Factors Affecting The Process Of Phytoremediation

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Abstract

In recent decades phytoremediation technique had been successfully utilized for its possible application in the field of remediation of contaminated sites. Both inorganic and organic contaminants are responsible for the pollution of environment i.e. soil and water. Phytoremediation because of its cost effectiveness and no generation of any secondary by-products has been given preference over other method of treatment as they are responsible for generation of secondary by-product that further requires treatment. Various types of plants are being employed in this technique. Various environmental factors including pH, availability of fertilizer, initial concentration of contaminant and activity of microbes plays an important role important role in the process of phytoremediation. Various factors that affect the process of phytoremediation are discussed in the present paper with main aim to develop the understanding among the researcher so that phytoremediation technique can be employed very easily.

Keywords: *Remediation; Contaminants; pH, microbial activity*

Introduction

In contemporary society, the rapid expansion of industry and agriculture has led to the emission of various hazardous chemicals into the environment. Contaminants, in particular, represent a substantial threat to ecological balance and food security (Arora et al., 2018). These contaminants infiltrate soil and water through diverse human activities, persisting indefinitely and transitioning between different environmental compartments. This pollution may result in the incorporation of contaminants into the food chain, endangering ecosystems and human well-being (Gaur et al., 2018). A range of techniques has been utilized to rehabilitate contaminated environments, falling into the categories of biological, physical, and chemical methods (Chandra et al., 2013). However, many of these strategies can be costly, alter soil characteristics, disrupt microbial communities, and potentially cause secondary contamination (Thijis et al., 2016). Bioremediation, an ecologically responsible approach to environmental restoration, encompasses the use of plants, microorganisms, and animals to mitigate contamination. Phytoremediation, a subset of bioremediation, has gained significant attention due to its reliance on plants and encompasses processes like translocation, accumulation, transport, transformation, and volatilization of contaminants (Eskander & Saleh, 2017). Phytoremediation is recognized as an environmentally sustainable and promising technology. Nonetheless, phytoremediation faces specific challenges. Limited bioavailability of contaminants in the soil and constraints on plant biomass can curtail its effectiveness. Various methods have been developed to enhance the efficiency of phytoremediation, including microbiological, physical, chemical, agronomic, and genetic engineering approaches (Bell et al., 2014). The discovery of plant species with phytoremediation potential is also crucial for the advancement of this technique. A crucial aspect that demands attention is the management of biomass contaminated with pollutants of organic or inorganic nature. Present disposal methods, such as composting, compaction, pyrolysis, leaching, incineration, and direct disposal, often proves to be expensive and hold the potential for inducing secondary pollution (Kovacs & Szemmelveisz, 2017). An analysis of current research trends reveals that while there has been an escalating emphasis on enhancing phytoremediation technology, the issue of disposing of contaminated biomass has not received adequate consideration. To address these concerns, this paper updates the classification and influencing factors of phytoremediation and offers recommendations for the further development and widespread adoption of this environmentally responsible technique. Ultimately, addressing the challenges of low remediation efficiency and the appropriate disposal of contaminated biomass is essential for the sustained success of phytoremediation in combatting organic or inorganic contamination.

Uptake, Translocation and Tolerance Mechanism of Contaminants

Soil has different chemical composition and absorption properties that can affect the mobility and bioavailability of contaminants (Ren et al., 2018). However, bioavailability affects the efficiency of phytoextraction of target contaminants. Therefore, bioavailability is a limiting factor and very small fraction of soil contaminant is bioavailable for uptake of plants (Lasat, 2002). Mobility of soil contaminants can be enhanced by adding of some chemicals such as CDTA, EDTA, DTPA, EGTA, EDDHA, citric acid and NTA etc. Therefore, helps in increasing the absorption rate of contaminants into the plants (Muthusaravanan et al., 2018). Various contaminants are not bioavailable to the plant due to insoluble in nature. However, bioavailability of plant increases by releasing a variety of root exudates, and change of rhizosphere, pH, or by increase in contaminants solubility (Dalvi and Bhalerao, 2013). The uptake and translocation of contaminants ion transporters and complexing agents in the plant is mediated by a wide variety of molecules. These transporters or H^+ coupled carrier protein are also called channel protein that are located in the plasma membrane of the root cell and necessary for the up-liftmen of the contaminants from the soil. They can transport contaminants in cellular membrane from root to shoot that can be mediated by influx-efflux of contaminants translocation (Mosa et al., 2016). Plants have specific and efficient mechanisms to translocate and store micronutrients and also produced chelating agents depending upon change in pH and redox reaction responsible for solubilisation and transportation of contaminants even if they are present at very low concentration (Tangahu et al., 2011). The translocation occurs in plant from root to shoot requires the membrane transportation method through channel protein in root cells. In root the transportation occur through symplast method while in xylem root it takes place by apoplast method. Inside the endodermis of a root there is an impermeable suberin layer of cell wall known as casperian strips which prevents the flow of the solute straight from the soil solution into the root xylem (Taiz L & Zeiger E, 2002). An organic pollutant mainly passes by the simple diffusion method between root symplast and xylem apoplast (Peer et al., 2005). The transport of the inorganic require membrane protein for the transportation from root endodermis to the root xylem while the chelated inorganic transported by organic acid during xylem transportation (Pilon-Smits, 2005). The accumulation of the toxic pollutants generally takes place at the places where they have less harmful effect on essential cellular processes (Baby et al., 2010). The vacuoles and cell wall are some of the places where accumulation occurs at the cellular level (Burken, 2003). The uptake of inorganic substance was affected by the presence of rhizosphere. When the level of essential element decreases in the plant it is balanced by uptaking through micorhizal fungi as the metal reaches to its phytotoxic level the uptake decreases (Frey et al., 2000.; Pilon-Smits, 2005). The toxicity inside the cytosol of a plant increases with the accumulation of the contaminants in order to minimize the effect of toxicity in cytosol in plant have to detoxify them. In the second line of defence mechanism such as activation, chelation and compartmentalization of contaminants decrease the effect of toxicity (Manara, 2012; Dalvi & Bhalerao, 2013).

Factors affecting Phytoremediation

Nature of soil pH

pH is one of the most important factor that affects the capacity of phytoremediation (Willscher et al., 2017). pH of soil influences the adsorption and desorption of environmental pollutants from the soil (Chein et al., 2018). The efficiency of soil to adsorb the positively charge metals increases with increase in pH of soil (Apple & Ma, 2002). Whenever the pH value of soil is high metal ion pollutants are generally present in less soluble in nature.

Synthetic inorganic fertilizer

Use of fertilizer may increase the plant growth and biomass production. Moreover, the inclusion of synthetic fertilizer may intensify the phytoremediation technologies (Chandra et al., 2015). The main elements of synthetic fertilizer are N, P, and K (Nitrogen, Phosphorus, and Potassium) (Pathak et al., 2010). Nitrogen plays a very important role in the synthesis of chlorophyll, and protein hence becomes helpful in the growth of the plants (Muñoz-Huerta et al., 2013). P is essential for formation of roots and flower while K is accountable for stem and root maturation. Hence, N, P, K are the essential elements for fertilization (Fageria & Moreire, 2011). Although, Fertilizer may have negative impact on the absorption and utilization of nutrients whereas it decreases the shoot length if over fertilization is done (Bindraban et al., 2015).

Activity of microbes

Microbial activity in the rhizosphere (root soil boundary) is an important parameter that has a great impact in plant growth and hence metals absorption too. Microbes play a very important role in many notable activities linked with nutrients acquisition, cell elongation, metal detoxification and alleviation of stress in plants. Jeong et al. (2012) determined the ability of phosphate solubilizing bacteria for amplify Cd bioavailability and phtyoextraction prospective of *Brassica juncea* and *Abutilon theophrasti*. Phosphate solubilizing bacteria solubilize the insoluble phosphate of soil into soluble plant available form by secreting several different organic acid hence are able to stimulate plant nutrition and growth (Khan et al., 2014).

Concentration of pollutants

Uptake of pollutants from soil takes place on the basis of its concentration (Hellstorm, 2004). Few pollutants, especially at higher concentration may compete with micro and macro nutrients such as P, Ca, Mg or Fe and thus effect the plant growth or life process by increasing the toxicity (Nagajyoti et al., 2010). For a plant it is tougher to accumulate or degrade the higher concentration of contaminants (Meagher, 2000).

Conclusion

Phytoremediation is considered as one of the most promising green technology for the remediation of both organic and inorganic pollutant present in soil or in water. This technique has gained enormous attention in developing countries mainly because of its cost and other advantageous over other method of treatment. However the application of this method requires knowledge regarding the various factors that impact the removal efficiency pollutants like pH, microbial activity, concentration of pollutants, type of plants etc. This paper gives information regarding the factors on which the process of phytoremediation is dependent for the highest remediation of contaminated sites. There is number of research is required to be conducted around the globe so that efficiency can be increased, reduction in time required for the phytoremediation technique can be reduced.

References

Arora, N. K., Fatima, T., Mishra, I., Verma, M., Mishra, J., & Mishra, V. (2018). Environmental sustainability: challenges and viable solutions. *Environmental Sustainability*, *1*, 309-340.

Appel, C., & Ma, L. (2002). Concentration, pH, and surface charge effects on cadmium and lead sorption in three tropical soils. *Journal of environmental quality*, *31*(2), 581-589.

Baby, J., Raj, J. S., Biby, E. T., Sankarganesh, P., Jeevitha, M. V., Ajisha, S. U., & Rajan, S. S. (2010). Toxic effect of heavy metals on aquatic environment. *International Journal of Biological and Chemical Sciences*, *4*(4).

Bell, T. H., Joly, S., Pitre, F. E., & Yergeau, E. (2014). Increasing phytoremediation efficiency and reliability using novel omics approaches. *Trends in biotechnology*, *32*(5), 271-280.

Bindraban, P. S., Dimkpa, C., Nagarajan, L., Roy, A., & Rabbinge, R. (2015). Revisiting fertilisers and fertilisation strategies for improved nutrient uptake by plants. *Biology and Fertility of Soils*, *51*(8), 897-911.

Chien, S. W. C., Chen, S. H., & Li, C. J. (2018). Effect of soil pH and organic matter on the adsorption and desorption of pentachlorophenol. *Environmental Science and Pollution Research*, *25*, 5269-5279.

Chandra, S., Sharma, R., Singh, K., & Sharma, A. (2013). Application of bioremediation technology in the environment contaminated with petroleum hydrocarbon. *Annals of microbiology*, *63*(2), 417-431.

Chandra, R., Saxena, G., & Kumar, V. (2015). Phytoremediation of environmental pollutants: an eco-sustainable green technology to environmental management. *Advances in biodegradation and bioremediation of industrial waste*, 1-29.

Dalvi, A. A., & Bhalerao, S. A. (2013). Response of plants towards heavy metal toxicity: an overview of avoidance, tolerance and uptake mechanism. *Ann. Plant Sci*, *2*(9), 362-8.

Eskander, S., & Saleh, H. (2017). Phytoremediation: an overview. *Environmental science and engineering, Soil pollution and phytoremediation*, *11*, 124-161.

Fageria, N. K., & Moreira, A. (2011). The role of mineral nutrition on root growth of crop plants. *Advances in agronomy*, *110*, 251-331.

Frey, B., Zierold, K., & Brunner, I. (2000). Extracellular complexation of Cd in the Hartig net and cytosolic Zn sequestration in the fungal mantle of Picea abies–Hebeloma crustuliniforme ectomycorrhizas. *Plant, Cell & Environment*, *23*(11), 1257-1265.

Gaur, N., Narasimhulu, K., & PydiSetty, Y. (2018). Recent advances in the bio-remediation of persistent organic pollutants and its effect on environment. *Journal of cleaner production*, *198*, 1602-1631.

Hellstrom, A. (2004). Uptake of organic pollutants in plants. *Department of Environment and Assessments, Swedish University of Agricultural Sciences, Uppsala*.

Jeong, S., Moon, H. S., Nam, K., Kim, J. Y., & Kim, T. S. (2012). Application of phosphate-solubilizing bacteria for enhancing bioavailability and phytoextraction of cadmium (Cd) from polluted soil. *Chemosphere*, *88*(2), 204-210.

Khan, M. S., Zaidi, A., & Ahmad, E. (2014). Mechanism of phosphate solubilization and physiological functions of phosphate-solubilizing microorganisms. *Phosphate solubilizing microorganisms: principles and application of microphos technology*, 31-62.

Kovacs, H., & Szemmelveisz, K. (2017). Disposal options for polluted plants grown on heavy metal contaminated brownfield lands–a review. *Chemosphere*, *166*, 8-20.

Lasat, M. M. (2002). Phytoextraction of toxic metals: a review of biological mechanisms. *Journal of environmental quality*, *31*(1), 109-120.

Manara, A. (2012). Plant responses to heavy metal toxicity. *Plants and heavy metals*, 27-53.

Meagher, R. B. (2000). Phytoremediation of toxic elemental and organic pollutants. *Current opinion in plant biology*, *3*(2), 153-162.

Mosa, K. A., Saadoun, I., Kumar, K., Helmy, M., & Dhankher, O. P. (2016). Potential biotechnological strategies for the cleanup of heavy metals and metalloids. *Frontiers in plant science*, *7*, 303.

Muthusaravanan, S., Sivarajasekar, N., Vivek, J. S., Paramasivan, T., Naushad, M., Prakashmaran, J., ... & Al-Duaij, O. K. (2018). Phytoremediation of heavy metals: mechanisms, methods and enhancements. *Environmental chemistry letters*, *16*(4), 1339-1359.

Muñoz-Huerta, R. F., Guevara-Gonzalez, R. G., Contreras-Medina, L. M., Torres-Pacheco, I., Prado-Olivarez, J., & Ocampo-Velazquez, R. V. (2013). A review of methods for sensing the nitrogen status in plants: advantages, disadvantages and recent advances. *sensors*, *13*(8), 10823-10843.

Nagajyoti, P. C., Lee, K. D., & Sreekanth, T. V. M. (2010). Heavy metals, occurrence and toxicity for plants: a review. *Environmental chemistry letters*, *8*, 199-216.

Pathak, H., Mohanty, S., Jain, N., & Bhatia, A. (2010). Nitrogen, phosphorus, and potassium budgets in Indian agriculture. *Nutrient Cycling in Agroecosystems*, *86*, 287-299.

Peer, W. A., Baxter, I. R., Richards, E. L., Freeman, J. L., & Murphy, A. S. (2006). Phytoremediation and hyperaccumulator plants. *Molecular biology of metal homeostasis and detoxification: from microbes to man*, 299-340.

Pilon-Smits, E. (2005). Phytoremediation. *Annu. Rev. Plant Biol.*, *56*, 15-39.

Ren, X., Zeng, G., Tang, L., Wang, J., Wan, J., Liu, Y., ... & Deng, R. (2018). Sorption, transport and biodegradation–an insight into bioavailability of persistent organic pollutants in soil. *Science of the total environment*, *610*, 1154-1163.

Taiz, L., & Zeiger, E. (2002). Plant Physiology. Sinauer Assoc. *Inc. Publ., Sunderland, Mass.*,, 1-690.

Tangahu, B. V., Sheikh Abdullah, S. R., Basri, H., Idris, M., Anuar, N., & Mukhlisin, M. (2011). A review on heavy metals (As, Pb, and Hg) uptake by plants through phytoremediation. *International journal of chemical engineering*, *2011*.

Thijs, S., Sillen, W., Rineau, F., Weyens, N., & Vangronsveld, J. (2016). Towards an enhanced understanding of plant–microbiome interactions to improve phytoremediation: engineering the metaorganism. *Frontiers in Microbiology*, *7*, 341.

Willscher, S., Jablonski, L., Fona, Z., Rahmi, R., & Wittig, J. (2017). Phytoremediation experiments with Helianthus tuberosus under different pH and heavy metal soil concentrations. *Hydrometallurgy*, *168*, 153-158.