Chapter 14
Bioextraction: The Interface of Biotechnology and Green Chemistry

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The interfacial face of bioextraction arises as it uses the technologies in which plants clean up the contaminated sites by immobilizing the contaminants in the soil. This technique is mostly applied to heavy metals in soil sediments and sludges. These metals are either trapped within the root system or taken up to the tissues by selected fast growing plant species. These species are grown under normal farming conditions until they reach their maximum size. Throughout the growth period, amendments are added to soil to increase availability of metals to plants. When the plants are mature, metal specific chelating agents are applied to the harvested biomass for the recovery of accumulated metals [1]. So, selection of plant materials is an important factor for this technique. Therefore, two main strategies are proposed to clean up toxic metals from soil. The first approach is the use of metal hyper-accumulator species for cleaning up of soil, as they can take up significant amount of metals from contaminated soils, but their low annual biomass production tends to limit its ability. This problem can be overcome by using high biomass plants that can be easily cultivated. So, the efficiency of this technique is determined by two key factors: metal hyper-accumulating capacity and biomass production [2].

Plant-based environmental remediation technology has been widely pursued in recent years as greener cost effective strategy to trap metals and radionuclide contaminants that are in mobile chemical forms which are most threatening to human and environmental health. Once the removal of contaminants is complete the soil generated from this process is fertile and is able to support the growth of plants [1].

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This technology has been applied at a number of sites all over the world. Examples include Magic Marker site in New Jersey and a Daimler Chrysler site in Detroit, Michigan (induced accumulation of lead in soil); Argonne National Laboratory-West (mercury, silver, chromium in soil/sediment removed by whole plant harvesting). This technique can also be merged with other techniques, like it can be used in conjunction with electrochemical technology to remove contaminants (such as cesium-137), which bioextraction technology alone cannot remove and many more permutations and combinations can be tried [1].

14.1 Disadvantages of Metal Extraction Process, its Environmental Concerns and Need of Bioextraction

The tremendous increase in the use of heavy metals over the past few decades has inevitably resulted in an increased flux of metallic substances in the environment. Industrial processes like petroleum refining, metal refining, coal combustion, tanning, metal extraction, electroplating, paints and pigments, the manufacture of batteries etc. discharge effluents in solid, liquid, and gaseous forms. They contain heavy metals such as lead, chromium, cadmium, nickel, arsenic, etc. But the major sources of heavy metals in the environment are traditional chemical processes for extraction of heavy metals. There are various disadvantages of these metal extraction processes like requirement of sufficient concentrations of elements in ores, environmental unfriendliness as huge amount of waste is generated, economically noncompetitive, nonrecovery of metals from low grade deposits i.e. minerals and inefficient use of energy.

Also, lot of metal containing effluent is produced during these processes, which is discharged as such without any treatment. This causes heavily loaded metal contaminated sites due to metal toxicity and non-biodegradability. The heavy metals are easily percolated through the soil and further trapped and biomagnified along the food chain via consumption of affected plants and animals. The increased concern about the environment and stringent national and international regulations on water pollution and the discharge of heavy metals makes it essential to develop efficient and cost effective technologies for their removal. Hence, it is the utmost need to extract metal ions (not only from the low grade ores but also from the contaminated sites) by the methods which are eco-friendly and greener in nature. The answer is provided by the nature itself: bioextraction.

14.2 Brief Description of Bioextraction Process

Bioextraction incorporates a range of technologies that not only use plants to remove, reduce, degrade, or immobilize environmental pollutants from soil and water, for restoration of contaminated sites to a relatively clean, non-toxic environment but also use microbes to extract metals from the low grade ores. This