A_2$ reported higher mean values ($45.5 \pm 8.4$, $78.1 \pm 12.9$, $79.9 \pm 18.7$ and $46.4 \pm 8.2$) during northeast monsoon and the remaining ponds $V_1$, $K_1$, $T_1$ and $T_2$ was observed with higher mean values $127.9 \pm 33.3$, $92.8 \pm 18.9$, $96.1 \pm 25.5$ and $46.7 \pm 8.2$) during southwest monsoon season.

In the following year also higher mean values of chlorophycean members were observed during northeast and southwest monsoon season of the study period. A high
mean value of 145.3 ± 30.0, 66.2 ± 8.9, 100.4 ± 12.1, 1.31 ± 14.9 and 47.2 ± 5.3 were resulted from V₁, V₂, K₂, T₁ and T₂ ponds is northeast monsoon season respectively. During southwest monsoon the pond K₁, A₁ and A₂ showed maximum mean values of chlorophycean members (119.1 ± 12.9, 94.4 ± 13.4 and 60.1 ± 4.9) and non-monsoon season showed low mean values of chlorophycean members (Table 42).

Statistical analysis on two way ANOVA (Table 43) revealed that the chlorophycean members were significantly influenced by the seasons (F = 24.89; F = 10.27; P<0.05) and ponds (F = 12.55 and F = 8.22; P<0.05) in both the years of observation. Correlation coefficient studies on Chlorophyta showed significant positive relationship with DO (except V₁ and A₁ in the year 2010 – 2011) and negative correlation with temperature, pH, BOD, NO₃ and phosphate at 5% level in most of the ponds (Table 39 and 40) of the study period.

5.3.2.2. Bacillariophyta (Diatoms)

The second dominant group of phytoplankton observed from the experimental ponds was Bacillariophyta (Diatoms). During non monsoon months (May and April) higher cell densities of diatoms (88 x 10^3 cells and 72 x 10^3 cells/m³) were collected from V₁ and V₂ ponds with the percentage contribution of 30.77 and 20.85%. Lower cell densities were reported during August and January during 2009 – 2010. The ponds K₁ and K₂ contributed higher cell densities of diatoms (80 x 10^3 cells/m and 76 x 10^3 cells/m³) during July and February months respectively with 33.27 and 27.94 percentages. Meanwhile lower cell densities of diatoms were reported during northeast monsoon months. From the Thovalai taluk of Kanyakumari district T₁ and T₂ ponds contributed 29.63 and 51.95 percentages (Fig.64) of diatom population to the total phytoplankton. Maximum cell densities (76 x 10^3 cells and 112 x 10^3 cells/m) were observed during non
monsoon months (March and April). From Agastheeswaram taluk the ponds A₁ and A₂ produced maximum of \(73 \times 10^3\) cells/m\(^3\) and \(45 \times 10^3\) cells/m\(^3\) with the percentage of 39.85 and 17.71% respectively. During monsoon months lower cell densities were observed from the above ponds (Fig. 68). The ponds T₂ (51.95%) and A₁ (39.85%) contributed maximum percentages of diatom members.

In the year 2010 – 2011 also the cell densities of diatom showed great variation in the ponds V₁ and V₂ and showed higher cell densities during southwest monsoon months (July and August) with the percentage contribution of 33.95 and 26.66%, K₁ and K₂ pond contributed 45.78 and 26.38 percentage of diatom population with higher cell densities of \(109 \times 10^3\) cells/m\(^3\) and \(62 \times 10^3\) cell/m\(^3\) during the month of June and April (Fig. 69). Likewise the ponds T₁ and T₂ produced maximum cell densities during June and August \((85 \times 10^3\) cells/m\(^3\) and \(125 \times 10^3\) cells/m\(^3\)) with the percentage contribution of 30.36 and 57.95% (Fig. 65). Lower cell densities were reported during December and January. The pond A₁ and A₂ showed higher densities of diatom during non monsoon months (March and April) with \(86 \times 10^3\) cells/m\(^3\) and \(57 \times 10^3\) cells/m\(^3\) respectively. The observed percentage was 31.65 and 21.34 (Fig. 65). The ponds K₁ (45.78%) and T₂ (57.95%) contributed more percentage of diatoms in the second year of the study period.

Seasonal observation of diatoms resulted are shown in (Table 41). In the first year of the study period among the eight experimental temple ponds except V₂ all the remaining ponds showed higher mean values during non monsoon season. The reported mean values are \(77.3 \pm 11.2\), (V₁); \(67.3 \pm 10\) (K₁); \(64.9 \pm 12.1\) (K₂); \(59.1 \pm 12.3\) (T₁); \(88.2 \pm 16.6\) (T₂); \(70.1 \pm 2.6\) (A₁) and \(35.9 \pm 9.7\) (A₂) respectively. The pond V₂ showed a mean value of \(61.0 \pm 11.4\) during southwest monsoon season.
In the following year (2010 – 2011) the ponds V₁, K₂, T₁, A₁ and A₂ showed maximum mean values of diatom population during non monsoon season (Table 42). The values are 70.9 ± 5.7 (V₁), 73.7 ± 5.7 (K₂), 72.5 ± 10.9 (T₁), 74.1 ± 8.4 (A₁) and 51.4 ± 4.6 (A₂). The ponds V₂, K₁ and T₂ showed maximum mean values (68.5 ± 63; 72.7 ± 7.7 and 110.0 ± 12.8) during southwest monsoon season. In both the years of study low mean values of diatoms were observed during northeast monsoon season.

Statistical analysis of two way ANOVA on seasonal variation of diatom showed a significant influence of seasons (F = 16.16; F = 5.41; P<0.05) and ponds (F = 18.89; F = 9.96; P<0.05) during the year 2009 – 2011 (Table 44). Correlation coefficient studies showed positive correlation with temperature (V₁, K₁, K₂, T₁ and T₂), pH (V₁, K₁, T₁, T₂, A₁ and A₂), BOD (except V₂ and K₂), phosphate (K₁, K₂, T₁, T₂, A₁ and A₂) and nitrate (except V₂ and A₂). It also showed a negative relationship with DO (except V₁ and V₂) at 5% level. In the following year also a positive correlation was noted with temperature, BOD, phosphate and nitrate in selected ponds (Table 39 and 40).

5.3.2.3. Cyanophyta

The third group of phytoplankton observed from the temple ponds were cyanophyta or blue green algae (BGA) or cyanobacteria. The cell densities of blue green algae showed variations in each pond. In the year 2009 – 2010 during non monsoon months (March and April) maximum cell densities (65 x 10³ cells/m³ and 50 x 10³ cells/m) were collected during August and November the minimum blue green algae were collected (22 x 10³ cells/m³ and 29 x 10³ cells/m³) from the ponds V₁ and V₂ (Fig. 70). The percentage contribution was 18.99 and 33.03% respectively (Fig. 64). The K₂ and K₁ ponds also showed higher densities of 71 x 10³ cells/m³ and 60 x 10³ cells/m³ during March and April with the minimum contribution in the month of September and
October (24 x 10^3 cells/m^3 and 21 x 10^3 cells/m^3) during the first year of the study period. The percentage of blue green algae observed was 24.28 and 20.64 (Fig. 64). Similarly T1 and T2 ponds reported higher cell densities during non-monsoon months (113 x 10^3 cells/m^3 and 38 x 10^3 cells/m^3) against minimum cell densities in the month of October with the percentage of 43.56 and 17.30. The collected blue green algae from the A1 and A2 ponds of Agastheswaram taluk showed maximum cell densities during June (47 x 10^3 cells/m^3) and May (130 x 10^3 cells/m^3) with the minimum contribution during January (31 x 10^3 cells/m^3) and November (67 x 10^3 cells/m^3) respectively. From these ponds the total contribution of 36.06 and 56.67 percentages of blue green algal forms were recorded (Fig. 64). In these ponds the maximum percentage contribution were observed in T1 (43.56%) and A2 (56.67%) during the first year of study.

In the year 2010 – 2011 the maximum cell densities of blue green algae were collected during March (52 x 10^3 cells/m^3), April (142 x 10^3 cells/m^3), February (66 x 10^3 cells/m^3) and May (107 x 10^3 cells/m^3) against the minimum cell densities of 22 x 10^3 cells/m^3 in January, 68 x 10^3 cells/m^3 in November, 31 x 10^3 cells/m^3 in February and 44 x 10^3 cells/m^3 in December from the ponds V1, V2, K1 and K2 respectively (Fig. 71). The percentage contribution observed was 15.78, 47.28, 21.95 and 40.66 (Fig. 65). The remaining temple ponds T1, T2, A1 and A2 contributed 19.05, 16.62, 22.64 and 52.23 percentages to the total biomass. The cell densities were higher during June (52 x 10^3 cells/m^3) May (42 x 10^3 cells/m^3), March (57 x 10^3 cells/m^3) and April (149 x 10^3 cells/m^3) against the minimum of 21 x 10^3 cells/m^3 in January, 17 x 10^3 cells/m^3 in November, 26 x 10^3 cells/m^3 in August, 73 x 10^3 cells/m^3 in September respectively. Among the eight ponds V2 (47.28%), K2 (40.66%) and A2 (52.23%) were observed with maximum percentage contribution of cyanophycean members.
In the year 2009 – 2010 cyanophycean members showed great variations in different seasons with high mean values and the results are shown in Table 41. Among the eight ponds except A₁ all the remaining ponds showed higher mean cell densities of cyanophycean members during non-monsoon seasons. A mean value of 46.9 ± 2.4, 118.8 ± 16, 58.5 ± 1.2, 63.0 ± 11.3, 45.8 ± 2.5, 34.9 ± 2.9 and 111.8 ± 13.7 were reported from V₁, V₂, K₁, K₂, T₁, T₂ and A₂ ponds respectively. Low mean values were observed during monsoon seasons. The pond A₁ showed a higher mean value of 41.6 ± 4.0 during southwest monsoon and low mean value of 34.6 ± 2.3 during northeast monsoon season.

In the following year 2010 – 2011 higher mean cell densities of cyanophycean members were reported from the ponds and the results are shown in Table 42. It revealed that during non monsoon season except the pond T₁ all the remaining ponds showed higher mean values of cyanophycean members during non-monsoon season. Maximum mean densities of 46.7 ± 4.0, 125 ± 12.4, 60.1 ± 4.4, 76.2 ± 10.6, 37.1 ± 4.1, 51.2 ± 4.7 and 127.9 ± 19.7 were recorded from V₁, V₂, K₁, K₂, T₂, A₁ and A₂ respectively. Lower mean cell densities were observed during monsoon seasons. The pond T₁ was recorded with maximum mean values of 47.3 ± 4.5 cyanophycean members during southwest monsoon season and low mean density was noticed during northeast monsoon season of the study period.

Statistical analysis of two way ANOVA (Table 45) indicated a significant influence of seasons and ponds in the seasonal distribution of blue green algae in both the years of study (F = 13.50 and 35.10; F = 13.59 and 61.95 P<0.05 level). Correlation studies revealed a significant positive correlation with pH, BOD, phosphate and nitrate at 5% level. It also showed a negative relationship with DO in the study periods (Table 39 and 40).
5.3.2.4. Euglenophyta

The minor group reported from the temple pond was Euglenophyta. In all the ponds the cell density was lower in non monsoon months (Fig. 72). In V₁, V₂, K₁ and K₂ ponds the euglenophycean members were maximum of \(16 \times 10^3\) cells/m\(^3\) (October), \(15 \times 10^3\) cells/m\(^3\) (August) \(11 \times 10^3\) cells/m\(^3\) (September) and \(13 \times 10^3\) cells/m\(^3\) (October). Likewise the ponds T₁, T₂, A₁ and A₂ also reported higher cell densities of \(18 \times 10^3\) cells/m\(^3\), (July), \(11 \times 10^3\) cells/m\(^3\) (August) \(9 \times 10^3\) cells/m\(^3\) (October) and \(13 \times 10^3\) cells/m\(^3\) (September) respectively during the first year of the study period (2009 – 2010).

In the following year (2010 – 2011) also maximum cell densities were observed during September and October, April and August (\(24 \times 10^3\) cells/m\(^3\), \(14 \times 10^3\) cells/m\(^3\) \(12 \times 10^3\) cells/m\(^3\) and \(9 \times 10^3\) cells/m\(^3\)) from the ponds V₁ and V₂. Lower cell densities of euglenophytes were collected during December, April, June and May from the above ponds. A higher cell density of \(14 \times 10^3\) cells/m\(^3\) was collected during October month from the pond T₂ (Fig. 73).

The percentage contribution of euglenophytes is shown in (Fig. 64). It was 3.74 (V₁), 2.30 (V₂) 2.87 (K₁), 1.84 (K₂), 3.31 (T₁), 2.75 (T₂), 1.73 (A₁) and 2.12 (A₂) percentages respectively in the first year of the study period. In the second year also the percentages of euglenophytes were lesser and the results are shown in Figure 65. It was 4.49 (V₁), 2.32 (V₂), 2.88 (K₁), 1.76 (K₂), 2.64 (T₁), 2.85 (T₂), 1.69 (A₁) and 1.97 (A₂) percentages from the temple ponds.

Seasonal mean values of the resulted euglenophytes from the temple ponds of the year 2009 – 2010 are shown in Table 41. A high mean value of \(10.1 \pm 1.18, 5.5 \pm 0.7, 7.9 \pm 2.3, 4.4 \pm 0.5, 8.5 \pm 1.5, 5.3 \pm 1.1, 4.4 \pm 1.8\) and \(5.6 \pm 1.0\) from the ponds (V₁, V₂, K₁, K₂, T₁, T₂, A₁ and A₂) during southwest monsoon and lower mean values were reported during non- monsoon and northeast monsoon. Likewise, higher cell densities of euglenophycean members were collected from the temple ponds and the resulted values
are shown in Table 42. It was maximum of 12.4 ± 1.1, 6.0 ± 0.9, 8.9 ± 1.4, 5.1 ± 1.0 and 6.1 ± 0.9 from the ponds V₁, V₂, K₁, K₂ and T₂. While the pond T₁, A₁ and A₂ showed higher cell densities during southwest monsoon season (6.4 ± 2.1, 5.2 ± 0.7 and 5.5 ± 1.6) of the year 2010 – 2011.

Statistical analysis by two way ANOVA revealed a significant influence of seasons (F = 25.49; F = 14.94) and ponds (F = 8.12; F = 9.52) at P< 0.05 level during the study periods (Table 46). Correlation coefficient studies showed significant positive correlation with phosphate, nitrate, temperature and DO in most of the ponds during the study periods (Table 39 and 40).

5.3.3. Species composition of phytoplankton

A total of 184 phytoplankton species along with 69 genera were recorded in the experimental ponds during the year 2009 – 2010 (Table 47), comprising 18 genus with 41 species of blue greens, 26 genus with 68 species of green algae, 21 genus with 62 species of diatoms and 4 genus with 13 species of euglenophytes were identified.

In the year 2010 – 2011 from the eight temple ponds of the district a total of 74 genera with 203 species were identified which belonged to the class chlorophyta, cyanophyta, bacillariophyta and euglenophyta. 31 genus with 74 species belonged to Chlorophyta, 17 genus with 47 species to Cyanophyta, 22 genus with 67 species to Bacillariophyta and 4 genus with 15 species to Euglenophyta were recorded (Table 48).

5.3.3.1. Chlorophyta

The number of species collected doing the study period was assigned in seven order following Fritsch’s (1935) classification as Chlorococcales, Zygnumatales, Volvocales, Cladophorales, Ulotrichales and Chaetophorales.
In the year 2009-10 the ponds $V_1$ and $V_2$ contributed 10 genus 18 species and 7 genus 15 species under the order Chlorococcales. Volvocales order reported a single species only in $V_1$ and not collected from $V_2$. The Ulotrichales were found with 1 genus 3 species from each of the ponds ($V_1$ and $V_2$). The Cladophorales order was not represented by the above ponds. Where a single genus with one and three species from the order Oedogoniales. 7 genera 20 species and 5 genera 14 species were collected under Zygnematales. Totally 21 genera 44 species from $V_1$ and 14 genera 35 species from $V_2$ were collected (Table 48). The ponds $K_1$ and $K_2$ contributed 8 genus 15 species and 13 genus 20 species under the order Chlorococcales. $K_2$ alone donated a single species under Volvocales whereas 1 genus 4 species were registered under the order Ulotrichales. The Chaetophorales and Cladophorales were distributed with 1 species each. The order Oedogoniales with 3 and 2 species from the $K_1$ and $K_2$ ponds. 6 genera with 16 and 7 genera with 23 species under Zygnematales were collected. Totally $K_1$ and $K_2$ donated 18 genera 40 species and 25 genera 52 species. The $T_1$ and $T_2$ ponds produced 6 genus 13 species each under Chlorococcales, a single species of Volvocales (only $T_1$), a single genus with 4 and 1 species of Ulotrichales and a single species of Cladophorales (only $T_1$) were collected. A single genus with 2 and 1 species under Oedogoniales, 7 genera 11 species and 4 genera with 11 species were collected under the order Zygnematales. During the study period the total of 17 genera 31 species and 12 genus 26 species were collected from the ponds $T_1$ and $T_2$. The ponds $A_1$ and $A_2$ registered 6 genus 11 species and 5 genus 10 species under Chlorococcales, the order Ulotrichales includes a single genus with 2 species in $A_1$ and a single species in $A_2$. The order Volvocales and Cladophorales were not collected. Chaetophorales order donates single genus with single species in both the ponds. The Oedogoniales order was registered with a single genera (2 species), 4 genera 10 species and 7 genera 14 species of Zygnematales were collected. A
total of 13 genera 26 species, 14 genera 25 species were collected and identified during 2009 – 2010.

In the pond V₁, the order Chlorococcales were reported with 12 genus 27 species, Volvocales with a single species, Volvocales with 1 genus 1 species, Ulotrichales with 1 genus 4 species, Chaetophorales with 1 genus 2 species, Oedogoniales include 3 species under a single genus and Zygnematales with 7 genera 18 species. Totally V₁ showed 23 genus 55 species. The V₂ pond with 6 genera 14 species, Volvocales 1 species, Ulotrichales 2 species 1 genus, Oedogoniales include a single genus with 3 species and Zygnematales include 3 genera 10 species and the total contribution was 12 genera 30 species. K₁ and K₂ ponds donated 10 genera with 17 and 20 species under the order Chlorococcales and K₁ alone reported a single species under Volvocales, 3 species under Ulotrichales and in K₂ pond member under these order were not collected during the study period. A single species Cladophorales and Chaetophorales were recorded. The Oedogonials includes 1 genus 3 species and Zygnematales order produced 7 genus 12 species and 5 genus 10 species by K₁ and K₂ pond respectively. Totally these ponds donated 22 genera 38 species and 17 genera 32 species in the year 2010-11. The T₁ and T₂ ponds contributed 11 genera 23 species and 9 genera 18 species of Chlorococcales, 1 species of Volvocales, 1 genus 3 species by T₁ pond and 1 genus 2 species under Ulotrichales by T₂ pond. The order Cladophorales contributed a single genus with 1 species (T₁) and 2 genus 2 species (T₂), Chaetophorales showed 2 genus 3 species and a single species by T₁ and T₂ ponds. 1 genus with 4 species was found under the order Oedogoniales. The order Zygnematales presented 7 genera 24 species and 3 genera 9 species during the study period by the pond T₁ and T₂. A total of 24 genera 58 species and 16 genera 32 species were collected (Table 48). The A₁ and A₂ ponds resulted a total of 20 genera 41 species and 16 genera 31 species. 8 genera 15 species, 7 genera 11
species, a single genus with two and three species were collected under Chlorococcales, Volvocales and Ulotrichales. The order Cladophorales were collected with a single species and Chaetophorales with 2 genera 2 species from A₁ pond alone. The Oedogoniales order showed 1 genus 4 and 3 species, 7 genera 17 species and 6 genera with 13 species were collected under Zygnematales.

In the year 2009-10 the pond V₁ (44 species), V₂ (35 species), K₁ (40 species) and K₂ (52 species) donated maximum chlorophycean members to the total phytoplankton. Among the eight ponds V₁ (55 species), T₁ (58 species) and A₁ (41 species) contributed maximum chlorophycean members during the year 2010 – 11. Totally 26 genera 68 species in the first year and 31 genera 74 species in the second year of the study period was reported.

The collected taxa are shown in Tables 47 and 48. During the study periods the genus Closterium was noticed with 14 species, Scenedesmus with 11 species, Pediastrum includes 9 species, Cosmarium was noticed with 8 species and all the remaining genus were represented by lesser number of species. The percentage frequencies of the collected member are presented in Tables 47 and 48. In both the years of investigation the genus Chlorella was found with highest percentage frequency as 4.47% (2009 -10) and 1.37% during the year 2010 -11 and the lowest frequency of 0.086 was shown by Cosmarium bidentatum and Hyalotheca (0.07%) respectively.

5.3.3.1a. Key to the genera of chlorophyta

1. Cells in coenobia with uniform size .................................................................2

1. Cells of half or one-fourth of coenobia are of smaller size ..........................3

2. Cells spherically arranged in alternating tiers ................................. Eudorina

2. Cells spherical with large reproductive cells in the posterior side .............. Volvox
3. Unicellular, cells of varying shapes, chloroplasts one to many .................4
4. Unicellular free living, or held in common mucilage ............................5
5. Unicells simple, spherical or elongated without any appendages ............6
6. Cells spherical, chloroplast cup shaped or laminate with pyrenoids .......Chlorella
7. Cells ellipsoidal, chloroplast parietal, ..............................................7
8. Cells polygonal with or without short spines .....................................13
9. Cells forming compact colonies ......................................................10
10. Cells arranged forming radiating flat spherical or cylindrical colonies ......11
11. Colony macroscopic forming a net with coenocytic cells .................Hydrodictyon
12. Colonies spherical indefinite forming net like compound colonies or with globose cells connected by mucilaginous pads .................................................................13
13. Cells with rounded angles .........................................................Tetraedron
14. Colonies flat plate like, cells in groups of variable shapes ...............Coelastrum

7. Chloroplast parietal, with a single pyrenoids cells with radiating bristles.....................................................................................Golenkinia
8. Cells cylindrical to cresent shaped with spine .................................Schroederia
9. Cells enclosed in mucilage envelope or forming loose colonies ..........16
10. Cells arranged in varying shapes ..................................................12
11. Colonies microscopic ......................................................................15
12. Colonies spherical indefinite forming net like compound colonies or with globose cells connected by mucilaginous pads .................................13
13. Cells connected by mucilaginous pads ...........................................Coelastrum

6. Cells spherical, chloroplast parietal, with one to many pyrenoids ........Chlorococcum

128
14. Colonies flat irregular, cells in two planes oblong, ellipsoidal ........................15
14. Cells of the colony with appendages ......................................................16
15. Colonies 2 – 8 cells arranged in two rows with parallel ...................... Scenedesmus
15. Colony plate like with 4 – 64 cells, cells multinucleate ...................... Pediastrum
16. Cells enclosed in mucilage colony interconnected with each other by mucilage ..................................................18
16. Cells enclosed in mucilage, free from each other ...............................17
17. Cells ovoid to ellipsoidal shape ......................................................... Oocystis
17. Cells are usually quadrately arranged ................................................. Crucigenia
18. Cells elongated ..................................................................................19
18. Cells lunate or ovate – cuneate ............................................................20
19. Cells without mucilage envelope ....................................................... Ankistrodesmus
19. Cells within mucilage envelope ..........................................................21
20. 2 – 8 or more cells in mucilage envelope ................................. Quadrigula
20. Cells fairly regularly arranged back to back without mucilage envelope ..........21
21. Cells 4 – many within mucilage envelope ...................................... Kirchneriella
21. 4 to 16 cells without mucilage envelope .......................................... Selenastrum
22. Filaments without any mucilaginous sheath .......................................23
22. Filaments differentiated into base and apex .......................................24
23. Filaments unbranched cells cylindrical producing rhizoids ...............Rhizoclonium
23. Filaments branched ...........................................................................24
24. Filaments branched ................................................................. Cladophora
24. Filaments attached .............................................................................. Ulothrix
25. Erect system, filaments enclosed in a gelatinous sheath ................. Chaetophora
25. Basal system well developed ............................................................. Stigeoclonium
26. Filaments unbranched, cells long, and cylindrical ......................... Oedogonium
26. Filaments unbranched without cup cells ........................................ Mougeotia

27. Chloroplasts stellate without conjugation tube .................................. Zygnema

27. Chloroplasts spirally arranged and ribbon like with conjugation tube
........................................ Spirogyra

28. Cell wall unsegments without pores ................................................. 30

28. Cell wall segmented with construction or forming semicells ................. 29

29. Cells cylindrical elongated with central constriction .......................... 30

29. Cells showing diversity of forms, cells with two halves called semicells.... 31

30. Cells elongate curved attenuated towards each end with two chloroplasts
................................................................ Closterium

30. Cells short unconstricted cell wall smooth with longitudinal ridges
................................................................ Netrium

31. Cells solitary or in colonies isthmus plane ......................................... 32

31. Thread like colonies with girdle like thicking or isthmus ....................... 33

32. Cells elongated and cylindrical with slight constriction ..................... 33

32. Cells short compressed or radiating with deep constrictions ............... 34

33. Apices of cells truncate or rounded, base of semi cells plane
........................................................................................................ Pleurotaenium

33. Cells compressed vertical view fusiform or elliptical ......................... 35

34. Cells with apical incision and lobed margin ................................... 35

34. Cells without incision and with spines ......................................... 36

35. Apical incision with moderately lobed margin ................................. Euastrum

35. Cells compressed with deeply lobed margin ..................................... Micrasterias

36. Cells with a central protubesance ................................................ 37

36. Cells deeply constricted ......................................................... 38
37. Semi cells showing clear isthmus .......................................................... Cosmarium

37. Cells triangular, fusiform, elongate or cylindrical ................................. 40

38. Cells slightly constricted ............................................................... Hyalotheca

38. Cells short triangular or fusiform .................................................... Desmidium

5.3.3.2. Bacillariophyta

The bacillariophycean members of the present study were reported under the orders Centrals and Pennales. They are illustrated in Tables 47 and 48. In the first year of the study period 2009 – 2010 a single species was collected under the order Centrales from V₁, V₂, K₂, A₁ and A₂ ponds. However 13 genera 34 species, 16 genera 27 species, 15 genera 31 species and 13 genera 22 species were collected from V₁, V₂, K₁ and K₂ ponds respectively. The remaining ponds T₁ with 12 genera 25 species, 18 genera 40 species (T₂), 18 genera 32 species (A₁) and 10 genera 23 species (A₂) were collected. A total of 14 genera 35 species (V₁), 19 genera 28 species (V₂), 15 genera 31 species (K₁), 14 genera 23 species (K₂), 12 genera 25 species (T₁), 19 genera 42 species (T₂), 19 genera 33 species (A₁) and A₂ pond with 11 genera 24 species were collected (Table 47).

In the year 2010 – 2011 except K₂ all the seven ponds were observed with a single species under the order centrales and the pond K₂ alone produced 2 species. The pond V₁ and V₂ donated 19 genera 48 species and 17 genera 33 species. 21 genera 50 species and 11 genera 30 species were collected from K₁ and K₂. T₁ and T₂ contributed 15 genera 38 species, 20 genera 49 species and 15 genera 35 species and 14 genera 33 species were recorded under the order pennesales in pond A₁ and A₂ (Table 48).

In the study periods the pond T₂ (42 species), A₁ (33 species), K₁ (50 species) and T₂ (49 species) ponds contributed maximum number of phytoplankton under the class
Bacillariophyta. A total of 21 and 22 genera with 62 and 67 species were recorded and shown in table 47 and 48.

The bacillariophyta or diatoms dominated the ponds T₁ and A₁ during the year 2009 – 2010, whereas in the following year K₁ and T₂ showed higher percentage contribution of diatoms. The genus *Navicula* documented with 14 species, *Nitzschia* and *Cymbella* with 9 species, *Gomphonema* with 7 species, *Fragilaria* and *Pinnularia* with 6 species each. The highest frequency of 1.90% was reported by *Fragilaria intermedia* and *Surirella elegans* with the lowest percentage frequency (0.07%).

### 5.3.3.2a. Key to the genera of Bacillariophyta

1. Valves centric and radially symmetric .................................................................2

1. Valves isobilateral, sometimes medianly asymmetric, boat or needle shaped with pinnate wall markings, having raphe or pseudoraphae...........................................4

2. Cells discoid generally free ................................................................................3

2. Cells in filaments of cylindrical cells, walls punctuate .........................*Melosira*

3. Cells with marginal row of striation and central smooth zone .................................................................................................*Cyclotella*

3. Cells showing well developed raphe.................................................................8

4. Valves straight, rod shaped or needle shaped with a pseudoraphe .......................................................................................5

4. Valves with raphe .................................................................................................8

5. Frustules of various shapes forming clumps .......................................................6

5. Frustules fusiformed forming ribbons .......................................................*Fragilaria*

6. Frustules elongate, straight needle shaped with capitate poles, also forming clumps ...........................................................................*Synedra*

6. Frustules attached by sides ....................................................................................7
7. Frustules attached by sides forming continuous ribbons ........................5
7. Frustules attached in zig-zag chains, cells with median swelling
                      .......................... **Tabellaria**

8. Fully developed raphe present with one valve ..............................9
8. Fully developed raphe on both the valves .................................10

9. Frustules bend in girdle view narrowly elliptic, valves with a rim
                      ................................. **Achnanthes**
9. Frustules ovoid elliptical with marginal band .............................. **Cocconeis**

10. Raphe not occupying apical axis ...........................................11
10. Raphe occupying apical axis ................................................16

11. Keels without canal dots .....................................................12
11. Keels with canal dots or lateral wings ...................................13

12. Frustules bend and curved ..................................................12
12. Frustules look like half cells with enlarged mid region narrow curved polar region
                      ................................. **Rhopalodia**

13. Keel with canal dots, frustules generally single .......................14
13. Keel with canal dots forming wings .....................................23

14. Narrowly elangated cells apices united by sides forming ribbons, found gliding
                      ................................. **Bacillaria**
14. Cells arranged otherwise ....................................................15

15. Keel margin on one half, lies opposite to that of other margin
                      ................................. **Hantzschia**
15. Keel opposite to unkeeled margin of the other half ................. **Nitzschia**

16. Crescent shapted or sigmoid ..............................................17
16. Boat shaped, elongate, wedge shaped ................................. 20

17. Cresent shaped ................................................................. 18

17. Sigmoid ................................................................. 19

18. Axial field expanded in middle ................................... *Amphora*

18. Axial field not expanded ........................................... *Cymbella*

19. With transverse and longitudinal striae ......................... *Gyrosigma*

19. With transverse and oblique striae .......................... *Pleurosigma*

20. Valve boat shaped .................................................. 21

20. Valve otherwise ..................................................... 27

21. Frustules with septa .................................................. *Mastogloia*

21. Frustules without septa ............................................. 22

22. Raphe extending with a siliceous rib like thickening .............. 23

22. Raphe without bordering ribs ...................................... 24

23. Frustules broadly oval egg shaped or slipper shaped, costae extend inwards from margin ........................................ *Surirella*

23. Valves with enlarged central area, frustules broadly elliptic ........ *Diploneis*

24. Transverse markings formed of punctae ...................... *Neidium*

24. Central area not extending to margin, ornamentations caused by punctae ........................................ *Navicula*

25. Frustules elongated, central area not extending to margin, ornamentations caused by costae ........................................ *Pinnularia*

25. Frustules wedge shaped or clavate larger at one end transversely asymmetric ........................................ *Gomphonema*
5.3.3.3. Cyanophyta

The collected members of cyanophyta were noticed under five orders as Chroococcales, Oscillatoriales, Rivulariales, Nostocales and Scytonematales. The pond $V_1$ contributed 6 genera 10 species, $V_2$ with 5 genus 8 species, $K_1$ and $K_2$ with 6 genera 9 species, 8 genera 13 species ($T_1$), 5 genera 9 species ($T_2$), 6 genera 7 species ($A_1$) and 8 genera 16 species by $A_2$ ponds respectively by the order Chroococcales. The second order Oscillatoriales were recorded with 2 genus 6 and 10 species in $V_1$ and $V_2$. The pond $K_1$ and $K_2$ donated 3 genera 9 species and 2 genera 8 species. 4 genera 9 species, 2 genera 4 species, 3 genus with 9 and 8 species were collected from $T_1$, $T_2$, $A_1$ and $A_2$ ponds respectively. The third order Rivulariales donated 2 genus with 2 species ($V_1$ and $A_2$). No member was collected from $K_1$, $K_2$ and $T_2$ ponds. The remaining $A_1$ and $T_1$ ponds were represented by a single species. The order Nostocales was represented by 2 genus 2 species ($V_1$, $T_1$ and $A_2$). The pond $V_2$ showed a single genus with 2 species and $K_1$ with 2 genus 3 species. The order Scytonematales was found with a single species in $V_1$, $K_1$, $A_1$ and $A_2$ ponds. Totally $V_1$ pond produced 13 genera 21 species, 8 genera 20 species by $V_2$ pond, 12 genera 22 species ($K_1$), 9 genera 18 species ($K_2$), 14 genera 26 species ($T_1$), 7 genus 13 species ($T_2$), 12 genera 19 species ($A_1$) and 16 genera 29 species ($A_2$) respectively. During the year 2009 – 2010, $T_1$ and $A_2$ ponds contributed a maximum of 21 and 29 species than the remaining ponds (Table 47).

In the second year of the study period the ponds $V_1$ and $V_2$ donated 7 genus 15 species and 8 genus 18 species. $K_1$ and $K_2$ produced 8 genera 16 species and 7 genera 17 species. However 6 genera with 15 and 10 species were assessed to $T_1$ and $T_2$ ponds. The $A_1$ and $A_2$ produced 8 genera each with 12 and 20 species were recorded under the order Chroococcales. The second order Oscillatoriales contributed maximum number of species
during the study periods. The pond $V_1$ and $V_2$ donated 5 genera 10 species and 4 genera 12 species. A maximum of 3 genera 12 species and 4 genera 13 species were collected from $K_1$ and $K_2$ ponds. The pond $T_1$ and $T_2$ collected 3 genera 11 species and 2 genera 6 species. However the ponds $A_1$ and $A_2$ donated 3 genus 6 species and 4 genus 13 species respectively. The third order Rivulariales donated a single species from $V_1$, $K_1$, $K_2$ and $A_1$ ponds. Whereas $V_2$ and $A_2$ ponds were represented by a single genus with 2 species each they were absent in $T_1$ and $T_2$ ponds (Table 48). The order Nostocales was represented by 2 genus each from ponds $V_1$ and $V_2$ with 3 and 6 species. The ponds $K_1$ and $K_2$ donated single genera with 4 species and 2 genera 4 species. A single genus with 3 species from $T_1$ pond and a single species from $T_2$ ponds were collected. The $A_1$ and $A_2$ ponds donated 2 genus 4 species each. Totally 15 genera 29 species, 15 genera 38 species, 13 genera 33 species and 14 genera 35 species were registered from $V_1$, $V_2$, $K_1$ and $K_2$ ponds respectively. A total of 10 genera 29 species, 9 genera 17 species, 14 genera 23 species and 15 genera 39 species were collected from $T_1$, $T_2$, $A_1$ and $A_2$ ponds during the study period 2010 – 2011. Among the eight ponds $V_2$ (38 species), $K_2$ (35 species and $A_2$ (39 species) were reported with maximum cyanophycean members. In the 2009 – 2010, 18 genera 41 species and 17 genera 47 species (2010 – 2011) were recorded (Table 47 and 48).

Then temple ponds $T_1$ and $A_2$ in the first year, and $V_2$, $K_2$ and $A_2$ during the second year of observation were noticed with the highest percentage contribution of cyanophycean members (Table 47 and 48). The genus *Oscillatoria* was reported with 13 species and *Microcystis* with 6 species. The highest percentage frequency was shown by *Microcystis aeruginosa* (4.83%) and the lowest by *Synechocysis pevolekii* (0.071%) as represented in Table 47.
5.3.3.3a. Key to the genera of Cyanophyta

1. Thallus unicellular, colonies or pseudoparenchymatous .......................................2

1. Thallus Multicellular, uniseriate, branched or unbranched .................................11
   2. Thallus free in colonies ................................................................................3
   2. Thallus unicells or grouped in to colonies ......................................................5

3. Cells single or few together in a shapeless colony ..............................................4

3. Cells generally many in a colony .................................................................7
   4. Cells spherical ..........................................................................................8
   4. Cells elongated .......................................................................................8
      Gloeothece

5. Cells without mucilaginous envelope .............................................. Synechocystis

5. Cells with distinct envelope .................................................................6
   6. Sheath vesicular ...................................................................................6
      Gloeocapsa
   6. Sheath smooth .....................................................................................6
      Chroococcus

7. Cells with definite arrangement ..............................................................10

7. Cells without arrangement ........................................................................8
   8. Cells typically well packed into microscopic colonies ..................... Microcystis
   8. Cells loosely arranged in microscopic colonies ........................................9

9. Cells rounded ..........................................................................................9

9. Cells cylindrical ......................................................................................9
   10. Cells in flat colonies ................................................................. Merismopedia
   10. Cells pear shaped ...............................................................................10
      Gomphosphaeria

11. Trichomes made of uniseriate and undifferntiated cells ..........................12

11. Trichomes multiseriate with differentiated cells ........................................15

12. Trichomes straight ...............................................................................13

12. Trichomes spirally coiled .......................................................................14
13. Trichomes with prominent sheath .................................................................14
13. Trichomes without prominent sheath .......................................................Oscillatoria
14. Sheath confluent with filament ...............................................................Phormidium
14. Sheath firm with single or bundle of trichomes .......................................15
15. Single trichome with sheath .................................................................Lynghya
15. Trichomes without sheath ......................................................................17
16. Filaments long homogenous, spirals narrow and compact .................Spirulina
16. Filaments short, spirals broad, showing distinct cross walls of cells ..........Arthrospira
17. Trichomes broaded at the base and gradually tapering .........................19
17. Trichomes uniformly broad throughout ................................................18
18. Trichomes free in formless gelatinous mass .........................................Anabaena
18. Trichomes in definite colonies ...............................................................20
19. Filaments forming spherical thalli, without terminal heterocyst ...........21
19. Filaments free with terminal heteroajst .................................................Calothrix
20. Thallus rounded with pellick .................................................................Nostoc
20. Thallus parallel lamellate ......................................................................21
21. Filaments with false branching, ............................................................Scytonema
21. Filaments unbranched, more or less in radiate hemispherical colony ........Rivularia

5.3.3.4. Euglenophyta

In the year 2009 – 2010 the number of species collected under the class Euglenophytes were kept under a single order Euglenales. In the year 2009 – 2010, 4 genera 9 species and 2 genera 5 species were collected from $V_1$ and $V_2$. The pond $K_1$ and $K_2$ registered 3 genus each with 6 and 7 species. The pond $T_1$ and $T_2$ produced 4 genera 8 species and 2 genera 4 species. A maximum of 3 genera each from $A_1$ and $A_2$ ponds with
5 and 4 species were collected. The pond V₁ contributed 4 genera 13 species as maximum (Table 47) contribution of Euglenoids.

In the following year (2010 – 2011) the ponds V₁ and V₂ donated 4 genera 12 species and 3 genera 7 species to the total phytoplankton. 3 genera 8 species, 4 genera 9 species, 4 genera 11 species and 3 genera 6 species were collected from K₁, K₂, T₁ and T₂ ponds. The ponds A₁ and A₂ contributed 3 genera 9 species and 4 genera 8 species. Among the experimental ponds V₁ donated a maximum of 4 genera 12 species (Table 48).

The Euglenophyta was represented by 4 genus namely Phacus, Euglena, Lepocinclis and Trachelomonas. 13 species in the first year and 15 species in the second year were reported. Phacus with 7 species, Euglena with 6 species, Trachelomonas with 2 species and Lepocinclis with one species were collected. The percentage frequency of Phacus caudatus was maximum 0.55%. The minimum of 0.07% was donated by Euglena oxyuris (Table 47 and 48). The systematic status of different orders and genus are represented in table 50.

5.3.3.4a. Key to the genera of Euglenophyta

1. Cells with chloroplasts.................................................................2
1. Cells with periplast ...............................................................2
   2. Cells enclosed in lorica .................................................. Trachelomonas
   2. Cells with single flagellum .........................................................13
3. Cells fusiform, cylindrical, gradually narrowing, attaining different shapes
   .............................................. Euglena
3. Cells with regid periplast of different definite shapes .........................4
   4. Cells more or less flattened with striations and terminating in a spine
      ....................................................... Phacus
   4. Cells round or oval shaped tailpice seen as projections ............... Lepocinclis
5.3.4. Seasonal Distribution of Phytoplankton

In the first year of study period (2009 – 2010) during monsoon season the green algal members recorded were *Chlorella vulgaris, Chlorococcum humicola, Closterium, Coelastrum microsorum, Cosmarium, Desmidium swartizii, Euastrum inerme, Hydrdictyon reticulatum, Golenkinia radiata, Mougeotia scalaris, Oedogonium, Pediastrum, Scenedesmus, Schroederia, Spirogyra, Stigeoclonium subsecundum, Ulothrix, Volvox aureus and Zygnema cirumcarinatum* (Plate 8 to 15). The blue green algae observed were *Aphanocapsa roeseana, Chroococcus minutus, C. turgidus, Lyngbya, Oscillatoris sancta, O. subbreris and Phormidium anomala* (Plate 5 to 7). The diatoms like *Achnanthus lanceolata, Amphora coffeaeformis, A.ovalis, Bacillaria, Cyclotella meneghiniana, Cymbella gricilis, C. obtuse, C. prostrate, C.sumatrensis, C. tumida, Fragilaria intermedia, Gomphonema montanum, G. parvulum, Melosira granulata, Navicula mutica, N. pupula, N.phylepta, N. salinarum, Neidium dubium, Nitzchia obtusa, N. subtilis, Pinnularia interrupta, Surirella elegans and Synedra ulna* were reported (Plate 16 to 19). The euglenophycean members observed from the experimental ponds like *Euglena, Phacus and Lepocinclis* were observed in the experimental ponds.

During non-monsoon period the green algae genus like *Chlorella, Closterium, Euastnum, Kirchneriella, Micrasterias, Oedogonium, Oocystis, Scenedesmus Pediastrum, Rhizochlonium, Spirogyra, Tetraedron, Ulothrix and Zygnema* were observed (Plate 8 to 15). Enormous number of blue green algae like *Anabaena, Microcystis, Aphanocapsa, Aphanothece, Arthrospira, Calothrix, Chroococcus, Gloethece, Gloecapsa, Merismopedia, Nostoc, Oscillatoria, Rivularia* were observed during non-monsoon months. The diatom genus like *Diploneis, Fragilaria, Navicula, Nitzschia, Cocconeis,
Pinnularia, Rhopalodia and Synedra abundantly found in this season. Species of Euglena, Phacus and Trachelomonas were observed under euglenophytes during the study period (Plate 20).

Very rarely genus like Scytonema, Gomphosphaeria, Synechocystis, Gloeocystis, Gyrosigma, Hantzschia, Pleurosigma, and Tabellaria were recorded in the year 2009 - 2010.

In the succeeding year 2010 - 2011 during monsoon season the chlorophycean members were recorded at Pediastrum, Scenedesmus, Cladophora, Oedogonium, Chlorella, Desmidium, Kirchneriella, Crucigenia, Pleurotaenium, Chaetophora, Selenastrum, Ankistrodesmus, Zygnema, Stigeoclonium, Cosmarium, Coelastrum and Ulothrix. The cyanophycean members reported were Chroococcus, Oscillatoria, Lyngbya truncicola and Phormidium. The bacillariophycean members like Navicula, Achnanthus, Amphora, Pinnularia, Gomphonema, Fragilaria, Synedra, Cyclotella, Nitzchia, Melosira, Nedium and Surirella were observed. The euglenophytes were reported that Phacus manginii, Euglena polymorpha and Euglena gracilis.

In the non-monsoon season the Chlorophycean algae were reported that the genus like Chlorella, Closterium, Tetraedron, Pediastrum, Scenedesmus, Rhizoclonium, Ulothrix, Oedogonium, Chlorococcum, Oocystis, Euastrum, Eudorina, Golenkinia, Hydrodictyon, Hyalotheca, Gloeocystis, Mougheatia and Quadrigula. Blue green algae like Microcystis, Osillatioria, Anabaena, Nostoc, Synechocystis, Aphanocapsa, Aphanothece, Chroococcus and Merismopedia were observed abundantly during the non-monsoon season. The diatoms like Navicula, Pinnularia, Fragilaria, Nitzchia, Gomphonema and Synedra were found in enormous number. Euglenophycean members
like *Euglena, Phacus, Lepocinclis* and *Trachelomonas* were reported during the non-monsoon months of the second year study period.

Rarely genus like *Hyalotheca, Gyrosigma, Hantzschia, Pleurosigma* and *Spirulina* were reported during 2010 - 2011.

**5.3.5. Sequential Blooms**

In the early months of non-monsoon, as a result of gradual increase of temperature along with nutrients luxurious growth of *Microcystis aeruginosa, Oscillatoria princeps, Merismopedia elegans* and *Scenedesmus quadricauda* were collected abundantly in all the ponds especially V$_2$, T$_1$ and A$_2$ ponds which showed the ‘blooms’. *Microcystis aeruginosa* produced blooms (V$_2$) during May (2009 – 2010) and December (2010 – 2011). At the end of October *Oscillatoria princeps* and *Merismopedia elegans* produced ‘blooms’ (2009 – 2010) in A$_2$ and T$_1$ showed *Scenedesmus quadricauda* more resulting in blooms (Plate 21).

**5.3.6. Pollution indicators**

During the period of investigation genus like *Anabaena, Oscillatoria, Chroococcus, Merismopedia, Microcystis, Scenedesmus, Ankistrodesmus, Closterium, Oocystis, Chlorella, Phacus, Euglena, Fragilaria, Synedra, Navicula, Gomphonema* and *Nitzschia* were observed as pollution indicators (Table 47 and 48).

**5.3.7. Species diversity**

Species diversity index of phytoplankton recorded during the period of investigation is represented in Figures 74a and b. During the year 2009 – 2010 species diversity values ranged from a minimum of 1.05 in March to a maximum of 4.28 in September at V$_1$, whereas in V$_2$ it varied from 1.09 (September) to 2.79 (July). In K$_1$ the
values ranged from a minimum of 1.13 (December) to a maximum of 3.68 (August) and from 1.40 (February) to 3.87 (September) in K₂ and from 1.68 (May) to 3.57 (August) in T₁ and from a minimum of 1.60 (April) to the maximum of 3.57 (October) at T₂. In A₁ and A₂ the values were minimum of 1.1 (February) and 1.41 (April) to the maximum of 2.98 (November) and 2.74 (September).

In the second year of the study period (2010 – 2011) the diversity index ranged from 2.08 (April) to 4.87 (November) in V₁, from 1.82 (April) to 3.76 (June) in V₂. In K₁ the minimum species diversity value of (2.17) was reported in April against the maximum of 4.11 during September (Fig. 75a and b). The values ranged between 1.92 in May and 3.99 in November (K₂) and from 1.23 (July) to 3.81 (January) in T₁. A minimum of 0.91 (April) and a maximum of 3.17 (September) was reported in T₂. In A₁ and A₂ the minimum values (1.35 and 1.43) were reported during March and August against the maximum of 3.56 and 2.99 during July and February respectively.

5.3.8. Species richness index

Species richness index recorded in the experimental ponds during the year 2009 to 2010 is illustrated in Figures 74a and b. The species richness index of the year 2009 – 2010 ranged from a minimum of 2.13 (April) to a maximum of 4.56 (November) in V₁ and from 1.85 (September) to 4.03 (March) in V₂. The values ranged between 1.53 (April) to 3.86 (August) in K₁ and varied from a low value of 1.73 (June) to a high value of 3.76 (October) in K₂. In T₁ and T₂ the minimum richness index of 2.51 (March) and 2.63 (November) against the maximum of 4.39 (July) and 3.95 (May). The values ranged from 1.25 (June) to 4.08 (September) in A₁ and in A₂ the value of 2.63 during December and maximum of 3.61 during February was observed.
In the following year (2010 – 2011) the richness index was low (2.17) during May and high (4.81) during December in V₁. In V₂ the values ranged between 2.28 (April) and 4.28 (January). The richness index ranged from a minimum of 1.71 (May) to a maximum of 4.36 (August) in K₁ and from 2.56 (February) to 4.49 (November) in K₂. In T₁ and T₂ the values remained low as 1.89 and 1.43 (June and May) to a high value of 4.61 (December) and 3.82 (August). The values ranged from 2.25 (June) to 4.33 (October) in A₁ and from 1.58 (April) to 3.93 (July) in A₂ during the study period (Fig. 75a and b).

5.3.9. Species evenness

The species evenness index observed from the experimental ponds during the study period (2009 – 2010) is shown in Figures 74a and b. In V₁ and V₂ the value ranged from 0.37 (March) and 0.45 (October) to 0.89 (September) and 0.62 (July). In K₁ and K₂ the low values of 0.35 (December) and 0.40 (April) were resulted against the high values of 0.72 (August) and 0.70 during September. T₁ and T₂ showed 0.43 (February) and 0.35 (March) as minimum values against the maximum of 0.79 (August) and 0.69 in October. In A₁ and A₂ the minimum value of 0.37 (February) and 0.39 (April) against the maximum value of 0.65 (November) and 0.61 (December) during the study period 2009 -2010.

In the following year (2010 – 2011) the species evenness values showed low values of 0.63 (May), 0.55 (April) and 0.62 (April) in V₁, V₂ and K₁ against the high values of 0.98 (November), 0.90 (July) and 0.95 (September) respectively. During the study period 0.57 (May), 0.54 (July) and 0.41 (April) were the low values observed against the high values of 0.91 (November), 0.88 (March) and 0.81 (September) in pond K₂, T₁ and T₂. In A₁ the minimum values was resulted (0.51) during January against the maximum of 0.85 during July and in A₂ the minimum of 0.50 during August and maximum of 0.73 during April respectively (Fig. 75a and b).
5.3.10. Dominance Index

The dominance index values recorded in the experimental ponds during the year 2009 to 2010 are represented in Figures 74a and b. In February a low value of 0.73 (February) was recorded against a high value of 1.43 (August) in V₁ and a minimum of 0.65 (September) to a maximum of 1.17 (March) in V₂ was recorded. The minimum of 0.43 and maximum of 1.52 was reported in K₁ during April and November respectively. In K₂ and T₁, 0.88 (February) and 0.40 (April) was the lowest values against the highest values of 1.73 (June) and 1.22 (August) in T₂ a minimum value of 0.74 (November) was registered against the maximum of 1.57 (March). In A₁ and A₂ the values ranged from 0.57 (May) to 1.13 (September) and 0.81 (October) to 1.47 (June) respectively.

In the following year the value ranged between 0.74 (July) and 1.88 (November) in V₁. In V₂ a minimum of 0.87 (February) and a maximum of 1.43 (June) was reported. In K₁ and K₂ the observed values varied from a minimum of 1.11 (February) and 1.02 (September) against the maximum of 1.63 (June) and 1.52 (April) respectively. In T₁ the minimum value reported was 0.92 (March) against the maximum value of 1.47 during December (Fig. 75a and b). The values remained low (0.87) in May and (0.77) August against the high value of 1.67 (August) and 1.58 (March) in T₂ and A₁ ponds. In A₂ the minimum and maximum dominance index values was 0.92 (December) and 1.73 (April) during the study period 2010 – 2011.

5.3.11. Phytoplankton indices

Several phytoplankton indices were reported to evaluate the status of freshwater environments. An analysis was made on compound index as shown in Table 49. Among the eight ponds the pond V₁, K₁, K₂, T₁ and T₂ showed mesotrophic nature as the value of
compound index ranged from 1 – 3. The remaining temple ponds represented Eutrophic nature ($V_2$, $A_1$ and $A_2$) as it showed the compound index value above three.

The selected temple ponds reported a good account of several species with high species diversity and most of them are Eutrophic in nature.

5.4. Discussion

Phytoplankton forms the photoautotrophic free floating unicellular, filamentous and colonial diverse group of organisms which are important for all aquatic habitats and the productivity is directly related to the density of phytoplankton population (Venkateswarlu, 2006). Nutrient composition of the sediment, physico-chemical characters of water and sediment anthropogenic factors and pollutants play a key role in the composition of phytoplankton (Harilal, 2005; Rout and Borah, 2009).

5.4.1. Phytoplankton Population

Phytoplankton occurs most abundantly in all the freshwater ecosystem with different growth rates on the population of Chlorophyta, Cyanophyta, Bacillariophyta, Xanthophyta, Euglenophyta etc. (Murugan, 2008). A complex interaction was observed between the biotic and abiotic factors which produce maximum phytoplankton population (Ravisankar et al., 2006 and Sobha et al., 2007). In the present investigation maximum cell density was noticed in $V_1$ pond. As it was surrounded by agriculture fields, runoff by rainfall from this field with rich minerals mainly, nitrate and phosphate concentration causes more growth of phytoplankton populations (Hergendrader, 1980; Mali and Gajaria, 2004). The environmental variables such as pH, temperature, phosphate and nitrate concentrations of the aquatic ecosystem made a decisive role in the determination of phytoplankton population (Tiwari and Shukla, 2007; Umavathi and Logankumar, 2008).
5.4.1.1. Phytoplankton cell densities with peaks

In all the experimental ponds the cell density of a particular group of phytoplankton reached maximum density during monsoon or non-monsoon months or in both the periods showing uni or bi or trimodel peaks (Fig. 62a and b; 63a and b). Unimodel peaks of phytoplankton in the monsoon months were reported from the ponds A_1 and A_2 (Fig. 62b) during the first year of observation and from A_2 pond in the second year of study period (Fig. 63b). Such type of peak was reported from the studies of Divekar and Deshmukh (2006); Bhagat et al. (2009) and Ganai et al. (2010a) in their freshwater studies on ponds. During monsoon heavy load of surface runoff enter into the ponds along with elements like organic matter, calcium, phosphate and nitrate which may influence the growth of phytoplankton in the experimental ponds.

During the period of study bimodel peaks were reported from the ponds V_1, V_2, K_1, K_2 and T_2 ponds during the two years of the study period (Fig. 62a and b; 63a and b). Maximum cell densities with primary peaks were reported during monsoon months (August, October and November). Similar trend existent in the studies Sharma et al. (1982); Srivastava (2002), Kavitha and Balasingh (2007) and Pailwan et al. (2008). This is mainly because of soil nutrients that enter from the nearby areas of the study pond as evidenced from the report of Sonaware et al. (2010). The experimental pond T_1 in both the years of observation showed a trimodel peak, representing a primary peak in February, a secondary peak and tertiary peak cell densities during July and December. Similar observations were also made from V_1 and A_1 ponds during the year 2010 – 2011. The present observation coincides with the previous report of Kant and Kachroo (1971); Joshi (1983); Pandey et al. (1995); Ravishankar et al. (2006); Janjua et al. (2009) in their studies. However several researchers have reported bimodal and unimodel pattern of
seasonal distribution of phytoplankton during monsoon and non-monsoon months (Das and Srivastava, 1956; Sharma et al., 1982; Jaiswal 1983). Higher levels of nutrients, increasing day length with maximum light intensities, higher concentration of phosphorus and low water levels during non-monsoon months may be responsible for the phytoplankton peak in the present study. Similar observations were made by several reporters (Devika et al., 2006; Vasanthakumar and Vijayakumar, 2011).

Various physico-chemical and biological characteristics are involved simultaneously and they cause fluctuations of plankton density. Several researchers reported that factors like total alkalinity (Vallenweider, 1968), moderate transparency (Tiwari and Shukla, 2007), grazing of zooplankton (Diana et al., 1997), nitrogen and chloride (Beeton, 1965), seasonal variability (George and Michael, 1969), pH and phosphate concentrations of the water (Mohar and Singh, 2010) had a decisive role in the higher population density in the freshwater ecosystem.

5.4.2. Percentage contribution of different groups

The phytoplankton observed from the eight ponds of the present investigation belonged to Chlorophyta, Cyanophyta, Bacillariophyta and Euglenophyta. They showed great variation in their distribution pattern, cell density, species diversity and in their percentage contribution Subha and Chandran (2005); Sivakumar and Senthilkumar (2007); Thirugnamoorthy and Selvaraju (2009); Ramanujam and Siangbood (2009) have reported similar groups of algae in their studies. In general, luxurious growth of chlorophycean members determines the healthier aquatic ecosystem and a diatom assemblage indicates water quality (Stewart et al., 1999; Brajesh and Pandey, 2001). Euglenophyta have great ecological amplitude in their occurrence exhibiting various levels of pollution (Tiwari and Srivastava, 2004). Devi and Charya (2007) has pointed
out that the abundant growth of cyanophycean population in aquatic ecosystem reflects the polluted status.

5.4.2.1. Chlorophyta (Green algae)

The word chlorophyta was first adopted by Smith (1953) which means “Green plants”. Fritsch (1935) used the term chlorophyceae which literally means “Green Algae”. This forms the ancient largest group of algae including 425 genera and 6,500 species (Sharma, 1996). Its thallus structure varies from unicellular, colonial, filamentous, branched or unbranched and often with heterotrichous nature. The photosynthetic pigments are localized in chromatophores of various shapes, with the predominance of chlorophyll ‘a’ and ‘b’ over the carotene and xanthophyll pigments (Verma et al., 2011).

In the present investigation it was found that Chlorophycean algal growth is dominated over Bacillariophyceae, Cyanophyceae and Euglenophyceae. Among the eight ponds V1, V2, K1 and K2 were reported with 46.50, 43.62, 39.58 and 47.57 percentages of chlorophycean members during the first year (Fig. 64) and V1, T1 and A1 ponds contributed 45.78, 47.95 and 44.02 percentages in the second year of the study period (Fig. 65). Such higher percentage of chlorophycean members were reported from the studies of Murugan (2008) in the temple tank at Kanchipuram. Jose et al., (2008) from the temple ponds of Ernakulam, Kerala, Baruah and Kakati (2009) from the temple pond of Assam and Jayashankara et al. (2010) from the temple pond of Udupi district, Karnataka and Ramanujam et al. (2012) from different water bodies of Mehalaya. The seasonal observation of chlorophycean members showed great fluctuations in their distribution. In both the years of study luxurious growth of green algal members were collected during northeast and southwest monsoon seasons (Tables 41 and 42). Statistical
analysis evidenced the influence of seasons in the abundance of chlorophycean members and significant positive correlation was reported with dissolved oxygen and phosphate contents. Similar findings were reported by Bhagat et al. (2009). Chlorophyceae was widespread and the most dominant group among the algal groups of the present study was mainly due to the high dissolved oxygen content during monsoon season of the pond $V_1$ (8.03 mg/L), $V_2$ (6.79 mg/L), $K_1$ (7.38 mg/L) and $K_2$ (6.98 mg/L) in the year 2009 – 2010. In the following year also the dissolved oxygen concentration remained high in $V_1$ (7.35 mg/L), $T_1$ (6.38 mg/L) and $A_1$ (6.25 mg/L) respectively. The observation of the present investigation is in agreement with the reports of Jana (1974); Singh (1979), Singh and Nayak (1990); Bajpai and Agarkar (1997); Devika et al. (2006); Balasingh et al. (2008); Rajagopal et al. (2010a) who observed maximum chlorophycean members during monsoon months in their studies with high dissolved oxygen contents. Moreover it was also reported that nutrients like phosphate, nitrate and factors like temperature and rainfall had a significant influence in the distribution of chlorophycean population. The seasonal mean temperature of ponds $V_1$, $V_2$, $K_1$, $K_2$ (2009 – 10) $V_1$, $T_1$ and $A_1$ ponds (2010 – 2011) ranged from 26.5°C to 27.52°C during the study period. This is in agreement with the findings of Hutchinson (1967) and Janjua et al. (2009). It was also revealed that the average temperature, quite satisfactory dissolved oxygen and phosphate concentrations (0.72 to 0.82 mg/L) of the present study was influenced by rain water and surface runoff from the nearby fields may influence the abundant growth of green algal members. The studies of Rani et al. (2004); Ghazvan et al. (2006); Tas and Gonulol (2007); Misra et al. (2009b); Mohan (2009) also support the present findings. Moreover the nutrients of the sediment were also high, which had a vital role in influencing the growth of green algal members as evidenced in Unni (1984); Nandan and Aher (2005).
5.4.2.1a. Species composition of chlorophyta

In the first year of the study period (2009 – 2010) a total of 184 phytoplakton species and in the following year a total of 203 species were documented. Out of this 26 genera with 68 species and 31 genera with 74 species of green algal members under seven orders were recorded (Table 47). Previous studies highlighted that the species composition of green algal members were maximum than other groups. Ida et al. (2004) reported 46 species in which 17 species belonged to chlorophyta. Kiran et al. (2005) observed 17 species of chlorophyta, among the total phytoplankton of 34 species. Balasingh (2003) observed 38 species of chlorophyta, among the 53 algal species in Koothankulam bird sanctuary pond. In 2010, she collected a total of 38 species from a perennial pond in this district and noticed 18 chlorophycean members. Among the seven orders the order chlorococcales occupied the top most position representing 13 genera with 24 species (Table 47) in the first year and 15 genera with 32 species during the second year of study. In both the years the order of occurrence was Chlorococcales > Zygnematales > Ulotrichales > Oedogoniales > Chaetophorales > Cladophorales.

The chlorococcales order represents 10 genera 18 species in V₁, 7 genus 15 species in V₂, in K₁ 8 genus 15 species and K₂ 6 genus and 13 species. In the remaining ponds 13 genus 20 species in T₁ and 6 genus 13 species in T₂ were collected. Likewise A₁ shows 6 genus 11 species and A₂ with 5 genus 10 species were noticed under this order (Table 47). Several researchers reported maximum number of phytoplankton species under the order chlorococcales. Sudeep et al. (2008) in the two lakes of Mysore, Sivakami et al. (2008a) in Ayyakondan channel of Tiruchirapalli, Tiwari and Shukla (2007) in few water bodies at Kanpur have noted the same in their studies. Factors like pH, temperature, light intensity, phosphate and nitrate concentrations were involved in the luxurious growth of chlorophycean members as reported by Wani and Subla, (1990);
Gautant *et al.* (1993); Pandey *et al.* (1994); Tiwari *et al.* (2001); Sedamkar and Angadi (2003); Asmon (2005) in their studies.

The pH values of the temple ponds during the study period fluctuated from a minimum annual mean of 7.11 to 7.79 mg/L in the first year and ranged from 7.38 to 7.59 mg/L which favours the higher growth of chlorococcales in all the ponds and supported by Munawar (1970); Seenayya (1971) and Gahotri *et al.* (1980). The suitable temperature and higher phosphate content of the present investigation may also influences the higher species composition of chlorococcales. Among the ponds V₁ pond was observed with maximum number of chlorococcales which was previously reported by Shamal (2011) in her studies on chlorophyta of Kanyakumari district.

In both the years of observation the second dominant order reported was zygnematales represented by 8 genus 33 species and 9 genus 28 species. The other orders cladophorales, ulotrichales, volvocales chaetophorales and oedogonales were reported with lesser numbers during the period of investigation. A remarkable observation noticed was after rain (September and October months), maximum numbers of chlorophycean members were collected mainly by the fluctuation in the physico-chemical parameters and nutrient concentrations. Similar observations were made by Rana (1991 and 1996); Pundhir and Rana (2002); Chellappa *et al.* (2004); Hosmani and Linganniah (2002); Sanap *et al.* (2008). In A₂ pond the distribution of genus *Cosmarium, Closterium* and *Scenedesmus* were low as the pond shows lesser concentration of calcium and magnesium. Similar findings were pointed out by Murugan and Subramaniyan (2008) in Porur lake. Genus like *Spirogyra, Cosmarium, Oedogonium, Pediastrum, Chlorella,* and *Ankistrodesmus* were abundantly collected from all the ponds. The present findings are in agreement with the reports by Dey *et al.* (2008), Perumal and Anand (2008); Ramanujam
and Singhbood (2009). The percentage frequency of *Ankistrodesmus*, *Crucigenia*, *Scenedesmus* and *Pediastrum* were more during the study period which is involved with the findings of Gharib and Halim (2006) in the lake Nassar. Abundant growth of *Ankistrodesmus* and *Scenedesmus* in the pond A₁ was designated as indicators of organic pollution with high nutrient load as revealed by Biswas and Konar (2001); Rani and Reddy (2004). Among the eight ponds K₂ pond was recorded with more desmids. Genus like *Desmidium*, *Closterium*, and *Cosmarium* indicates better water quality as pointed out by Munawar (1974). In the present study the alkaline nature of the ponds, supported a rich growth of *Pediastrum* and *Zygnema* during monsoon months (June and July) which showed an unpolluted nature in those months as evidenced by the report of Subramani (2007). Mesotrophic nature of V₁, K₁ and K₂ pond during the study period indicated a rich growth of *Closterium* and *Scenedesmus* species (Plate 8 to 15). This observation is in agreement with Chellappa et al. (2008). The eutropic nature of V₂, A₁ and A₂ ponds showed a luxurious growth of the genus *Spirogyra* and *Closterium* (*C. acerosum*) and this is also evidenced by the similar findings of Bajpai and Agarkar (1997) and Adesalu and Nwanko (2008). During the study period the genus *Closterium* contributed 14 species as the highest and the order of distribution was *Closterium* > *Scenedesmus* > *Pediastrum* > *Cosmarium* and the remaining genus were reported with less number of species and similar studies were made by Arulmurugan et al., 2010 in the temple tanks of Kerala.

In the present investigation the genus *Closterium* was noticed with 14 species, *Cosmarium* with 8 species, *Scenedesmus* and *Pediastrum* by 11 and 9 species respectively which remains as a remarkable feature. Similar findings were made by Mahajan and Nandan (2008) from the freshwater environment of Maharashtra with 10 species of *Closterium*, 14 species of *Cosmarium*, 5 species of *Scenedesmus* and 6 species of *Pediastrum*. Desh et al. (2010) pointed out 10 species of *Closterium*, 14 species of
*Cosmarium, Pediastrum* with 6 species and 5 species to *Scenedesmus* from the freshwater ecosystems of North Eastern Ghats. Geetha and Kerkar (2009) reported 11 species of *Closterium* and 17 species of *Cosmarium* in their studies. Ramanujam and Siangbood (2009) reported 9 species of *Cosmarium*, 11 species by Perumal and Anand (2008) in their studies. Sanap et al. (2008) and Deshmukh and Gundle (2007) observed 12 species of *Scenedesmus* from Nashik and Maharashtra region. The genus *Pediastrum* was also reported with several species. Umamaheswari (2011) and Shamal (2011) has reported 7 and 9 species in their studies. Panikkar et al. (2012) also reported 14 species of *Scenedesmus* and 12 species of *Pediastrum* from the freshwater environment of Kerala.

In this district most of the temples are surrounding by agriculture fields. The nutrients from the field enriched the chlorophycean distribution of the study ponds, as evidenced by the reports of Jones and Knowlton (1993); Allyson et al. (2005). The ecological status, water quality and less polluted nature of the ponds were determined by the highest percentage frequency of *Spirogyra* and *Mougeotia* as suggested by Verma and Mohanty (1995) and Shah (2000) in their studies.

In the present observation the members of Chlorophyta and Bacilliophyta showed maximum percentage in two ponds each during the year 2009 – 2010. But in the following year maximum percentage of Cyanophyta and Chlorophyta were noticed from three ponds each and two ponds were dominated by the members of Bacillariophyta. Euglenophyta was reported with lesser percentage contribution in all the eight ponds.

5.4.2.2. Bacillariophyta (Diatoms)

Diatoms the Bacillariophyceae are the major group of eukaryotic algae found in marine, freshwater, habitats as well as in moist soils, rock surfaces and other subaerial situations. They are considered as one of the fundamental players in the physical and
biochemical processes that characterize the ecosystem thereby playing a significant role in earth’s bio-geochemistry (Graham and Wilcox, 2000). Diatoms include a large number of unicellular and colonial genera which differ from other algae in the shape of their cells. The main feature is the presence of highly silicified cell wall which is composed of two overlapping valves.

A great fluctuation in their cell density was recorded in the present study, the ponds T<sub>2</sub> and A<sub>1</sub> contributed 51.95 and 39.85 percentage as maximum in the year 2009 – 10 and 45.78 and 57.95% was observed as the highest in K<sub>1</sub> and T<sub>2</sub> ponds during the year 2010 – 2011. Similar findings of higher percentage of diatom population was reported by Sivakumar and Senthilkumar (2007); Rout and Borah (2009); Ramadosu and Sivakumar (2010). Kavitha and Balasingh (2007) also found higher contribution of diatom population in a sacred grove pond of this district.

In the present observation Bacillariophyta occupied the top most position in T<sub>2</sub> (2009 – 2010), K<sub>1</sub> and T<sub>2</sub> ponds (2010 – 2011) of this district and showed great seasonal variation in their distribution. Among the eight ponds except V<sub>2</sub>, K<sub>1</sub> and T<sub>2</sub> remaining ponds showed higher mean values during non-monsoon and southwest monsoon season T<sub>2</sub> and A<sub>1</sub> ponds during the study periods (Tables 41 and 42).

Statistical analysis by two way ANOVA also evidenced the influence of seasons on diatom population (Table 44). Correlation studies reported a significant positive correlation with temperature, pH, phosphate and nitrate contents in most of the ponds. Seasonal fluctuation registered maximum in non-monsoon months. The present observation is in agreement with the reports of Jawale and Patil (2009); Bhagat et al. (2009); Jadhav and Chavan (2009); Pareek et al. (2011) in their studies on freshwater environment. Maximum bacillariophycean population during rainy season of the present
investigation is also evidenced by the observations of Velecha and Bhatnagar (1988); Tripathy and Pandey (1990); Kulshrestha and Joshi (1991); Dubey and Boswal (2009) in their studies on diversity of phytoplankton. A number of factors influence the distribution of diatoms in water body such as change in water temperature (Jayaraman et al., 2003 and Kumar et al., 2005), alkaline pH (Ravikumar et al., 2006; Padhi et al., 2010; Christi et al., 2011), nitrate and phosphate (Kumari et al., 2007 and Bhattacharya et al., 2011), dissolved oxygen content (Jose and Patel 1991; Chitra and Meera, 2004) of the water bodies which becomes more conducive for the growth of diatoms in the present observation is evidenced by the above factors.

5.4.2.2a. Species composition of Bacillariophyta

In the year 2009 – 2011 the Bacillariophytes were recorded with 21 genera 62 species and in the following year 22 genera 67 species under the order centrals and pennenales were collected and presented in tables 47 and 48. The present observation is in agreement with the findings of 22 genus 24 species by Mishra (2007), 21 genus 42 species by Murugesan and Sivasubramanan (2008a) 58 taxa of diatoms by Suryavanshi et al. (2009) from the freshwater bodies in Ahmed region (MS) India, 29 taxa in a temple pond at Assam by Baruah and Kakati (2009), 48 species by Bhosale et al. (2010a), and 21 genus with 22 species by Padhi et al. (2010) from the freshwater systems of Maharastra and Orissa.

In the two years of study the genus Navicula was found abundantly with 14 species, Nitzschia with 9 species, Gomphonema with 7 species, Fragilaria and Pinnularia with 6 species each. Similar findings were reported by several researchers. Ramanujam and Siangbood (2009) have reported 13 species of Navicula and 24 species by Bhattacharya et al. (2011) from Kolcatha city. From the 4 lakes of Satara district,
Maharashtra Bhosale et al. (2010b) reported 10 species of *Navicula*, 11 species of *Nitzschia*, 6 species of *Cymbella* and 5 species of *Pinnularia*. The percentage frequency of *Fragilaria* was maximum of 1.90 and 1.3 and *Surirella elegans* with lowest percentage frequency (Table 47 and 48). Luxurious growth of *Navicula* and *Nitzschia* species reported the eutrophic nature of the ponds T2 and A1. This is also evidenced by the reports of Bhattachariya et al. (2011). Garib and Halim (2006) has pointed out that Ministry of Science and Technology (1994) has announced the genus *Cyclotella* and *Melosira* as bio-indicators of Oligo-mesotrophic nature of freshwater environments and the ponds with higher contribution of diatoms were used to indicate the good water quality (Hill et al., 2000b). The present study showed higher contribution of diatom population in T2 (2009 – 2010), K1 and T2 (2010 – 2011). The ponds were without any weeds, kept clean and not used for any domestic purposes which may be the reason for its abundant growth. The selected diatom members from the temple ponds are shown in plate 16 to 19.

### 5.4.2.3. Cyanophyta (Blue green algae)

The third groups of phytoplankton observed from the experimental ponds were cyanophyta or blue green algae or myxophyta or cyanobacteria. This is the most diverse and widely distributed group of algae in which the pigments are localized in the peripheral portion of the protoplast and include chlorophyll a, carotene, distinctive xanthophyll, blue pigment (C – Phycocyanin) and a red pigment (C – Phycoerythrin). Another unique feature of cyanophyceae is the primitive type of nucleus, which lack nucleolus, and membrane. These algae can tolerate high range of temperature and form the dominant group in the present study (Selvakumar and Sundararaman, 2009; Verma et al., 2011).
In the first year of the study period, the ponds $T_1$ and $A_2$ contributed maximum of 43.56 and 56.67% of blue green algae (Fig. 64). However in the second year the ponds $V_2$, $K_2$ and $A_2$ showed maximum of 47.28, 40.66 and 52.23% percentages than the remaining ponds (Fig. 65). The higher percentage of cyanobacteria of the present investigation is in agreement with Tiwari et al. (1996); Rani and Reddy (2004); Susheela and Toppo (2006); Muthukumar et al. (2007); Sivakami et al. (2008b); Gehlot and Barupal (2010); Chakraborty et al. (2010). It is well known that the members of Cyanophyta dominate among the phytoplankton of the ponds as a result of ample sunlight, high pH, TDS, DO, phosphate and nitrate (Thajuddin et al., 2002; Naik et al., 2005; Ansari et al., 2008; Neelam et al., 2009; Joseph, 2012).

Seasonal studies of the present investigation showed higher mean values during non-monsoon in most of the ponds and $T_1$ and $A_1$ contributed maximum Cyanophycean members during southwest monsoon (Tables 41 and 42). Many researchers have reported maximum contribution of Cyanophycean members during non-monsoon months (Sahib 2004; Kavitha, 2006; Grover and Chrzanowski, 2006; Ranjan et al., 2007; Khanna and Yadav, 2009).

Analysis of two way ANOVA also indicated the influence of season in the abundance of cyanophycean members. Correlation analysis also revealed the significant positive relationship with pH, temperature and nutrient concentrations. pH is an important factor in determining the abundance of cyanobacteria and the favourable range of 6.7 to 7.8 indicates luxurious growth of this group. The maximum annual mean pH reported in the ponds with highest percentage of bluegreen was 7.4 to 7.9. Such similarities were noticed by Healey (1982) and Kirsten and Arnald (1993). Kumari et al. (2007) also reported positive correlation with pH in her studies. The rich diversity was
also favoured by ample sunshine with optimum temperature (27°C – 28.5°C) of the ponds. This is also in agreement with the observations of Menawar (1974); Singh (1979); Wilkuzhiak (1998); Divedy and Pandey (2002); Chellappa et al. (2008). In the present study cyanophyceae showed significant correlation with temperature in both the years and similar observation was made by Ganai et al. (2010a). It was also evident from the study that biological oxygen demand favours the growth of cyanobacteria and showed significant positive correlation (Tables 39 and 40) at 5% level. Similar findings were made by Boominathan (2005) and Vijayakumar et al. (2005).

Observations in the annual mean values of alkalinity in ponds (A2, T1, V2 and K2) showed a range of 71.8 ± 23.68 to 110.17 ± 26.78 mg/L (Table 3 and 4) which favours a rich diversity of cyanobacteria as suggested by Jackson (1971) who pointed out a suitable range of alkalinity 50 to 110 mg/L.

A rich concentration of nutrients mainly phosphate and nitrate influences the growth of Cyanobacteria. Many researches reported the importance of phosphate on the growth of Cyanobacteria (Harilal, 2005; Anand, 1998; Chellapa et al., 2004). Smith (1983) suggested the role of phosphate and nitrate as pre-requisite elements for the abundance of cyanobacteria. The importance of nitrate was emphasized by Lannineer et al. (1982); Hentry et al. (1984); Venu et al. (1984); Ashokkumar and Singh (2000); Naik et al. (2005).

Luxurious growth of cyanophycean members during non-monsoon season was mainly due to the rich nutrient sources of the ponds, influenced greatly by the leaching process of fertilizers from the nearby agriculture field that affect the growth of population (Hujare, 2008b; Karibasappa et al., 2009). Reynolds and Walshy (1975) found the optimum temperature for cyanophycean growth as 25 – 30°C. In the present study during
non-monsoon and southwest season the temperature was noticed below 30°C and above
25°C which was favourable for the high production of cyanophycean members. It agrees
with the observations of Nandan and Patel (1984); Bhatt et al. (1999); Murugesan and
Sivasubramaniyan (2008b). In the northeast monsoon season by the influence of rain, the
volume of the pond water has increased and this may be the reason for the lower
population of cyanophycean members.

5.4.2.3a. Species composition of Cyanophyta

During the period of investigation 18 genera 41 species and 17 genera 47 species
were reported under five orders. Chroococcales and Oscillatoriales were represented by
more genus (Plate 5 to 7). The dominant order chroococcales of the present investigation
showed maximum contribution of species during the study periods (Tables 47 and 48).
Such higher contribution of species were reported by Srivastava (2006); Joseph and
Balasingh (2009a); Joseph (2012) in the ponds of Kanyakumari district. Among the 18
genera of cyanophycean members, Oscillatoria ranked first with thirteen species and the
genus Microcystis was observed with six species in the study periods. The percentage
frequency of Microcystis aeruginosa was 4.83 and 0.071% and that was the lowest
frequency produced by Synechocystis pevalekii (Table 47). The present observation is
evidenced by the following findings of the researchers. Mishra (2007) has reported five
species of Microcystis and 5 species of Oscillatoria. Patil and Chaugule (2009) observed
7 species of Oscillatoria, 10 species by Ramanjuam and Singhbood (2009), Muthukumar
et al. (2007) found 10 species of Oscillatoria in their studies. The genus Microcystis was
observed with 6 species by Dey and Bastia (2010) and Jain et al. (2011) also collected 5
species of Microcystis in their studies on freshwater systems. Rich nutrient availability
and conducive water quality parameters favour the growth of cyanophycean members
especially the genus *Microcystis* and *Oscillatoria* of the present study is in agreement with the reports of Sivakami *et al.* (2008a) and Lashari *et al.* (2009). The species *Oscillatoria subbrevis, Microcystis aeruginosa, Merismopedia elegans* were abundantly collected in the T₂, A₂ and V₂ ponds of the present observation. These species have also been reported from the eutrophic water bodies (Bajpai and Agarker, 1997; Pundhir and Rana 2002). Gupta and Bhadauraya (2007) indentified *Microcystis aeruginosa, Anabaena, Oscillatoria* and *Spirulina* as indicators of organic pollution while Ahmed (1996); Vareethiah and Haniffa (1998) reported *Microcystis aeruginosa* as indicators of sewage pollution. Species of *Chroococcus, Aphanocapsa, Anabaena, Synechocystis, Phormidium, Nostoc* and *Merismopedia* were collected during monsoon months especially during August – September after rain by the rich availability of nitrates and phosphates (Yusoff *et al.*, 2002; Rodriguez and Osuna, 2003). Members like *Scytonema, Lyngbya* and *Microcystis* were indicators of bad water quality (Devi and Charya, 2007).

**5.4.2.4. Euglenophyceae**

Euglenophycean members were lesser in their distribution and occupied as the last group of the present study. They are free swimming algal flagellates found in a variety of environment with rich organic matters (Verma *et al.*, 2011). In the present observation it was maximum of 3.74 and 4.49% during the study periods (2009 – 2010). Such lower percentage contribution of Euglenophytes were reported earlier by several contributions, 6.38% by Kavitha and Balasingh (2007) 14.28% by Balasingh and Shamal (2007), 5.66% by Balasingh *et al.* (2008) and 4.65% was observed from the studies of Balasingh (2010) from a perennial pond in Kanyakumari district. Desh *et al.* (2010) also pointed out a low percentage (4.29%) in his studies.
Seasonal observation reported higher mean values during southwest monsoon and lower values in the other seasons. Factors like pH, low oxygen content and higher temperature were responsible for its luxurious growth. The higher pH (7.79 and 7.59) low concentrations of dissolved oxygen (4.90 mg/L), higher temperature (28°C) of the (A1) pond have favoured the growth of Euglenophytes in the present observation. This is evidenced by Munawar (1970); Seenayya (1971); Thirugnamoorthy and Selvaraju (2009) in their studies on freshwater ponds. The higher concentration of nitrates in the pond also supported the growth of Euglenoids and it is in agreement with the findings of Munawar (1974). In the present study only four genera were namely *Phacus, Euglena, Trachelomonas* and *Lopocinclis* were collected (Tables 47 and 48). Similar species were contributed from the observations made by Hosmani (2008) from Dharwar, Karnataka. *Euglena* was observed with 6 species in the present observation and this is also similar to the findings of Jasprica *et al.* (2006) who found 4 species of *Euglena* in the freshwater ecosystem (Plate 20).

**5.4.3. Biological indices**

Biological indices offer cheap, fast and effective means of finding the pollution status of waters (Jose and Sreekumar, 2006). It includes species diversity, richness, dominance and evenness that depend upon the distribution of phytoplankton. Several researchers made an attempt to describe the structure of algal community numerically in terms of species diversity (Eloranta, 1976; Poiner and Kennedy, 1984). Diversity indices help to assess and rank the pollution status on species composition (Borowitzcha, 1972).

**5.4.3.1. Species diversity**

Species diversity of phytoplankton depends upon the number of species, distribution and planktonic blooms that occur within the population. In the present
observation among the eight ponds $V_1$ pond was reported with species diversity of 4.87 (November) as maximum against the low value of 0.91 (April) in $T_2$ during the study periods. This may be due to the heavy rainfall of that area, which carries nutrients through runoff from the surrounding the agricultural fields.

Literature cited by several researchers pointed out similar observations (Bose and Gorai, 1993; Mendhe, 1996, Kanungo et al., 2005 and Sivakami et al., 2008b). Higher species diversity indicates a well balanced algal community and representation of several species. It increased with richness and evenness of phytoplankton (Vadrucci et al., 2007; Rajagopal et al., 2010a). Low diversity values of $T_2$ pond was mainly due to the water loss through outlet fast water currents and silting process (Biggs and Close 1989) and this indicates the polluted nature of water (Odum, 1971).

5.4.3.2. Species richness Index

Species richness is a measure of the uniform distribution and its total number of individuals among taxa, a phenomenon common to suitable systems (Leghari et al., 1999; Kanagasabapathi and Rajan, 2010). The values were high in $V_1$ pond (4.81) during December and low (1.25 in $A_1$) in June. Higher values were related with heavy rainfall (Hosmani and Bharathi, 1980) and also evidenced the tolerance of species under moderate stress (Hill et al., 2000a).

5.4.3.3. Species evenness index

Evenness index indicated the equal distribution and complexity of all the species in an ecosystem (Khanna and Yadav, 2009). Higher values were reported during non-monsoon (April) with 0.63 in $K_1$ pond and lower value of 0.61 in December ($A_2$) month of the study periods. Similar findings were reported by Burchardt et al. (2006). Evenness indices coincide with species diversity (Jony, 1976). High values resulted in April month
of the present study indicates the level of pollution in the particular month as the water level of the pond remains low and maximum contribution of *Microcystis aeruginosa* was collected. It is supported from the findings of Joseph (2012). Monitoring and conservations are essential phenomenon of the freshwater ecosystem and indices like species diversity, richness, evenness and dominance were used and discussed by many researchers (Ho and Peng, 1997; Stewart, 1999; Hill *et al.*, 2000a). As Venkateswarlu (1981) pointed out pollution load of any aquatic ecosystem will be assessed using diversity index as a reliable index in biomonitoring process.

### 5.4.3.4. Dominance Index

Dominance index refers to the number of dominant species of the community (Whittakar, 1965). In the present observation higher values were reported during monsoon month in most of the ponds (K1, T1, T2, A2 etc.) and this may be affected by the rich nutrient sources of the ponds.

### 5.4.4. Eutrophication and Algal Bloom

The physico-chemical changes in the environment may accept particular species and induce the growth and abundance of other species which leads to succession. Low diversity of cyanobacteria was attributed to a massive bloom of *Microcystis aeruginosa* in pond V2, which causes severe nuisance because of visual appearance and production of toxin (Carmichael, 1994) with unpleasant odour produced by substances such as geosmin (Juttner, 1987). *Microcystis* is one of the dominant organisms in the present freshwater system which are exposed to constant sunshine water with low salinity and nitrogenous nutrients as evidenced by Frankelin (1972); Paerl *et al.* (1984); Paerl (1991); Rani and Reddy (2004); Vasconcelos *et al.* (1996); Chaudhary and Meena (2007) observed *Microcystis aeruginosa* blooms in their studies. In a lake at Mysore Joseph and
Yamakanamardi (2011) have reported *Microcystis aeruginosa* bloom throughout the year. Vijayvergia (2012) have also reported heavy blooms of *Microcystis aeruginosa* in Udaisagar lake at Udaipur. In the present study *Oscillatoria* was collected throughout the study period. *Oscillatoria princeps* and *Merismopedia elegans* also produced blooms in A2 pond and the present investigation (Plate 21) is evidenced by Massaut (1999); Yusoff et al. (2002); Rodriguez and Osuna (2003); Shamal and Balasingh (2007). *Scenedesmus quadricauda* blooms (during March 2009) were noted in pond T1 and this is in agreement with the report of Tiwari and Shukla (2007). *Oscillatoria* and *Microcystis* blooms indicated the presence of organic pollution (Jackson, 1998; Olaleye and Adedeji, 2005; Periyanayagi et al., 2007 and Ansari et al., 2008) and eutrophicated nature of ponds (Jose et al., 2008).

Phytoplankton encountered in the water bodies reflected the ecological condition of the freshwater bodies and hence used as biological indicators in water quality assessment (Hill et al., 2000b). Diatom genera like *Navicula, Nitzschia, Fragilaria, Synedra* and *Gomphonema* of the present study was referred as pollution tolerant species (Rajendran et al., 1990). Blue green algae such as *Oscillatoria, Microcystis, Chroococcus* and Euglenophycean members such as *Phacus* and *Trachelomonas* were reported as pollution indicators (Palmer, 1969). Devi and Charya (2007) reported that members like *Lyngbya* and *Microcystis* were the indicators of bad water quality. Water with *Spirogyra, Staurastrum, Euastrum, Zygnema* and *Pediastrum* reflected the better quality of water (Subramani, 2007).

The rich diversity of the present study is evidenced by the result of various factors such as decreased nutrient fluxes and low biomass (Revelante and Gillmartin, 1980), a clear environment (Roslin and Lazarus, 1998) and the impact of water currents on
phytoplankton distribution. The dominant distribution of green algae and diatom population in the temple ponds ($K_1$ and $T_2$) indicate better water quality and most of the ponds remain unpolluted.

The different algal groups have gained much importance in the modern biotechnology. Several green algae like $Chlorococcum$, $Chlorella$, $Scenedesmus$, were used as good sources of vitamin yielders, source of protein, contributor of oxygen, bio fuels etc. (Srivastava, 2010) and to-day serves as Green gold. Cyanophycean members constitute as suitable potential source with biotechnological interest as bio-fertilizers ($Oscillatoria$, $Nostoc$, $Anabaena$, $Scytonema$ etc.), protein yielders ($Spirulina$), antimicrobial studies and in several bioremediation techniques (Zaccaro et al., 2010; George and Namashivayam, 2012). The diatoms like ($Navicula$, $Nitzschia$, $Cyclotella$ and $Amphora$) are used as feed in aquaculture field (Balasingh, 2003). The minor group Euglenophyta is used to assess the pollution status (Chaudary and Meena, 2007).

From this study it can be concluded that the temple ponds of Kanyakumari district have a great diversity with several algal taxa indicating the economically valuable resources which can be used in the field of biotechnology and the phytoplankton encountered in the water body may reflect the ecological status of the freshwater environment.
6. SUMMARY

Freshwater ecosystem helps in recycling of nutrients and assessment of water quality is essential and a vital phenomenon for human welfare. Among the several freshwater resources, ponds are formed naturally or constructed with high productivity. Unfortunately day by day due to the rapid growth of human population, industrialization and urbanization most of the freshwater ecosystems including the temple ponds become polluted. In this district most of the temples are provided with ponds and named as temple ponds. They may be inside or outside the temples and water from these ponds are used mainly by the devotees for washing the idols. Like the other perennial and ephemeral ponds of this district temple ponds are also used for domestic purposes. A remarkable feature of the pond is the absence of aquatic weeds. Understanding the quality of water and the diversity studies of temple ponds in this district remains a wide gap. Hence the present investigation is aimed at investigating the qualities of water, sediment, productivity nature and phytoplankton diversity for a period of two years from January 2009 to February 2011 in eight selected ponds of this district.

Water samples were collected monthly from the eight selected temple ponds (V\textsubscript{1} to A\textsubscript{2}) and factors like pH, temperature, dissolved oxygen, biological oxygen demand, total dissolved solids, CO\textsubscript{2}, alkalinity, chloride, calcium, magnesium, sodium, potassium, sulphate, nitrate and phosphate were estimated using standard procedures.

A major factor that determines the functioning of freshwater ecosystem is temperature which is a catalyst, an activator and a controller. It ranged from 21.6\textdegree C (T\textsubscript{1}) to 30.7\textdegree C (A\textsubscript{2}). Higher mean values were observed during non-monsoon season in all the ponds mainly caused by greater solar radiation, low water level and clear atmosphere. pH is another essential factor that reflects the pollution status. It ranged from 6.11 (K\textsubscript{1}) to the