CHAPTER - 1

Introduction

A necessary feature of sustainable development is to take care of the planet, protect the environment and make proper use of natural resources (Mansourri *et al.*, 2016). Lakes are important ecosystems that provide various services, and stress factors such as eutrophication and climate change threaten their ecological functions (Dornhofer *et al.*, 2016). Ponds, lakes and reservoirs constitute 65% of freshwater ecosystems worldwide and are regarded as vulnerable globally (Tan *et al.*, 2015). Anthropogenic activities degrade freshwater ecosystems thereby affecting ecological integrity and functioning, and subsequently their use for domestic, industrial and agricultural purposes (Venkatachalapathy and Karthikeyan, 2015). Lakes supply water for irrigation, drinking, fisheries, recreation, thus has significant economic and recreational value. Water provides shelter, oxygen, food, nutrients and all other necessary requirements for the growth and maintenance of aquatic communities. In limnetic ecosystems, water quality depends upon physical, chemical, and biological factors (Upadhyay *et al.*, 2012). The quality alters with seasonal variations in temperature, amount of rainfall, transformation and accumulation of biotic matter and agricultural residues (Barman *et al.*, 2015). Water quality has a direct influence on the type and distribution of community. Excessive changes in water quality may threaten the community structure as well as lead to loss of valuable biodiversity. Aquatic resources possess enormous potential to contribute towards remediation of polluted waters (Goswami *et al.*, 2012).

Availability of good quality water is an indispensable feature for preventing disease and improving quality of life. Deterioration in water quality is known to affect human interests directly. Access to safe drinking-water is essential for human health. Thus adequate and potable supply of water must be available to all (WHO, 2011). Suitability of potable water is evaluated using water quality indices (WQI) that serve as tools for management strategies and improvement of water quality. The WQI are numeric expressions used to transform large quantities of ecological data related to water quality into a single number that represents the water quality level (Abbasi, 2002). Monitoring of water quality has the highest priority in Environmental Protection Policy (Simeonov *et al.,* 2002) as it helps to control and minimize the incidence of pollutant-oriented problems, and provides water of appropriate quality for drinking, irrigation, recreation and industry. Traditional approaches to assess water quality are based on a comparison of certain experimentally determined parameters with existing guidelines (Debels *et al.*, 2005). Water Quality Index provides a tool for simplifying the report of water quality data (Liou *et al.,* 2003). The index ranges from 0 to 100 and is widely used to solve problems pertaining to data management. It is also used to evaluate successes and failures in management strategies for improving water quality. A large number of effective indices have been developed to assess water quality data that can be communicated to the general public (Salmoni *et al.*, 2011). The need for clean water is considered as one of the biggest problems of the global environment (Xhelal *et al.*, 2014).

Water quality assessment involves the analysis of physico-chemical, biological and microbiological parameters that reflect the biotic and abiotic status of the ecosystem (Verma *et al.,* 2012). Parameters such as temperature, turbidity, nutrients, hardness, alkalinity, DO are some of the important factors that determine the growth of living organisms in aquatic ecosystems and provide valuable information on water quality (Smitha *et al.*, 2013; Khare and Shukla, 2013). These properties of water help in identification of sources of pollution, for conducting further investigations on the eco-biological impacts and also for initiating necessary steps for remedial actions in case of polluted water bodies (Ekwenye *et al.,* 2008). Over the years discharge of urban, industrial, and agricultural wastes has added the quantum of various harmful chemicals to the water bodies considerably altering their inherent physico-chemical characteristics (Kim *et al.*, 2001). The alteration in physico-chemical parameters leading to eutrophication has become a widely recognized problem of water quality deterioration (Jayakumar *et al.*, 2009). The monitoring of quality in such surface waters by estimating physico-chemical parameters is among the major environmental priorities, as it permits direct assessment of the status of ecosystems that are exposed to deleterious anthropogenic factors (Vandysh, 2004; Kalyoncu and Serbetci, 2013). In the past 50 years, a considerable literature is available to identify impacts and sources of increased nutrient levels on the quality of receiving waters (Smith, 2003).

Ecological studies have shown that chemical measurement reflects water quality at a given time while biological assessment reflects conditions that have existed in a given environment over a long period of time (Odiete *et al.*, 2003). The health of lakes and their biological diversity are directly related to health of almost every component of the ecosystem (Kumar *et al.*, 2011).

Planet earth is endowed with a rich variety of life forms. Water is the principal medium for living beings and the teaming millions of living organisms are the first life forms originated in water (Wetzel, 1995). Aquatic ecosystems are the one of the diverse ecosystems in the world. Water is considered as a universal solvent as it has the ability to dissolve many organic and inorganic compounds (Qureshimatva and Solanki, 2015). The quality of water generally refers to the component of water present at the optimum level that is suitable for the growth of aquatic plants and animals. Aquatic organisms need a healthy environment to live and adequate nutrients for their growth. The productivity of aquatic ecosystem depends on the physico-chemical characteristics of the water body (Agbaire and Obi, 2009). It can be obtained in aquatic ecosystem only when the physico-chemical parameters are present at optimum level (Verma *et al.*, 2012). Phytoplankton communities are widely distributed in aquatic as well as terrestrial ecosystems. In aquatic ecosystems phytoplankton forms the first ring of food chain, affecting the efficiency of this environment (Ozedon, 2013). Phytoplankton composition is a trophic indication of the water mass. In addition, phytoplankton species are used as an indicator for determining the nutrient level which is the basis for preparing and monitoring the strategies towards lake management (Buzzi, 2002). In modern times, phytoplanktons are important as a means of controlling pollution in aquatic ecosystem, bio-fertilizers for crops, in sewage treatment and in purification of eutrophic waters (Kumar *et al.*, 2011). These organisms are very sensitive to the aquatic environment in which they live and any change in the properties of water can cause alteration in their community structure and functioning (Jafri and Gunale, 2006). Therefore, studies on phytoplankton populations serve as a reliable tool in biomonitoring to assess the pollution status of aquatic water bodies (Mathivanan *et al.*, 2007). Among phytoplanktons, diatoms are potential indicators of water quality due to their sensitivity and strong response to physico-chemical and biological changes (Suphan *et al.*, 2012). Fluctuation of diatom species to various environmental changes can be an early indication of freshwater ecological problems and hence small changes in water quality make diatoms very powerful indicators of pollution (Van Dam *et al.*, 1994).

Water is an essential natural resource for sustaining life and is likely to become critically scarce in the coming decades due to continuous increase in demand by a rapidly increasing population and expanding economy of the any nation (Sridhar *et al.*, 2006). Greater emphasis is being laid on its economic use and better management. Unplanned management has resulted in tremendous disarray development of industry, agriculture and disposal of untreated public sewage water, and other human and animal wastes into rivers, lakes and reservoirs. Thus there is a continuous deterioration of water quality and biotic resources (Elmaci *et al.*, 2008).

Hydrobiological study is a pre-requisite in any aquatic system for assessing its potentialities and to understand the differences between trophic levels and food webs. Furthermore, environmental conditions such as topography, water movement, oxygen, temperature and nutrients that characterize particular water mass also determine its biotic composition. Thus, the nature and distribution of flora and fauna in the aquatic system are mainly controlled by the fluctuations in its physico-chemical characteristics (Vijayakumar and Subramaniyan, 2013). Poor water quality is often associated with increased trophic state which in turn disturbs numerous ecosystem services (Meybeck and Helmer, 1996).

Natural eutrophication is a slow and gradual process, occurring over centuries due to nutrient-rich soil washing into lakes. In contrast, human-induced eutrophication can occur over time frames as short as a decade (Addy and Green, 1996). Although it has taken only six decades for anthropogenic influence to turn many freshwater lakes eutrophic, studies suggest that recovery may take 1000 years, even under the best of circumstances (Carpenter and Lathrop, 2008). There are two sources of eutrophication *viz.*, point and non point sources. The term ‘point source’ refers to any visible confined transportation like a channel, a discrete fissure or pipe, a tank *etc.* from which pollutants are leached. ‘Non-point sources’ are grouped into agricultural and live stock runoff, residential and urban runoff (Carpenter *et al.*, 2011). Runoff, especially from urban and agricultural areas, carries fertilizers, pesticides, sediment and/or industrial effluents when discharged into a water body accelerate eutrophication (Smith *et al.*, 1999). Severe eutrophication, often results in hypoxic conditions, disrupting normal food web and ecosystem processes by creating a dead zone where no animal life can sustain (Smaya, 2008).

In recent years, accumulation of trace metals from natural sources and anthropogenic activities in the aquatic ecosystem has become a major problem throughout the world. These metals may accumulate to toxic levels and can cause severe impact on the aquatic organisms without any visible sign (Giguere *et al.*, 2004). Trace metals occur at very low levels in a given system and are among the most harmful of the elemental pollutants (Lee *et al.*, 2007). Trace elements such as copper (Cu), iron (Fe), chromium (Cr), manganese (Mn), zinc (Zn) and nickel (Ni) are essential metals since these elements play important roles in biological systems, whereas cadmium (Cd) and lead (Pb) are non-essential metals, and are toxic, even in trace amounts (Fernandes *et al.*, 2008). These metals or their compounds discharged from industries, farmlands, municipal urban water runoffs and agricultural activities enter into surface water. Trace Metals may also enter into aquatic system through leaching of rocks, airborne dust, forest fires and vegetation (Fernandez, 2000). Metal pollutants when compared with other aquatic pollutants, are less visible but their effects on the ecosystem and humans are extensive due to their toxicity and ability to accumulate in the aquatic organisms (Edem *et al.*, 2008). Due to slow degradation, metals are continuously being deposited and incorporated in water, sediment and aquatic organisms (Linnik, 2000). During transportation, metals undergo numerous changes due to dissolution, precipitation, sorption and complexation phenomena which affect their bioavailability (Akcay *et al.*, 2003; Nicolau *et al.*, 2006). Thus, contamination with metals may cause devastating effects on the ecological balance of aquatic environments and the diversity of aquatic organisms (Suziki *et al.,* 1988). Metals are bio-concentrated or bio-accumulated in one or several compartments across food webs (Otitoloju and Don-Pedro, 2004).

Metal bio-accumulation can be of importance from the public health point of view, especially for humans at the end of food chain. An important link in the transfer of metals from soil/sediment to man is plants (Lozak *et al.,* 2001). The distribution of metals in sediments can provide evidence of the anthropogenic impact on aquatic ecosystems and therefore aid in assessing the risks associated with discharged waste (Tsai, 2003). The entry of metallic pollutants into a water body, either natural or artificial, can occur in dissolved and particulate form. Depending on physico-chemical conditions, the pollutants in dissolved form can precipitate. Some of the widely used metals include automobiles, mining industries, pesticides, house-hold appliances, dental amalgams, paints, photographic papers and photo chemicals (Hutchinson *et al.,* 1993). Some metals are also essential as micronutrients for life processes in animals and plants. Concentrations of trace elements in water vary due to physiological, environmental and other factors. Bio-accumulation of metals can take place only when the rate of uptake by the organism exceeds the rate of elimination, and may cause cytotoxic, mutagenic and carcinogenic effects in the organism. Measurement of trace metal concentrations in water helps the evaluation of water quality. The concentration of pollutants in an aquatic environment depends upon the chemical composition of sediment as well as the type and amount of absorbed pollutants (Chambers and Prepas, 1994).

Environmentally benign and sustainable biological measures have become attractive options for the *in situ* remediation of polluted surface waters (Wu *et al.,* 2014). The distribution and behaviour of many aquatic macrophytes are often correlated with water quality (Romero and Onaindia, 1995). Detecting environmental pollution by using biological material is a cheap, reliable and simple alternative to the conventional sampling methods (Zurayk *et al.*, 2001). A number of organisms such as mosses, periphyton, fish and vascular plants have been successfully used in remediation of water bodies (Porvari, 1995). Aquatic macrophytes accumulate considerable amounts of heavy metals in their tissues and are proposed as pollution-monitoring organisms (Shine *et al.*, 1998). Metal bio-accumulation depends upon numerous biotic and abiotic factors, such as temperature, pH and dissolved ions in water (Lewander *et al.*, 1996).

Aquatic macrophytes play a role in oxygen production, nutrient cycling, water quality control, and sediment stabilization. These plants play important role in providing habitat and shelter for aquatic life and are considered as efficient heavy metal accumulators. As a result they have been successfully used as biological monitors and remediates of environments contaminated with heavy metals (Vardanyan and Ingole, 2006). Phytoremediation is considered an effective, low cost and preferred clean-up option for moderately contaminated areas. Although the capacity of aquatic macrophytes to accumulate metals is well documented their potential to accumulate heavy metals differs markedly among species (Demirezen and Aksoy, 2004). Uptake and accumulation of elements by plants may follow two different paths, *i.e.* the root system and the foliar surface (Sawidis *et al.*, 2001). Plant species vary in their capability to remove and accumulate heavy metals. Some species may accumulate specific heavy metals, such as the *Spirodela polyrhiza* is known to accumulate Zn (Markert, 1993).

Macrophytes act as good bio-filters by accumulating heavy metals from the surrounding environment and also have the tendency to bio-accumulate heavy metal residues present in water or the sediment stratum. All these released pollutants have a great ecological impact on the water quality and especially on environmental resistance of aquatic macrophytes. According to Ikem *et al.* (2003) sediments are important sinks for various pollutants like heavy metals and play a significant role in the remobilization of contaminants in aquatic systems under favourable conditions and in interactions between water and sediment. Unlike organic pollutants, natural processes of decomposition do not remove heavy metals. Instead they accumulate in aquatic biota and can be converted to organic complexes, which may be even more toxic (Edward *et al.,* 1998).

According to the Indian environmental managers and researchers the condition of freshwater resources in India and their management as a serious environmental problem which includes nutrition enrichment, acidification, domestic and agricultural waste, sewage and industrial effluents (Parashar *et al.,* 2008; Laskar and Susmita, 2009). Almost 70% of surface and ground water reserves in India have been contaminated by biological, organic and inorganic wastes (Shekhar *et al.,* 2008).

Standing water bodies in Goa and in the country in general are used for various activities *viz.,* fishery management, recreation and drinking purpose. There is an urgent need to conserve these water bodies in the interest of mankind for ecological, cultural and touristic purposes. As these water bodies are important in various ways, it is imperative as well as challenging to assess their present status and to study pollution problems associated with them. Despite human interference, freshwater systems have hardly been studied in the state of Goa. In light of this lacuna, present study was initiated in selected water bodies with the following aims and objectives.

Aims and objectives:

1. To survey the sources of eutrophication of water bodies in Goa,
2. To determine physical, chemical and biological characteristics of water body and to identify their trophic status,
3. To study seasonal variations in water quality parameters in the water bodies as affected by pollutants,
4. To survey macrophytes and phytoplanktons from polluted and non polluted water bodies,
5. To analyze trace metals present in water bodies and their accumulation by aquatic macrophytes and
6. To study restoration measures using phytoremediation process in selected water bodies.