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Heavy Metals Removal by Multi Species and Multimedia Constructed Wetland: A Review

Vivek Ramchandra Raut[1] and G.R. Munavalli[2]

[1]*M.Tech. Student (Civil Environmental Engg). Civil Engineering Department Walchand College of Engineering, Sangli*
[2]*Civil Engineering Department Walchand College of Engineering, Sangli*
E-mail: [1]vivekraut009@gmail.com, [2]guru.munavalli@walchandsangli.ac.in

Abstract—*The industrial and domestic wastewater is responsible for causing various damages to the environment and adversely affecting the health of the people. Heavy metals are often discharged by a number of industries, such as metal plating facilities, mining operations and tanneries; this can lead into the contamination of freshwater and marine environment. This paper summarizes the results of implementation of constructed wetlands in the treatment of metal containing water and evaluates their performance with respect to various metal removal mechanisms. The role of adsorbents as substrate and vegetation within wetland systems are also examined to determine the possibility of enhancing the metal removal efficiency for future applications. Metal contaminated waters including industrial wastewater and sewage are also evaluated regarding their removal efficiency within constructed wetland systems.*

Keywords: *Adsorption, Constructed Wetland, Heavy metals, Low cost adsorbent, Macrophytes, Plant uptake.*

1. INTRODUCTION

Heavy metals are universal environmental pollutants that arise from a variety of industrial, commercial, and domestic activities [3]. Heavy metals are not biodegradable and can lead to accumulation in living organisms, causing various diseases and disorders. It is well known that some metals are harmful to life, such as Sb, Ni, Cr, Cu, Pb, Mn, Hg, Cd As, etc. [11]. Conventional methods for heavy metal removal from aqueous solution include chemical precipitation, electrolytic recovery, ion exchange/chelation and solvent extraction/liquid membrane separation. But these methods are often cost prohibitive having inadequate efficiencies at low metal concentration. Some of these methods, furthermore, generate toxic sludge, the disposal of which is an additional burden on the techno-economic feasibility of treatment procedures [15].

Constructed wetlands have been considered a possible solution to the long-term remediation of heavy metal discharging industries. Constructed wetlands to treat influent having heavy metals may provide a continuous, low-cost and effective solution to a growing problem for various industries today. There are a number of physical, chemical and biological processes in purification, like sedimentation, filtration, adsorption, microbial decomposition and chemical transformation. Adsorption may play an important role in the removal process. Consequently, it is important to select those substrates of high ecological activity and adsorption capacity. There has been some recent work that has attempted to investigate the influence of different substrates. Some of the agricultural materials can be effectively used as a low cost sorbent in constructed wetland as substrate. Various macrophytes in constructed wetland have been shown to play important roles in wetland biogeochemistry through their active and passive circulation of elements [16].

Heavy metals are effectively removed in CWs by a combination of physico-chemical and biological removal processes [6]. Despite a lot of recent research efforts, the understanding of the complex removal processes, how they interact and which are the major influencing factors, is still rather incomplete. A reason for this is that CWs depend on the interaction of many different components, including the substrate, sediment, vegetation and water column [12].

2. REVIEW OF PREVIOUS WORK DONE

Literature survey has been carried out on a constructed wetland for heavy metals removal and it discussed in this section.

2.1 Removal of heavy metals in constructed wetland

Metal removal within constructed wetlands has been attributed to various mechanisms including sedimentation, filtration, chemical precipitation and adsorption, microbial interactions, and uptake by vegetation. Specifically, the major processes are responsible for metal removal in constructed wetlands including binding to sediments and soils, precipitation as insoluble salts, and uptake by plants and bacteria. [6].

A few scientists studied on the heavy metal removal performance by a laboratory-scale wetland system treating storm runoff. The removal efficiencies and rates for metals monitored ranged from 81.7 to 91.8% and 36.6–372.7 mg/ m2/day for Cu, 75.8–95.3% and 30.8–387 mg/m2/day for Pb, and 82.8–90.4% and 33.6–362.1 mg/m2/day for Zn respectively. Results for the storm simulation showed that the metal loadings leaving the system remained very low with the wetland system retaining over 99% of the metals. Wetland receiving storm water can be an efficient sink for heavy metals. This paper shows that constructed wetland can be used for removal of heavy metals efficiently [11].

A few scientists studied on studied on the potential for constructed wetlands for wastewater treatment and reuse in developing countries and he concluded that the discharge of heavy metals into the aquatic environment by industrial wastewater was one of the primary threats to the ecosystem. Conventionally, heavy metals can be removed by a range of physicochemical treatment technologies such as precipitation, ion exchange, electrochemical, and membrane processes. However, the aforementioned technologies are expensive and energy intensive. These papers show that constructed wetlands have been proposed to offer a low cost and low maintenance treatment alternative for industrial effluent, especially in developing countries than other conventional technologies [7].

2.2 Significance of various vegetation species within Constructed Wetland

Some researchers observed that vegetation is one of the principal components to remove pollutants within wetland systems. Macrophytes may assimilate pollutants directly into their tissues, provide an environment for microorganisms to grow, and usually act as catalysts for purification reactions especially in their rhizosphere. Wetland plants including Typha latifolia, Phragmites australis, Glyceria fluitans, and Eriophorum angustifolium were found to be tolerant to high concentrations of metals [9].

A few scientists studied on observed that wetland plant species differ greatly in their abilities to accumulate and translocate metals. Metal removal can be significantly enhanced by the selection of appropriate plant species. They investigated the application of different plant species in constructed wetlands receiving tannery wastewater. In this study the survival of different plant species in subsurface horizontal flow constructed wetlands receiving tannery wastewater was investigated. Five pilot units were vegetated with Canna indica, Typha latifolia, Phragmites australis, Stenotaphrum secundatum and Iris pseudacorus, and a sixth unit was left as an unvegetated control. These papers indicated that macrophytes plays important role in heavy metals removal and different species have different uptake capacity [2].

2.3 Heavy metals removal potential of various adsorbing support media

Some researchers studied that industrial wastewater treatability studies have demonstrated heavy metal uptake by wood, wood products and plant fiber-derived materials. Wood fiber sorption capacities for dissolved heavy metals were on the order of 5–10 mg/g. In this work the ability of cork and yohimbe bark wastes to remove Cu(II) and Ni(II) from aqueous solutions has been studied. When comparing both biomaterials, yohimbe bark waste was found to be the most efficient adsorbent for both metals studied [14].

Some researchers studied that wide range of low cost adsorbents obtained from chemically modified plants wood waste has been studied and most studies were focused on the removal of heavy metals ions such as Cd, Cu, Pb, Zn, Ni and Cr (VI) ions. The most common chemicals used for treatment on waste plants wood are acids and bases. Chemically modified plant wastes vary greatly in their ability to adsorb heavy metal ions. Chemical modification in general improved the adsorption capacity adsorbent probably due to higher number of active binding sites after modification, better ion exchange properties and formation of new functional groups that favor metal uptakes [5].

Some researchers evaluated that wood chips were suitable due to their ability to attenuate heavy metals in roadway runoff. The results of this research indicate that wood chips are effective for short-term attenuation of heavy metal concentrations in roadway runoff, but provide little permanent removal. Relative to the influent heavy metal concentration distribution in time, effluent from a wood chip treatment device receiving sheet flow runoff exhibits lowered heavy metal concentrations that are prolonged over longer time periods. These paper shows that various low cost adsorbents like wood chips, waste wood etc. have higher affinity for heavy metals so they can enhance heavy metal removal mechanism if they are use in constructed wetland as substrate media. [13]

2.4 Heavy Metal Reduction for Industrial and Domestic Wastewater

A few scientists assessed the feasibility of treating industrial wastewater within pilot-scale wetland in Argentina. Average metal removal efficiencies were 83, 82, 69, and 55% for Fe, Cr, Ni, and Zn, respectively. In addition, metal concentration in macrophytes tissues increased significantly where metal concentration in the roots was 2–3 times higher than in leaves. However, only a small fraction of metal retained (7, 2, and 4% of the Cr, Ni, and Zn, respectively) in the wetland was stored in the macrophytes tissue. Retained metals were stored mainly in the sediment compartment [4]. A few scientists tested compost-based and gravel-based vertical flow constructed wetland treatment systems to treat wastewater from an oil refinery in Pakistan. The results indicated that the purifying efficiency was low at the beginning but it improved gradually with the growth of plants and biofilm. The significant removal of heavy metals including Fe2+, Cu2+, and Zn2+ was observed. Total amounts in whole Phragmites plants (roots, rhizomes, and culms), in the compost-based and gravel-based constructed wetlands, respectively, were 35.5 and 27.6 mg/m2 for copper, 82.4 and 58.9 mg/m2 for iron, and 18.5 and 13.6 mg/m2 for zinc. Plant tissues took up significant amounts of metals (35–56%) in this study. [1]

The research findings of some researchers reported that heavy metals such as Cu, Cd, Zn, Pb, Ni, and Co could be readily removed by constructed wetland systems though the metal removal efficiency seems to be influenced by the types of media used and the types of wastewater to be treated. Four laboratory scale gravel-filled subsurface-flow constructed wetland units planted with cattails were fed with primary treated domestic wastewater at a constant flow rate of 25 mL/min. The carbon oxygen demand (COD) removal efficiency was independent of increasing metal loading while nitrogen removal efficiency deteriorated progressively with increasing metal loading. The relative effect of the heavy metals was found to increase in the following order: Zn<Pb<Cd. The metal seems to exhibit some inhibitory effect on nitrogen uptake by cattail plants. However, the uptake of Zn, Pb, Cd, and Cu by cattail plants was insignificant compared to other removal pathways based on the mass balance analysis. These studies provide useful information for some metal containing industrial wastewater combined with sewage for treatment by constructed wetlands. The potential of constructed wetland treating industrial wastewater and sewage is enormous based on these studies. In order to enhance metal removal efficiency, proper control of inflow metal loading, selection of substrate media, selection of vegetation species, and design of wetland systems need to be further investigated [8].

3. CONCLUSION

Constructed wetlands possess the potential to treat metal contaminated waters. The metal removal mechanisms within wetland systems mainly include sedimentation, filtration, chemical precipitation and adsorption, microbial interactions, and uptake by vegetation. Different macrophytes uptake different heavy metals with different concentrations, so selection of macrophytes play an important role and also multi species can enhance heavy metal removal efficiency. Various adsorbing materials have grater affinity for heavy metals. These can be used as substrate in constructed wetland to enhance removal efficiency of heavy metals, and also various adsorbents have different affinity towards heavy metals, so multimedia can enhance removal efficiency. Further research is needed to enhance the removal efficiency within constructed wetland receiving metal polluted waters. Constructed wetland can work as an efficient option for industrial wastewater to treat heavy metals discharge.

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