Heavy Metals Extracted From Soil And Aquatic Environments Via Phytoremediation

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Abstract- *Due to a variety of anthropogenic (industrial) activities as well as natural processes, the accumulation of heavy metals in soil has rapidly grown. Due to their non-biodegradability, heavy metals persist in the environment, pose a risk of contaminating crop plants, and may eventually build up in people's bodies due to biomagnification. Heavy metal poisoning poses a major hazard to both human health and the ecosystem because of its poisonous nature. Remediation of land contamination is therefore of utmost significance. A deeper comprehension of the mechanisms driving heavy metal accumulation and tolerance in plants is essential for increasing the effectiveness of phytoremediation.*

Keywords- switch grass, thermophilic compost, coir, heavy metals, bioremediation

I. INTRODUCTION

The amount of these harmful elements rises as they go from minor trophic rank to upper trophic rank (this phenomenon is known as bio-magnification). On the earth's surface, these heavy metals result in toxicological disturbances to organisms residing in the soil layer that can reduce their living population and their functioning On a decrease in the concentration of these metals, a variety of deficiency symptoms appear as well the growth

Fig 1.Placing plastic containers used for leachate collection atop pots with polluted soils treated with the various organic treatments but without switchgrass, (Middle): Switchgrass growing in vegetated pots in a lab with 24-hour lighting, (Bottom): After the experiment, soil from the pots was taken for analysis.

is reduced. In addition, if present in a larger amount, the transition metals disrupt cell function, alter normal metabolic processes to produce cell damage, and may even lead to death. Many molecules are targeted at cells whose structure/function is restricted, modified, or enhanced by mutation molecules [2] Thus, extreme accumulation of such heavy metals in plants can cause toxicity by altering important protein composition or restoring vital elements indicated by chlorosis, impaired growth, root rot, and impaired image systems, among other effects [3 4]. Heavy metals are considered one of the fatal inorganic pollutants from large parts of anthropogenic activities

Phytoremediation is the use of plants to partially or substantially remediate selected contaminants in contaminated soil, sludge, sediment, ground water, surface water, and waste water. It utilizes a variety of plant biological processes and the physical characteristics of plants to aid in site remediation. Phytoremediation has also been called green remediation, botano-remediation, agro remediation, and vegetative remediation. Phytoremediation is a continuum of processes,with the different processes occurring to differing degrees for different conditions, media, contaminants, and plants. A variety of terms have been used in the literature to refer to these various processes. This discussion defines and uses a number of terms as a convenient means of introducing and conceptualizing the processes that occur during phytoremediation. However, it must be realized that the various processes described by these terms all tend to overlap to some degree and occur in varying proportions during phytoremediation. Phytoremediation encompasses a number of different methods that can lead to contaminant degradation, removal (through accumulation or dissipation), or immobilization Efficient plants for phytoremediation are highly productive, good bioaccumulators with tolerance to high levels of pollution. Switchgrass (Panicum virgatum) is known for its high biomass production that allows it to remove excess nutrients from sites amended with dairy manure

Soil Analysis

The entire soil content from all pots, including those planted to harvest, were transferred into large plastic containers, and mixed thoroughly. Water content was determined gravimetrically for each experimental unit as the difference between fresh and oven-dry mass (about 10 g were dried for 48 h at 105 ◦C). pH and electrical conductivity (EC) were also determined using 10 g of fresh soil mixed in 20 ml distilled water using Fisher Scientific Accumet Portable APILO (pH/ORP meter) and Thermo Scientific Orion Star A222 Conductivity meter, respectively. The remaining soils in the plastic containerwere left to air dry for one week before being analyzed for total metals. Soils were ground using mortar and pestle. The ground soil was screened through 0.5 mm sieve and dried at 60 ◦C for several hours. Total heavy metal concentrations were analyzed using the ICP after following a microwave-assisted digestion of approximately 0.5 g soil in 16N concentrated nitric acid diluted to 50 ml with deionized water

Phytoremediation Processes There are a number of different forms of phytoremediation, discussed immediately below. Defining these forms is useful to clarify and understand the different processes that can occur due to vegetation, what happens to a contaminant, where the contaminant remediation occurs, and what should be done for effective phytoremediation. The different forms of phytoremediation may apply to specific types of contaminants or contaminated media, and may require different types of plants (the terms ‘plant’ and ‘vegetation’ will be used interchangeably to indicate all plant life, whether trees, grasses, shrubs, or other forms).

water that then undergoes rhizodegradation and phytodegradation. The primary considerations for ground-water contamination are the depth to the ground water and the depth to the contaminated zone. In-situ ground-water phytoremediation is essentially limited to unconfined aquifers in which the water table depths are within the reach of plant roots and to a zone of contamination in the uppermost portion of the water table that is accessible to the plant roots. Plant roots will not grow through clean ground water to a deeper contaminated zone. If in-situ remediation of deeper contaminated water is desired, modeling may be useful to determine if the water table can be lowered by the plants or through pumping, or if ground water movement can be induced towards the roots. However, modeling may be hindered by the uncertainty and seasonality of water uptake rates by plants. Careful field measurements and conservative estimates of water uptake will be necessary, and modeling results should be confirmed by observations of the water table. Deep ground water that is beyond the reach of plant roots could be remediated by phytoremediation after the water is pumped from the subsurface using extraction wells, and then applied to a phytoremediation treatment system. For ground-water containment, the rate of ground-water flow into the phytoremediation area should be matched by the rate of water uptake by the plants to prevent migration past the vegetation.

Surface Water and Waste Water

Surface water can be treated using rhizofiltration or phytodegradation, in ponds, engineered tanks, natural wetlands, or constructed wetlands. In some cases, the contaminated water can be used as irrigation water in which the contaminants then undergo rhizodegradation and phytodegradation. Soil, Sediment, and Sludge Contaminated soil, sediment, or sludge can be treated using phytoextraction, phytostabilization, rhizodegradation, phytodegradation, and phytovolatilization, or through vegetative cap applications. Phytoremediation is most appropriate for large areas of a relatively thin surface layer of contaminated soil,within the root depth of the selected plant. Deeper soil contamination, high contaminant concentrations, or small soil volumes might be more effectively treated using conventional technologies, although through future phytoremediation research,the capabilities of phytoremediation might be increased. Soil characteristics, such as texture and water content (degree of saturation), should be conducive to plant growth

Switchgrass Seed Preparation

Switchgrass seeds were grown in small plugs that were pre-filled with the experimental soil Fifteen switchgrass seeds were sowed into each plug. A total of 4 mL of solution

NPK fertilizer (100 80, 100 ppm, respectively) was added to the soil at the start. NO3− was made from 1000 mg L−1 pure NO3 − stock solution. P and K were made from KH2PO4 powder by mixing 0.349 g of the compound into 1 L de-ionized water. The plugs were transported to the University of Vermont (UVM) campus greenhouse. They were irrigated daily, kept in 12-h day/night cycle, and temperature was maintained at 21 ◦C. In the greenhouse, plants were not further fertilized until they germinated. Once germinated, plants were fertilized six times, every Monday and Friday for three weeks, using the facility’s standard NPK fertilizer at 17-4-17 at 150 ppm nitrogen.

Plant-Available or Bioavailable Heavy Metals

At the end of the 54-day incubation period, soils from the unvegetated pots were analyzed for metal bioavailability (defined here as plant-available fraction) using a nonaggressive extractant method. This method was chosen to extract the fraction of heavy metals that is less strongly adsorbed to soil and more mobile and therefore of an interest from an environmental water quality standpoint. In contrast, a substantial fraction of the heavy metals extracted using chemically aggressive reagents may not be bioavailable especially under natural environmental conditions.

A 10g subsample of air-dried soils from the unvegetated pots was taken, combined with 25 mL of 0.01 M CaCl2 solution, and the suspension was shaken for 24 h on a mechanical shaker at room temperature Solution was filtered through Ahlstrom filter paper 642 (particle retention of 2 µm), and filtrate was analyzed in triplicates using the inductively coupled plasma optical emission spectrometry (ICP-OES/AES, Optima 3000DV, Perkin Elmer Corp, Norwalk, CT, USA).

Advantages

(1) Early estimates of the costs of phytoremediation indicated a substantial savings over the cost of traditional technologies. As actual cost data are developed during pilot-scale studies, it appears that phytoremediation will be a lower-cost technology, although actual costs of routine application of phytoremediation are still unclear.

(2) Phytoremediation has been perceived to be a more environmentally-friendly “green” and low-tech alternative to more active and intrusive remedial methods. As such, public acceptance could be greater.

(3) Phytoremediation can be applied in situ to remediate shallow soil and ground water, and can be used in surface water bodies.

(4) Phytoremediation does not have the destructive impact on soil fertility and structure that some more vigorous conventional technologies may have, such as acid extraction and soil washing (Greger and Landberg, 1999). Instead, the presence of plants is likely to improve the overall condition of the soil, regardless of the degree of contaminant reduction.

Disadvantages

(1) A significant disadvantage of phytoremediation is the depth limitation due to the generally shallow distribution of plant roots. Effective phytoremediation of soil or water generally requires that the contaminants be within the zone of influence of the plant roots. Selection of deep- rooted plants and the use of techniques to induce deep rooting could help alleviate this disadvantage.

(2) A longer time period is likely to be required for phytoremediation, as this technology is dependent on plant growth rates for establishment of an extensive root system or significant above-ground biomass. For example, in one estimate the low growth rate and biomass of hyperaccumulators meant that remediation of metals could not be achieved within even 10 to 20 years (Ernst, 1996). Another estimate was that a heavy-metal- contaminated site would require 13 to 14 years to be remediated, based on a field trial using Thlaspicaerulescens (Salt et al., 1995). Strategies to address this potential difficulty include the selection of faster-growing plants than hyperaccumulators, and the harvesting of the vegetation several times a year. A field demonstration of lead phytoextraction had three harvests of Indian mustard in one growing season to achieve acceptable levels of lead in the soil (Blaylock et al., 1999). However, a long time for remediation may still occur with a high biomass plant; a period of 12 years was calculated for removal of 0.6 mg/kg of cadmium, based on realistic willow tree biomass production rates and experimentally- determined cadmium uptake rates (Greger and Landberg,1999). A need for rapid attainment of remedial goals or imminent re-use of the land could eliminate some forms of phytoremediation (such as phytoextraction and rhizodegradation) as an alternative. However, other forms of phytoremediation, for other media, might occur at faster rates, such as rhizofiltration for cleaning upcontaminated water.

(3) Plant matter that is contaminated will require either proper disposal or an analysis of risk pathways. Harvesting and proper disposal is required for plant biomass that accumulates heavy metals or radionuclides in phytoextraction and rhizofiltration, and may be necessary for other forms of phytoremediation if contaminant accumulate within the plant. The biomass may be subject to regulatory requirements for handling and disposal, and an appropriate disposal facility will

need to be identified.

For example, sunflower plants that extracted 137Cs and 90Sr from surface water were disposed of as radioactive waste (Adler, 1996). The growth of plant matter represents an addition of mass to a contaminated site, since 94% to 99.5% of fresh plant tissue is made up of carbon, hydrogen,and oxygen (Brady, 1974) which come from offsite and the atmosphere. Should the phytoremediation effort fail, an increased mass of material will need to be remediated.

II. CONCLUSION

Heavy metal pollution is a vital issue for agricultural production and food health due to the toxic effects and rapid accumulation in the environment. To prevent or mitigate heavy metal contamination and revegetate the contaminated soil, a variety of techniques have been developed. Phytoremediation has been proven to be a promising technique for revegetation of heavy metal-polluted soil with a good public acceptance and shows a variety of advantages compared with other physicochemical techniques. The application of heavy metal hyperaccumulators is the most straightforward approach for phytoremediation, and hundreds of hyperaccumulator plants have been identified so far. However, phytoremediation with these natural hyperaccumulators still suffers from a few limitations, as it is a time-consuming process, which takes a very long time to clean-up heavy metal-contaminated soil, particularly in moderately and highly contaminated sites. This may partially be due to slow growth rate and low biomass production of these hyperaccumulators. Therefore, improving plant performance is a critical step for developing high effective phytoremediation. Fortunately, genetic engineering approach has been emerging as a powerful tool to modify plants with desired traits such as fast grow, high biomass production, high heavy metal tolerance and accumulation, and good adaption to various climatic and geological conditions. Hence, good understanding of the mechanisms of heavy metal uptake, translocation, and detoxification in plants, and identification and characterization of different molecules and signaling pathway, will be of great importance for the design of ideal plant species for phytoremediation via genetic engineering. Genes involved in heavy metal uptake, translocation, sequestration, and tolerance can be manipulated to improve either heavy metal accumulation or tolerance in plants. In addition, chelating agents and microorganisms can be used either to increase heavy metal bioavailability, which facilitates heavy metal accumulation in plants, or to improve soil health and further promote plant growth and fitness

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