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MINI REVIEW

Review on Single Technology for Heavy Metal Remediation

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Streams and rivers are the freshwater biome, which also includes lakes and ponds. They usually begin at a source in higher and cooler climates than their mouths, which is where they empty into larger bodies of water, traditionally other water channels or the ocean. Plants are an important part of freshwater ecosystems, adding oxygen to water, detoxifying it and serving as a source of food for animals dwelling there. Rivers and streams are created by precipitation, melting ice or springs. These moving bodies of water flow through channels in which the bottom is known as the bed and the sides as the banks. Rivers can be wide and deep, and many empty into larger bodies of waters such as oceans or lakes. Streams are smaller and can converge to create rivers. Rivers and streams are fresh water and hold up to 3 percent of the Earth's fresh water. Freshwater plants include algae, bulrushes and cattails, and freshwater animals include crayfish, fish and eels.

Algae of many types populate streams and rivers, but only in specific locations. Generally, it isn't found near their mouths where water is clearer and colder and often faster moving. It shows up near the middle of the stream or river, when water temperature decreases, water slows and the banks draw farther apart. An alga is a simple plant, but provides oxygen to the water it populates as well as a food source to animals living in it.

Cattails are common in ponds and lakes as well as on the shores of slow-moving streams and rivers. Examples include common cattail (Typha latifolia), native to India, and dwarf cattail (*Typha minima*), also called bulrush, miniature cattail and least cattail. . Cattails, when planted in streams or ditches, may remove pollutants from the water, but they can also become invasive in many aquatic environments.

Three types of plants usually live in rivers and streams: algae, mosses and submerged plants. Calmer rivers or streams may have emergent plants, or plants that are grounded to the waterway's bed, but their stems, flowers and reach extend above the water line. Emergent plants include cattails, flowering rush and bulrushes. Algae are free-floating plants without any true stems, leaves or roots. Stonewort, plankton algae and chara can be found in many rivers and streams. Mosses grow in clumps and have only simple leaves. Mosses usually are found growing on rocks within the bodies of water. Submerged plants grow completely beneath the water, attaching to the bed of the river or stream. These plants can be found in nearly any section of the river, and they can grow in clumps or individually. Examples of submerged plants include pondweeds, coontails, wild celery and waterweed.

Animals that do not possess a backbone are known as invertebrates. These include all types of crustaceans, worms, snails and insects. Crustaceans such as crayfish, shrimp, some types of lobster and certain crab species live in streams and rivers. Insect larvae, including the mayfly, caddisfly and stonefly, gestate in streams. Beetles can be found in streams that are extremely clean and have plenty of rocks for the insects to stand on.

Phytoremediation is considered an innovative, economical, and environmentally compatible solution for remediating some of the heavy metal contaminated sites. Phytoremediation is a general term used to describe various mechanisms by which living plants alter the chemical composition of the soil matrix in which they are growing. Essentially, it is the use of green plants to clean-up contaminated soils, sediments or water. The advantages of this technique are evident in that the cost of phytoremediation is much less than traditional in situ and ex situ processes; plants can be easily monitored to ensure proper growth; valuable metals can be reclaimed and reused through phytoremediation; phytoremeditation is the least destructive method among the different types of remediation because it utilizes natural organisms and the natural state of the environment can be persevered. Specifically, several subsets of metal phytoremediation have been developed and they include: (1) phytostablization, in which plants stabilize the pollutants in soils, thus rendering them harmless; (2) phytoextraction, in which heavy metal hyperaccumulators, high-biomass, metal-accumulating plants and appropriate soil amendments are used to transport and concentrate metals from the soil into the above–ground shoots, which are harvested with conventional agricultural methods; (3) phytofiltration or rhizofiltration, in which plant roots grown in aer-

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ated water, precipitate and concentrate toxic metals from polluted effluents; and (4) phytovolatilization, in which plants extract volatile metals (e.g., Hg and Se) from soil and volatilize them from the foliage (Raskin and Ensley, 2000). Plants play important role in all subsets of phytoremediation. Metal tolerant plants with lower metal accumulation are preferred for phytostablization, and heavy metal hyperaccumulators are the best choice for phytoextraction, while plants that can adapt the wetland conditions are useful for phytofiltration. Vetiver grass (*Vetiveria zizanioides*), due to its unique morphological and physiological characteristics has been commonly known for its effectiveness in control of soil erosion and sediment control (Greenfield, 1995; Grimshaw, 2000; Bevan and Truong, 2002), in addition to its tolerance to extreme soil conditions including heavy metal contamination (Truong and Baker, 1996).

In Australia, *V. zizanioides* has been successfully used to stabilize mining overburden and highly saline, sodic, magnesic and alkaline (pH 9.5) tailings of coalmines as well as highly acidic (pH 2.7) arsenic tailings of gold mines (Truong, 1999). In China, it has been demonstrated that *V. zizanioides* is one of the best choices for revegetation of Pb/Zn mine tailings due to its high metal tolerance (Xia and Shu, 2001; Shu et al, 2002), furthermore, this grass can be also used for phytoextraction because of its large biomass. Recent research also suggests that *V. zizanioides* also has higher tolerance to acid mine drainage (AMD) from a Pb/Zn mine and wetland microcosms planted with this grass can effectively adjust pH and remove SO4 2-, Cu, Cd, Pb, Zn and Mn from AMD (Shu, 2003). All of these demonstrate that *V. zizanioides* has great potential in phytoremediation of heavy metal contaminated soils and water, and an integrated vetiver technique can be developed for phytoremediation. The most conspicuous characters of vetiver grass includes its fast growth, large biomass, strong root system, and high level of metal tolerance, therefore, vetiver grass is an important element for phytoremediation.

The principles of phytoremediation system are to clean up contaminated water which include identification and implementation of efficient aquatic plant; uptake of dissolved nutrients and metals by the growing plants; harvest and beneficial use of the plant biomass produced from the remediation system (Lu, 2009). The most important factor in implementing phytoremediation is the selection of an appropriate plant (Roongtanakiat et al., 2007, Stefani, 2011) which should have high uptake of both organic and inorganic pollutants, grow well in polluted water and easily controlled in quantitatively propagated dispersion. The uptake and accumulation of pollutants vary from plant to plant and also from specie to specie within a genus (Singh, 2003). The economic success of phytoremediation largely depends on photosynthetic activity and growth rate of plants (Xia and Ma., 2006), and with low to moderate amount of pollution (Jamuna,and Noorjahan, 2009). Many researchers have used different plant species like water hyacinth (*Eichhornia crassipes*) (Jamuna, and Noorjahan, 2009), water lettuce (*Pistia stratiotes*) (Fonkou et al., 2002), duckweed (lemna), bulrush (Typha), vetiver grass (*Vetiveria zizanioides*) and common reed (*Phragmites australis*) for the treatment of water. They have used these species for different types of contaminated waters, effluents etc.

Plants play important role in all subsets of phytoremediation. Metal tolerant plants with lower metal accumulation are preferred for phytostablization and heavy metal hyperaccumulators are the best choice for phytoextraction, while plants that can adapt the wetland conditions are useful for phytofiltration. Vetiver grass (*Vetiveria zizanioides*), due to its unique morphological and physiological characteristics, has been commonly known for its effectiveness in erosion and sediment control (Greenfield, 1995; Grimshaw, 2002) in addition to its tolerance to extreme soil conditions including heavy metal contamination (Truong and Baker, 1996). In Australia, *V. zizanioides* has been successfully used to stabilize mining overburden and highly saline, sodic, magnesic and alkaline (pH 9.5) tailings of coalmines as well as highly acidic (pH 2.7) arsenic tailings of gold mines (Truong, 1999). In China, it has been demonstrated that *V. zizanioides* is one of the best choices for revegetation of Pb/Zn mine tailings due to its high metal tolerance (Xia and Shu, 2001; Shu et al, 2002), furthermore, this grass can also be used for phytoextraction because of its large biomass. Recent research also suggests that *V. zizanioides* has higher tolerance to acid mine drainage (AMD) from a Furthermore, vetiver was found to have strong absorption abilities to ammonia and N dissolved in water. In addition vetiver showed a quite high removal rate for phosphorus. The removal of heavy metals from domestic and industrial waters has become an important application in water and wastewater treatment systems. At present, single technology for heavy metal remediation (Phytoremediation) is

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