Chapter 10
Molecular Overview of Heavy Metal Phytoremediation

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ABSTRACT

Metal toxification has remained one of the problems with the advent of industrial revolution. Plant based remediation are showing increasing promise for use in soils contaminated with organic and inorganic pollutants. A large number of plant families has been identified which has shown significant result in detoxification of heavy metals. Hyperaccumulator plant is capable of sequestering heavy metals in their shoot tissues. High tolerance to HM toxicity is dependent on a reduced metal uptake or increased internal sequestration, which depends on plant and environmental condition. Recent progresses on understanding cellular/molecular mechanisms of metal tolerance by plants are reviewed. This chapter aims to focus on molecular mechanism involved in heavy metal detoxification and tolerance by plants. A different method by which plant effectively converts toxic metal in less toxic compounds has been explained in this chapter. Further, mode of accumulation and sequestration of metals have been explained which are utilized by hyper accumulators.

INTRODUCTION

Phytoremediation can be defined as the process of utilizing plants to absorb, accumulate, detoxify and render harmless, contaminants in the growth substrate (soil, water and air) through physical, chemical or biological processes (Cunningham & Berti, 1993). Plant based remediation are showing increasing promise for use in soils contaminated with organic and inorganic pollutants. For removal of contaminants from soil, phytoremediation involves different processes, such as enzymatic degradation, that potentially lead to contaminant detoxification (Van Aken, 2008). However, despite great promise, rather slow removal rates and potential accumulation of toxic compounds within plants might have limited the application of phytoremediation (Eapen, Singh & D’souza 2007).

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Phytoremediation is proposed as a cost-effective alternative for the treatment of contaminated soils. Topsoil would be preserved and the amount of hazardous material reduced significantly (Ensley, 2000). In recent years, public concerns relating to ecological threats caused by heavy metal led to intensive research of new economical plant based remediation of contaminated soil namely chemical, physical and microbiological methods are costly to install and operate (Danh, Truong, Mammucari, Tran & Foster, 2009). The ability to hyperaccumulate metals in above ground tissue without phytotoxic effects has evolved in almost 500 plant species mainly those in the Brassicaceae family (Kramer, 2010). At least three processes make a major contribution to the ability to hyperaccumulate/hypertolerate metals.

1. Enhanced root uptake and loading into xylem.
2. Superior root to shoot translocation and
3. Efficient detoxification via chelation and sequestration predominantly within leaf cell vacuoles (Clemens, kim, Neumann, & Schroeder, 2002).

WHAT ARE HYPERACCUMULATOR PLANTS?

The term “hyperaccumulator” describes a number of plants that belong to distantly related families, but share the ability to grow on metalliferous soils and to accumulate extraordinarily high amounts of heavy metals in the aerial organs, far in excess of the levels found in the majority of species, without suffering phytotoxic effects. Three basic hallmarks distinguish hyperaccumulators from related non-hyperaccumulating taxa: a strongly enhanced rate of heavy metal uptake, a faster root-to-shoot translocation and a greater ability to detoxify and sequester heavy metals in leaves (Rascio & Navari, 2011).The term “hyperaccumulator” was coined for plant that actively take up exceedingly large amount of one or more heavy metals from the soil. Moreover heavy metals are not retained in the roots but are translocated to the shoots and accumulated in above ground organs, especially leaves at conc. 100-1000 fold higher than those found in non hyperaccumulating species. They show no symptoms of phytotoxicity (Reeves

Table 1. Cost of soil treatment

Treatment	Cost ($/Ton)	Additional Factors
Vitrification	75-425	Long-term monitoring
Landfilling	100-500	Transport/excavation/monitoring
Chemical treatment	100-500	Recycling of contaminants
Electrokinetics	20-200	Monitoring
Soil washing	120-200	Transport/Monitoring
Low temp. thermal Desorption	45-200	Transport/Monitoring
Incineration	200-600	-
Vitrification	700	-
Pneumatic fracturing	8-12	-
Excavation/Retrieval Disposal	270-460	Transport/Monitoring
Disposal alone	35-60	-

Saxena, 1999.

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