Chapter 10
Phytoremediation of Nickel:
Mechanisms, Application and Management

Ackmez Mudhoo
University of Mauritius, Mauritius

Zhi-Qing Lin
Southern Illinois University – Edwardsville, USA

ABSTRACT

Nickel (Ni) is one of the toxic heavy metals, and is recognized for its negative effects on the environment where it bioaccumulates and poses a serious threat to human and environmental health. Treatments of nickel pollution need to be done with the consideration that toxic nickel ions (Ni^{2+}) are converted into less toxic chemical forms so that its toxicity to human health and the environment is reduced. Phytoremediation is an emerging green technology that combines the disciplines of plant ecophysiology, soil chemistry, and microbiology to clean up Ni-polluted soils and waters. This solar–driven biological process is now being viewed as an ecologically sustainable alternative to the environmentally destructive or conventional physio-chemical remediation technologies. This chapter gives an overview of the environmental chemistry, speciation, and toxicity of Ni, elaborates on the removal of Ni by phytoremediation processes reported in recent literature, and highlights the key economic and management aspects of Ni phytoextraction.

INTRODUCTION

In recent decades, significant amounts of metals (including nickel (Ni)) have being added to the environment through various agricultural activities (such as agrochemicals usage and long–term application of metal contaminated sewage sludge in agricultural soils) and industrial activities (such as waste disposal, waste incineration, vehicle exhausts, and coal–fired power plants, as well as natural geological sources). All these pollution sources cause accumulation of toxic metals and metalloids in agricultural soils and water bodies, which poses a serious threat to food safety and potential health risks due to accumulation of toxic metals in agricultural products (Khan, 2005).

DOI: 10.4018/978-1-4666-0134-5.ch010

In particular, many of these pollutants are also known carcinogens (Ensley, 2000). Widespread agricultural soil contamination has significantly decreased the extent of arable land available for cultivation worldwide (Grêman et al., 2003).

Unlike organic pollutants, toxic metals and radionuclides cannot be eliminated by chemical or biological transformation. Although it is possible to reduce their toxicity by alternating their chemical speciation, metal pollutants are generally persistent in the environment. The costs associated with the clean–up of organic and inorganic pollutants can be overwhelming, even in developed countries. Given the nature and extent of contamination worldwide as well as high costs associated with physical and chemical remediation, biotechnologies (such as microbial biotransformation, and phytoremediation) have become a much attractive and environmental–friendly strategy for the clean–up of a broad spectrum of hazardous organic and inorganic pollutants (Mrak et al., 2008; Pilon–Smits, 2005). The plant–based environmental remediation has been widely pursued by governments and industries as a favorable low impact cleanup technology applicable in both developed and developing nations (Raskin & Ensley, 2000; Robinson et al., 2003a). This chapter specifically provides an overview of the environmental chemistry, speciation and toxicity of Ni, and then elaborates on the removal of Ni by phytoremediation technology. Hyperaccumulation mechanisms involved in the uptake of Ni by plants, the use of chelating agents (or chelators) in enhancing Ni uptake and translocation in plants, and the application of genetic engineering technology in Ni phytoremediation will be addressed.

Pytoremediation: A Green Technology for Environmental Cleanup

Phytoremediation is defined as the use of green plants and plant-associated microbes to remove, contain, or render harmless contaminants (such as metals, organic compounds, and radioactive compounds) in the environment. This definition recognizes all plant–influenced biological (Zouboulis & Katsoyiannis, 2005), chemical, and physical or engineered processes that can be applied to aid the uptake, sequestration, degradation, and biotransformation of contaminants in the environment.

Phytoremediation is a solar energy driven green technology, and that is often favored over some other conventional remediation methods. It is cost competitive and has low disturbance and wider public acceptance (Suresh & Ravishankar, 2004; Rajakaruna et al., 2006). Substantial research efforts are currently underway to explore the economic and ecological values of this green technology (Ghosh & Singh, 2005). Phytoremediation takes advantages of the unique and selective uptake capabilities of plant root systems, together with the translocation, bioaccumulation, and degradation abilities of plants. In appropriate situations, phytoremediation can be an alternative to other harsher remediation technologies of incineration, thermal vaporization, solvent washing, or other soil washing techniques, which essentially destroy the biological component of the soil and can drastically alter soil chemical and physical characteristics. Some advantages of phytoremediation compared to classical remediation include the following: more economically viable using the same tools and supplies as agriculture; less disruptive to the environment and does not involve waiting for new plant communities to recolonise the site; more likely to be accepted by the public as it is more aesthetically pleasing then traditional methods; avoids excavation and transport of polluted materials thus reducing the risk of spreading the contamination and has the potential to treat sites polluted with more than one type of pollutant. Some drawbacks associated with phytoremediation are: dependency on the growing conditions required by the plant (i.e. climate, geology, precipitation, temperature); large scale operations require access to agricultural equip-

Related Content