International Journal of Engineering & Scientific Research (IJMRA Publications)
Vol. 6 Issue 5, May 2018,
ISSN: 2347-6532 Impact Factor: 6.660
Journal Homepage: http://www.esrjournal.com Email: esrjeditor@gmail.com
Double-Blind Peer Reviewed Refereed Open Access International Journal - Included in the International Serial Directories Indexed & Listed at: Ulrich's Periodicals Directory ©, U.S.A., Open J-Gage as well as in Cabell's Directories of Publishing Opportunities, U.S.A

PROSPECTS OF USING GENETICALLY MODIFIED PLANTS TO COLLECT AND ACCUMULATE VALUABLE OR HAZARDOUS METALS

Dr. Virendra Kumar Singh, Associate Professor

Deptt. Of Biochemistry

RSM College, Dhampur (Bijnor) UP 246761

Abstract

Traditional and physio-chemical methods were used to clean up contaminated soil. These methods are expensive, not very effective, especially for large-scale cleanups, and bad for the environment because they destroy natural habitat and leave ugly scars on the landscape. As a result, new biological methods like bioremediation, phytoremediation, and zoo remediation are being developed to clean up the environment.Heavy metals are elements with metallic properties that have an atomic mass higher than 20 and a specific gravity higher than 5 g cm^3. Arsenic (As), cadmium (Cd), chromium (Cr), copper (Cu), mercury (Hg), lead (Pb), and zinc are the most common heavy metals that pollute water (Zn). Metals occur naturally in the soil. A lot of dangerous materials, like heavy metals, were put into the environment by natural and human activities, which pollutes the soil, air, and water. Some metals, such as Zn, Cu, manganese (Mn), nickel (Ni), and cobalt (Co), are micronutrients that plants need in small amounts to grow. Other metals, such as Cd, Pb, and Hg, have unknown biological functions. At higher levels, these metals are toxic to plants, animals, and even humans. Heavy metal, unlike organic pollutants, doesn't break down and stays in the soil for a long time.

Keywords: Plants, heavy metals, biological methods, soil

Introduction

When it comes to decontamination of soil and water, bioremediation is becoming increasingly important as an alternative solution. Green plant remediation—the use of green plants to eliminate, contain or render harmless toxins in the environment—may be an effective, ecologically nondestructive and inexpensive cleanup strategy. New paths for boosting phytoremediation effectiveness may be opened through genetic engineering of plants to enhance metal absorption, transport, and storage.

All living species are poisoned by the rising concentrations of elemental contaminants due to rapid industrialization, increased human and agricultural activity, current farming techniques, as well as poor waste disposal systems.

Since the creation of radionuclides, contamination has also been an issue.Second-half 20th century nuclear technologies. Radiation from other sourcesnaturally occurring radioactive elements, such as uranium, are among those contaminated.

Radium, radon, and thorium are all radioactive elements. Environmental and human health dangers have been recognized.As a result of the contaminants, a number of cleanup solutions have been developed.

However, some of these technologies are prohibitively expensive, thus there has been a shift in focus. Funding for conventional weapons systems has instead gone toward the development of"bioremediation," a process in which microbial and plant materials are used to clean up hazardous waste. Organic waste, heavy metals, and radionuclides all benefit from bioremediation. These biomass-based solutions are more acceptable than conventional treatment approachesbecause of its low cost and strong efficacy in detoxifying even highly diluted substanceseffluents and reducing the volume of sludge that must be disposed of. It also gives you the option to customize itbiomass regeneration and/or nondestructive desorption strategies being developed metal extraction in a precise manner.

However, the accumulation of metals in soils is increasing the danger of leaching into ground and surface water, plant absorption, and human consumption.Metals, both necessary and non-essential, can be harmful if they have a high bioavailability.

Metal absorption in plants with subsequent translocation and concentration in plants' aboveground organs is referred to as phytoextraction, whereas hazardous ions are retained in contaminated substrates and immobilized in the roots during phytostabilization.

Finding effective phytoremediating plants was made by focusing on naturally occurring ecotypes (genotypes) found in polluted areas. While heavy metal tolerance clones were selected over time in vitro in the greenhouses, some progress was made as well. Phytoremediation at extremely contaminated places may be made possible by genetic engineering improvements to responsive genotypes. Different genes important for metal transport and homeostasis, antioxidant defense responses or xenobiotic detoxification can be used for modification. As part of the so-called "genoremediation" process, bacterial genes are engineered to boost their remediation ability, and then incorporated into plant genomes as a result. Genetic engineering has been shown in recent decades to be an effective approach for increasing the phytoremediation capability of plants from various taxonomic groupings.

Strategies for Plant-Based Metal Remediation

As a method of bioremediation, phytoremediation involves the utilization of plants and their related bacteria. As a result of the plants' various phytoremediation methods such as phytodegradation and rhizofiltration as well as their phytoextraction and phytostabilization,

The sound of thunderous thrashing Characteristics in general Experiments on plant growth Cu-dependent enzymes such as superoxide dismutase (SOD) and cytochrome C oxidase (COX) decrease in activity, immunological factors including cholesterol and its lipoprotein distribution shift, and Zinoky battery manufacture is adversely affected. Zinoky battery manufacturing is also affected. Atomic number Z, atomic weight at. wt. atomic weight, specific density SD, density D, melting point MP, boiling point BP 22 Plants Engineered for Heavy Metal Absorption Removal from Soil 437 phytovolatilization to cleanse soil and water polluted with many organic contaminants. In order to remove metals from contaminated soil, plants used a variety of phytoremediation methods such as rhizofiltration, stabilization, extraction/accumulation, and volatilisation.

Plant roots are used in rhizofiltration to remove metals from polluted wastewater. The roots of the plants absorb and collect metals. The hairy roots elicited in some plants by the Agrobacterium infection were also used for radionuclides and heavy metals rhizofiltration.

In order to avoid or minimize metal mobility and bioavailability, phytostabilization simply immobilizes soil through plant roots. Even if the concentration of metals is not lowered, the movement of metals in the surrounding environment is prevented by phytostabilization.

phytoextraction is a technique that uses plants to absorb and concentrate/accumulate contaminants from polluted soils. It is possible to use the plant components for metal recovery and then dispose of the ashes in landfills after harvesting. There are various phytoremediation technologies, but this one is the most successful of them all. When metals from the soil are taken up by plants and transformed into volatile form, they are released into the atmosphere through transpiration.

Phytoremediation plant

There are naturally occurring populations of metal-tolerant, hyperaccumulating plants. However, due to their tiny size and limited biomass output, these plants aren't the best candidates for phytoremediation. When it comes to heavy metal tolerance and accumulation, plants with strong growth typically have lower levels of both. Bioremediation plants must meet the following requirements:

(1) Ability to accumulate the metal(s) intended for extraction, preferably in above ground parts plants that do not translocate metals to the above-ground parts could be useful for phytostabilization and landscape recreation;

(2) tolerance to the metal concentrations accumulated;
(3) fast growth and highly "effective"

When it comes to phytoremediation, the ability to withstand metal toxicity and hyperaccumulation is more significant than high biomass production. As a result, each element's soil and plant chemistry must be taken into account independently for an effective development of phytoremediation. Although phytoextraction of only one metal is the aim, metals seldom occur alone, and adaptive tolerance may be required for numerous metals at the same time. Taking out more than one metal at a time is possible in some situations.

Using Plant Genetic Engineering to Improve Metal Phytoremediation

Due to the restricted habitat range or size of plants exhibiting remediation potential and native plants' inability to withstand and collect pollutants, widespread use of phytoremediation may be limited. Metal phytoremediation plants can be increased in biomass and metal absorption capability by a variety of methods, including agronomic procedures, soil supplements, and traditional breeding.

In order to improve phytoremediation efficiency, plants should be able to grow outside of their collection area, have a large root system, and grow quickly. They should also be able to accumulate high levels of heavy metals in their easily harvestable parts, tolerate soil pollution, and produce a large amount of biomass when contaminated. To create plants that have all of the above characteristics, it is impossible to use standard breeding procedures, as these approaches are time and labor-intensive as well as subject to several other biological restrictions. But biotechnological technologies, primarily genetic engineering, have made quick and important contributions to crop improvement by the introduction into candidate plants of an array of novel genes and features that may be used to enhance the phytoremediation potential for metal removal.

The mechanisms through which metals are absorbed and stored

An essential need for metal hyperaccumulation is that plants have the ability to withstand large levels of metals in their tissues and cells. Metal hyperaccumulating plants have the capacity to solubilize metals from the soil matrix, effectively absorb them in the root, and translocate them to the shoot.

Many miles-long root surfaces have been produced for the reception of elemental nutrients from soil and water. Iron, Zinc, and perhaps other metal accumulating plants emit metal chelating chemicals into the soil's rhizosphere, which aids in metal solubilization and absorption. phytosiderophores like mugenic and avenic acids are secreted by plants in response to nutritional metal ion deficiency. These acids improve the bioavailability of soil-bound metals and aid in their transport into plant tissues. Plant roots are also known to alter the rhizosphere's pH or redox potential, which contributes to the mobilization of plant nutrients. There are several hyperaccumulator plants that produce organic acids such as citric and other metal chelators that lower the rhizosphere pH and make metal cations more readily accessible for uptake by plants. Metal absorption can be facilitated or inhibited by the organic acids, which can form a compound with it outside the root to impede its uptake.

Mechanisms of metal uptake and accumulation

Plants must be able to withstand high levels of metals in their tissues and cells in order to be able to hyperaccumulate them. There are metal hyperaccumulating plants that have the ability to solubilize soil metals and absorb them into the root where they can be transferred to the stem.

Root surfaces designed for the absorption of elemental nutrients from soil and solutions reach many kilometres in area. For example, some of the plants that accumulate iron, aluminum, and probably zinc emit metal chelating chemicals into the soil, which aids in the solubilization and absorption of the metal. Nutrient metal ion deficiency triggers the production of phytosiderophores, such as mugenic acids, which enhance the bioavailability of metals firmly bonded to the soil. By altering rhizosphere pH and/or redox potential, plant roots are also known to have an effect on plant nutrient mobilization. Citric, malic, malonic and oxalic acids are often excreted by hyperaccumulator plants and function as metal chelators and lower the rhizosphere pH, making metal cations accessible. There are two ways in which the organic acids might aid in metal absorption or impede it by building a compound with it outside the root.

Metals enter the roots through the apoplast. Only a portion of the total metal is able to enter cells; the rest is either carried deeper into the apoplast or is attached to compounds in the cell wall. Chemical receptors with a high affinity are found on root surfaces. Metal transporters must be efficient if the metals being transported are to be delivered. Zinc transporter (ZIP) proteins, which are involved in Zn2+ and iron transfer, are the subject of research. For every gram of fresh weight of Thlaspicaerulescens roots, there are three times as many zinc transporters as there are in a non-accumulator. Metals are transferred into the symplast by crossing the membrane of the root cell. A lack of nutrients and stress can lead to the uptake of hazardous metals and ions by ZIP-1, ZIP-2, ZIP-3, and ITR-1 (Fe transporter). Due to the continuity of root epidermis and cortex, heavy metals are transferred apoplastically into plant tissue. These cell walls operate as barriers for apoplastic diffusion into the endodermis and casparian strip in order for metals in root cells to reach their final destination, the xylem. Root–shoot metal translocation is likely to be mediated by transpiration pump and involves metal transporters transporting metal ions from the root symplast to the xylem apoplast. Free histidine has been found to be a metal chelator in nickel hyperaccumulator Alyssum, increasing metal tolerance and translocation to the shoot. Metals in xylem exudates were discovered to be linked to organic acids in the zinc hyperaccumulator. Plants' ability to translocate nutrients into their shoots depends on the xylem loading mechanism, which can take the form of antiport, cation-ATPases, or ion channels. It is important to note that chelators such as malate and citrate have been shown to be involved in xylem translocation. It is through metal transporters in the shoot cell membrane that xylem and shoot apoplasts are exchanged for metal ions.

Metal-binding ligands may be induced by trace metal exposure. Particularly for Cd, it appears that metallothionein-like proteins play a major role in mediating metal absorption and accumulation. Ag biokinetic changes in bivalves are influenced by the presence of other ligands, such as sulfide. The absorption of trace metals appears to be unaffected by the addition of trace metals to metal-rich granules. Metals, on the other hand, play an important role in the accumulation of marine organisms. Metals such as Ag and Cd and Cu and Zn can lower the amount of dissolved Hg that is absorbed. Cd uptake is also affected when mussels are pre-exposed to Zn, which has a similar transport route. Most likely due to barnacles' reliance on detoxification processes, where metals collect in granules and have a relatively low biological activity, they are less sensitive to trace metal exposure than mussels. Metal accumulation in animals appears to be more influenced by tissue body load and detoxification destiny of metals than by exposure routes or exposure regimes themselves. Trace metal buildup in wild populations of bivalves may also be influenced by environmental conditions and exposure histories.

Phytoremediation-related genes of interest

Toxic materials are taken up by plants in the same manner as necessary elements are, making phytoremediation a physiological process. Metal absorption, transport, and storage by hyperaccumulating plants are under investigation, and a better understanding of this mechanism is necessary for the creation of transgenic plants with enhanced phytoremediation capabilities,

Metal uptake may be improved in a variety of ways, including expanding uptake sites, altering uptake selectivity to lessen the competition of undesirable cations, and boosting intracellular binding sites. Each metal has a unique molecular process for absorbing, transporting, and storing it. The search for the genes and proteins responsible for plants' absorption of iron has progressed quite a bit. There has also been research into Zn membrane transporters with high affinity. The development of plants for phytoremediation will benefit from the manipulation of metal transporters and the targeting of metal in the vacuole.

Genes suited for phytoremediation can be found in hyperaccumulators, an excellent source of these organisms. Tissue-specific promoters and regulatory control hold considerable potential for the development of plants that remove radionuclides and elemental contaminants. With the help of metals, organic acids create complexes. Malate concentrations were high in plants that were resistant to zinc and copper. These plants include acids and acid anions that play a role in metal storage or transit inside the plant. It is possible to construct transgenic plants that produce ligands that precisely dissolve metals for phytoremediation. Research into the development of simple compounds with selective chelation abilities that plants may produce and secrete into the rhizosphere while concurrently developing plants capable of transporting protein for the metal chelate is worthwhile. The free histidine in xylem exudates of Ni hyperaccumulator was discovered to be a metal chelator. The xylem exudates can be changed to increase the plant's ability to accumulate nickel. Metal sequestration and buildup can be mediated through the cation diffusion facilitation family.

Phytoremediation: advantages and disadvantages

Phytoremediation has various advantages. Low prices compared to standard remediation technologies, environmental friendliness and landscape friendliness, or a large reduction in the volume of contaminated waste for disposal are the most crucial factors. Since conventional remediation methods are prohibitively expensive for many sites, this type of in-situ cleanup may be used on virtually any one of them. Some drawbacks to this green technology exist, though. This method's primary flaw is the lengthy time necessary for cleanup, which has to do with plants' limited ability to collect significant quantities of heavy metals and maintain normal development in hazardous environments. Slow growth and poor biomass accumulation also restrict plant remediation capacity. Plant roots are able to reach toxins in the soil, hence phytoremediation is most successful at locations with low contamination levels. In addition, phytoremediating plants are generally distinct ecotypes that occupy certain habitats, making it challenging to cultivate them in various environmental circumstances. Finally, despite the good public impression of phytoremediation, incorrect biomass disposal might raise the danger of heavy metal contamination in the food chain. To improve the efficacy of phytoremediation, genetic engineering of plant genotypes is being investigated as a potential solution. Here we have proposed several possible transformation-based solutions to the most significant phytoremediation issues.

Conclusion

Metal absorption, transportation, and sequestration are all processes that can be used to help design transgenic plants for phytoremediation. It has proven possible to create transgenic plants that can degrade harmful mercury compounds into less toxic volatile forms, as well as plants that can tolerate cadmium and selenium. Proteins involved in intracellular metal sequestration can be overexpressed, which can lead to increased metal storage inside cells. Overexpression of plasma membrane transporters regulated by certain promoters can also result in increased accumulation.

The utilization of edible crops for phytoremediation is not feasible because heavy metals enter the food chain through human or animal ingestion.There is a lot of information out there on how metals affect the expression of certain proteins. Phytoremediation candidate genes and proteins may also be found using proteome and DNA array technologies. The results of these technologies might lead to a better knowledge of plant metal metabolism, which could lead to crucial environmental remediation applications.Bioremediation is an eco-friendly and cost-effective solution, however translation of this information into useful technologies is needed immediately.

Acknowledgement

The author is thankful to Dr. R. N. Kewat, Associate Professor, Deputy of Biochemistry, ND University, Faizabad for providing necessary help & suggestions during the course of the study.

References

[1] Lee JH, An overview of phytoremediation as a potentially promising technology for environmental pollution control. (2013)

[2] Ma JF, Nomoto K. Effective regulation of iron acquisition in graminaceous plants—the role of mugineic acids as phytosiderophores. Physiol Plant. (1996)

[3] Sunitha MSL, Prashant S, Anilkumar S, Rao S, Narasu ML, Kavi Kishore PB Cellular and molecular mechanisms of heavy metal tolerance in plants: a brief overview of transgenic plants overexpressing phytochelatin synthase and metallothionein genes. (2013)

[4] Salt DE, Kramer U. Mechanisms of metal hyperaccumulation in plants. In: Raskin I, Ensley BD, editors. Phytoremediation of toxic metals: using plants to clean up the environment. (2000)

[5] Bizily SP, Rugh CL, Meagher RB. Phytodetoxification of hazardous organomercurials by genetically engineered plants. Nat Biotechnol. (2000)

[6] Newman LA, Reynolds CM Bacteria and phytoremediation: new uses for endophytic bacteria in plants. (2005)

[7] Leszczyszyn OI, Schmid R, Blindauer CA Toward a property/function relationship for metallothioneins: histidine coordination and unusual cluster composition in a zincmetallothionein from plants. (2007)

[8] Ali H, Khan E, Sajad MA Phytoremediation of heavy metals—concepts and applications. (2013)

[9] Ellis DR, Sors TG, Brunk DG, Albrecht C, Orser C, Lahner B, et al. Production of S methyl selenocysteine in transgenic plants expressing selenocysteine methyltransferase. BMC Plant Biol. (2004)

[10] Zhang Y, Liu J Transgenic alfalfa plants co-expressing glutathione S-transferase (GST) and human CYP2E1 show enhanced resistance to mixed contaminates of heavy metals and organic pollutants. (2011)