



Review Article

Phytoremediation of chromium: an overview

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Abstract

Chromium is the 17th most abundant elements of the earth's crust and has various valence state i.e., III to IV but the trivalent (III) and hexavalent (IV) is the most stable form. The trivalent Cr (III) is less toxic whereas the hexavalent (VI) is highly toxic and mobile. Chromium is the nonessential element of a plant however it gets translocated alongside other essential elements. Cr can cause metal toxicity which may cause severe damage to plants and animals. Chromium contamination poses great threats to the environment in recent years. Chromium is utilized for enormous scope in numerous businesses including metallurgical, electroplating, paints production and shades, tanning, preservation wood, making in chemical compound. The remediation process is using various technologies which go from in situ nitrification and soil incineration to excavation and landfilling, soil washing, soil flushing, and solidification and stabilization by electrokinetic systems. All these techniques are expensive and enhances to facilitate to the environments. Phytoremediation is seen as financially savvy and profoundly proficient in remediating the substantial metal-contaminated sites.

Keywords Chromium, Hyperaccumulators, Contaminants, Phytoremediation.

Introduction

In the earth's mantle Chromium is observed as the 17th most abundant element. The chromium is found with other elements. Chromium is produced over 20,000 tons every year and a billion tons are unused accumulations in a country like Greenland, Canada, and the USA. The chromium shows a various oxidation state from -2 to +6 but the +3 and +6 is the most stable form (Cotton and Wilkinson, 1980). Comparing to the trivalent and hexavalent form of Cr, the trivalent is less toxic and mobile while the hexavalent is carcinogenic to humans (Yassi and Nieboer, 1988). Differing on the oxidative states the harmfulness differs from each site. In the plant, the chromium is a nonessential element, so it takes up with essential elements such as sulfate on the other side, in humans it is essential, but access can cause harm. The pollution by heavy metals shows the peak of increase from the initial 20th century (Nriagu, 1979; Ensley, 2000).

Heavy metals and other radioactive particles cannot be transformed by chemical as well biochemical treatment, like pollutants. Heavy metal contamination can be reduced by using chemical treatment, but it will not remove all the contaminants (Qu et al., 2021; Cunningham and Ow, 1996).

On the type of polluted sites, availability of plants, and the levels of the contaminants, the remediation process is chosen (Thangavel and Subburam 2004). There are four types of phytoremediation, they are:

Phytostabilization

This technique uses in the stabilization of the heavy metal in the contaminated soil. These techniques can be done by controlled of many factors like pH, reaction of the plants and transpiration by the plants, etc. This method has more advantages than the ancient way of treatment on the remediation at the large-scale area with the low. The remediation process though has advantages on the low contamination, it has drawbacks to process on the elevated concentration sites which may cause the effect on the plants.

Phytofiltration

Phytofiltration is one of the method of phytoremediation, this method is effective where large amount and low concentration of water are involved (Miller, 1996). Phytofiltration plants are

need to have a sufficient amount of biomass in root or surface area of root (Dushenkov and Kapulnik, 2000).

Phytovolatilization

Phytovolatilization is also known as biofiltration. This method is done by uptake of metals by plant and transpiration of the uptake contaminants. The plants take up the contaminants from the contaminated sites which further gets transported to the plants or done the modified of the contaminants and lastly it gets evaporated. This technique is best as there is no waste to dispose to the environment, which makes less erosion to the area and further adds to the no disturbance to the contaminated site (Heaton et al., 1998).

Phytoextraction

This technique can be applied easily by using a plant that can take up the contaminants and translocated them to its various components of the plant. These plants can be further disposed of using Phyto mining techniques. There are two methods of Phytoremediation which are used for cleanup the contamination of heavy metals. Firstly, it can use the hyperaccumulator plants to naturally take up the metals. Secondly, the uses of high biomass plants by means of chelating agents. (Huang et al., 1997; Salt et al., 1998; Lombietal, 2001; Chen et al., 2004).

Chromium tolerance and hyperaccumulation

Plants that tend to take up heavy metals are known as hyperaccumulators. Cr accumulator plants should have the capacity to accumulate $> 1,000 \text{ mg kg}^{-1}$ (Reeves and Baker 2000). Cr as a non-essential element gets taken up with other essential elements such as sulfate ions to the plants (Shanker et al., 2005a). So, mainly plants absorption takes place in roots $>$ shoots $>$ leaves. Upon absorption by roots, Cr is poorly translocated and is largely retained in the roots. The most important factors on hyperaccumulators plants are the bioconcentration factor (BCF) and translocation factor (TF). These factors usually help in the evaluation of the plants to take up on metal stress and ability to accumulate.

Rafati et al., (2011) reported that *Populous alba* and *Morus alba* has the properties to take up the Cr from the different contaminated site by various organs. The report showed the leaves have the maximum no of accumulation of concentration as compared to the other parts. This shows the high accumulating power that's given as a potential hyperaccumulator in phytoremediation. Other species have also been reported a potential for this technique such as *Pluchea indica* which showed a high accumulation rate and translocated up to leaves. The report by Mellem and coworkers highlights the *Amaranthus dubius* tolerance on Cr (VI) concentrations.

The species *Ipomoea aquatica* is reported to be a potential hyperaccumulator of chromium. These species reveal to have no toxicity effect up to high concentration. It has been reported that species *I. aquatica* can tolerate 28 mg L^{-1} Cr

(VI). Last but not the least, it's also been reported by Barbosa and coworkers show the potential of Cr(III) phytoremediation in *Genipaamericana*, which in the contaminated watersheds, its showed the seeds take up a high amount of contaminated Cr and showed the storage in roots at the translocation.

Chromium uptake, accumulation and translocation

Chromium, translocation pathway is yet not fully known. However, as a non-essential element to the plants, it may be presumed that it is taken up along with essential elements such as sulfate and water (Shanker et al., 2005a). In aqueous media, the uptake of chromium depends on their pH, oxidative state of their chromium and its concentration, level of salinity, and the presence of dissolved salts (Babula et al., 2008). Among the various heavy metals, chromium is less mobilizing. The amount Cr is gathered maximum in the roots followed by leaves and afterward fruits (Ramachandran et al. 1980). Roots can accumulate 100 folds higher Cr than the shoots (Zayed et al., 1998b). It is likely because of the poor translocation of this component because of the insoluble Cr components formation. Some of the studies show that Cr can form certain complexes with organic acids and increase Cr VI uptake by mycorrhizal fungi (Davies et al., 2001).

Cr uptake by plants depends on the species of the plants as well as the Cr oxidative state. The uptake of Cr III is a passive process whereas Cr VI is an active process. Since chromium is an essential element, the Cr VI needs a metabolism to take up with other essential elements such as sulphate, but Cr III doesn't need it. The Cr VI also completes with other elements such as Fe, S, and P.

Advantages

Comparing to the various traditional or other techniques, phytoremediation is the greatest technique for handling the contaminated sites. The phytoremediation technique shows various studies on a pilot scale as well as in full scale. These studies show various promises on the technique, feedbacks, and drawbacks on various issues such as plants, sites, and the concentration. There has been various project running through the world on this technique. These methods are reasonably the scientific technique which many researchers are practical experiences and study. This method is highly applicable to most of the contaminated areas, though we need to find the appropriate plants according to the condition. it is a vision of a sustainable environment that be able to regain the area without adding more contamination to it. Not only does this method benefit the environment has it also given the idea of commercialization. Phytoextraction shows a promise for the cleanup of wastewater such as groundwater, industrial waste, municipal waste, etc., especially on the organic contamination. The proficiency of full-scale phytoremediation in normal conditions is fundamentally lower than lab-scale looks into in the meantime, focal points of this treatment strategy cause concerning high consideration and solicitations for future natural cleaning techniques (Gomes et al., 2013).

Limitation of phytoremediation

Phytoremediation offers economical, low support, condition benevolent, and inexhaustible resource for the remediation of contaminated sites. In some situations, for instance, pesticide-loaded soil or groundwater, phytoremediation might be essentially helpful and simple on-the-pocket in situ procedure that can be utilized to dispose of toxin matters. Initially, there gives off an impression of being a broadening hole among the science and application (Ernst, 2005); there are shockingly hardly any uses of metal-hyperaccumulators plants for remediation (Chaney et al., 2000; Li et al., 2003). Second, significant desires are currently positioned on genetic modification to which it should produce model plants for using in commercial to take up for metal contamination (Ruskin, 1996; Rugh, 2004). Even though alteration can create ideal plants for hyperaccumulators, but on the other side, it creates concern in the public over the utilization of genetically modified plants which leads to the banned of utilization on the modified plants.

This technique even though useful, there has also been several drawbacks. Before taking to practice these, it has to be considered on various fields such as concentration of the contaminants, the availability of the hyperaccumulating species, and many more (Chaudhry et al., 1998; Angle and Linacre, 2005). The selected species to grow must have the availability to germinate in the soil conditions, the concentration of the contaminated site, and the area climatic conditions. When the local species in the contaminated site is not available due to various reasons, it needs to be taken a hyper accumulative foreign plant to the areas of the con. The biggest limitation on phytoremediation is played by the time factors. Furthermore, it is also limited by the bioavailability of the pollutant. The cleanup of the plants by the available product does not ensure how much it the take-up of heavy metals so the green clean-up is not complete. So, in this situation it needs to use the advanced technologies by putting chelates (Salt et al., 1998) or engineering-based technologies to enhance the efforts of the biological method. To implement such techniques, it needs a professional such as researchers or scientists to oversee it, along with it a skill people in doing the projects and the solution on the hyper accumulative plants that should be easily available in all the sites. Laminated sites, which will create an ecological imbalance.

Conclusion

Phytoremediation is a green technology that has great potential to remediate the contaminated sites. Comparing to the other methods, it is less expensive and can be achieved with the available plants in the areas. In addition to this, it is friendly to the environment as compared to other methods. Further research on these methods and practices will help to develop this method. The potential good hyperaccumulators plants, the proper study of an area of contamination, and knowledge of practices need to study further for effective results for the benefits of society and mankind.

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