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A Review on Removal of Heavy Metals from Contaminated Water using Hydroponics Technique

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Abstract: ***Heavy metals are among the important among the contaminations in the environment. Eventhough, several methods are already available for removal of these contaminants, but most of them are costly and are difficult to get optimal results. Currently, phytoremediation, phytoaccumulation and phytostabilisation are emerging, effective and affordable technological solution used to extract or remove inactive metals and metal pollutants from contaminated water. These technologies are environmental friendly and potentially cost effective. This paper aims to review details about the removal of heavy metals of lead, cadmium, zinc and chromium. Additionally, it describes several plants and their growing conditions and their adsorption rate in various parts of the plants.***

Keywords: lead, chromium, phytoremediation, phytoaccumulation, phytostabilization

1. Introduction

In the industrial areas, the freshwater sources are getting polluted due to the presence of heavy metals. This pollution by heavy metals can cause serious environmental and health problems. Heavy metals are those which are having a density greater than 6 g/cm^3. This has turned out to be a global issue and is considered by various environmentalists as it requires suitable consideration due to its ill effects. The most commonly seen heavy metals in the wastewater includes arsenic, copper, cadmium, lead, chromium, nickel, mercury and zinc. When these heavy metals are released into the natural environment without proper treatment or preventive measures, it can cause a serious threat to the public health because of their contents and can lead to its generation in the food chain. They are the results from residential dwelling, infiltration and discharge due to direct or indirect human activities. The main sources of these contaminants are urbanization, industrialization and human activities.

2. Phytoremediation

The reed plant (Phragmitesaustralis) has a phytoremediation ability ranging from 50 ppm to 500 ppm in the removal of heavy metals, with and without using a nutrient solution [Al-Akeel et.al, 2010]. pH and salinity affects the phytoremediation ability to remove cadmium, lead and nickel by Phragmitesaustralis from contaminated water [Bello et.al 2018]. The results showed Phragmitesaustralis removed 93% of cadmium, 95% of lead and 84% of nickel over a period of 6 weeks [Bindu et.al 2010]. The shallow raceways containing 20, 40, 60mg/l of cadmium spiked with Hoagland solution, the plants of equal heights grown for a period of 20 days. A set of two raceway were used one comprised of nutrient solution with no metal supply and other of nutrient medium with plants with no metal supplement. There was chlorosis in leaves of the plant due to accumulation of heavy metal. This showed the plant has a capability for the accumulation of heavy metal. The comparison with lead treatment containing DTPA with lead treatment containing EDTA at the fourth week showed that there was a higher concentration of lead in plant tissues in lead treatment containing EDTA [Boonyapookana et.al 2013]. The study on phytoaccumulation of lead by three plant species such as Helianthus annuus, Nicotianatabacum, and Vetiveriazizanioides, grown in hydroponic solution containing $Pb(NO_3)^2$ at concentraation of 0.25 and 2.5 mM lead in the presence or absence of chelating agents (EDTA or DTPA) have resulted in the conclusion. A study on phytoremediative removal of lead by Ecilptaalba considering parameters such as lead concentration, contact time and pH values [Noufal et.al 2017]. Five concentration of lead (40,50,65,85,100 ppm) were selected and used for three replicates. The plant showed higher removal efficiency of 99.2% at 50 ppm after 7 days. The best removal efficiency of 98.95% at 100 ppm occurred at pH 7. It is suggested that the plant can be used in the biological treatment of polluted water. The accumulation of lead in plants showed a decrease in height of the plant and there was a decrease in stomatal conductance not to a greater extent [Romeiro et.al 2006]. The study was conducted to assess the lead adsorption by Ricinus Communis grown in nutrient medium containing different concentration such as 0, 100, 200 and 400 µmol/L for 28 days under greenhouse condition. Biometric analyses, photosynthetic rates and lead content were analysed in plant solution, roots and shoots. Vetiveria zizanioides has shown optimum growth at a pH 6–9 and good removal conditions for 5–20mg/L of lead and chromium [Singh et.al 2015]. The removal of lead and chromium from synthetic wastewater using Vetiveria zizanioides and the effect of pH, initial concentration of metals, and time for removal of lead and chromium has also been studied at a period of 15 days. The plant saplings received light from bulbs and hydroponic system consisted of 50% nutrient solution and 50% tap water. The removal of lead is about 80 to 94% and chromium is about 78%. Most of the chromium was stored in the stem and most of the lead was stored in roots. The concentration of heavy metal decreased with the germination percentage of seeds. The Raphanussativus, Vignaradiata and Cicerarietinum can accumulate lead and aluminium to a maximum permissible limit about 15mM, 25mM and 35mM, 5mM and 10Mm respectively[James et al., 2014]. In the EAPR system, there was a 93% reduction of lead and phytoremediation showed 99% removal of lead [Rudy et.al 2013]. The plant used in the study was water lettuce (Pistiastratiotes) and it was observed that accumulation of copper and lead was higher in plant roots. The absorption of the metallic element by Eichhorniaspesiosa by EAPR method was very less when compared to that of phytoremediation due to high precipitation of lead within the aquatic plume throughout the electromigration method. The water hyacinth showed high ability of copper (Cu) adsorption than that lead (Pb) adsorption [Rudy et.al 2015]. Growth reduction and chlorosis were the physiological changes induced by metals in Sorghum bicolour and Carthamustinctorius[Chami et.al 2015]. Ipomoea aquaticaforsk showed the ability to grow under high concentration of lead, stored in root and lower stem with the help of caulofiltration which can break and spread, making root and shoot practical plant for the removal of lead under constructed wetlands condition. Various parameters such as physical, chemical, biological were tested for the effluents which showed that the organic and nutrient load is high in municipal effluent compared with sewage mixed industrial effluent. The plant showed a removal efficiency of 80% for lead and 99% for nickel. The bioconcentration factor showed that the plant is a moderate metal accumulator for lead and copper [Bedapati et.al 2016].

3. Uptake and Accumulation of Zinc, Cadmium, Lead and Chromium

After 96 hours of incubation the lead content in roots of plants such as viciafaba, pisum sativum and phaseolus vulgaris was about 90-95% and lead transported to the above-ground plant parts was about 5-10% [Piechalaka et.al 2010]. The accumulation of lead and calcium was better in sunflower compared with other plants. The plant species showed dissimilar abilities of phytoextraction and heavy metal transportation from the values of BCF (Bioconcentration factor) and TF (Translocation factor) [Niu et.al 2007]. Lead and chromium appeared to accumulate in or on the plant roots (eight marsh plants Cyperusesculentus, ScirpusValidus, Spartina patens, Scirpusrobustus, Distichiisspicata, Triglochinmaritima, Spartinaalterniflora, and Spartinafoliosa) with no translocation into plant tops. Zinc, cadmium, and nickel were translocated into aerial portions of the marsh plants [Lee et.al 2008]. A competition between the phosphorus for macronutrient and lead for plant growth was present when there is a greater concentration of lead in roots due to adsorption and bioaccumulation mechanism. The Salviniaauriculata can be used as biosorbent for industrial effluents in the metal removal process [Espinoza et.al 2005]. The combination of Ethylene Diamine Tetra Acetic acid (EDTA) and Indole-3- Acetic acid (IAA) increased lead accumulation in leaves of Medicago Sativa as compared to plants under lead solution alone. This technique is used in non-hyperaccumulator species for the lead accumulation [Martha L. Lopez et.al 2005]. The lead was first accumulated in the root parts and then transported and precipitated in leaves, stems and all other parts of the plant. This lead concentrate in corn plant could bring serious effects on organisms in the food chain [Carl et.al 1974]. The accumulation of heavy metal by cucumber and Brassica juncea is varied by different cultivation temperatures [Takeda et.al 1999]. The lead content in the root was high in CS plants and in the shoot it was the same in both CS and NCS plants. In CS plants the accumulation of zinc was high and cadmium was low. In NCS plants the generation of zinc was low and cadmium was high [Tanhan et.al 2007]. The photosynthetic rate decreases when grown in lead aquatic medium in Eichhornia crassipes [SangitaBaruah et.al 2012]. The plant Dahogntou was more sensitive to increased lead concentration so that Weishanhu and Yizhibi can be used in the phytostabilization of lead-contaminated soils [Shufeng Wang et.al 2014]. The highest removal efficiency of 93.56% was achieved by napier grass at 10 ppm lead concentration, 0.3 g/l NaCl concentration and a 45 day time period [Hongsawat et.al 2018]. Respond surface methodology a statistical method, using three operational variables, lead concentration, NaCl, the time period was used to determine the results. The lead accumulation in water hyacinth induced growth changes and it is suggested water hyacinth is a feasible plant for the hyperaccumulation of lead used in wetlands [Malar et.al 2014]. Martha L. Lopez et.al 2005

4. Rhizofiltration

Maximum lead was accumulated in roots of a medicinal plant Plectranthusamboinicus and accumulation in leaf was limited [Ignatius et.al 2014]. With the combination of mass balance equations and metal uptake kinetics, it is concluded that the plant accumulates lead particularly in root biomass [Brijesh et.al 2011]. The growth of the plant Colocasiaesculenta was not retarded at low levels of lead and the translocation of lead from root to shoot was about 68%. The plant is considered as a potential option for lead phytoextraction and it can also remediate lead-contaminated soils [Shoffikul et.al 2016]. Membrane transport mechanism is responsible for intracellular lead uptake which is the important step in developing rhizofiltration systems. Most of the lead was accumulated in the tip of the root [Meyers et.al 2007]. Photosynthetic pigments increased the initial time of the treatment which further decrease with time. Lead concentration has the tendency to cause oxidative damage in leaves of Talinum species due to increased cell death [Abhay et.al 2012]. Pistiastratiotes have acceptable bioaccumulation efficiency, great biomass production and great short term removal of lead and the plant has rhizofiltration capacity in the removal of lead and cadmium [Veseley et.al 2011]. The hydrilla and duckweed have greater potential to remove lead in shorter period. The kinetic rate of duckweed is studied and it showed that kinetics and mechanism of uptake is complicated. These wetland species can transform harmful lead into harmless byproduct and a nutrient for biological productivity [Gallardo et.al 2002]. Eichhorniacrassipes has great potential to remove lead compared to other metals and the highest accumulation was in roots compared to shoots [Amit et.al 2014]. There was no lead and chromium accumulated in the plant and there was an increase in the concentration of copper in plant tissues with increasing concentration of solutions [Anit et.al 2015]. The heavy metals were accumulated more in roots compared to shoots and it was concluded that Brassica has great potential to remediate lead, zinc and cadmium in the aquatic environment [Anamika et.al 2009]. The younger plants were more tolerant to lead and zinc ions compared to older plants.

While in the older plant the phosphorous concentration increased with lead and zinc ions [Ngoc et.al 2018]. Pterismultifida can accumulate 90% of lead compared to arsenic and cadmium. The concentration of lead and cadmium was more in roots [Farzana et.al 2019]. At a period of 4 months, Vetiver Zizanioides showed 100% removal of lead, mercury and coliform [Girija et.al 2016].

5. Conclusions

The amount of heavy metal that enters the plants by mass flow is based on its concentration in the hydroponic solution. The amount of heavy metal adsorption by root interception depends on the amount of available metal in the hydroponic solution available to the root. Based on the study, it can be said that highly polluting heavy metal can be removed by different kinds of plants based on the concentration of contaminants. Lead can be removed to even 100 per cent by using highly lead tolerant plants and a good hyperaccumulator. The studies shows thatVetiver Zizanioides can remove 100% of lead, mercury and coliform. This review draws attention to metal accumulation in edible plants, certain wild plants and medicinal plants at various conditions.

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