An Overview On Phytoremediation

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Abstract

Phytoremediation is a technique of utilizing the plants directly or indirectly to remove the pollutants present in the soil or water. This technology in recent decades had gained enormous attention mainly due to its cost effectiveness and no generation of secondary by product. Both organic and inorganic pollutants get remediated by using this technology. A better understanding regarding the various processes involved in phytoremediation such as phytostabilization, phytoextraction, rhizodegradation, rhizofiltration, phytodegradation, and phytovolatization would prove to be very significant in order to utilise this technique for remediation of polluted soil or water sites.

Keywords: *Water Pollution; Organic Pollutant; Inorganic pollutant; rhizodegradation*

Introduction

The soil and water quality are continuously deteriorated as a result of overpopulation, urbanization, industrialization, overuse of inorganic fertilizers as well as overconsumption of water resources (Balanarayanan & Vetrivel, 2012). Organic and inorganic pollutants are generally released into the environment by anthropogenic activities such as oil spills, use of fertilizers (pesticides, herbicides), various chemicals are used by industrial activities (Laghlimi et al., 2015). Some of the inorganic pollutants are also released by natural activities in the earth crust. Heavy metals are mostly drifted due to anthropogenic activities and are harmful effect to humans and are considered as one of the toxic inorganic contaminants (Stankovic et al., 2012). Inorganic contaminants do not decompose easily and stay in water and soil for a long time. However, inorganic substances deteriorate the quality of water and soil because of its persistent in nature for longer duration (Sharma & Pandey, 2014). From they can be absorbed by the aquatic animals including other invertebrates shows the lethal effects or toxicity due to access of absorption which led to the harmful effect on their biological functions such as metabolic activities, growth, reproduction and development (Zhang et al., 2017). It also shows the harmful effect to the human being as well. However some of the these elements are essential at low concentration for proper growth of aquatic animals and plants but if they are ingested in higher concentration then it may causes toxicity (Stankovic et al 2014.; Velma & Tchounwou, 2010.; Vieira et al., 2012). Over the few decades, phytoremediation is defined as a green technology in which plants are utilized for the removal of inorganic and organic contaminants from water and soil (Lee 2013). Currently phytoremediation is an emerging technology which has the ability if improving the quality of water and soil and by remediating the toxic pollutants (Sinha et al., 2007). In phytoremediation, hyper accumulator plants

absorbs the contaminated substances than the normal plants as a result of which these are found to be more helpful in removing, immersing, degrading or destabilising the contamination of pollutants like heavy metals too (Raskin et al, 1997). Conventionally, various physical and chemical techniques such as soil washing, extraction, pumping, aeration, air stripping, incineration, solidification, thermal desorption, enzymatic degeneration, adsorption and ion exchange for remediation of contaminants (Scullion, 2006). However, conventional method is very expensive and harmful as it produces secondary wastes and that has potential too in damaging the environment (Sharma & Pandey., 2014). Application of phytoremediation may be 10 times cheaper than application of conventional method in removing of contaminants from the soil and water (Nascimento and Xing, 2006). From the past many years, phytoremediation techniques have been widely used due to its low cost and environment-friendly in nature. Plants on the basis of biomass, depth root zone, growth rate, and their ability to tolerate the contaminants are being selected for its possible application in the process of phtytoremediation (Chirakkara et al., 2016). Phytoremediation is a highly promising method that uses various plants and microbes to remediate or accumulate various types of contaminants such as metals, pesticides, petroleum, explosives, polyaromatic hydrocarbons (PAH), and other organic compounds from soil and water (Dietz & Schnoor, 2001, Meagher, 2000). As compared to physical and chemical techniques phytoremediation has various advantages such as it is less expensive, easy to manage, provide aesthetically pleasant environment, soil stabilization, carbon sequestration at the time of cleaning up the environment. On the other hand, phytoremediation has other benefits such as application of such plants for reprocessing it into woodchips, and bio energy resources (LeDuc and Terry 2005).

Phytoremediation Strategies

In phytoremediation techniques, uses various types of plants species based on their special properties such as fast growing, high biomass and competitive and ability to tolerate the highly polluted environment (Leguizamo et al., 2017). The process of the phytoremediation includes the following steps such as phytostabilization, phytoextraction, rhizodegradation, rhizofiltration, phytodegradation, and phytovolatization (Chatterjee et al., 2013).

Phytoextraction

Phytoextratraction is also referred as phytoaccumulation (Ghori et al., 2016). In phytoextraction, the contaminants are absorbed and translated by aerial parts such as shoot, stem and leaves of the plants (Iqbal et al., 2015). The phytoextraction is a technique in which contaminants uptake from soil and water yet it requires the translocation of contaminants for accumulation from harvestable part of the root to above ground part of the shoot (Brennan & Shelley., 1999). Additionally, many studies shows that in translocation process plants required some condition such as presence of pollutant i.e. metals in soluble form so that it can be taken up by the plant easily, plant roots have capacity to absorb metals, then it gets chelated by plants and further gets translocated by the plants (Gupta et al., 2016).

Phytostablization

In phytostablization technique, heavy metals are stabilized in soil and water through absorption and accumulation process by rhizopshere of the plant species or root (Pinto et al., 2015). Therefore, stabilization restrain the bioavailability of contaminants as well as it reform through contaminants precipitation by different organic and inorganic amendments such as biosolids, composting manure, fly ash and NPK fertilizers, limestone, dolomite, red mud etc (Radziemska et al., 2017). Unlike Phytoextraction, this process prevents the accumulation of contaminants and minimizes their leaching to deeper soil or underground water. Phytostablizaton is only focuses on to segregate the contaminants from the root into the soil. Therefore, this technique does not have the permanent solution for the removal of pollutants from the contaminated environment. (Vangronsveld et al.,2009).

Phytodegradation

Phytodegration is also named as phytotransformation. In phytodegradation, degradation of pollutants is carried out by breaking down the contaminants by application of some plant species after absorbing them by secreting some enzymes such as dehydrogenase, oxygenase, reductase and inorganic nutrients (Vishnoi & Srivastava, 2008 , Zayed & Terry, 2003). This can be performed through enzymatic metabolic process of plant root or shoot cells. The enzymes have the ability to increase the rate of degradation which leads to breakdown the contaminants into less toxic and tiny particles, so that plants can be used as growth activator (Rao et al., 2014).

Phytovolatization

Phytovolatization is also called evapotranspiration mechanism that can be mainly utilised for the remediation of Hg, Se and other organic solvent contamination (Karami & Sumsuddin, 2010). In Photovolatization, uptake of contaminants from the soil by direct and indirect ways of volatization from stem and leaves and from the root zone of the plants respectively. Therefore they convert into less toxic volatile form before releasing into the environment through stomata and hence decrease the harmful effect on environment by remediating the toxic substance (Limmer & Burken, 2016; Rascio & Navari-Izzo, 2011).

Rhizodegradation

The hydrocarbons that act as pollutants such as PAHs or pentachlorate can be decomposed by the activity of microorganism in the rhizosphere (Rhodes., 2010). This mainly depends upon the interaction between the groups of species along with the plant. The contaminants gets converted in to the non-toxic form via enzymatic and metabolic process by microorganisms that are well develop in the medium that is rich in carbon source and hence can provide the essential medium for the development of soil microflora (Gkorezis et al., 2016).

Rhizofilteration

Rhizofilteration is almost same as phytoextration but in this plants raised in constructed wetland using hydroponic system are used for the remediation of contaminants (Horne, 2000). Artificial medium such as vermiculite mixed sand has created in hydroponic setup. Therefore, plants used as hydraulic barrier for removal of contaminants from ground water, surface water by creating upward flow absorb into the root tissue, concentrate & precipitate them (Roy et al., 2015). The plant which has high surface area with fibrous root and root hairs are more desirable for effective remediation (Tomé et al., 2008). This techniques mostly used for treatment of groundwater or wastewater polluted by heavy metal of radioactive elements such as Ra, U and Cs (Tomé et al., 2008; Mikheev et. al, 2017; Yang et al., 2015). This method is especially used for the treatment of groundwater or wastewater polluted with heavy metals or radionuclides, such as Ra, U, and Cs.

Conclusion

The application of the native plants in the remediation of sites i.e. soil or water body cain be remediated by the application of phytoremediation technique. There are several mechanisms are involved in the remediation of these contaminated sites. They are phytostabilization, phytoextraction, rhizodegradation, rhizofiltration, phytodegradation, and phytovolatization. There is a need of understanding the various processes that are involved in the remediation of contaminants that can be remediated using phytoremediation technique. In addition to this, understanding about the various mechanisms that are involved in the remediation of contaminants would also be helpful in knowing the various limitations related to the application of this technique for the remediation of contaminated sites.

Reference:

Balanarayanan, S., & Vetrivel, K. (2012). Environmental degradation and human welfare: A critical study. *ZENITH International Journal of Business Economics & Management Research*, *2*(5), 39-51.

Brennan, M.A.; Shelley, M.L. A model of the uptake, translocation, and accumulation of lead (Pb) by maize for the purpose of phytoextraction. Ecol. Eng. 1999, 12, 271–297.

Bhatia, M., & Goyal, D. (2014). Analyzing remediation potential of wastewater through wetland plants: a review. *Environmental Progress & Sustainable Energy*, *33*(1), 9-27.

Chatterjee, S., Mitra, A., Datta, S., & Veer, V. (2013). Phytoremediation protocols: an overview. *Plant-based remediation processes*, 1-18.

Chirakkara, R. A., Cameselle, C., & Reddy, K. R. (2016). Assessing the applicability of phytoremediation of soils with mixed organic and heavy metal contaminants. Reviews in Environmental Science and Bio/Technology, 15, 299-326.

Dietz AC, Schnoor JL (2001) Advances in phytoremediation. Environ Health Perspect 109:163–168.

Gkorezis, P., Daghio, M., Franzetti, A., Van Hamme, J. D., Sillen, W., &Vangronsveld, J. (2016). The interaction between plants and bacteria in the remediation of petroleum hydrocarbons: an environmental perspective. *Frontiers in microbiology*, *7*, 1836.

Ghori, Z., Iftikhar, H., Bhatti, M. F., Sharma, I., Kazi, A. G., & Ahmad, P. (2016). Phytoextraction: the use of plants to remove heavy metals from soil. In *Plant metal interaction* (pp. 385-409). Elsevier.

Gupta, N., Ram, H., & Kumar, B. (2016). Mechanism of Zinc absorption in plants: uptake, transport, translocation and accumulation. *Reviews in Environmental Science and Bio/Technology*, *15*, 89-109.

Horne, A. J. (2000). Phytoremediation by constructed wetlands. *Norman Terry*.

Iqbal, M., Ahmad, A., Ansari, M. K. A., Qureshi, M. I., Aref, I. M., Khan, P. R., ... & Hakeem, K. R. (2015). Improving the phytoextraction capacity of plants to scavenge metal (loid)-contaminated sites. *Environmental Reviews*, *23*(1), 44-65.

Karami, A., &Shamsuddin, Z. H. (2010). Phytoremediation of heavy metals with several efficiency enhancer methods. *African Journal of Biotechnology*, *9*(25), 3689-3698.

Laghlimi, M., Baghdad, B., El Hadi, H., & Bouabdli, A. (2015). Phytoremediation mechanisms of heavy metal contaminated soils: a review. Open journal of Ecology, 5(08), 375.

Limmer, M., &Burken, J. (2016). Phytovolatilization of organic contaminants. *Environmental Science & Technology*, *50*(13), 6632-6643.

LeDuc D, Terry N (2005) Phytoremediation of toxic trace elements in soil and water. J IndMicrobiolBiotechnol 32:514–520

Leguizamo, M. A. O., Gómez, W. D. F., & Sarmiento, M. C. G. (2017). Native herbaceous plant species with potential use in phytoremediation of heavy metals, spotlight on wetlands—a review. *Chemosphere*, *168*, 1230-1247.

Lee, J. H. (2013). An overview of phytoremediation as a potentially promising technology for environmental pollution control. *Biotechnology and Bioprocess Engineering*, *18*(3), 431-439.

Meagher RB (2000) Phytoremediation of toxic elemental and organic pollutants. CurrOpin Plant Biol 3:153–162

Mikheev, A.N.; Lapan, O.V.; Madzhd, S.M. Experimental foundations of a new method for rhizofiltration treatment of aqueous ecosystems from 137 Cs. J. Water Chem. Technol. 2017, 39, 245–249.

Nascimento, C. W. A. do, & Xing, B. (2006). *Phytoextraction: a review on enhanced metal availability and plant accumulation. Scientia Agricola, 63(3), 299–311.*

Pinto, A. P., De Varennes, A., Fonseca, R., & Teixeira, D. M. (2015). Phytoremediation of soils contaminated with heavy metals: techniques and strategies. *Phytoremediation: Management of Environmental Contaminants, Volume 1*, 133-155.

Radziemska, M., Vaverková, M.D., Baryła, A., 2017. Phytostabilization-management strategy for stabilizing trace elements in contaminated soils. Int. J. Environ. Res. Public Health 14, http://dx.doi.org/10.3390/ijerph14090958.

Rao, M. A., Scelza, R., Acevedo, F., Diez, M. C., & Gianfreda, L. (2014). Enzymes as useful tools for environmental purposes. *Chemosphere*, *107*, 145-162.

Rascio N, Navari-Izzo F (2011). Heavy metal hyper-accumulating plants: how and why do they do it? and what makes them so interesting? Plant Science 180(2):169-181.

Raskin, I., Smith, R. D., & Salt, D. E. (1997). Phytoremediation of metals: using plants to remove pollutants from the environment. *Current opinion in biotechnology*, *8*(2), 221-226.

Rhodes, C. J. (2013). Applications of bioremediation and phytoremediation. *Science progress*, *96*(4), 417-427.

Roy, M., Giri, A. K., Dutta, S., & Mukherjee, P. (2015). Integrated phytobial remediation for sustainable management of arsenic in soil and water. Environment international, 75, 180-198.

Sharma, P., & Pandey, S. (2014). Status of phytoremediation in world scenario. *International Journal of Environmental Bioremediation & Biodegradation*, *2*(4), 178-191

Scullion J (2006) Remediating polluted soils. Naturwissenschaften 93:51–65.

Sinha, R. K., Herat, S., &Tandon, P. K. (2007). Phytoremediation: role of plants in contaminated site management. In *Environmental bioremediation technologies* (pp. 315-330). Springer, Berlin, Heidelberg.

Stankovic, S., Jovic, M., Stankovic, A. R., & Katsikas, L. (2012). Heavy metals in seafood mussels. Risks for human health. *Environmental Chemistry for a Sustainable World: Volume 1: Nanotechnology and Health Risk*, 311-373.

Stankovic, S., Kalaba, P., &Stankovic, A. R. (2014). Biota as toxic metal indicators. *Environmental Chemistry Letters*, *12*(1), 63-84.

Tomé, F. V., Rodríguez, P. B., & Lozano, J. C. (2008). Elimination of natural uranium and 226Ra from contaminated waters by rhizofiltration using Helianthus annuus L. *Science of the total environment*, *393*(2-3), 351-357.

Vangronsveld, J., Herzig, R., Weyens, N., Boulet, J., Adriaensen, K., Ruttens, A., Thewys, T., Vassilev, A., Meers, E., Nehnevajova, E., Van der Lelie, D., Mench, M., 2009. Phytoremediation of contaminated soils and groundwater: lessons from the field. Environ. Sci. Pollut. Res. 16, 765–794.

Velma, V., &Tchounwou, P. B. (2010). Chromium-induced biochemical, genotoxic and histopathologic effects in liver and kidney of goldfish, Carassiusauratus. *Mutation Research/Genetic Toxicology and Environmental Mutagenesis*, *698*(1-2), 43-51.

Vieira, M. C., Torronteras, R., Córdoba, F., &Canalejo, A. (2012). Acute toxicity of manganese in goldfish Carassiusauratus is associated with oxidative stress and organ specific antioxidant responses. *Ecotoxicology and environmental safety*, *78*, 212-217.

Vishnoi, S.R., Srivastava, P.N., 2008. Phytoremediation-green for environmental clean. In: The 12th World Lake Conference, pp. 1016–1021.

Yang, M.; Jawitz, J.W.; Lee, M. Uranium and cesium accumulation in bean (Phaseolus vulgaris L. var. vulgaris) and its potential for uranium rhizofiltration. J. Environ. Radioact. 2015, 140, 42–49.

Zayed AM, Terry N (2003). Chromium in the environment: factors affecting biological remediation. Plant and Soil 249:139-156.

Zhang, T., Lu, Q., Su, C., Yang, Y., Hu, D., &Xu, Q. (2017). Mercury induced oxidative stress, DNA damage, and activation of antioxidative system and Hsp70 induction in duckweed (Lemna minor). *Ecotoxicology and environmental safety*, *143*, 46-56.