Heavy Metal Removal by Using Water Hyacinth: A Review

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Abstract - Water pollution has become one of the most serious problems of today’s civilization. In the last few years considerable amount of research has been done on the potential of aquatic macrophytes for pollutant removal or even as bio-indicators for heavy metals in aquatic ecosystems. Water hyacinth (Eichhornia crassipes) is a fast growing, free-floating aquatic weed. Floating aquatic plants are capable of assimilating large quantities of trace elements and heavy metals, some of which are essential for plant growth. The uptake of these elements is often increased when plants are cultured in wastewater containing high levels of macronutrients. They have the ability to absorb heavy metals. Heavy metals and other trace contaminants enter surface and groundwater in various ways and adversely affect flora and fauna. Hence, the removal of such impurities is necessary. Water hyacinth is one of the aquatic plant species successfully used for wastewater treatment. It is very efficient in removing pollutants like suspended solids, BOD, organic matter, heavy metals and pathogens. Thus, the plants hold promise as a natural water purification system, which could be established at a fraction of the cost of a conventional sewage treatment facility. The study conducted in this regard revealed how efficiently wastewater could be treated using the plant water hyacinth.

Keywords: Heavy metals, water hyacinth, aquatic plant, macronutrients, Biosorption

I. INTRODUCTION

The water crises is a huge problem in India, because the contamination of large quantity of water. Water is the important component for all living organisms. Human being depends on fresh water for drinking, irrigation of crops, and industrial uses as well for production, transportation, recreation and waste disposal. In many regions of the India, the amount and quality of water available to meet human needs are limited. The gap between freshwater supply and demand will widen during the coming century because of climate change and increasing consumption of water and increasing population. The change in water quality also varies due to a change in chemical composition of the underlying sediments and aquifer [1]. The most anthropogenic sources of metals are industrial, petroleum contamination and sewage disposal. Water pollution by heavy metals is a major environmental problem in the modern world. Some of the pollutants like Lead (Pb), Arsenic (As), Mercury (Hg), Chromium (Cr) specially Hexavalent Chromium, Nickel (Ni), Barium (Ba), Cadmium (Cd), Cobalt (Co), Selenium (Se), Vanadium (V), Oils and Grease, Pesticides, etc are very harmful, toxic and poisonous even in ppb (parts per billion) range. There are some minerals which are useful for human and animal health in small doses beyond which these are toxic. Zinc (Zn), Copper (Cu), Iron (Fe), etc fall into this category [2].

II. HEAVY METAL

Heavy metals are defined as metallic elements that have a relatively high density compared to water. With the assumption that heaviness and toxicity are inter-related, heavy metals also include metalloids, such as arsenic, that are able to induce toxicity at low level of exposure. Heavy metals are also considered as trace elements because of
their presence in trace concentrations (ppb range to less than 10ppm) in various environmental matrices. Their bioavailability is influenced by physical factors such as temperature, phase association, adsorption and sequestration [3].

A. Sources of Heavy Metal

Environmental pollution from hazardous metals and minerals can arise from natural as well as anthropogenic sources. Natural sources are: seepage from rocks into water, volcanic activity, forest fires etc. Following are the various heavy metal and their sources: [2]

- Chromium (Cr) - Mining, industrial coolants, chromium salts manufacturing.
- Lead (Pb) - lead acid batteries, paints, E-waste, Smelting operations, coal- based thermal power plants, ceramics, bangle industry.
- Mercury (Hg) - Chlor-alkali plants, thermal power plants, fluorescent lamps, hospital waste (damaged thermometers, barometers), electrical appliances etc.
- Arsenic (As) - Geogenic/natural processes, smelting operations, thermal power plants.
- Copper (Cu) - Mining, electroplating, smelting operations.
- Vanadium (Va) - Spent catalyst, sulphuric acid plant.
- Nickel (Ni) - Smelting operations, thermal power plants, battery industry.
- Cadmium (Cd) - Zinc smelting, waste batteries, e-waste, paint sludge & Incinerations
- Molybdenum (Mo) - Spent catalyst.
- Zinc (Zn) - Smelting, electroplating.

B. Permissible Limit of Heavy Metals Along With Their Sources and Effects

<table>
<thead>
<tr>
<th>Sr. No.</th>
<th>Pollutant</th>
<th>Major Sources</th>
<th>Effects on human health</th>
<th>Permissible level mg/l</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Chromium</td>
<td>Mines, mineral sources</td>
<td>Damage to the nervous system, fatigue, irritability</td>
<td>0.05</td>
</tr>
<tr>
<td>2</td>
<td>Lead</td>
<td>Paint, pesticide, smoking, automobile emission, mining, burning of coal</td>
<td>Mental retardation in children, developmental delay, paralysis, sensor neural deafness and, acute or chronic damage to the nervous system, kidney.</td>
<td>0.1</td>
</tr>
<tr>
<td>3</td>
<td>Mercury</td>
<td>Pesticides, batteries, paper industry</td>
<td>Tremors, minor psychological changes, spontaneous abortion, damage to nervous system, protoplasm Poisoning</td>
<td>0.01</td>
</tr>
<tr>
<td>4</td>
<td>Arsenic</td>
<td>Pesticides, fungicides,</td>
<td>Bronchitis, dermatitis, poisoning</td>
<td>0.02</td>
</tr>
<tr>
<td>5</td>
<td>Copper</td>
<td>Mining, pesticide production, chemical industry, metal piping</td>
<td>Anemia, liver and kidney damage, stomach and intestinal irritation</td>
<td>0.1</td>
</tr>
</tbody>
</table>
Nickel
Fuel production, electroplating, pigments, ceramics, batteries, food production, making jewellery, valves, magnets,
Acute poisoning, Allergies, Adverse pregnancy outcomes, Cancer
1.0

Cadmium
Welding, electroplating, pesticide fertilizer, Cd and Ni battens, nuclear fission plant
Lung disease, Lung cancer, Bone defects, increased blood pressure, kidney damage, bronchitis, gastrointestinal disorder, bone marrow, cancer
0.06

Zinc
Refineries, brass manufacture, metal Plating, plumbing
Cause damage to nervous system
15

C. Various Processes for Removal of Heavy Metals

<table>
<thead>
<tr>
<th>Metal</th>
<th>Removing agent</th>
<th>Major method</th>
<th>Other method</th>
</tr>
</thead>
<tbody>
<tr>
<td>Heavy metals in water</td>
<td>Natural zeolite, Conductive electroactive</td>
<td>Ion exchange</td>
<td>Biosorption, immobile-zation in matrix, complexation, Bioremediation</td>
</tr>
<tr>
<td>Chromium ions</td>
<td>Activated carbon</td>
<td>Ion exchange adsorbents</td>
<td>Chemical sedimentation, surface absorption and reverse osmosis</td>
</tr>
<tr>
<td>Mercury</td>
<td>Activated carbon, Bentonite</td>
<td>Ion exchangers</td>
<td>Reduction, precipitation, extraction and ion exchange</td>
</tr>
<tr>
<td>Arsenic</td>
<td>Polypyrole and its composites, polyvinyl alcohol</td>
<td>Oxidation</td>
<td>Capacitive deionization, adsorbents and surfactants</td>
</tr>
</tbody>
</table>

III. WATER HYACINTH

Water hyacinth (Eichhornia crassipes) is a noxious weed that has attracted worldwide attention due to its fast spread and congested growth, which lead to serious problems in navigation, irrigation, and power generation. On the other hand, when looked from a resource angle, it appears to be a valuable resource with several unique properties [5]. The water hyacinth is the most important of the world’s noxious fresh-water plants. Water hyacinth is a free-floating perennial aquatic plant native to tropical South America. With broad, thick, glossy, ovate leaves, water hyacinth may rise above the surface of the water as much as 1 m in height. The leaves are 10-20 cm across, and float above the water surface. They have long, spongy and buibous stalks. The feathery, freely hanging roots are purple black. An erect stalk supports a single spike of 8-15 conspicuously attractive flowers, mostly lavender to pink in colour with six petals. One of the fastest growing plants known, water hyacinth reproduces primarily by way of runners or stolons which eventually form daughter plants. It also produces large quantities of seeds, and these are viable up to thirty years. The common water hyacinth (Eichhornia crassipes) is a vigorous grower known to double its population in two weeks [6]. Fig. I shows the different parts of water hyacinth (Eichhornia crassipes).
IV. LITERATURE REVIEW

Various studies were carried out by renowned experts from around the state on water hyacinth and heavy metal removal by using water hyacinth. In 2003, S.H. Hasan et al. carried out study on removal of zinc from wastewater by water hyacinth. The water hyacinth has been successfully utilized for the removal of Zn from simulated wastewater samples. In this study, it has been found that growth rate in general and relative growth rate in particular of the plant decreases with the increase of metal ion concentration. The rate of mobility of the metal is slow in the root than that for the top of the plants. It has also been found that the percentage removal of the metal from the aqueous solution decreases with increasing initial concentration of the metal.

Xiaomei Lu et al., (2004) have done the study on Removal of Cadmium and Zinc by Water Hyacinth, Eichhornia crassipes. In this study the Phytoremediation potential of water hyacinth Eichhornia crassipes, for the removal of cadmium (Cd) and zinc (Zn) and phytoaccumulation of heavy metals, Cd and Zn, by water hyacinth E.crassipes, was studied. Water hyacinths were cultured in tap water, which was supplemented with 0.5, 1, 2 and 4 mg/L of Cd and 5, 10, 20, and 40 mg/L of Zn, and were separately harvested after 0, 4, 8 and 12 days. The experiment showed that both Cd and Zn had effects on plant relative growth. Removal of metals from solution was fast especially in the first four days. The accumulation of Cd and Zn in shoots and roots increased with the initial concentration and also with the passage of time.

Wahab Oluwanisola and Liasu Adebayo (2010), have done the study on Phytoremediation potential of some heavy metals by water hyacinth. In this work, the phytoremediation potential of water hyacinth plant (Eichhornia crassipes) was investigated on some metals. The plants were grown for 7 days each in phytoremediation tanks containing a solution of 100 ppm concentration of either Potassium (K), Sodium (Na), Zinc (Zn), Lead (Pb), Iron
(Fe), Cadmium (Cd), Magnesium (Mg), Copper (Cu) or Calcium (Ca). The change in fresh weight was examined. The percent removal of the metals by the plant was determined using atomic absorption spectrometry on the acid digest of the plant. The biomass decreased insignificantly in the water hyacinth grown in the test solution and increased by 5.72% in the control.

In 2013, Ajibade F. O. et al., carried out study on Phytoremediation Efficiencies of Water Hyacinth in Removing Heavy Metals in Domestic Sewage (A Case Study of University of Ilorin, Nigeria). This study was carried out to check the suitability and efficacy of water hyacinth in domestic sewage treatment. Three treatments of water hyacinth replicated two times were used in the study. These treatments include no water hyacinth (control), 1kg and 2kg water hyacinth plant density cultures. The system was designed based on Completely Randomized Design (CRD). Sewage samples were collected during the growth of water hyacinth. Purification of water hyacinth on sewage was rapid during the first three weeks in the sewage cultured with water hyacinth and there was low absorption in nutrients in the last two weeks when attaining maturity. Parameters such as Cl, Fe, Cu, Mn, Pb, K, F, Nitrate and Sulphate were drastically reduced throughout the course of the study.

N. K. Brahma and A. K. Misra, (2014) have done the study on Study of heavy metals content in water, water hyacinth and soil of Rupahi Beel, Nagaon, Assam (India). This study was undertaken for assessing the level of heavy metals such as copper, nickel and zinc in water, water hyacinth and soil samples of Rupahi Beel, Nagaon, Assam. Metals were detected using flame atomic absorption spectrophotometry. The results revealed that by and large all the three metals are present in all the samples. The average concentration of Cu, Ni and Zn in both water and soil of the Beel are in the order Ni < Cu < Zn. However, the concentration in water hyacinth (both in root and leaf) is in the order Cu < Ni < Zn. The metal concentration in water hyacinth is much more than both in water and soil that signifies the absorption capacity of it.

In 2014, Gomati Swain et al., carried out study on Phytoremediation of Copper and Cadmium from Water Using Water Hyacinth, Eichhornia Crassipes. In this study, the phytoremediation potential of water hyacinth Eichhornia crassipes, for the removal of copper (Cu) and Cadmium (Cd). Young plants of equal size were grown in tap water and supplemented with 0.35, 0.70 and 1.05 mg/L of Cu and 0.27, 0.54 and 0.81 mg/L of Cd individually for 25 days. The experiment showed that both Cu and Cd had effects on plant relative growth. The plant at all the concentrations used in the experiment removed approximately more than 90% of Cu and Cd. Removal of metals from water was fast especially in the first five days. The accumulation of Cu and Cd in roots and stems increased with the initial concentration.

Mary Lissy P. N. and Dr. G. Madhu (2011) have done the study on Removal of Heavy Metals from Waste Water Using Water Hyacinth. In this paper the main focus was on studying the efficiency of water hyacinth in removing dissolved solids, B.O.D, heavy metals mainly chromium and copper from the waste water, and the effect of the growth of water hyacinth on the pH of the waste water. To achieve this objective, water hyacinth was grown in synthetic wastewater prepared by adding varying concentrate ions of Cr and Cu. The concentrations of heavy
metals, pH, B.O.D and total dissolved solids were noted in the waste water before and after cultivating water hyacinth and compared the results with the standard values. They have concluded that when the plants were collectively grown, the removal of pollutants from the water was very high. The experimental results have shown that about 65% removal of heavy metals could be achieved by water hyacinth.

In 2014, Matindi C. N et al., carried out study on Analysis of Heavy Metal Content in Water hyacinth (Eichhornia crassipes) from Lake Victoria, Kenya. A study was conducted to determine the concentration of heavy metals in E. crassipes along the shoreline of Winam Gulf on Lake Victoria, Kenya. In this work, plant samples were dried under room temperature for two weeks followed by overnight oven drying at 105°C. They were then ground using an electric grinder. Dry ashing on 2g of powdered plant material was conducted at 600°C in a furnace for 4hrs. For water samples, 5ml was measured and dry ashed for 2hrs. The ash was then digested in 5ml of concentrated nitric acid and made to 100ml with distilled water. The digested samples were then analyzed for eight metals. Pb²⁺, Fe²⁺, Cu²⁺, Zn²⁺, Mn²⁺, Cr²⁺, Cd²⁺ and Ni²⁺ were detected in the samples with concentrations ranging from 0.02≤ 21ppm of dry mass. Concentration of some metals in roots was found to be up to 3 times higher than in leaves and stems. Based on their study they have conclude that, Eichhornia crassipes act as a means of removal for heavy metals from Lake Victoria and also be utilized as an indicator for pollution. Since this plant grows extensively on the Lake’s water surface it can be used for this purpose and later be converted as biomass.

V. CONCLUSIONS

Based on the above study following conclusion are drawn:

- Eichhornia crassipes is a good biosorbent for heavy metals and can remove upto 65% of heavy metal by root and leaves uptake capacity. It can also be said that the roots of water hyacinth are better accumulators of the metals than leaves.
- Water hyacinth (Eichhornia crassipes) could effectively phytoremediate contaminated water containing metals such as Potassium (K), Sodium (Na), Zinc (Zn), Lead (Pb), Iron (Fe), Cadmium (Cd), Magnesium (Mg), Copper (Cu) and Calcium (Ca), thus; reducing the environmental hazard that could arise from untreated waste water to the ecosystem.
- Water hyacinth can be used as a sustainable and eco-friendly approach to waste water treatment and for removal of heavy metals.

REFERENCES


