CHAPTER - 7

To study the restoration measures using phyto-remediation process in selected water bodies.

7.1: INTRODUCTION

Large scale industrialization and production of various chemical compounds have lead to trace metal pollution and ecological degradation of aquatic environment (Baldantoni *et al.,* 2004). The persistence of trace metals in the ecosystem and their bioaccumulation through food chains causes health hazards to humans (Wagner, 1993). Plants that absorb and accumulate trace metals are used to remove pollutants from the ecosystem. Various species show different capacities for metal uptake (Marchand *et al.,* 2010). Aquatic plants can accumulate trace metals in roots, stems and/or leaves (Jakson *et al.,* 1998). In aquatic systems, where pollutant inputs are discontinuous and pollutants are quickly diluted, analyses of plant tissues provide vital information of metal accumulation (Baldantoni *et al.,* 2005). Aquatic macrophytes are widely distributed in various wet environments, from fresh to salt water (Bonanno and Guidice, 2010). Various studies have indicated (Vahdati and Khara, 2012; Rai and Singh, 2016) that aquatic plants can improve the lake ecosystem by mitigating pollutant concentrations in contaminated soils and water (Odjegbal and Fasidi, 2004). In order to qualify as bioindicator species, plants must be able to grow without any effect in the presence of the pollutant, accumulate the pollutant in its tissue and concentrate the pollutant in its tissues to a significant level (Ugya *et al.,* 2015).

Phytoremediation using aquatic plants is evolving as a cost-effective alternative, thus considered as 'Green Revolution' in the clean-up technologies (Guittonny-Philippe *et al.,* 2014). Accumulator species accumulate relatively large amounts of pollutants, without obnoxious effects (Ravera *et al.,* 2003). The bio-accumulation factor (BAF) and translocation factor (TF) are most important plant features in phytoremediation with respect to uptake of metals, their mobilization into plant tissues, and storage in the aerial plant biomass (McGrath and Zhao, 2003). Plants with more than one BAF and high root-to-shoot metal translocation are ideal for phytoremediation and called hyper-accumulators (Garbisu and Alkorta, 2001). In the aquatic systems, hydrophytes have the potential to uptake heavy metals and extract large concentrations of metals into their roots and translocate them to surface biomass (Ghosh and Singh, 2005).

The ecological tolerance of different categories of aquatic plant species vary depending on their specific habits and habitats (Lu *et al.*, 2010). Macrophytes are used in remediation of polluted water bodies because of their high capability to accumulate toxic elements (Skinner *et al.*, 2007).

Many water bodies in the state of Goa are infested by macrophytes like *Salvinia molesta, Eichhornia crassipes, Hydrilla verticillata, Pistia stratiotes, Heterophyllum ceratophyllum etc*. The present study was carried out to test the suitability of three dominant macrophytes *viz., S. molesta, E. crassipes* and *P. stratiotes* for trace metal accumulation in selected water bodies. Also, the BAF of trace metals like Fe, Mn, Cu, Ni, Zn and Pb in the selected plant roots and shoots was calculated. Besides, the capability of these macrophytes in translocating analyzed trace metals in their aerial parts was determined by calculating TF.

7.2: MATERIALS AND METHODS

The trace metal analyses from water, sediment and the three dominant aquatic macrophytes *viz., S. molesta, E. crassipes* and *P. stratiotes* were carried out during pre-monsoon, monsoon and post-monsoon seasons. The BAF and TF were calculated as follows:

1. BAF= Metal concentration in plant tissue / Metal concentration in water (Klavins *et al.*, 1998).

2. TF= Metal concentration in root / Metal concentration in shoot (Wu and Sun, 1998).

7.3: RESULTS AND DISCUSSION

7.3.1: Bioaccumulation factor (BAF)

The ratio between trace metal concentration in plant and that of the media (water/sediment) expresses the BAF (Abd-Elmoniem, 2003). This reflects the affinity of an aquatic macrophyte to a specific metal element or pollutant. Metal accumulations by macrophytes are affected by metal concentrations in water and sediments (Lu *et al.,* 2004). The ambient metal concentration in water can be the major factor influencing the metal uptake efficiency (Rai and Chandra, 1992).

Good accumulator is recognized by its ability to absorb/uptake continuous metal and to bio accumulates it in its tissues (Zhu, *et al.*, 1999). BAF values calculated for selected aquatic plants are depicted in **Table 55**. During present study BAF for Fe was 0.77 in *P. stratiotes,* 2.28 in *S. molesta* and 2.33 in *E. crassipes*. Highest BAF was recorded in *E. crassipes* followed by *S. molesta* whereas the least BAF was recorded in *P. stratiotes* indicating poor accumulation ability for Fe.

BAF for Mn in *P. stratiotes* was 5.40 followed by *E. crassipes* (7.86) while it was highest in *S. molesta* (32.32). Thus, it is concluded that *S. molesta* is hyperaccumulator of Mn followed by *E. crassipes* and *P. stratiotes*. Lowest BAF for Cu was recorded in *S. molesta* (1.60) followed by *E. crassipes* (4.12) while being highest in *P. stratiotes* (5.22) indicating *P. stratiotes* as the highest accumulator of Cu. Ni was accumulated in lower concentration by *P. stratiotes* (0.03) followed by *E. crassipes* (1.14) whereas *S. molesta* accumulated highest amount of this element with a BAF of 2.51.

Zn accumulation was lowest in *E. crassipes* (0.73) followed by *P. stratiotes* (0.85) while *S. molesta* accumulated highest amount with BAF of 1.07. BAF for Pb was 2.48 in *P. stratiotes* followed by *E. crassipes* (2.94) while *S. molesta* (3.06) a better accumulator. These metals occur as impurities in fertilizers, metal-based pesticides, compost, manure and solid waste that get into the water bodies. Aquatic plants growing in the study area exhibited variations in trace metal concentrations. The roots/brown fronds *S. molesta* absorbed more amounts of metals compared to shoots. According to Abdel-sabour (2010) roots of aquatic plants accumulate greater amount of trace metals than the stems and leaves. Zhu *et al.* (1999) reported the main route of heavy metal uptake in aquatic plants is through the roots. According to Deng *et al.* (2004) metals get accumulated in roots but sometimes shoots of macrophytes may show levels far above the toxic concentration indicating an internal detoxification metal tolerance mechanism.

The present study revealed that the metal uptake was more during the dry season than in monsoon, which is in confirmation with the observation of Gulati *et al.* (1979). This can be attributed to elevated temperatures in dry season that enhances evapo-transpiration which transports metals at a faster rate from the soil solution to roots, leaves and stems. Low water pH during dry season is known to increase metals bioavailability in hydrophytes. The absorption of metals depends upon the degree and extent of exposure of the water body to anthropogenic activities, size of the water body, amount of rainfall, life cycle of an exposed plant species, besides light intensity, oxygen and even the age of the sampled plant from that particular sampling point (Siriwan *et al.,* 2006). The macrophytes analyzed in the present study were found suitable for phytoremediation process as they were found to be potential scavengers of trace metals from water.

Bio-accumulation factor (BAF) of trace metals is highest within the selected free floating plants. It is mainly influenced by bioavailability of the metals in both external (sediment and water-associated) and internal (plant and animal-associated) environmental factors (Ndeda and Manohar, 2014). George and Gabriel (2017) reported that *S. molesta* accumulated Mn, Ni, Zn and Pb effectively. Abdel-Sabour *et al.* (2010) reported that *E. crassipes* has been intensively studied as a bioindicator, and is reported to effectively concentrate a number of contaminants within a broad concentration range. Odjegbal and Fasidi (2004) reported that *P. stratiotes* was found suitable for accumulation of Cu and Zn.

In the present study, the BAF for analyzed metals was in the following order:

Fe - *Eichhornia* > *Salvinia*> *Pistia*

Mn - *Salvinia* > *Eichhornia* > *Pistia*

Cu - *Pistia* > *Eichhornia* > *Salvinia*

Ni - *Salvinia* > *Eichhornia* > *Pistia*

Zn - *Salvinia* > *Pistia* > *Eichhornia*

Pb - *Salvinia* > *Eichhornia* > *Pistia*

7.3.2: Translocation factor (TF)

The movement of metal-containing sap from root to shoot of aquatic macrophytes is termed as translocation which is primarily controlled by processes like root pressure and leaf transpiration (Lasat, 2000). Some metals are accumulated in roots, due to physiological barriers against their transport to the aerial parts, while others are easily transported (Lu *et al.*, 2004). TF being the ratio between concentrations of a trace element accumulated in root tissues by that accumulated in shoot tissues and higher TF implies poorer translocation capability. Translocation of metals by macrophytes takes time and varies with species, presence of metal transporters and availability of binding sites, energy, environmental conditions like pH, photosynthesis, temperature *etc.* metabolic levels and regulatory proteins present in plants (Williams *et al.* 2000; Ghosh and Singh, 2005). Yanqun *et al.* (2005) reported that when the TF value is greater than 1, the plants are considered as 'accumulator species', whereas when TF value is less than 1 the plants are considered as excluder species. TF values greater than 1 indicate that there is transport of metal from root to leaf (Zhao *et al.*, 2003) and sequestration in leaf vacuoles and apoplast (Lasat *et al.*, 2000).

TF of metals in the studied macrophytes are presented in **Table 56**. TF for Fe was 1.9 in *P. stratiotes* followed by *E. crassipes* (2.88) while it was highest in *S. molesta* (3.20). Mn recorded a TF value of 1.43 in *E. crassipes* followed by *S. molesta* (2.12) and *P. stratiotes* (2.50). TF for Cu was 1.66 in *S. molesta* followed by *E. crassipes* (7.25) and *P. stratiotes* (7.65). TF for Ni was 4.0 in *P. stratiotes* followed by *S. molesta* (4.58) and *E. crassipes* (5.8). Zn recorded a TF value of 1.40 in *E. crassipes* followed by *P. stratiotes* (1.63) and *S. molesta* (2.5). Pb recorded TF value of 1.45 in *E. crassipes* followed by *S. molesta* (3.9) and *P. stratiotes* (5.0).

Results showed differences in TF values thereby indicating the preferential accumulation/uptake and translocation of metals. In the present study, all the plant species showed a root to shoot translocation factor greater than 1 for all the metals. This

Table 55: Bioaccumulation factor of selected macrophytes.

Metal	***Salvinia molesta***	***Eichhornia crassipes***	***Pistia stratiotes***
Fe	2.28	2.33	0.77
Mn	32.32	7.86	5.4
Cu	1.60	4.12	5.22
Ni	2.51	1.14	0.03
Zn	1.07	0.73	0.85
Pb	3.06	2.94	2.48

Table 56: Translocation factor of selected macrophytes.

Metal	***Salvinia molesta***	***Eichhornia crassipes***	***Pistia stratiotes***
Fe	3.02	2.88	1.59
Mn	2.12	1.43	2.5
Cu	1.66	7.25	7.65
Ni	4.58	5.8	4.0
Zn	2.5	1.40	1.63
Pb	3.9	1.45	5.0

suggests that these macrophytes can be effectively used for the phytoremediation of aquatic water bodies contaminated with heavy metals.

Lower TF values of 1.59 for Fe in *P. stratiotes*, 1.43 for Mn in *E. crassipes*, 1.66 for Cu in *S. molesta*, 1.40 for Zn in *E. crassipes* and 1.45 for Pb in *E. crassipes* were recorded during pre- and post-monsoon season indicating better translocation of metals. Amongst the three selected macrophytes, *E. crassipes* recorded maximum translocation. This may be attributed to unique morphological and anatomical peculiarities of the plant (Akinbile and Yusoff, 2012). Metal uptake by aquatic plants involves transport across the plasma membrane of root cells, loading in xylem tissues, translocation, detoxification, and subsequently metal sequestration at cellular levels (Lombi *et al.*, 2002). A good hyperaccumulator is recognized by its ability to amass metals primarily in the shoots, both at low and high exogenous metal concentrations (Antosiewicz, 1992). Translocation was also favoured by factors like low pH and high temperature of water. The elevated temperatures in dry season enhance evapotranspiration, thereby transporting metals at a faster rate from the water to roots and shoots. Besides, low water and sediment pH during dry season increases metal bioavailability in hydrophytes (Rai *et al.*, 1995).

In the present study, the TF for analysed metals was in following order**:**

Fe - *Pistia* > *Eichhornia* >*Salvinia*

Mn - *Eichhornia* > *Salvinia* > *Pistia*

Cu - *Salvinia*> *Eichhornia* > *Pistia*

Ni - *Pistia* > *Salvinia*> *Eichhornia*

Zn - *Eichhornia* > *Pistia* >*Salvinia*

Pb - *Eichhornia* > *Salvinia* >*Pistia*

Brun *et al.* (2001) observed that the mobility of metals in aquatic plant species varies among species. In the present study, all three species proved to be good accumulators. After assessing the potential of selected aquatic macrophytes as a tool to reduce trace metal contamination and as remediator species, the awareness on technical information related to phytoremediation will greatly increase. However, care should be taken while selecting the contaminated site, target contaminant, and efficacy of the aquatic plant selected.

In future, additional studies are required to understand the mechanism of action of the aquatic plants. With the advancement in the field of genetic recombination technology, genetically engineered plants can be instrumental in the phytoremediation approaches towards cleaning of aquatic environment. Also combined use of other approaches like phytostabilization, phytofiltration, phytovolatilization, phytodegradation and phytotransformation besides phytoremediation need to be attempted.