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Phytoremediation of Heavy Metals Using Aquatic Macrophytes

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Abstract:

Heavy metals as environmental pollutants have increased and it has been clear that Phytoremediation may be a satisfactory and suitable method to measure amount of heavy metals. Hydrophytes due to existence in ecosystem are useful indicators for heavy metal pollution. The ability of aquatic plants to accumulate heavy metals was examined in three different hydrophytes (*Eichhornia crassipes*, *Pistia stratiotes*, *Salvinia molesta*). Wet digestion method was employed for extraction of metals in samples by and through a solution containing HNO3 and HCL. Atomic Adsorption Spectrophotometry was employed for measurement of the heavy metals. Metal enrichment was found to be dependent on the plant species in different levels. The most efficient plant species in accumulating heavy metals were Eichhornia crassipes.

Keywords: Heavy metal, Phytoremediation, Atomic adsorption spectrophotography, Hydrophytes.

1.0 Introduction

Water is our most precious natural resource. It is the foundation of rich environmental cycle that is responsible for the great abundance and diversity of life on earth. Water pollution is the introduction of substances whose character and quantity alter the water's natural quality and impair its usefulness, and it is offensive to sight, smell, or taste (Jameel, 1998). The rapid expansion and increasing sophistication of the chemical industries in the past century and particularly over the last thirty years indicate that there has been an increase in quantity and complexity of toxic waste effluents.

Freshwaters are perhaps the most vulnerable habitats, and are often changed by the activities of man. This essential resource is becoming increasingly scarce in many parts of the world due to severe impairment of water quality. Chemical analysis of water provides a good indication of the chemical quality of the aquatic system, but does not integrate ecological factors such as altered riparian vegetation or altered flow regime and therefore, does not increasingly reflect the ecological state of the system (Karr *et al.,* 2000). Water resources are sources of water that are useful or potentially useful to humans. The basis of bioremediation is that all organisms remove substances from the environment to carry out growth and metabolism. Bioremediation does not involve only the degradation of pollutants it can be used to clean unwanted substances from air, soil, water and raw materials for industrial processing. Bioremediation, which is one of the recent technologies, is described as the use of micro-organisms to destroy or immobilize waste materials (Shanahan, 2004). Bioremediation helps in cleaning up of ground water sources, soils, lagoons, and sludge and waste streams. Bioremediation is the application of a biological treatment, mainly microbes, to clean up hazardous contaminants in soil and surface or subsurface waters. These micro-organisms can be used to transform them to less harmful forms. Bioremediation is a pollution treatment technology that uses biological systems to catalyze the destruction, or transformation, or removal of various chemicals to less harmful forms (Atlas, 1995). In the last decade industrialized nations have placed greater emphasis on restoring the environment. Much awareness has been directed towards the preservation of water quality and the restoration of contaminated surface and ground waters (Brierly, 1991). Thus wherever applicable, bioremediation proved to be a cost-effective means of restoring environmental quality. Its cost effectiveness as compared to chemical and physical treatment technologies especially for the dilute contaminants is the main driving force for the use of bioremediation. Although treatment of industrial effluents to remove organic contaminants has received the greatest emphasis, attention is now focused on metal since last two decades (Brierly, 1991). Increasing environmental pollution by heavy metals resulting from their increasing utilization in industrial processes is causing many problems for both human health and the aquatic systems. Bioremoval treatment processes have advantages in effectiveness in reducing the concentration of heavy metal ions to very low levels and in the use of inexpensive biosorbent materials (Wild and Bennemann, 1993). Cyanobacteria are organisms which can be easily separated from a solution by filtration, and are self-immobilized as a biofilm on a porous support such as polyurethane foam (Inthorn *et al.,* 2005) and hence, they can be used in remediation processes. Phytoremediation is an eco friendly approach for remediation of contaminated soil and water using plants. A number of chemicals, heavy metals and other industrial effluents are abundant in the coastal areas. These substances contribute a variety of toxic effects on living organisms in food chain. Green plants are now becoming increasingly popular as a means of restoring environmental contamination through phytoremediation.

Aquatic plants grow profusely in lakes and waterways all over the world and in recent decades their negative effects have been magnified by man's intensive use of water bodies. Eradication of the weeds has proved almost impossible and even reasonable control is difficult. Turning these weeds to productive use would be desirable if it would partly offset the costs involved in mechanical removal. Among other uses, there has been considerable interest in using aquatic plants as pollution control, especially that the accumulation of heavy metal ions by aquatic macrophytes from the water in which they are growing has been documented by a International Water Technology Conference, IWTC8 2004, Alexandria, Egypt number of authors (Dietz, 1973; Ray and White, 1979). This metal has been found to vary with plant species (Abo Rady, 1980; Low et al, 1984 and Sawidis et al 1991), with different parts of plant (Dinka, 1986; Chen et al, 1990 and Nir et al 1990), and with the kind of metal and its concentration in growth media (Lee et al, 1981; Mortimer, 1985; and Taylor and Growder 1993b). Water hyacinth is a free-floating perennial aquatic plant native to tropical and sub-tropical South America, and is now widespread in all tropic climates. The genus Eichhornia comprises seven species of water hyacinth among which E. crassipes is the most common and have been reported to grow very first. However, its enormous biomass production rate, high tolerance to pollution (Ebel et al., 2007), and absorption capacity of heavy-metal and nutrient qualify it for use in wastewater treatment (Ebel et al., 2007; Fang et al., 2007). A comprehensive study on the arsenic removal from water by E. crassipes was performed by Alvarado et al. (2008). The removal efficiency of water hyacinth was higher due to its high biomass production and favorable climatic conditions. Mishra et al. (2008) compared arsenic removal efficiency of E. crassipes, with other water plants. Water hyacinth represents a reliable alternative for arsenic bioremediation in aquatic system even though the plant may cause severe water management problems because of its huge vegetative reproduction and high growth rate (Giraldo and Garzon, 2002). So, the use of water hyacinth in phytoremediation technology should be considered carefully. It has been reported that Azolla has a high capacity to accumulate toxic elements such as mercury, cadmium, chromium, copper, nickel and zinc (Sela et al., 1989; Rai, 2008; Rai and Tripathi, 2009), and can be used to remove contaminants from wastewater (Bennicelli et al., 2004;Arora and Saxena, 2005; Rakhshaee et al., 2006).

Objectives

Bioremediation is a process in which a specialized consortium of natural organisms degrades the organic deposits. Usually the process of bioremediation is carried out using specially prepared, naturally occurring non- pathogenic microbes. Although bioremediation holds great promise for dealing with intractable environmental problems, it is important to recognize that much of this promise has yet to be realized. Specifically much needs to be learned about how microorganisms interact with different hydrologic environment. As this understanding increase, the efficiency and applicability of bioremediation will grow rapidly. In the present study an attempt is made to evaluate the absorbtion capacity of heavy metal by using three different hydrophytes. The main objectives of the study are, to find different macrophytes present in polluted areas and to assess the natural growth of macrophytes in polluted and non polluted areas and also the absorption capacity of selected macrophytes.

Area of Study

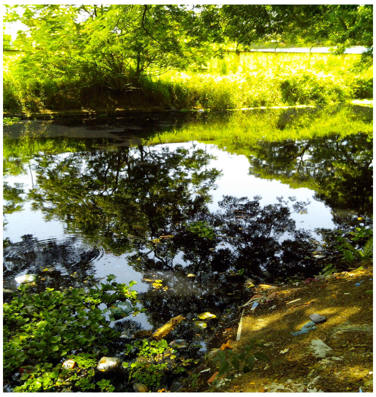
The main aim is to study bioremediation, the scope of using hydrophytes in waste water treatment. Here the site chosen for the study is Parvathy Puthanar and its tributaries.

Parvathy Puthanar is located in Thiruvananthapuram District of Kerala, and has a length of about 22 km from Thiruvallam to Channankara, about 18 km from Vallakkadavu (Thiruvananthapuram) to Channankara (Kadinamkulam Kayal) and has an average width of about 10 m and has depth of 3 m and has an altitude mean sea level . The commercial history of Parvathy Puthanar goes back to the pre-independence years of the then Travancore Kingdom and its rich trade. Agricultural produces were abundant along the fertile backwater regions and the coast. The intention behind a canal was to connect the backwaters of Travancore coast, and thereby establishing an inland waterway, which would promote the trade and industry of Travancore. The original idea behind this canal which we see today was conceived by Colonel Monroe, who was the Resident of Travancore, when Her Highness Maharani Sethu Parvathi Bai was ruling the state as Regent. Her Highness decided to implement the idea in 1824. The work was started in 1825 and completed in 1828. Later during the reign of His Highness Maharaja Sree Moolam Thirunal, as part of improving the efficiency of inland waterways throughout Travancore, the canal was extended to the south up to Thiruvallam, where the Karamana River joins the sea. Thus Parvathy Puthenar has two parts. The first was meant to link Thiruvananthapuram and Kadinamkulam Lake and the other to link Kollam and Paravur.

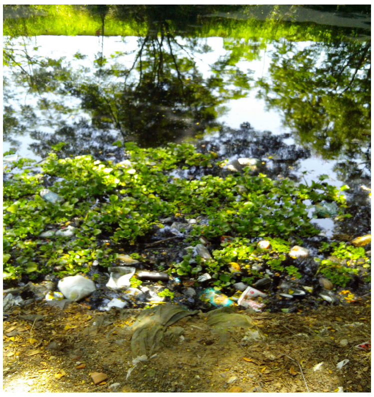
The Parvathy Puthanar, which once was clear water, is now in a polluted condition. The sewage farm of the Thiruvananthapuram Corporation, on the banks of the canal near Muttathara, dumps all the waste materials into the canal. In most of the parts the canal is covered with water- hyacinth and other weeds. This makes the transportation by boats difficult.

The Travancore Titanium Limited near Veli dumped directly to sea but the smaller industries which do not have any discharge or treatment facilities dump both solid and liquid wastes into the Puthanar. The waste and effluent from new hospitals, housing complexes and warehouses that are sprouting along the lake and other connecting water bodies like the Amayizhanjan Thodu will directly enter the lake area if an effective waste management system is not adopted. There are china-clay mines in the catchment areas. The English India Clays also produce large quantity of clay waste. All these eventually drain to the complex system, badly affecting the lake and subsequently the Puthanar.Parallel to the coast there is a chain of backwater lagoons interconnected with natural and artificial canals. Since the river, backwaters and the sea are interconnected, pollution of one water body is automatically transmitted to the next water body, ultimately resulting in coastal pollution.

a).Aakulam



b). Veli



c).Thumpa

2.0 Materials and Methods

The present investigation mainly deals with the wastewater systems and the scope of purification of this wastewater by biological process like phytoremediation using hydrophytes. For this purpose different sites were selected where waste disposal or discharge of waste water . These areas of the Parvathy Puthanar are found to be polluted due to different activities and hence these were selected as the waste water sources and examined for the further study. The different stations selected are 1. Akkulam, 2.Veli, 3. Thumba . Polluted water samples were collected from these areas. Examinations of water from different sites showed the presence of copper, Iron and traces of lead.

Samples like *Eichhornia* crassipes, *Pistia* stratiotes, *Salvinia molesta* were collected and were allowed to grow in the normal water for stabilization for two weeks. After two weeks they were put in trufs with collected samples to find out the absorption capacity. The metal uptake activity by the plants was determined by after two weeks clipping small portions of the plant parts and determining the metal concentration by atomic absorption spectroscopy after acid digestion of the samples. Samples were cut into small pieces, air dried for 48 hours and finally dried at 85 degree C in hot air oven for two hours. In warm condition, the samples were groud and passed through 1mm sieve. Fine powder samples (2.5g/50ml distilled water) were subjected to acid digestion by adding 8ml concentrated nitric acid on hot plate and filtrate was distilled up to 50ml distilled water. Heavy metal analyses were performed on an atomic adsorption spectrophotometer.

3.0 Result and Discussion:

Macrophytes are aquatic plants, growing in or near water that are emergent, submerged or floating. Macrophytes are beneficial to lake because they provide food and shelter for fish and aquatic invertebrates. They also produce oxygen, which helps in overall lake functioning, and provide food for some fish and other wildlife. Heavy metal pollution is one of the main problems for the ecosystem due to technological development. Diverse industrial wastes have aggravated the problem of water pollution. This problem becomes complex because of the qualitative and quantitative differences in pollution according to the industries involved, and due to the non-degradability of inorganic pollutants like heavy metals which are hazardous when discharged into a water body. Several studies have shown that constructed wetlands are very effective in removing heavy metals from polluted wastewaters. Algae and aquatic plants play a key role in aquatic ecosystems because they are at the base of food webs. Also, they are a food resource and provide oxygen and shelter for many aquatic organisms. They also contribute to the stabilisation of sediments and bio concentration of compounds and are used as bioremediatives. Direct discharge of contaminants increase the concentration of trace elements in aquatic systems, thus resultinn in their accumulation in sediments.In aquatic systems, where pollutant inputs are discontinuous and pollutants are quickly diluted, analyses of plants provide time-integrated information about the quality of the system. Phytoremediation has several advantages and is the most significant one in study of sub-lethal levels of bioaccumulated contaminants within the tissues/components of organisms, which indicate the net amount of pollutants integrated over a period of time. Biomonitoring of pollutants using some plants as accumulator species, accumulate relatively large amounts of certain pollutants, even from much diluted solutions without obvious noxious effects.

All plants have the ability to accumulate heavy metals. Metals cannot be broken down and when concentrations inside the plant cells accumulate above threshold or optimal levels, it can cause direct toxicity by damaging cell structure (due to oxidative stress caused by reactive oxygen species) and inhibit a number of cytoplasmic enzymes. In addition, it can cause indirect toxic effects by replacing essential nutrients at cation ex- change sites in plants. Baker proposed, however, that some plants have evolved to tolerate the presence of large amounts of metals in their environment.

Field studies were conducted to find out the contaminated water logging areas and also to find out excess growth of macrophytes in the contaminated .Water samples were collected from contaminated areas of Parvathy puthanar such as Aakulam, Veli and Thumba. Examinations of water from different sites showed the presence of heavy metals copper, Iron and traces of lead. *Eichhornia* sp, *Pistia* sp, *Salvinia* sp were collected and treated in the collected water in different trufs to find out the absorption capacity of heavy metals. Aquatic macrophytes are unchangeable biological filters and they carry out purification of the water bodies by accumulating dissolved metals and toxins in their tissue. A phytoremediation study was carried out to ascertain the degree of heavy metal absorption in the following aquatic macrophytes. The aquatic plants (biomonitors) *Eichhornia* sp, *Pistia* sp, *Salvinia* sp was collected. Based on the absorption capacity observed in macrophytes was **Eichhornia** sp>*Pistia* sp,> *Salvinia* sp. It was also noticed that the amount of heavy metals is higher in the water collected from Akkulam.

The selected aquatic plants (biomonitors) ie *Eichhornia* sp, *Pistia* sp, *Salvinia* sp were allowed to grow for three months. After the third month plants were thoroughly washed to remove all adhered soil particles. Samples were cut into small pieces, air dried for 48 hours and finally dried at 85° C in hot air oven for two hours.

In warm condition, the samples were ground and passed through 1 mm sieve. Macrophytes fine powder samples (2.5 g/50 mL distilled water) were subjected to acid digestion by adding 8 mL concentrated nitric acid on hot plate and filtrate was diluted up to 50 mL with distilled water. Heavy metals analyses were performed on an Atomic Adsorption Spectrophotometer.

This study reveals that the observed level of copper in *Eichhornia* sp (124-220 ppm), *Pistia* sp(100-175 ppm),*Salvinia* sp(95-120 ppm), The order of accumulation of copper observed was *Eichhornia >.Pistia >Salvinia.* Graphical representations were done by means of taking mean value of the given data.

Phytoremediation has several advantages and is the most significant one in studyof sub-lethal levels of bioaccumulated contaminants within the tissues/components of plants/ organisms, which indicate the net amount of pollutants integrated over a period of time. Biomonitoring of pollutants using some plants as accumulator species, accumulate relatively large amounts of certain pollutants, even from much diluted solutions without obvious noxious effects.

Table 1: showing the concentration of copper, iron and lead in three different Samples.

Name of the sample	Name of metals	Concentration of metals
Aakulam	Copper Iron Lead	250 ppm 50ppm 20ppm
Veli	Copper Iron Lead	120 ppm 65ppm 40ppm
Thumba	Copper Iron Lead	Below 50 ppm 75ppm 110ppm

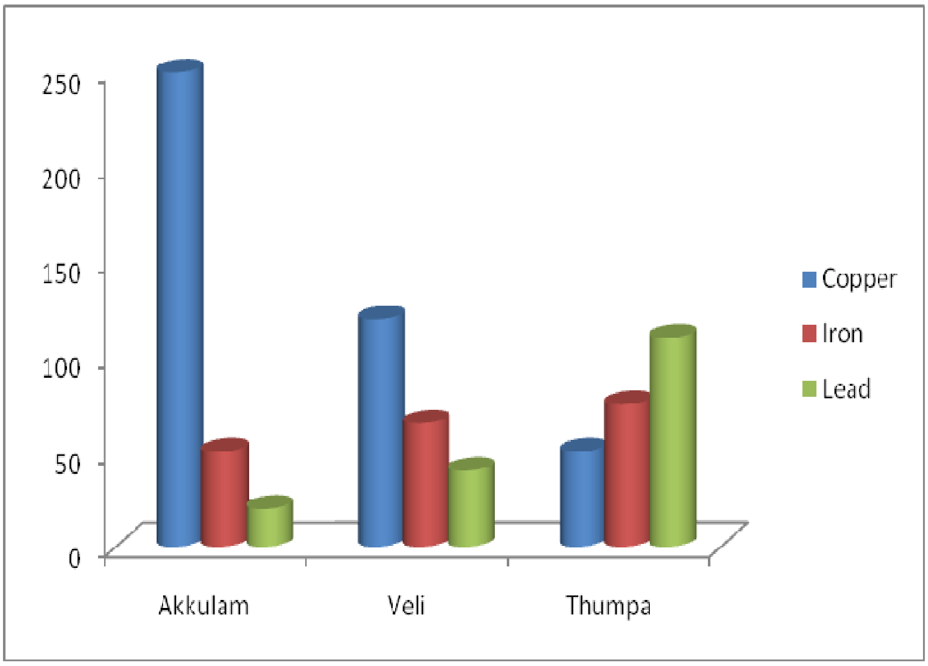
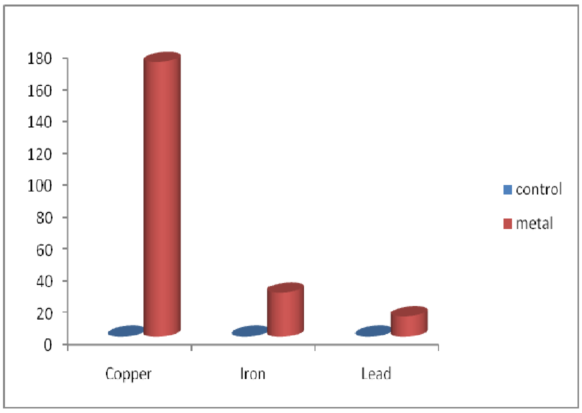


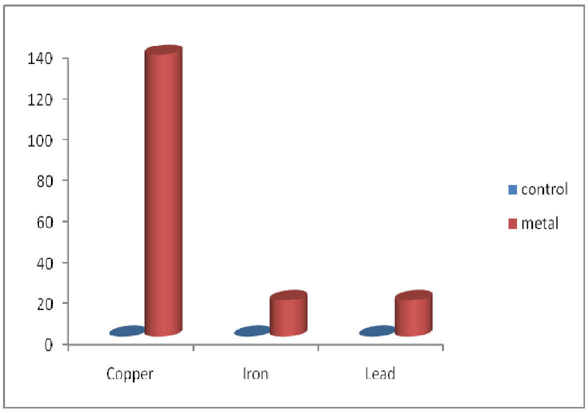
Fig. 1: Heavy metal concentration

Table 2: showing the concentration of copper, iron and lead in three different plants.

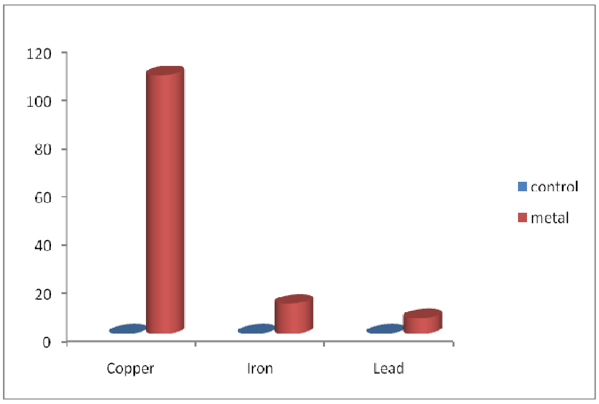
Name of the plants	Name of the metals	Concentration of control material	Concentration of metals	Mean Value
Eichhornia sp	Copper Iron Lead	0 0 0	124-220 ppm 25-30 ppm 10-15 ppm	172ppm 27.5ppm 12.5ppm
Pistia sp	Copper Iron Lead	0 0 0	100-175 ppm 15-20 ppm 15-20 ppm	137.5ppm 17.5ppm 17.5ppm
Salvinia sp	Copper Iron Lead	0 0 0	95-120 ppm 10-15 ppm 5-8 ppm	107.5ppm 12.5ppm 6.5ppm



Eichornia sps



Pistia sps



Salvinia sps

4.0 Conclusions

Bioremediation integrates the tools of many disciplines. As each of the disciplines advances and as new cleanup needs arise, opportunities for new bioremediation techniques will emerge. As these new techniques are brought into commercial practice, the importance of sound methods for evaluating bioremediation will increase. The fundamental knowledge base underlying bioremediation is sufficient to begin implementing the three-part evaluation strategy the committee has recommended. However, further research and better education of those involved in bioremediation will improve the ability to apply the strategy and understanding of the fundamentals behind bioremediation. The most serious pollutants in water streams are those derived from effluents discharged from the industrial plants. Unfortunately, the waste waters of these plants are discharged directly without any treatment into water streams.

This study revealed that the observed level of copper in *Eichhornia* 124-220 ppm, *Pistia*100-175ppmand in *Salvinia* 95-120 ppm. It was also noticed that the amount of copper is higher in collected water.

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