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Review Of Metal Uptake, Plant-Metal Interaction And Transport In Plants In View Of Phytoremediation

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Abstract: *Phytoremediation employs the engineered use of green plants and their associated micro biota for the in-situ treatment of contaminated soil and ground water. It is cost effective, and aesthetically pleasing as the plants can be easily monitored and metals absorbed by the plants may be extracted from harvested plant biomass and then recycled. Effectiveness of phytoremediation process is based on the ability of plants to absorb metals and other toxic substances and effectively transport it to other aerial part of the plants such as root, stem, branches, leaves and seeds. This paper therefore reviews metal uptake process, plant-metal interactions and transport of metals within plants used for phytoremediation process.*

Keywords: *Phytoremediation, Metal uptake, Plant-metal interaction and Transport*

I. Introduction

Many plants experience slow transport of metals from root surface into the root and this is a limiting factor [1]. Every other metal, except volatile mercury, is transported into plant via soil solution. The solubility of these metals is highly restricted as a result of their adsorption to soil particles. The soil provides binding sites which most often is not selective for any specific metals. Soil can bind calcium as strong as cadmium. Cation exchange sites and carboxylic group associated with organic matter provide nonspecific binding site for clay soil. However some soils are selective, hence, they have the ability to bind some metals more than others. Such site may bind cadmium stronger than calcium especially when the sites are covered with a thin layer of hydrous aluminium, manganese and iron. According to [2], even at low concentration, selective sites maintain cadmium activity in the soil solution. On the other hand, lead lacks mobility in soil because it is often precipitated as insoluble carbonates, hydroxides and phosphates. Therefore for metals to move from soil into the plant, metal solubility is a fundamental prerequisite for lead phytoextraction. Metal transport from soil bulk to plant roots is accomplished based on two mechanisms namely: convection or mass flow and diffusion [3]. By convection, soluble metal ions in soil water move from solid bulk of the soil to surface of root. As the plant leaves transpire and lose water to the atmosphere, more water is absorbed by the roots of the plant from the soil to replace the lost water. Hydraulic gradient from bulk soil to the root surface is created by the plant's water uptake. The rate at which different metal ions are absorbed by the root of the plants is not the same. Some ions via mass flow are absorbed by plant's root faster than others. As a result, a depleted zone in the soil is created around the roots and a concentration gradient is formed from the bulk soil solution and soil particles holding the adsorbed elements, to the solution in contact with the root surface. This concentration gradient is the driving force of that makes ions to diffuse toward the depleted layer surrounding the roots [4].

Effect of Soil Microorganisms on Metal Uptake

Microorganisms in the soil often dwell symbiotically with plant roots where their interactions often result to enhancement of the root potential for metal uptake. In the course of metabolism, some microorganisms are known to excrete organic substances which also increase bioavailability of some essential metals such as iron and manganese and make it easier for plant root to absorb them [1]. These organic substances excreted by microorganism do also change the chemical properties of some toxic metals such as cadmium and lead and influence their solubility in the soil [5]. Blake *et al.*, (1993), [6], reported the use of a strain of *Pseudomonas maltophilia* to significantly reduce highly mobile and toxic Cr^{6+} to nontoxic and immobile Cr^{3+}. Toxic ions such as Pb^{2+} and Cd^{2+} have been reported to be well reduced to their immobile forms and hence they were minimized in the environment.

Uptake and Transport of Substances in Plants

In plants, different substances are conveyed from root to other parts of the plants via the phloem and the xylem. While water and mineral salts are transported via xylem, organic substances such as hormones and glucose are transported via phloem. The driving force involving for movement of water and mineral salt via xylem is transpiration while hydrostatic pressure is the driving force for movement of organic materials through phloem. Xylem vessels not only conduct water and mineral salts but they support the plant by their rigid elongated and lignified tubular dead structures. On the other hand, living companion cells and phloem sieve tube, sieve plates and cytoplasm elements are used for translocation of solutions of organic solutes [7]. Water uptake into the plant is by osmosis into root hair cells. The reason why many plants have numerous root hair cells is to increase the surface area of the root for absorption. Most mineral elements such as metal exist in the form of ions. Uptake is greatest in region of the root hairs. Uptake occurs mainly by active transport into the root hair cells [8]. The existence of water potential (WP) suggests that water movement is facilitated by osmosis process. And from the root to the leaves water and mineral ions are transported via three pathways including root pressure, capillarity and cohesion tension. Root pressure is created by the ions of mineral as they are transported actively via endodermal cells into xylem vessels in the root. This gives a negative water potential of the xylem and as a result water enters the xylem by osmosis. The small diameter of xylem vessels makes them too narrow for passage of water and this brings about capillarity. According to [9], as water evaporates from the leaves, it creates water potential gradient which enhances movement of water from the root through the xylem in a process known as cohesion tension.

Toxicity of Heavy Metals in Plants

The presence of heavy metals in the plant affects both plant growth characteristics and often leads to production of metabolites. Goyer, (1997), [10], described the three molecular mechanisms that characterize heavy metal toxicity in plants and they are:

(a) Autoxidation reaction which is common with transition metals such as iron and copper. It is self oxidation process which involves production of reactive oxygen species.

(b) Non-redox-reaction of heavy metals such as cadmium and mercury which leads to blocking of essential functional groups in biomolecules.

(c) Displacement reaction of different kinds of heavy metals which displaces essential metal ions from biomolecules.

II. Conclusion

Phytoremediation potential of a plant depends on the ability of the plant to absorb pollutant via the root hairs into the root and the further transportation of the pollutant to different parts of the plants by the help of transpiration and hydrostatic pressure as driving forces. As a result, a polluted environment can be cleaned up and the metals absorbed recovered by phytomining process.

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