CHAPTER-II

PHYTOREMEDIATION CAPABILITIES OF SELECTED AQUATIC WEEDS AND TREATMENT OF CPIE

2.1. INTRODUCTION

Industrial effluents from electroplating discharges contain higher amount of metals, especially Chromium. Trace amount of heavy metal is essential for human metabolism, Chromium is essential for metabolism of fatty acids, glucose and protein. Trivalent Chromium occurs naturally in the environment as an essential nutrient (Bahijri and Mufti, 2002) whereas hexavalent Chromium (Cr(VI)) is most toxic form and a well carcinogenic and mutagenic to living organisms (Kotas and Stasicka, 2000; Ramakrishna and Ligy, 2005; Prabakaran et al., 2007 and Ashwini and Seeta, 2009) because of its high solubility, ability to penetrate the cell membrane and strong oxidizing ability (Shanker and Pathmanabhan, 2004). The toxicity is due to the ability of the metal ions to bind to protein molecules and prevent replication of DNA and subsequent cell division.

Chromium and its compounds are widely used in various industries such as metal finishing, electroplating, aluminum anodizing, leather tanning, textile dyeing, wood preservation and in the manufacture of paints, dyes, petroleum refining, iron and steel, pulp and paper (Romero-Gonzalez et al., 2006; Huaxiao et al., 2009; Das and Mishra, 2010; Poornima et al., 2010). Among them the leather, tanning and electroplating industry causes the highest Chromium pollution in India. In India, about 2000-32000 tons of elemental Cr annually escape into the environment from tanning industries. Chromium occurs in several oxidation states ranging from \( \text{Cr}^{2+} \), \( \text{Cr}^{3+} \) to \( \text{Cr}^{6+} \) in which \( \text{Cr}^{3+} \) and \( \text{Cr}^{6+} \) exist in stable states.
Excessive Cr exposure causes skin ulceration, perforation of nasal septum, lung carcinoma, respiratory cancer, contact dermatitis, kidney damage and damage to various proteins, nucleic acid leading to mutation and carcinogenesis and even death in extreme cases (Mehra and Juneja, 2003; and Sahu et al., 2007).

Various methods have been employed to clean-up water bodies contaminated by effluents. The different methods are: physical method, chemical method and biological method. Physical and chemical methods of wastewater treatment are invariably cost intensive and cannot be employed in all industries especially in developing and under developed countries. These methods include absorption (Lazaridis et al., 2005), biosorption (Santhikumar et al., 2010), adsorption (Mohapatra et al., 2004) ion exchange (Ingelezakis and Loizidoropoulou, 2003) chemical precipitation (Kurniawan et al., 2006), chemical reduction, reverse osmosis, carbon adsorption (Yan and Viraraghavan, 2001; Meena and Rajagopal, 2003), membrane filtration (Ndiaye et al., 2005) electro chemical methods; electrowinning (Bolger and Szlag, 2014), electrodialysis (Marder et al., 2004), electrodeionization (Lu et al., 2010), membrane less electrostatic shielding electrodialysis/electrodeionization (Dermentzis, 2010; Dermentzis et al., 2010), electrocoagulation-flotation (Hu et al., 2005), nanofiltration (Ahmed et al., 2006), electrolysis (Chen et al., 2007), coagulation-flocculation (Kurniawan et al., 2006), chemical oxidation (Merzouk et al., 2009), ultrafiltration, phyto extraction (Schnoor, 1997), membrane separation (Applegate, 1984), sedimentation (Walker and Hurl, 2002), complexation (Stoveland et al., 1979).

These technologies are complicated, expensive, energy and labour intensive, metal specific, and inefficient in treating large quantities (Mishra and Tripathi, 2008
and Manuela et al., 2010) and are not able to completely remove the heavy metals (Manuela et al., 2010) and generate waste products. Compared with chemical/physical methods, biological processes have received more interest because of their cost effectiveness, lower sludge production and environmental friendliness. There is an urgent need to develop low-cost, effective, and sustainable methods for their removal or detoxification of effluent.

Phytoremediation offers an alternative, economical and effective procedure which can be successfully used (House et al., 1999). Phytoremediation is defined as the use of green plants to remove pollutants from the environment which was first proposed by Chaney, (1983). Use of plants for heavy metal removal from wastewater offers a promising technology (Miretzky et al., 2004; Mishra and Tripathi, 2009). Phytoremediation offers a cost effective treatment, for large volumes of water having low concentration of contaminants and is an efficient, nonintrusive, environment-friendly technology (Schwitzguebel, 2000 and Miretzky et al., 2004) for clean-up of a broad spectrum of hazardous organic and inorganic pollutants (Pilon-Smints, 2005), phytoremediation is further a biocompatible, passive process which is faster than other natural processes, generates minimum secondary wastes, has greater social acceptability, cheaper method, is completed within a short period of time, requires much lesser energy, a completely natural system and very easy to regenerate (Choo et al., 2006). It can be performed with minimal environmental disturbance, applicable to a broad range of contaminants, where organic pollutants may be degraded to CO₂ and H₂O removing environmental toxicity. Phytoremediation has also been called green remediation, botano-remediation, agro remediation and vegetative remediation (Andrew, 2007) and is most suitable for developing countries
Phytoremediation involves phytoextraction (Kumar et al., 1995), rhizofiltration (Dushenkov et al., 1995), phytostabilization (Salt et al., 1995), phytovolatilization and phytodegradation. Phytoremediation has recently become a subject of public and scientific interest and the key topic of many researchers (Antonkiewicz and Jasiewicz, 2002; Igwe and Abia, 2006). The economic success of phytoremediation largely depends on the availability of plant species, photosynthetic activity, growth rate of plants and the ability to tolerate and accumulate high concentration of heavy metals (Baker and Whiting, 2002).

Currently there are about 420 species belonging to about 45 plant families recorded as hyperaccumulators of heavy metals (Cobbett, 2003). There are many plants which can tolerate the presence of Chromium and accumulate them within the plant body in the root, stem and leaves (De et al., 2008). The metals are converted into less harmful substances within the plants or in the form of gas and is released into the air in the process of transpiration (Schnoor, 2002; Kamaludeen and Ramaswamy, 2008). Several studies have shown that constructed wet lands are very effective in removal of heavy metals from polluted wastewaters.

Many scientists have focussed on accumulation of heavy metals by aquatic macrophytes (Fritioff and Gregor, 2006 and Radic et al., 2010) such as *Lemna minor* (duck weed), *E. crassipes* (water hyacinth) (So et al., 2003), *Pistia stratiotes* (water lettuce) (Sridhar, 1986), *Ceratophyllum demersum* (Coontail) (Devi and Prasad, 1998; Arvind and Prasad, 2005), *Oenanthe javanica* Blume (water Dropwort), *Polygonum amphibium* L. (Sharp Dock), *Lepironia articulata* Retz. (Calamus), *Hydrocotyle umbellata* L. (Pennywort) (Prasad and Freitas, 2003), *Elodea Canadensis* (American elodea, Canadian pond-weed) (Pamela et al., 1997), *Phragmites australis* Cav. (Reed)
(Aslam et al., 2007; Bragato et al., 2006), *Scirpus tabernaemontani* (C.C. Gmel.) Palla. (Zebra rush) (Skinner et al., 2007) and *I. aquatica* (Water Spinach), *Azolla caroliniana* (Water ferns) (Rahman and Hasegawa, 2011), *Typha latifolia* L. and *Cyperus malaccensis* (Lam.) Palla. (Yadav and Chandra, 2011). Among the various plant species, aquatic macrophytes attain the greatest interest in the field of phytoremediation. Aquatic plants uptake on heavy metals are varied based on their species to species as well as metal to metal.

In this study, two aquatic plants, *E. crassipes* and *I. aquatica* were used to determine their potential in removing Cr of various concentrations from Chromium solutions. *E. crassipes* (Water hyacinth) belongs to the family pontederiaceae, an erect free floating herbaceous plant, spread throughout the world and its name *Eichhornia* was derived from well-known 19 century Prussian politician J.A.F. Eichhorn (Singh and Tripathi, 2007). *E. crassipes* is a fast growing submerged aquatic plant that originated in tropical South America and is now widespread in all tropic climates known for big biomass production (Singhal and Rai, 2003), large uptake of nutrients and contaminants (Rai, 2009), high tolerance to pollution (Ebel et al., 2007), growing abundantly throughout the year and tolerating drought well, because it could survive in moist sediments up to several months.

These plants can accumulate heavy metals up to 100,000 times greater than the amount in the associated water. Therefore these macrophytes have been used for heavy metal removal from contaminated water bodies (Mishra et al., 2009 and Rolli et al., 2010). Liao and Chang, 2004 reported water hyacinth to be a promising candidate for phytoremediation of wastewater polluted with heavy metals. Macrophytes have enormous potential to accumulate heavy metals inside their body.
from the liquid environment (Maine et al., 2006; Phetsombat et al., 2006; Singh and Singh, 2006; Sasmaz et al., 2008 and Kousar and Puttalal, 2009). Several studies have also concluded that *E. crassipes* more efficient in the phytoremediation of dilute solutions of heavy metals (Mishra et al., 2008).

*Ipomoea aquatica* (water spinach) (Convolvulaceae) is a semi aquatic, tropical plant and it is found throughout the tropical and subtropical regions of the world and also both plants are abundant in Kanyakumari District. This species takes up metals from water, produces an internal concentration several folds greater than their surroundings and shows much higher metal accumulating capacity than non-hyper accumulating terrestrial plants (Gandhi et al., 2013).

These two plants showed better tolerance towards higher concentration of industrial effluents including Chromium. Biochemical studies on the various parts such as leaves, stems and roots of *E. crassipes* and *I. aquatica* were carried out in order to find the reason behind their higher tolerance towards the effluents. Biochemical constituents such as protein, carbohydrates, chlorophyll a, b, total chlorophyll and carotenoid contents of different parts of the plants were estimated at different effluent concentration for different periods of exposure. Eventhough the values were significantly modified the plant showed better tolerance towards the effluent. Thus it is feasible to use this plant in phytoremediation of metal-containing industrial effluents. Hence in the present study *E. crassipes* and *I. aquatica* were tested for their toxic metal accummulation capacity and to understand their ability in the phytoremediation of Chromium, the predominant metal in CPIE.