CHAPTER - 2

Review of Literature

2.1: General limnology

Water is called elixir of life and its importance was realized way back in 640-546 B.C. Limnology deals with the structural and functional interrelationships of organisms of inland waters as their dynamic physical, chemical, and biotic environments affect them. The pioneering work in limnology was initiated by Forel (1869) on Lake Geneva and published a list of bottom fauna. Hence he is regarded as the '*Father of Modern Limnology*' as he gave an impetus to study this subject intensively. Forbes (1887) worked on Lake Microcosm and described interaction between biota and environmental factors. The above studies laid a firm foundation for Limnology and Hydrobiology. First Fresh Water Biological station was established by Fritsch (1888), to study various lakes, as a result of which limnology flourished in Europe and America. A number of reports are available on Limnobiotic studies of water. Different physico-chemical parameters of surface water yielded useful data towards understanding of the nature of water environment and the changes that occur due to intense human interference. Broad based ecological assessment of fresh water ecosystems with interdisciplinary approach has been followed by many limnologists. Literature on ecology of fresh water systems is available in the reviews (Alley, 1949; Hutchinson, 1957). In India limnological studies were initiated in 1930's. Extensive work has been carried on fresh water reservoirs (Pruthi, 1933; Iyangar, 1940; Bhardwaja, 1940; Gonsalves and Joshi, 1946; Rao, 1953; Gulati ans Wurtz, 1980).

In recent years, increase in human population, demand for food, land conversion, and use of fertilizer have led to faster degradation of many freshwater resources (Jayakumar *et al.*, 2009; Venkata Subba, 2012). Urban, industrial, and agricultural wastes have altered physico-chemical characteristics of water bodies (Kim *et al.*, 2001). The monitoring of quality of such surface waters by estimating physico-chemical parameters is among the major environmental priorities (Vandysh, 2004).

2.2: Physico chemical and diversity studies

Victor Hensen's discovery of plankton in 1887 opened up a new vista in the field of limnology. West and West (1907), Hodgetts (1921) and Pearsall (1921) published a detailed account of the factors controlling the periodicity of fresh water algae. Storm (1924), Howland and Lucy (1931) and Yoshimura (1932) studied several fresh water lakes with respect to various parameters and distribution of phytoplanktons. Fritsch and Rich (1937) recorded 14 new species and 25 new varieties of desmids, from Belfast Pan in Pretoria, among which unicellular forms were present in abundance, while filamentous forms were relatively scarce. Objectionable phytoplanktons and their control in lakes were dealt by Prescott (1938) and reported that nitrates, phosphates, oxidizable organic matter and pH were responsible for their distribution. Bailey (1938) studied the ecology of phytoplankton of Lake Michigan and reported that the diatoms showed considerable seasonal variation especially *Synedra*. Gonzalves and Joshi (1946) worked on the seasonal occurrence of algae in a tank at Bandra, Mumbai and recorded four new taxa. Patrick (1948) studied the factors affecting distribution of diatoms and reported that the chemical and physical analyses of the sediments corresponded with the changes indicated by diatom communities. Thresh *et al.* (1949) analyzed chloride of surface waters and attributed its higher amounts to chloride to pollution. Krishnamurthy (1954) worked on the diatomic flora of south Indian lakes and recorded four new diatoms species. Gandhi (1955) studied and identified various species of fresh water diatoms *viz., Achnanthes elata, Achnanthes fasciata, Ceratoneis iyengarii, Cymbella powaiana, Diploneis subsmithii* and *Eunotia cholnokyi* from Pratabgad, Rajastan. Singh

(1960) recorded the phytoplankton ecology of inland waters of Uttar Pradesh and attributed high percentage of Euglenophyceae to high amount of carbon di-oxide. George (1966) made a comparative study of phytoplankton ecology of fish tanks from Delhi and reported that compared to temperate waters, the tanks in Delhi showed richer variety of organisms. The largest number of genera was noted among the green algae. Desmids were poorly represented in the tanks. Munnawar and Zafar (1967) studied the distributional pattern of phytoplanktons of polluted and unpolluted lakes of Hyderabad and pointed out the importance of chemical parameters and their impact on algal growth. Bharathi and Hosmani (1973) made an extensive survey of hydrobiology of ponds and lakes of Dharwad and observed that heavily polluted ponds showed decreased production during summer, and recorded different species of algae that appeared as blooms. Dellon and Rigler (1975) studied correlation between total N, P and phytoplanktons and concluded that these two nutrients were important for algal blooms. Bharathi and Hosmani (1976) studied and reported that increased P, Ca, low pH and high degree of organic pollution accelerated the bloom of Cyanophyceae. Singh and Swamp (1979) studied Lake Surah (Ballia) with special reference to the periodicity of sewage contamination on fresh water ecosystems. The Central Amazon Lakes were analyzed for physico-chemical and microbiological parameters by Rai and Hill (1982) and classified them as oligotrophic and eutrophic, based on the bacterial density, electrical conductivity, pH, dissolved, oxygen, silica and P content. Koschel *et al.* (1983) while studying Lake Breiber in Germany pointed out that calcite precipitation decreases the phytoplankton population DO and total phosphates. Raina *et al.* (1984) pointed out that nutrients like nitrates and phosphates play an important role in determining the trophic status of water bodies. Zutshi *et al.* (1984) revealed that low DO in Dal Lake was related to enhance microbial activity and increased rate of decomposition. Chtranshi and Bilgram (1986) investigated lentic ecosystems stressing importance of physico-chemical parameters in relation to the distribution pattern of phytoplanktons. Singh and Mahajan (1987) investigated the primary production in Ox-bow Lake and recorded that high temperature coupled with higher concentrations of P enhanced the rate of reproduction of *Microcystis aeruginosa*.

Puttaiah and Somasheker (1987) observed that high concentrations of carbon dioxide and low concentrations of oxygen significantly contributed to the abundance of Euglenoids in fresh waters of Mysore. Kurata and Yuji (1987) studied seasonal changes of various physico-chemical parameters in Lake Notoro, in Japan. The relationship between phytoplankton density in fish ponds and the level of DO at dawn was demonstrated by Daniel and Piedrahita (1988). Their study suggested that aqua culturists can raise DO levels by increasing algal biomass and not by reducing it.

Ikommikov (1990) observed that Ladoge Lake in Russia was polluted due to increased discharge of toxic substances that caused water quality deterioration, changes in species composition and other deleterious effects on the aquatic ecosystem.

Goel *et al.* (1994) reported that P and N ratio enhances the growth of blue green algae. Shaji and Patel (1994) highlighted phytoplankton ecology of a polluted pond at Anand in Gujarat and stressed that the physico-chemical parameters were responsible for increasing the phytoplankton populations. Boris *et al.* (1996) reported toxicity of Cyanobacterial blooms in Lake Lodoga formed by *Anabaena circinalis, A. flosaquae, A. lemmemani, Gleotrichia cichimilata and Microcystis aeruginosa*. Takans and Hino (1997) opined that high temperature promoted growth of diatoms in a hypertrophic Lake Barato in Japan. The importance of P in eutrophication of fresh waters and production of abundant phytoplanktons mainly by Cyanophyceae members was discussed by Correl (1998).

According to the study of Yoh *et al.* (1999) to succeed in combating Lake Eutrophication, cooperation of local inhabitants, small factories and farmers in reducing P discharge is essential. But the willingness of each one to cooperate would depend on the cooperation of other members and on the level of environmental concern of the society in general. They observed that the lake pollution increases with the total P released due to any of the above activities, and results in high pollution level in the lake. They reported that, with a greater cooperation among the people the water can remain clean.

Frank *et al.* (1999) studied the medium shallow Lake Grimnitzsee in Germany and characterized the lake as eutrophic. The Lake was restored by fast recovery of silicon concentration in the water column after diatom sedimentation, the re-suspension of planktonic diatom populations was implemented, after which there was moderate correlation between chlorophyll a concentration and light attenuation. Borse and Bhave (2000) analyzed dissolved carbon dioxide from a lake near Jalgaon and reported that it was maximum in summer and minimum in winter and was dependent on carbonates and bicarbonate levels in the water. They also observed that carbon dioxide and pH of water also had an impact on the water quality.

Nandan *et al.* (2001) studied seasonal fluctuation at Hertala Lake in Jalgaon and reported abundance of blue green algae was due to higher concentration of dissolved carbon dioxide, carbonates, total alkalinity, phosphates and chlorides. Nagarathna and Hosmani (2002) studied the factors influencing the bloom of *Nitzschia obtuse* in a polluted lake in Mysore. Correlation matrix and cluster analysis indicated that most of the physico-chemical parameters were inversely proportional to the growth of diatoms. Nandan and Aher (2005) assessed water quality of Haranbaree Dam in Maharastra using algal communities and recorded pollution tolerant genera like *Navicula, Oscillatoria* and *Euglena*. Mukhopadhyay and Dewanji (2005) investigated relationship between species of hydrophytes and Secchi disc visibility, pH, dissolved oxygen, electrical conductivity, total N, total P and chlorophyll-a concentration in two tropical ponds near Kolkata. They reported that *Alternanthera philoxeroides, Nymphoides hydrophylla, Lemna aequinoctialis,* and *Vallisneria spiralis* were dominant species that were found to subsist over wide amplitude of nutrient levels thereby showing their adaptability to highly eutrophic ecosystems.

Ranjani *et al.* (2007) studied physico-chemical characteristics of Ghariyarwara Pond in Nepal and observed dominance of Chlorophyceae throughout the year and seasonal variations in the other phytoplankton populations. Shiddamallayya and Pratima (2008) studied water quality of tank in Bhalki town of Bidar by analyzing pH, DO, hardness, Mg, chlorine, nitrite, sulphates and chemical oxygen demand. They observed positive co-relation between pH and Mg, DO and hardness. The study revealed that pH, hardness, silicon, total solids and sulphates were key factors that changed the chemistry of the water body.

Boyera *et al.* (2009) studied conditions like circulation, salinity, water quality patterns, sediments and disturbance in nutrients that frequently caused dense phytoplankton blooms of Florida Bay and in turn altered the structure and function of the estuary. Phytoplankton diversity in four lakes of Satara District in Maharashtra was investigated by Bhosale *et al.* (2010). They recorded 68 species of phytoplanktons and 13 species of filamentous algae belonging to Cyanophyceae, Chlorophyceae, Euglenophyceae, Dinophyceae, and Bacillariophyceae.

Suresh *et al.* (2011) studied two fresh water tanks from Davangere district in Karnataka to know the phytoplankton diversity and reported that, Bathi tank had low while Kundavada tank had high diversity of phytoplankton. Verma *et al.* (2011) studied physico-chemical parameters along with phytoplanktons of Kankaria Lake in Gujrat and reported that maximum number of physical and chemical parameters were within the desirable limit of WHO. Ladipo *et al.* (2011) studied the seasonal and spatial distributions of physico-chemical parameters to determine water quality in Lagos Lagoon. The study revealed that strong seasonal variation was the major controlling factor in the lagoon.

Studies of nutrient load and other limnological parameters of Sabke reservoir, Katsina state was analysed by Bala and Bolorunduro (2011). Except transparency, DO, pH, TDS and Nitrate values indicated significant variation between rainy and dry season. Vasanthkumar and Vijaykumar (2011) recorded diurnal variations in physico-chemical parameters of Bheema River and concluded that it is oligotrophic in nature.

Seasonal changes in water quality parameters of a rain fed Lake in Aurangabad were investigated by Smarat *et al.* (2012). They reported that total alkalinity and phosphates were beyond the permissible limits. Water quality and phytoplankton diversity from Gopeswar Temple Pond in Assam, was investigated by Baruah and Kakati (2012). They recorded 45 species of phytoplanktons representing Chlorophyceae, Cyanophyceae, Bacillariophyceae, Euglenophyceae, Chrysophyceae and Dinophyceae members and recorded phytoplankton population peaks in summer and monsoon periods. They also reported the presence of *Microcystis aeruginosa* and *Navicula cryptocephala* throughout the year indicating cultural eutrophication.

Algal flora in Kodaikanal Lake was studied by Singh and Balasingh (2012) and recorded 59 genera and 115 species of phytoplanktons, belonging to Chlorophyceae, Bacillariophyceae, Cyanophyceae, Dinophyceae, Euglenophyceae and Chrysophyceae. Rani and Sivakumar (2012) studied seasonal variations in phytoplankton population in three perennial ponds in Tamil Nadu and revealed that physico-chemical parameters influenced growth of phytoplanktons. Patel and Patel (2012) made a comparative study of the physico-chemical parameters of Lake Lodra and Lake Nardipur in Gujarat. Their study revealed that the both lakes were polluted due to anthropogenic activities.

Chandra *et al.* (2012) assessed drinking water quality of Porur Lake in Chennai, Hussain Sagar Lake in Hyderabad and Vihar Lake in Mumbai for various physico-chemical parameters. They reported that the parameters studied were manifold higher than the prescribed limit by the WHO & BIS standard. Saxena (2012) studied water quality and trophic status of Raipur Reservoir and placed it in meso-eutrophic category. Namdeo *et al.* (2013) made ecological evaluation of the physico-chemical characteristics in Barna Reservoir in Central India. Their study revealed that the ecology of Barna reservoir in different seasons showed dynamism in physico-chemical parameters which is attributed to factors like fertilizers, weathering of rocks and meteorological phenomenon in the catchment area.

Rashmi and Somashekar (2013) recorded phytoplankton diversity of Lakkinakoppa Pond Shivamogga. They reported 54 species of phytoplanktons belonging to the four major classes *viz.*, Bacillariophyceae, Chlorophyceae, Cyanophyceae and

Euglenophyceae that occurred throughout the study period. Ayyanna and Narayudu (2013) carried out hydrological study of fresh water Pond at Kakinada village, of Venkatapuram. The study revealed that the parameters were within permissible limits and the water was found suitable for domestic, irrigational and Pisciculture purpose. Patil *et al.* (2013) analyzed physico-chemical parameters of fresh water reservoir near Khanapur, Maharastra and reported that all the parameters were within permissible limits indicating that the water from reservoir was suitable for drinking and fishing purpose.

Kaparapu and Rao (2013) studied seasonal variations, correlation coefficient and biodiversity indices of phytoplankton of Riwada reservoir, in Andhra Pradesh. They reported 57 genera belonging to Chlorophyceae, Bacillariophyceae, Cyanophyceae and Euglenophyceae. Their study revealed that the reservoir had balanced phytoplankton community. Verma *et al.* (2013) studied physico-chemical parameters of Kankaria Lake in Gujarat and indicated that maximum number of physical and chemical parameters were within the desirable limit. Devi *et al.* (2013) studied limnological status of two temple ponds in Assam and revealed that rainfall, conductivity, water temperature and free carbon dioxide were responsible for variability in the plankton community.

Mahadik and Jadhav (2014) studied algal diversity of Ujani reservoir. They reported 75 species of phytoplanktons belonging to Chlorophyceae, Charophyceae, Bacillariophyceae and Cyanophyceae. Singh (2014) studied seasonal variations in the physico-chemical parameters of Gomti River in Lucknow and reported deteriorating water quality and unsuitability of water for domestic use. According to Hosmani (2014) climatic changes and variations in the physico-chemical constituents of the water are responsible for algal blooms. Mahesh *et al.* (2014) assessed trophic state of Dantaramakki Lake in Mysore using GIS technique and reported that the lake revealed mesotrophic state in February and March, and eutrophic state in April.

2.3: Biomonitoring and Nestedness analysis

Bere and Tundisi, (2010) studied the role of diatoms in the biological monitoring and stated promising future for using diatoms in characterization and monitoring of ecological conditions. Kalyoncu and Serbetci (2013) used OMNIDIA program for estimation of stream quality in Turkey and found that only a few diatom taxa indicated alfa-mesosaprobity and polysaprobity. Hosmani (2013) studied 20 Lakes of southern Karnataka using Palmer's index and reported that all the lakes were organically polluted. Bere *et al.* (2014) tested the applicability of diatom-based water quality assessment indices to urban streams in Zimbabwe and found that diatom indices exhibited consistent classifications and strong correlations with water quality variables.

Kavya and Savitha (2014) used OMNIDIA GB 5.3 software to study the degradation of two Lakes in Mysore. They reported that the diversity of Bacillariophyceae was considerably high in Karanji Lake when compared to Kukkarahalli Lake as a result of anthropogenic pollution. Nautiyal *et al.* (2015) examined the ecological status of epilithic diatom assemblages of Mandakini, a glacier-fed Himalayan river using OMNIDIA GB 5.3 software. The ecological values revealed that the assemblages were in β-mesosaprobic and mésotraphentic states.

Dalu *et al.* (2016) assessed the water quality of a river in Africa using diatom indices calculated by OMNIDIA software and reported non significant correlations between the diatom index values and nutrient concentrations. Venkatachalapathy and Karthikeyan (2016) used diatoms as bio-indicators to assess the water quality of surface waters and concluded that diatom indices can be a reliable tool for environmental impact assessment.

The concept of nestedness was proposed by Hulten (1937) to describe patterns of species composition within arctic and boreal biota. Atmar and Patterson (1993) studied species distribution patterns within habitat and method of identifying idiosyncratic species in a nested community in an archipelago. Matthews (2004) investigated the floras of 56 sedge meadow wetlands in northern Illinois (USA) to find the degree of nestedness in these communities and concluded that the nested pattern was closely related to site. Derek *et al*. (2004) studied whether habitat could produce a subset pattern of community structure and observed that nested subset pattern is a result of an ontogenetic habitat.

Joppa *et al.* (2010) stated that ecological networks are unusually nested when compared with loosely constrained random networks. Soininen *et al.* (2011) analyzed nestedness of diatom communities in freshwaters within a drainage basin in Helsinki and concluded that degree of nestedness was related mainly to water temperature, conductivity, and trophic status of the water, results suggested that habitat quality may be an important predictor of nestedness.

Karthick *et al.* (2011) studied nestedness pattern of stream diatoms in Central Western Ghats and found that the nested pattern by diatom community was highly significant, with high proportion of idiosyncratic and cosmopolitan species.

2.4: Trace metal contamination and accumulation of metals by aquatic macrophytes

Sobczynski and Siepak (2001) reported results of speciation analysis of selected heavy metals in bottom sediment samples from lakes in Wielkopolski National Park in Poland. Results revealed that Zn, Pb, Cd and Mn were found in higher amounts while Fe and Cu did not occur in any of the lakes. Agnieszka (2004) analyzed heavy metals and macronutrients from water, bottom sediments and leaves of *Nymphaea alba* and *Nuphar lutea* sampled from 14 eutrophic lakes in West Poland. The study revealed that the concentrations of macro- and micro-elements in the examined plants differed significantly and were dependent on chemical properties of the water and bottom sediments. The study also revealed that both the plants had the potential to monitor for these metals. Odjegba and Fasidi (2004) reported that *Pistia stratiotes* accumulates Hg and Zn. It was observed the concentration of accumulated metals was higher in root tissue rather than in shoot and concluded that the plant as effective phytoremediator species for the above metals.

Kumar *et al.* (2006) carried out biomonitoring study using 7 species *viz., Bergia odorata, Hydrilla verticillata, Ipomoea aquatica, Najas graminea, Nelumbo nucifera, Phragmites karka* and *Typha angustata* of Nal Sarovar Bird Sanctuary in Gujarat to ascertain the degree of trace element contamination. More accumulation in root was recorded than in the stem or leaves. Positive correlation between combinations of different metal-pairs was observed and the metal concentration varied as Zn> Cu > Ni > Co > Pb > Cd.

Vardanyan and Ingole (2006) analysed 45 macrophytes belonging to 8 families collected from two different physiographic locations *viz.*, Sevan Lake Armenia and

Carambolim Lake, Goa, India. Study revealed that the aquatic macrophytes play a very significant role in removing the different metals from the ambient environments thereby reducing the effect of high concentration of heavy metals from the Lake ecosystem. Sabine *et al.* (2006) reported that the most serious problems caused by eutrophication of shallow lakes in Germany are the disappearance of submerged macrophytes and the switch to a turbid, phytoplankton-dominated state. According to them if the concentration of total P is reduced it would result in increase water clarity. Vestena *et al.* (2007) studied Cd accumulation in *Eichhornia crassipes* and *Salvinia auriculata* and reported that both species were Cd accumulators.

Mishra *et al.* (2008) employed three aquatic plants *viz., Eichhornia crassipes, Lemna minor* and *Spirodela polyrhhiza* for the removal of heavy metals from coal mining effluents. Results revealed that combination of *E. crassipes* and *L. minor* was the most efficient for the removal of heavy metals while *E. crassipes* was the most efficient in monoculture. Translocation factor for metal concentration revealed that metals were largely retained in the roots of aquatic macrophytes. Analytical results showed that plant roots accumulated heavy metals approximately 10 times of its initial concentration present in the effluent. It was also reported that, these plants did not show metal toxicity symptoms when subjected to toxicity assessment therefore found to be suitable in phytoremediation of coal effluents.

Hillermannova *et al.* (2008) compared differences in the accumulation of trace metals by the individual groups of aquatic plants (submerged and emergent) and assessed a possible use of the individual plant species in phytoremediation techniques. Representative samples of water, sediments and aquatic macrophytes were taken from three anthropogenically loaded streams in six monitoring cycles. *Phalaroides* *arundinacea*, *Scirpus silvaticus* and *Rumex aquaticus* were analyzed for metal contents. The results of the research indicated that the accumulation of trace metals in plants was influenced by their ecological group (emergent – submerged). Submerged plants accumulated more amounts of metals as compared to emergent ones.

Dhir (2009) studied the capacity of *Salvinia natans* to accumulate heavy metals, inorganic nutrients, explosives from wastewaters and reported that *Salvinia natans* has properties such as high productivity, high sorption capacity and high metal removal potential and hence can be used in phytoremediation strategies. Abida *et al.* (2009) analyzed heavy metal concentration in water, sediments and fish from Madivala Lake. Heavy metal concentration, in water was in the order Pb > Cr > Cd > Ni, while in sediments it was Pb > Cr > Cd > Ni. The maximum concentration of heavy metals was found in kidney and liver, the order of heavy metal level in various organs is muscle >gills >liver >kidney. The presence of elevated levels of Pb and Cd was a concern as the fish from the Lake was consumed by local residents around the area.

Millaleo *et al.* (2010) stated that Mn is an essential element for plants, intervening in metabolic processes, like photosynthesis and as an enzyme antioxidant-cofactor. Its phytotoxicity is manifested in a reduction of biomass and photosynthesis, and biochemical disorders such as oxidative stress, under low pH and redox potential conditions in the soil. It is also reported that though Mn is an essential micronutrient it is toxic plants when present in higher concentrations. Xi *et al.* (2010) successfully demonstrated the use *Eichhornia crassipes* in treatment of swine waste water for N and P reduction.

Hariprasad and Dayananda (2011) reviewed the research articles pertaining to the uptake of heavy metal by plants through contaminated soil, their accumulation and potential threat to animal and human health. It was reported that the heavy metals in water bodies damage the aquatic organisms. Wei and Guihua (2011) reviewed articles pertaining to Fe as an essential element, its environmental impacts on physiology and ecology of aquatic organisms, sources, speciation, cycle and uptake mechanisms as well as its impact of on physiology and ecology of phytoplankton and aquatic plants in freshwater lakes. Othman *et al.* (2011) found that all six aquatic plant species *viz., Eichhornia crassipes, Hydrilla verticillata, Cabomba fuscata, Salvinia natans, Nelumbo nucifera* and *Pistia stratiotes* showed potential as ecological indicator for unhealthy aquatic ecosystems or as phytoindicator for heavy metal contaminants by accumulating Ar, Cu, Pb and Zn.

Christophe *et al.* (2011) carried out toxic metals assessment of Nokoue Lake by analyzing water and sediments samples and reported that Pb and Ar concentrations were higher. Roy and Kalita (2011) carried out analysis of heavy metals having estrogenic properties from three different sites around Guwahati city and concluded that the estrogenic heavy metal concentration in water was in the order Pb>Cr>Ni>Hg>Cd.

Thilakar *et al.* (2012) used aquatic macrophytes such as *Pistia stratiotes* L. and *Salvinia natans* (L.) in trace metal accumulation and phytoremediation of Cr and Cu contaminated aquatic environment. Their study revealed that both these species are ‘hyperaccumulators’ and can be effectively used in phytoremediation. Nirmal Kumar *et al.* (2012) studied heavy metal accumulation by *Nelumbo nucifera* Gaerth, *Typha angustata* Bory Chaub, *Ipomoea aquatica* Forsk and *Hydrilla verticillata* (L.f.) Royle, and also their concentration in water and sediment in a freshwater wetland (Varasda) in Central Gujarat. Their study revealed that trace metals in water increased after religious activities like idol immersion during post-monsoon.

Vahdati and Khara (2012) evaluated the concentration of heavy metals released by the urban, industrial and agricultural activities in Anzali lagoon. Also analyzed lead and cadmium accumulation in *Hydrocotyl eranocloides*, and *Ceratophyllum demersum*. The results revealed that amount of the absorption were significant in the stem of *Hydrocotyle*. Malik and Biswas (2012) stated that due to rapid industrialization, modern agriculture and other anthropogenic activities, heavy metal pollution in soil and water has become a serious threat to the human and animal health.

Siriwan *et al.* (2006) and Wolff *et al*. (2012) studied the toxicity and accumulation of heavy metals, Cd and Pb in two aquatic ferns, *viz., Salvinia cucullata* and *S. auriculata*. The roots of *S. cucullata* showed higher Cd and Pb contents than leaves suggesting that the metals were bound to the root cells and were partially transported to the leaves. *Salvinia auriculata* showed accumulation of Cd from polluted aquatic ecosystems. The results suggested that *S. auriculata* showed good potential for use as a bioindicator and it can be used in the biomonitoring of aquatic ecosystems contaminated by Cd.

Nsikak *et al.* (2013) reviewed speciation analysis of metals in sediments of aquatic ecosystems and agro systems. They suggested that speciation analysis should be adopted while conducting the assessment of trace metals in order to obtain useful information on species differing in accumulation potential of metals. Ekpo *et al*. (2013) investigated heavy metal concentrations in water, sediments and fish from Akampa area in Nigeria and reported that water and sediment samples showed higher concentrations of the studied metals that were above the WHO standards in water. They also reported bioaccumulation of metals in *Heterotis niloticus, Oreochromis niloticus* and *Clarias gariepicus*.

Loveson *et al.* (2013) successfully demonstrated the efficiency of duckweed, *Spirodela polyrrhiza* in improving the quality of two polluted wetlands of Eloor industrial area, in Kerala. Chiodi *et al.* (2015) studied heavy metal accumulation in different macrophytes by calculating the bioaccumulation factor and reported the trend of metal accumulation in shoots was in the order as *Lemna gibba>Potamogeton pectinatus>Ceratophyllum demersum>Eichhornia crassipes >Najas armata>Pragmites australis*. Ugya *et al*. (2015) used *Pistia stratiotes* for removal of heavy metals *viz.*, Hg, Cd, Mn, Ag, Pb, Zn from a stream polluted by waste water. The Bioconcentration (BCF) and Biotranslocation (BTF) Factors of each metals analyzed were determined. Study showed that *Pistia stratiotes* is a suitable candidate for effective removal of these heavy metals.

Das *et al.* (2016) studied the potential of *Eichhornia crassipes* for Cd remediation in a hydroponic system and observed high tolerance and accumulation capabilities. Rai and Singh (2016) discussed the benefits of using *Eichhornia crassipes* as cost-effective and eco-friendly in accumulation and absorption of the heavy metals from aquatic bodies, biofuel and biogas production through fermentation and decomposition and fertilizer production through composting/vermicomposting. George and Gabriel (2017) investigated the heavy metal decontaminating activity of *Salvinia molesta* from municipal waste water. Their study revealed that *S. molesta* was efficient in reducing the heavy metal concentration in the waste water.