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Review

Phytoremediation: a property of plant to clean up our environment

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Abstract: This review presents the idea of phytoremediation which is a generic term given to a set of technologies that uses different plants to contain, extract, degrade or immobilize contaminants from soil and water. Being a cost saving procedure compared to conventional treatments it has become an interesting method in remediation technology. Moreover, for developing countries like Bangladesh, along with the cost effectiveness, phytoremediation is also suitable for its environmental friendly and aesthetically pleasing approach. This paper reports about the mobility, bioavailability and plant response to the presence of harmful contaminants in our environment. It also gives an insight into the work done by authors, which focuses on modifying plants to have increased phytoremediation properties, studying the expression profile of miRNAs and their target genes responsible for phytoremediation. Thus, this paper attempted to provide a concise review on recent progresses in research and convenient applications of phytoremediation for environmental resources.

Keywords: phytoremediation; miRNA; gene; Bangladesh

1. Introduction

There is a growing trend in areas of land, surface waters and groundwater around the world affected by contamination from industrial and agricultural activities either due to ignorance, lack of vision, or carelessness (Hauqe *et al.,* 2016; Ross *et al.,* 2006; Yang *et al.*, 2013). For example, concentrations of Cu, Zn, Pb, Cr, Cd, Fe, and Ni estimated in soils and vegetables grown in and around an industrial area of a developing country, Bangladesh showed the following order of metal contents in contaminated irrigation water: Fe >Cu>Zn>Cr>Pb>Ni>Cd. (Ahmad and Goni 2010). Another study based on Dhaka Export Processing Zone (DEPZ) area showed slight variation in the order which is Zn>Cu>Sr >Pb>Ni>Cr >Li>Co>V>Se>As>Ag in composite industrial effluents (Ahmed *et al.*, 2012). The results revealed that the water present in the surface of this area is highly contaminated (Ahmed *et al.*, 2012). The most dangerous news is that a study provides a spatial assessment of the risk of arsenic contamination of the principal food of Bangladesh, rice, because of the use of arsenic polluted groundwater for irrigation (Ross *et al.*, 2006). So it has become very important for us to find a way to remove these contaminants from our environment.

Compared to other traditional remediation engineering techniques, phytoremediation is very much cost-effective and a fledgling technology intended to address a wide variety of surficial contaminants. It is a recent developed method of environmental clean-up. (Grichko *et al.*, 2000). Being an integrated multidisciplinary approach to the cleanup of contaminated soils, which combines the disciplines of soil chemistry, soil microbiology and plant physiology (Cunningham and Ow, 1996), phytoremediation has been applied to a number of contaminants in small-scale field and/or laboratory studies.

microRNAs (miRNAs) are approximately 21-nucleotide (nt) non-coding RNAs that play critical roles in gene expression regulation at the post-transcriptional level. In plants, cleavage of the target mRNA appears to be the prevalent method of post-transcriptional regulation (Brodersen *et al.*, 2008). Although miRNAs have been

intensively studied over the last few years, little research is performed on the role of miRNAs in various organic material stress responses like heavy metal (Ross *et al.*, 2006). Nevertheless, a number of studies verified the involvement of miRNAs in responses to different metal toxicities (Sunkar *et al.*, 2006), mostly using screenings like microarrays (Ding *et al.*, 2011) and deep sequencing of small RNA libraries (Zhou *et al.*, 2012a). These studies were performed on different species such as *Arabidopsis thaliana* (Kopriva 2006; Sunkar *et al.*, 2006), *Medicago truncatula* (Zhou *et al.*, 2012b), *Brassica napus* (Huang *et al.*, 2010; Zhou *et al.*, 2012a), *Oryza sativa* (Ding *et al.*, 2011), *Nicotiana tabacum* (Burklew *et al.*, 2012) and *Phaseolus vulgaris* (Valdés-López *et al.*, 2010).
Using these information, progresses have been made in practical application aspects of phytoremediation. Plant growth promoting bacteria are also used to increase the phytoremediation properties of plant (Das *et al.*, 2016). They all were reviewed and reported in this paper.

2. Techniques of phytoremediation

Phytoremediation of environmental components like water or soil contaminated by organic materials such as metals can be achieved by a number of techniques (Saxena *et al.*, 1999).

2.1. Phytoextraction

Phytoextraction relies on the ability of organic molecule-accumulating plants to transport and concentrate polluting components from soil into the harvestable above ground shoots (Salt *et al.*, 1998; Vassil *et al.*, 1998). The plant material can subsequently be used for non-food purposes (e.g. wood, cardboard) or ashed, followed by disposal in a landfill or, in the case of valuable components, the accumulated element can be recycled. The latter is termed phytomining (Chaney *et al.*, 1997).
For example a list of several metal hyperaccumulator species with respective metal accumulated is given in Table 1.

Table 1. Several metal hyperaccumulator species with respective accumulated metal.

Plant species	Metal	References
Thlaspi caerulescens, Arabidopsis halleri	Zn, Cd	(Reeves and Brooks, 1983; Baker and Walker, 1990) (Baker and Brooks, 1989; Cosio *et al.*, 2004)
Ipomea alpina	Cu	(Baker and Walker, 1990)
Acuminata Sebertia, Thlaspi goesingens, Alyssum bertolonii, Stackhousia tryonii	Ni	(Jaffré *et al.*, 1979), (Krämer and Chardonnens, 2001), (Chaney *et al.*, 1997) and (Bhatia *et al.*, 2005)
Arabidopsis thaliana	Zn, Cu, Pb, Mn, P	(Lasat, 2002)
Sonchus asper	Pb, Zn	(Yanqun *et al.*, 2005)
Corydalis pterygopetala	Zn, Cd	(Yanqun *et al.*, 2005)
Sedum alfredii	Pb, Zn	(Li *et al.*, 2005)
Helianthus anus	Cd, Cr, Ni	(Turgut *et al.*, 2004)

2.2. Rhizofiltration

This technique is used for cleaning contaminated surface waters or waste waters by adsorption or precipitation of organic contaminants onto roots or absorption by roots or other submerged organs of tolerant aquatic plants (Dushenkov *et al.*, 1995; Horne *et al.*, 2000).

2.3. Phytostabilization

The term denotes the use of plants to stabilize pollutants in soil (Berti and Cunningham, 2000). Phytostabilization of contaminant may employ plants to reduce leaching, runoff, and erosion (Berti and Cunningham, 2000; Burken *et al.*, 2000; Krämer and Chardonnens, 2001).

2.4. Phytodegradation

In phytodegradation, organic pollutants are converted by internal or secreted enzymes into compounds with reduced toxicity (Schnoor *et al.*, 1995; Salt *et al.*, 1998; Suresh and Ravishankar, 2004).

2.5. Rhizodegradation

Like phytodegradation, rhizosphere degradation involves the enzymatic breakdown of organic pollutants, but through microbial enzymatic activity. These breakdown products are either volatilized or incorporated into the microorganisms and soil matrix of the rhizosphere (Dzantor, 2007).

2.6. Phytovolatilization

The process refers to the release of pollutants from the plant to the atmosphere as gas. Although it works well for organics, this can be used for a few inorganics that can exist in volatile form, i.e. Se, Hg and As (Zayed *et al.,* 2000).

Finally, a combination of phytoremediation approaches can be used for more effective environmental restoration.

3. Molecular studies related to phytoremediation

So far, more than 400 plant species have been reported as major soil contaminant, metal hyperaccumulators, representing less than 0.2% of all angiosperms (Ross *et al.,* 2006; Yang *et al.,* 2013). Promising studies at molecular level shows that the major soil contaminant in our dying industrial area of our country, Zinc (Zn) uptake is regulated by ZIP family genes in *Arabidopsis thaliana* (Shahandeh and Hossner, 2000; Haque *et al.*, 2016). Another study shows that bermudagrass (*Cynodon dactylon*) and switchgrass (*Panicum virgatum*) can accumulate Chromium (Cr) (Shahandeh and Hossner, 2000), the major soil contaminant of our leather industrial area. Moreover, some other studies proved that regulating genes in transgenic plant like alo vera (Das *et al.*, 2016). In addition, increased ability of transgenic plants expressing the bacterial enzyme ACC deaminase to accumulate Cd, Co, Cu, Ni, Pb, and Zn (Grichko *et al.,* 2000). As the many impostant genes like ABC, ARF8 responsible for phytoremediation are regulated by microRNA, it could be targeted for regulating the phytoremediation properties of plants. Various miRNAs have been identified that are responsible for regulating the genes responsible for phytoremediation (Gielen *et al.,* 2012; Yang *et al.*, 2013). And expression profile of some crucial miRNAs and their corresponding target genes regarding phytoremediation properties have been checked in a native plant of our country named jute (*Corchorus olitorius*), the golden fiber of Bangladesh (Haque *et al.,* 2016). The results indicate that jute is an accumulator of Mn and Cr but not As. Jute would therefore be a good candidate in the remediation of soil rich in Mn and Cr (Haque *et al.*, 2016). And further modified regulation through miRNAs can improve the phytoremediation properties of jute as well as other plants.

4. Conclusions

Phytoremediation is a low-risk and attractive cleanup method. The research of phytoremediation is time-consuming and tedious despite of having a relatively simpler concept. But the process of soil removal and material extraction of various contaminants is even more disruptive and expensive. Hence, phytoremediation may be the best alternative for a developing country like Bangladesh. With the advancement in biotechnology, the potentials of hyperaccumulators may be significantly increased through specific organic contaminant gene identification and its transfer in certain promising species.

Conflict of interest

None to declare.

References

Ahmad JU and MA Goni, 2010. Heavy metal contamination in water, soil, and vegetables of the industrial areas in Dhaka, Bangladesh. Environmental Monitoring and Assessment, 166: 347-357.

Ahmed G, MA Miah, HM Anawar, DA Chowdhury and JU Ahmad, 2012. Influence of multi-industrial activities on trace metal contamination: an approach towards surface water body in the vicinity of Dhaka Export Processing Zone (DEPZ). Environmental Monitoring and Assessment, 184: 4181-4190.

Baker A and R Brooks, 1989. Terrestrial higher plants which hyperaccumulate metallic elements. A review of their distribution, ecology and phytochemistry. Biorecovery, 1: 81-126.

Baker AJ and PL Walker, 1990. Ecophysiology of metal uptake by tolerant plants, CRC Press, Boca Raton, FL.

Berti WR and SD Cunningham, 2000. Phytostabilization of metals. Phytoremediation of toxic metals: using plants to clean-up the environment. New York, John Wiley and Sons, Inc., pp.71-88.

Bhatia NP, KB Walsh and AJ Baker, 2005. Detection and quantification of ligands involved in nickel detoxification in a herbaceous Ni hyperaccumulator Stackhousia tryonii Bailey. Journal of Experimental Botany, 56: 1343-1349.

Brodersen P, L Sakvarelidze-Achard, M Bruun-Rasmussen, P Dunoyer, YY Yamamoto, L Sieburth and O Voinnet, 2008. Widespread translational inhibition by plant miRNAs and siRNAs. Science, 320: 1185.

Burken JG, JV Shanks and PL Thompson, 2000. Phytoremediation and plant metabolism of explosives and nitroaromatic compounds. Biodegradation of nitroaromatic compounds and explosives, pp. 239-276.

Burklew CE, J Ashlock, WB Winfrey and B Zhang, 2012. Effects of aluminum oxide nanoparticles on the growth, development, and microRNA expression of tobacco (Nicotiana tabacum). PLoS One, 7: 34783.

Chaney RL, M Malik, YM Li, SL Brown, EP Brewer, JS Angle and AJ Baker, 1997. Phytoremediation of soil metals. Current Opinion in Biotechnology, 8: 279-284.

Cosio C, E Martinoia and C Keller, 2004. Hyperaccumulation of cadmium and zinc in Thlaspi caerulescens and Arabidopsis halleri at the leaf cellular level. Plant Physiology, 134: 716-725.

Cunningham SD and DW Ow, 1996. Promises and prospects of phytoremediation. Plant Physiology, 110: 715.

Das N, S Bhattacharya and MK Maiti, 2016. Enhanced cadmium accumulation and tolerance in transgenic tobacco overexpressing rice metal tolerance protein gene OsMTP1 is promising for phytoremediation. Plant Physiology and Biochemistry, 105: 297-309.

Ding Y, Z Chen and C Zhu, 2011. Microarray-based analysis of cadmium-responsive microRNAs in rice (Oryza sativa). Journal of Experimental Botany, 62: 3563-3573.

Dushenkov V, PN Kumar, H Motto and I Raskin, 1995. Rhizofiltration: the use of plants to remove heavy metals from aqueous streams. Environmental Science and Technology, 29: 1239-1245.

Dzantor EK, 2007. Phytoremediation: the state of rhizosphere ‘engineering’ for accelerated rhizodegradation of xenobiotic contaminants. Journal of Chemical Technology and Biotechnology, 82: 228-232.

Gielen H, T Remans, J Vangronsveld and A Cuypers, 2012. MicroRNAs in Metal Stress: Specific Roles or Secondary Responses. International Journal of Molecular Sciences, 13: 15826-15847.

Grichko VP, B Filby and BR Glick, 2000. Increased ability of transgenic plants expressing the bacterial enzyme ACC deaminase to accumulate Cd, Co, Cu, Ni, Pb, and Zn. Journal of Biotechnology, 81: 45-53.

Haque S, AS Ferdous, S Sarker, M Islam, K Hossain and H Khan, 2016. Identification and expression profiling of microRNAs and their corresponding targets related to phytoremediation of heavy metals in jute (Corchorus olitorius var. O-9897). Biores. Comm., 2: 152-157.

Horne AJ, N Terry and G Banuelos, 2000. Phytoremediation by constructed wetlands. Phytoremediation of contamined soil on water, pp.13-39.

Huang SQ, AL Xiang, LL Che, S Chen, H Li, JB Song and ZM Yang, 2010. A set of miRNAs from Brassica napus in response to sulphate deficiency and cadmium stress. Plant Biotechnology Journal, 8: 887-899.

Jaffré T, W Kersten, R Brooks and R Reeves, 1979. Nickel uptake by Flacourtiaceae of New Caledonia. Proceedings of the Royal Society of London. Series B. Biological Sciences, 205: 385-394.

Kopriva S, 2006. Regulation of sulfate assimilation in Arabidopsis and beyond. Annals of Botany, 97: 479-495.

Krämer U and A Chardonnens, 2001. The use of transgenic plants in the bioremediation of soils contaminated with trace elements. Applied Microbiology and Biotechnology, 5: 661-672.

Lasat MM, 2002. Phytoextraction of toxic metals. Journal of Environmental Quality, 31: 109-120.

Li TQ, XE Yang, XF Jin, ZL He, PJ Stoffella and QH Hu, 2005. Root responses and metal accumulation in two contrasting ecotypes of Sedum alfredii Hance under lead and zinc toxic stress. Journal of Environmental Science and Health, 40: 1081-1096.

Reeves R and R Brooks, 1983. European species of< i> Thlaspi</i> L.(Cruciferae) as indicators of nickel and zinc. Journal of Geochemical Exploration, 18: 275-283.

Ross Z, JM Duxbury, SD DeGloria and DNR Paul, 2006. Potential for arsenic contamination of rice in Bangladesh: spatial analysis and mapping of high risk areas. International Journal of Risk Assessment and Management, 6: 298-315.

Salt DE, R Smith and I Raskin, 1998. Phytoremediation. Annual Review of Plant Biology, 49: 643-668.

Saxena P, S KrishnaRaj, T Dan, M Perras and N Vettakkorumakankav, 1999. Phytoremediation of heavy metal contaminated and polluted soils. Heavy metal stress in plants. Springer, pp.305-329.

Schnoor JL, LA Licht, SC McCutcheon, NL Wolfe and LH Carreira, 1995. Phytoremediation of organic and nutrient contaminants. Environmental Science and Technology, 29: 318A-323A.

Shahandeh H and L Hossner, 2000. Plant screening for chromium phytoremediation. International Journal of Phytoremediation, 2: 31-51.

Sunkar R, A Kapoor and JK Zhu, 2006. Posttranscriptional induction of two Cu/Zn superoxide dismutase genes in Arabidopsis is mediated by downregulation of miR398 and important for oxidative stress tolerance. The Plant Cell Online, 18: 2051-2065.

Suresh B and G Ravishankar, 2004. Phytoremediation-A novel and promising approach for environmental clean-up. Critical Reviews in Biotechnology, 24: 97-124.

Turgut C, M Katie Pepe and TJ Cutright, 2004. The effect of EDTA and citric acid on phytoremediation of Cd, Cr, and Ni from soil using< i> Helianthus annuus</i>. Environmental Pollution, 131: 147-154.

Valdés-López O, SS Yang, R Aparicio-Fabre, PH Graham, JL Reyes, CP Vance and G Hernández, 2010. MicroRNA expression profile in common bean (Phaseolus vulgaris) under nutrient deficiency stresses and manganese toxicity. New Phytologist, 187: 805-818.

Vassil AD, Y Kapulnik, I Raskin and DE Salt, 1998. The role of EDTA in lead transport and accumulation by Indian mustard. Plant Physiology, 117: 447-453.

Yang C, D Li, D Mao, X Liu, C Ji, X Li, X Zhao, Z Cheng, C Chen and L Zhu, 2013. Over expression of microRNA319 impacts leaf morphogenesis and leads to enhanced cold tolerance in rice (Oryza sativa L.). Plant, Cell and Environment, 36: 2207-2218.

Yanqun Z, L Yuan, C Jianjun, C Haiyan, Q Li and C Schvartz, 2005. Hyperaccumulation of Pb, Zn and Cd in herbaceous grown on lead–zinc mining area in Yunnan, China. Environment International, 31: 755-762.

Zayed A, E Pilon-Smits, M De Souza, Z Lin and N Terry, 2000. Remediation of selenium-polluted soils and waters by phytovolatilization. Phytoremediation of contaminated soil and water, pp. 61-83.

Zhou ZS, JB Song and ZM Yang, 2012a. Genome-wide identification of *Brassica napus* microRNAs and their targets in response to cadmium. Journal of Experimental Botany, 63: 4597-4613.

Zhou, ZS, HQ Zeng, ZP Liu and ZM Yang, 2012b. Genome-wide identification of Medicago truncatula microRNAs and their targets reveals their differential regulation by heavy metal. Plant, Cell and Environment, 35: 86-99.