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RESEARCH ARTICLE

A review on phytoremediation of Heavy metals from Soil by using plants to remove pollutants from the environment

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Abstract

At recent time increased soil pollution with heavy metals due to various human and natural activities creates this problem with the numerous hazards compounds into the environment. These hazardous compounds consists many type of organic pollutant and heavy metals which produce risk for human health. Many technologies used to solve this problem but they are expensive. For that reason using phytoremediation technology which is a tremendous, feasible, cost-effective 'green' technology based on the use of metal-accumulating plants to remove toxic metals, pesticides, explosives including radionuclides from soil and water. Therefore the aim of the present study is to describe the different mechanisms of phytoremediation and their potential work to remediate contamination from soil environment by using living plants.

Introduction

Soil and water contaminated with metals pose a major environmental and human health problem that is still in need of an effective and affordable technological solution. Microbial bioremediation has been somewhat successful for the degradation of certain organic contaminants, but it is ineffective at addressing the challenge of toxic metal contamination, particularly in soil (Salt, Blaylock et al. 1995). Although organic molecules can be degraded, toxic metals can only be remediated by removal from soil. The current state-of-the-art technology for the clean-up of toxic metal-contaminated soils is the excavation and burial of the soil at a hazardous waste site at an average cost of $1000000 per acre. In the US alone, the cost of cleaning up sites contaminated with toxic and radioactive metals is estimated to be $300 billion (Raskin, Smith et al. 1997). Therefore the use of phytoremediation green technology is feasible and cost-effective. Phytoremediation uses plants to clean up pollution in the environment. Plants can help clean up many kinds of pollution including metals, pesticides, explosives, and oil. The plants also help prevent wind, rain, and groundwater from carrying pollution away from sites to other areas. Phytoremediation works best at sites with low to medium amounts of pollution. Plants remove harmful chemicals from the ground when their roots take in water and nutrients from polluted soil, streams, and groundwater. Once inside the plant, chemicals can be stored in the roots, stems, or leaves; changed into less harmful chemicals within the plant; or changed into gases that are released into the air as the plant transpires (Lu, Li et al. 2014).

The idea of using metal acquired plants to remove heavy metals and other compounds was first introduced in 1983, but the concept has actually been executed for the past 300 years. The generic term 'Phytoremediation' consists of the Greek prefix phyto (plant), attached to the Latin root remedium (to correct or remove an evil). Phytoremediation is a cost effective, environmental friendly, aesthetically satisfied approach most suitable for developing countries. In spite of this potential, phytoremediation is yet to become a commercially available technology in India.

Advantages of Phytoremediation

Early research indicates that the phytoremediation technology is a promising cleanup solution for a wide assortment of pollutants and sites. (Chappell 1997). A momentous benefit of phytoremediation is that a variety of organic and inorganic compounds are amenable to the phytoremediation process. Phytoremediation can be used either as an in situ or ex situ application (Kapourchal, Kapourchal et al. 2009). In situ applications are frequently considered because reduces disturbance of the soil and surrounding environment and minimize the spread of contamination via air and waterborne wastes. An additional advantage of phytoremediation is that it is a green technology and when appropriately implemented is both environmentally friendly and aesthetically pleasing to the public (Gratão, Prasad et al. 2005).

Phytoremediation does not require expensive equipment or highly-specialized personnel, and it is relatively easy to implement. It is capable of permanently treating a wide range of contaminants in a wide range of environments. However, the greatest advantage of phytoremediation is its low cost compared to conventional clean-up technologies. For example, the cost of cleaning up one acre of sandy loam soil with a contamination depth of 50 cm with plants was estimated at $60,000-$100,000 compared to $400,000 for the conventional excavation and disposal method (Number, Ma et al. 1997). Hence the present review portray the different phytoremediation mechanisms and their potentials as remediation techniques that utilize the age long inherent abilities of living plants to remove pollutants from the environment but which are yet to become a commercially available technology in many parts of the world especially the developing countries.

Large areas of soils have been contaminated by heavy metals, which are deleterious to the existence, reproduction and development of living organisms including plants, animals and microorganisms. This phenomenon has even threatened the health of ecosystems and human beings themselves (Liu, Zhou et al. 2008). Because soils contaminated by toxic heavy metals have important characteristics such as concealment, delay, accumulation, regionalism, and irreversibility (Boularbah, Schwartz et al. 2006), soil remediation has not only received more attention in environmental science and engineering, but also becomes global problems to be solved urgently (Andon, Jean-Paul et al. 2004).

In Mysore, Karnataka, India 2012 industries was growing very faster compare to other activities. Due to industries pollution of wastes were loaded for air water and soil has increasing day by day. Collect the soil sample from land where wastes of industries were dumped. This sample used for his research work by dissolving the extracted soil sample in tri acid mixture method. In the present study it affirm that the heavy metals concentration is at the nearby maximum level. The results shows that iron varies from 2.5gm/kg to 6.7gm/kg, copper ranges from 6.8mg/kg to 20.3mg/kg, chromium occur in range of 6.6mg/kg to 22.0mg/kg, whereas zinc varies in range of 66mg/kg to 121 mg/kg and nickel was found in a range of 10mg/kg to 18.1mg/kg (Shivakumar, Srikantaswamy et al. 2012).

In research report of (Dheeba and Sampathkumar 2012) given from Tamil Nadu, India, is the object of that research, they was evaluated the physical properties and concentrations of various heavy metals of soil in different industries sites. Soil sample was collect from different seven industries outsides and analysed them. Electrical Conductivity (Alkorta, Hernández-Allica et al.), pH, Cation Exchange Capacity (CEC), Organic Matter (OM), Organic Carbon (OC) and heavy metals viz. Cu, Mn, Cr, Pb, Zn and Fe were analyzed. The maximum EC 6.41 dSm-1 was noticed in the soil sample collected from textile industry. The results showed that very high level of OC and OM were found in the soil contaminated by printing industry. The soil samples contaminated with cement and printing industries pollutants showed high CEC 26.4 and 38.7 m.eq /100g of soil. Different metals were found to be in higher level in different areas. High level of copper 28.9 ppm is noticed in sample collected from Tannery. The level of manganese in increasing order is Textile < Cement < Steel < Painting < Tannery < Welding. The maximum level of iron 46.6 ppm and zinc 13.6 ppm is noticed in sample collect near welding industry. The soil sample of tannery industry show high level of chromium 32.5 ppm and lead 15.7 ppm. However, compared this concentration with those obtained from locations of industrial activity, relatively high level of heavy metals was recorded, with different industries. Revolving all the heavy metals obtained at the study area, Zn, Pb and Cr influence in all the investigated zones of high industrial impact.

Mechanism of Phytoremediation

The mechanisms and effectiveness of phytoremediation depend on the type of contaminant, bioavailability and soil properties (Cunningham and Ow 1996). There are numerous ways by which plants clean up or remediate contaminated sites. The uptake of contaminants in plants occurs primarily through the root system, in which the principal mechanisms for preventing toxicity are found. The root system provides an enormous surface area that absorbs and accumulates water and nutrients essential for growth along with other non-essential contaminants (Alkorta, Hernández-Allica et al. 2004).

Phytoremediation consists of a collection of four different plant-based technologies, each having a different mechanism of action for the remediation of metal-polluted soil, sediment, or water. These include: phytoextraction, where plants absorb metals from soil and translocate them to the harvestable shoots where they accumulate. Although plants show some ability to reduce the hazards of organic pollutants (Hamlin 2002) and (Cunningham, Berti et al. 1995), rhizofiltration, which involves the use of plants to clean various aquatic environments; phytostabilization, where plants are used to stabilize rather than clean contaminated soil; phytovolatilization, which involves the use of plants to extract certain metals from soil and then release them into the atmosphere through volatilization; and, the greatest progress in phytoremediation has been made with metals (Ghosh and Singh 2005) and (Hamlin 2002)

Phytoextraction

This method additionally referred to as phytoaccumulation; it refers the uptake and translocation of metal contaminants within the soil by plant roots into the above ground parts of the plants. Phytoextraction is primarily used for the treatment of contaminated soils. To remove contamination from the soil, this approach uses plants to absorb, concentrate, and precipitate toxic metals from contaminated soils into the above ground biomass (leaves, shoots, etc.). Discovery of metal hyperaccumulator species reveals that plants have the potential to get rid of metals from contaminated soils. A hyperaccumulator is a plant species capable of accumulating one hundred times more metal than a common non-accumulating plant (Erakhrumen 2007). Metals like nickel, zinc and copper are the best candidates for removal by phytoextraction because it has been shown that they are preferred by a majority of plants (approximately 400) that uptake and absorb unusually large amounts of metals. There are many benefits of phytoextraction. The cost of phytoextraction is fairly inexpensive when put next to conventional ways. Another profit is that the contaminant is permanently far away from the soil. Additionally, the quantity of waste product that must be disposed of is substantially reduced (up to 95%) (Henry 2000) and in some cases, the contaminant can be recycled from the contaminated plant biomass.

The use of hyperaccumulator species is limited by slow growth, shallow root system, and tiny biomass production. In addition, the plant biomass must also be harvested and disposed of properly, complying with standards (Dhir 2013). There are many factors limiting the extent of metal phytoextraction including:

- Metal bioavailability within the rhizosphere
- Rate of metal uptake by roots
- Proportion of metal “fixed” within the roots
- Rate of xylem loading/translocation to shoots
- Cellular tolerance to toxic metals

The method is also generally limited to metals and different inorganic compounds in soil or sediment (Dhir 2013). In order for this clean-up method to be feasible, the plants must (1) extract large concentrations of heavy metals into their roots, (2) translocate the heavy metal into the surface biomass, and (3) produce an oversized quantity of plant biomass. Additionally, remediative plants must have mechanisms to detoxify and/or tolerate high metal concentrations accumulated in their shoots (Alkorta, Hernández-Allica et al. 2004).

Rhizofiltration

This process is similar to phytoextraction, but the plants are used primarily to address contaminated ground water rather than soil. The plants to be used for cleanup are raised in greenhouses with their roots in water rather than in soil. To acclimatize the plants, once a large root system has been developed, contaminated water is collected from a waste site and brought to the plants where it is substituted for their water source. The plants are then planted in the contaminated area where the roots take up the water and the contaminants along with it. As the roots become saturated with contaminants, they are harvested. Sunflower, Indian mustard, tobacco, rye, spinach, and corn have been studied for their ability to remove lead from water, with sunflower (Raskin, Smith et al. 1997). Rhizofiltration is a cost-competitive technology in the treatment of surface water or groundwater containing low, but significant concentrations of heavy metals such as Cr, Pb, and Zn (Hamlin 2002)

Table 1: Types of Phytoremediation Systems (Chappell 1997)

Treatment Method	Mechanism	Media
Rhizofiltration	Uptake of metals in plant roots	Surface water and water

		pumped through troughs
Phytotransformation	Plant uptake and degradation of organics	surface water, groundwater
Plant-Assisted Bioremediation	Enhanced microbial degradation in the rhizosphere	soils, groundwater within the rhizosphere
Phytoextraction	Uptake and concentration of metals via direct uptake into plant tissue with subsequent removal of the plant	soils
Phytostabilization	Root exudates cause metals to precipitate and become less bioavailable	soils, groundwater, mine tailings
Phytovolatilization	Plant evapotranspirates selenium, mercury, and volatile organics	soils, groundwater
Removal of organics from the air	Leaves take up volatile organics	air
Vegetative Caps	Rainwater is evapotranspirated by plants to prevent leaching contaminants from disposal sites	soils

Phytovolatilization

This process involves the use of plants to take up contaminants from the soil, transforming them into volatile forms and transpiring them into the atmosphere. Phytovolatilization also involves contaminants being taken up into the body of the plant, but then the contaminant, a volatile form thereof, or a volatile degradation product is transpired with water vapor from leaves. Toxic metals such as Se, As and Hg can be biomethylated to form volatile molecules that can be lost to the atmosphere. Although it was known for a long time that microorganisms play an important role in the volatilization of Se from soils, a plant's ability to perform the same function was only recently discovered. Phytovolatilization may also entail the diffusion of contaminants from the stems or other plant parts that the contaminant travels through before reaching the leaves (Raskin, Smith et al. 1997) and (Hamlin 2002)

Phytostablization

Phytostabilization, also known as phytorestoration, is a plant-based remediation technique that stabilizes wastes and prevents exposure pathways via wind and water er- osion; provides hydraulic control, which suppresses the vertical migration of contaminants in to groundwater; physically and chemically immobilizes contaminants by root sorption and by chemical fixation with various soil amendments (Flathman and Lanza 1998). Phytostabilization is most effective at sites having fine-textured soils with high organic-matter content but is suitable for treating a wide range of sites where large areas of surface contamination exist. Phytostabilization has benefits over other soil-remediation practices in that it is less environmentally evasive, less expensive, easy to implement, and offers aesthetic value (Ghosh and Singh 2005)

Bioaccumulation in various plant species

Marigold (Tagetes patula) and ornamental arum (Syngonia sp.) were grown on As spiked soils up to 10 mg As per pot or per kg soil to assess their properties as phytoremediators. Fifteen days old marigold and young plants of ornamental arum were transplanted to soils (Huq, Joardar et al. 2005). At flowering stage, the maximum arsenic concentration in the root, shoot and leaf of marigold were 1987.12, 5.45 and 3.50 mg/kg dry mass, respectively. The maximum arsenic concentrations in root and shoot of ornamental arum after two months were 14.27 and 12.14 mg/kg dry mass, respectively. The arsenic accumulating property of the Tagetes patula and Syngonia sp. appeared to be good sources to be exploited to phytoremediate arsenic contaminated soil (Huq, Joardar et al. 2005). From these observations with the two plants, it could be concluded that they have the characteristics to hyperaccumulate As from soil and could be used as a possible phytoremediators. The ornamental arum, however, is a better phytoremediator than marigold in extracting As from soil. (Huq, Joardar et al. 2005) have shown that edible arum is also a hyperaccumulator for As.

According to the research results, the effects of Cd, Cr, Cu, Ni, and Zn on Alfalfa Plant (Medicago sativa) were studied in this research. The seed germination of the alfalfa plant is seriously affected by 20 ppm of Cd, Cr, and by 40 ppm of Cu, Ni. The root and shoot growth are stimulated by 5 ppm of Cr, Cu, Ni, and Zn. Alfalfa plants did not show any capabilities to germinate and grow in a medium containing 20 ppm of Cd and Cr, and 40 ppm of Cu and Ni. However, alfalfa was able to germinate and grow efficiently at any Zn concentration evaluated in this research. This research indicates that the alfalfa plant may be grown directly in soils individually contaminated with moderate amounts of Cd, Cr, Cu, and Ni. Detailed studies need to be done in order to establish the maximum amount of Zn+2 that the plants may tolerate, and the ability of the alfalfa plants to germinate and grow in media containing mixtures of these heavy metals (Aydinalp and Marinova 2009).
Another research shows The ability of two ornamental plants zinnia and marigold to remove lead pollutants from contaminated soils was examined in this study lead analysis was conducted on the entire plant tissue. Different concentrations of lead was prepared and used for pot culture experiments (10,20,30,40,50mg kg-1) in soil lead concentration in soil under all treatments decreased when compared to the control(10,20,30,40,50mgkg-1) (Thamayanthi, Sharavanan et al.). In all treatments, lead accumulation in the plants was higher on day 6oth. Among these two species Zinnia elegans showed a greater potential for lead accumulation than marigold on day 60th. Zinnia elegans showed significant difference in lead accumulation compared to that from marigold**)**.Since Zinnia elegans has a high growth rate, in environmentally tolerant if may be a practicable alternative for leaching lead from the contaminated soil (Thamayanthi, Sharavanan et al.).

In another research Georgina Wild (Dahlia) ornamental plant was used in phytoremediation process for remediate the heavy metal lead and nickel at the various concentration ranging from 0.5, 1.0, 1.5, 2.0 mg/kg for nickel and 5.0, 10, 15, 20 mg/kg for lead separately in soil. The results revealed that as the concentration of heavy metal in soil increases, the overall length of plant decreases with respect to control (Sunita 2012). It was also observed that the shoots of the Dahlia are more tolerant than roots of dahlia plant and the biomass and seed germination also affected by the nickel and lead toxicity above the normal concentration (Sunita 2012).

Conclusion

Today the soil pollution with heavy metals is a precarious problem for environments. Many techniques used to resolve this problem, but these techniques are a costly and less effective, so the process phytoremediation, it has green process to accumulate heavy metal with the help of plants it has safe and polluted free process. Plants have a power to clean up the environment because they need some metals for its growth so they consumed that metal easily. Phytoremediation is unaffected to people who live and work around the area while it is being cleaned up and is perceived as a more natural solution than large amounts of equipment and noisy machinery. Phytoremediation can be undertaken for less than half the cost of other technologies. Phytoremediation projects need a lesser amount of continuance (Smith 1997).

Future Prospects

Present study clearly reveals that the ornamental plants are used to clean up the heavy metals from soil by phytoremediation are a polluted frees process and cost effective. Phytoremediations related mechanism play a better role for made polluted free soil water environment. The key problem to almost to any of the methods is of course that of time and inability to handle a diverse and very large amount of contamination. As the technology is better understood and further implemented, however, it will grow in its efficiency and ability and will no doubt grow.

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