Chapter 19
Metal Hyperaccumulator Plants and Environmental Pollution

Satish Chandra
H. N. B. Garhwal University, India

Yogendra Singh Gusain
College of Forestry Ranichauri, India

Arun Bhatt
G. B. Pant Engineering College, India

ABSTRACT

During evolutionary history of life on Earth, different life forms have undergone harsh environmental conditions. Plants have evolved multiple life forms and some of the specialist pioneer plants have the ability to colonize in hostile environmental conditions. Some plant taxa have the ability to accumulate high concentrations of potentially toxic trace elements (Ni, Zn, Cd, Se, As, Mn, Co, Cu, Pb, Sb, Tl) in their biomass. In some of these, taxa concentration of trace elements exceeds the concentration of macronutrients (e.g., Ca, K). Furthermore, metal hyperaccumulation is strongly associated with enhanced ability of these plants to detoxify the accumulated metal in the tissues. Such hyperaccumulation property has been reported in a total of approximately 500 Angiosperm species. This ability of the plants can be used for pollutant stabilization, extraction, degradation, or volatilization. The present chapter discusses heavy metals uptake mechanisms by plants and the potential of phytoremediation technique on treating heavy metal contaminated sides.

INTRODUCTION

The earth crust is the main source of inorganic elements in our planate Earth. The main part of earth crust is composed of igneous rocks which constitute 95% of earth crust and remaining 5% is composed of sedimentary rocks. In the sedimentary rocks shales constitute 80% followed by sandstones 15% and limestone 5%. The sedimentary rocks are derived from igneous rocks which are formed by the solidification of magma or the molten rock. The magma is composed of SiO_2, TiO_2, Al_2O_3, Fe_2O_3, CaO, MgO, MnO, FeO, Fe_2O_3, Na_2O and K_2O. These compounds are often referred to as major oxides because together they comprise 99% of any igneous rock. These are usually analyzed as elements but expressed as

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oxides because oxygen is generally not analyzed and hence sometimes called as major elements. There are many other elements viz. Nd, Sm, Eu, V, Sr, Yb, Hf, Ni, La, Ce, etc. whose abundance is generally much lower (parts per thousand or parts per million levels) and hence referred to as trace elements. The sedimentary rocks also contain large amounts of trace elements including Cu, Zn,Mn, Pb, and Cd (He *et al.,* 2005; Sen, 2014). By weathering, metals reached to soil and thus these rocks are the main source of minerals found in the soil. Therefore, chemical composition of the rock underneath also affects metal composition of soil. Consequently, serpentine soil has higher concentration of trace metals and lower nutrients while, loam soil has higher nutrients and lower trace elements. In addition to this, various anthropogenic activities (industrialization, urbanization) also cause elevation of trace elements concentration in the environment.

Trace Metals vs. Heavy Metals: A Terminological Puzzle

There is misappropriation of some terms of chemistry in biology. The metals are usually erroneously used for particular element and its compounds but, actually metals are defined as "*elements which conduct electricity, have a metallic luster, are malleable and ductile, form cations, and have basic oxides*" (Duffus, 2002). Thus, compounds of particular element do not fall under the category of metal. Furthermore, metalloid (semimetals) are defined as "*An element that has the physical appearance and properties of a metal but behaves chemically like a nonmetal*" as Boron (B), Silicon (Si), Arsenic (As), Germanium (Ge), Antimony (Sb), Tellurium (Te) etc (Duffus, 2002). The heavy metals are commonly known as potentially toxic substances and the term usually used for metals and semimetals (metalloids) that have been associated with contamination and potential toxicity. In the literature the term heavy metal is ill-defined and different authors have applied it in different ways (Birchon, 1965; Hampel, and Hawley, 1976; Hodgson *et al.,* 1988; Duffus, 2002; Pulford and Watson, 2003; Arthur *et al.,* 2005; Rascio and Navari-Izzo, 2011; Tangahu *et al.,* 2011; Oves *et al.,* 2016). Sometimes heavy metals are defined on the basis of density (metal heaving density above 7 g/cm $^{-3}$ (Bjerrum, 1936), above 6 g/cm $^{-3}$ (Davies, 1987), above 5 g/cm $^{-3}$ (Brewer and Scott, 1983; Webster, 1976), above 4 g/cm $^{-3}$ (Nostrand, 1964)) or atomic mass (more than Sodium (20) (Bennet, 1986; Lewis Sr., 1993)) or atomic number beyond Calcium (20) (Venugopal and Luckey, 1975; Walker, 1988) or metal with atomic number between 21 (Scandium) and 92 (Uranium) (Lyman,1995). Scott and Smith (1981) defined heavy metals as "*Element commonly used in industry and generically toxic to animals and to aerobic and anaerobic processes, but not everyone is neither dense nor entirely metallic.* These are *As, Cd, Cr, Cu, Pb, Hg, Ni, Se, Zn*". Duffus (2002) reviewed literature for the term heavy metal and concluded that it is a misleading and ill-defined term and thus should be abandoned. While, trace metals are defined by Duffus (2002) as "*A metal found in low concentration, in mass fractions of ppm (part per million) or less, in some specified source, e.g., soil, plant, tissue, ground water, etc*."These are sometimes described as micronutrients. The broad term trace element includes both metals and metalloids.

Metal Hyperaccumulation

The term hyperaccumulator is not scientifically defined. At present, hyperaccumulator plants are described under four rules: (i) the concentrations of heavy metal in shoots must reach hyperaccumulating level (lead >1000 mg/ kg, zinc>10,000 mg/kg, cadmium>100 mg/kg Dry Matter), (ii) the concentrations of heavy metal in above-ground part is 10–500 times more than that in plants from non-polluted

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