International Journal of Biosciences | IJB |
ISSN: 2220-6655 (Print), 2222-5234 (Online)
http://www.innspub.net
Vol. 14, No. 3, p. 191-206, 2019

INNSPUB

REVIEW PAPER OPEN ACCESS

Current scenario of phytoremediation: progresses and limitations

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Key words: Heavy metals, phytoextraction. Waste water.

http://dx.doi.org/10.12692/ijb/14.3.191-206 Article published on March 27, 2019

Abstract

Pollution is a permanent global dilemma and our environment is continuously being polluted by metals and organic contaminants. The cost of current engineering technologies, used so far to clear environmental contaminants, is billions of dollars. Conventional physicochemical treatments of soil have stimulated the development of new remediation technologies i.e. Phytoremediation, a plant based technique. Plants can extract heavy metals from soil by making complexes with metals and their own metabolites by a process of chelation. Despite this era of omics, the improvement in the technology can be carried out by exploring the new candidate plants and their key players (gene, proteins and enzymes, metabolites) involved in hyper-accumulation. There is a dire need to improve and use this technology as a tool of bioremediation for sustainable economy and to save our earth. This article is designed to probe the potential improvements in the research and development activities relating to different aspects of phytoremediation

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Introduction

Our ecosystems are becoming contaminated by environmental pollution and by the discharge of industrial effluents. It is a global issue because it has become a threat to human health particularly in the developing and under developed world. The increasing costs and limited efficiency of traditional physicochemical treatments of soil have spurred the development of new remediation technologies. Phytoremediation is a better technology and an eco friendly approach for remediation of contaminated soil and water using plants and, are relatively inexpensive since they are performed in situ and are solar-driven (Agunbiade *et al.*, 2009; Chehregani *et al.*, 2009; Di Lonardo *et al.*, 2011; Germaine *et al.*, 2006; Tripathi *et al.*, 2016). This technique consist of two components, one by the root colonizing microbes and the other by plants themselves, which degrade the toxic compounds to further non-toxic metabolites That's why it is gaining rapid interest. Selection and testing multiple hyper accumulators plants, protein engineering of phyto chelatin and membrane transporter genes and their expression would enhance the rate of phytoremediation making this process a successful one for bioremediation of environmental contamination (van de Mortel *et al.*, 2006). Plants have shown the capacity to absorb, uptake, and convert organic contaminants to less toxic metabolites in laboratory and field studies. Vegetation also plays a significant role in bioremediation. This is because plants stimulate the degradation of organic compounds in the rhizosphere by the release of root exudates and enzymes. Success of any plant-based remediation system depends on the interaction of plants with the surrounding soil medium and degrading microorganisms in the rhizosphere to remove contaminants, release of exudates that stimulate microbial activity and biochemical transformations around the root system and enhancement of mineralization at the root–soil interface that is attributed to mycorrhizal fungi and microbial concortia associated with the root surface (Merini *et al.*, 2009). There is a need of understanding the soil-plant-microbe interactions that determine the fate of organic contaminants in the soil-plant ecosystem (Karthikeyan and Kulakow, 2003).

An effective tool for the extraction of heavy metals from soils by plants is chelation. However, side-effects related to the addition of chelates were usually neglected and these are very important regarding metal leaching and effects on soil micro-organisms. Phytoremedation potential of EDGA and citric acid in leaching of Cd, Zn Cu and Pb has to be evaluated and its effects on microbial activity was studied on grass, lupine and yellow mustard which were grown on a moderately polluted acid (pH 4.5) sandy soil. It was observed that citric acid appeared to be degraded microbially within a few days after addition which limited its potential for long-lasting remediation studies. EDGA enhanced metal solubility but plant uptake did not increase accordingly. The metal shoot: root ratio increased upon addition of EDGA but it also reduced the net shoot and root biomass production of both lupine and yellow mustard. It was noted that bacterial biomass has been increased in both the citric and EDGA treated pots. On the other case it was noted that the number of microbivorous nematodes was greatly reduced upon addition of EDGA which was most likely related to the reduced biomass production. Furthermore, EDGA enhanced metal leaching in the lysimeter study which could lead to groundwater pollution.

Phytoremediation offers a cost-effective, non-intrusive, and safe alternative to conventional clean up techniques (Merini *et al.*, 2009) to reclaim soils contaminated with metals, hydrocarbons, pesticides, and chlorinated solvents (Wan *et al.*, 2016). This is not a new technique, but currently being re-examined as an environmentally friendly that helps to remove the contaminant from environment. It is an ecologically sound technology that uses ability of the plants to degrade, assimilate, metabolize, or detoxify contaminants (Ansari *et al.*, 2016). Simply we can say that the use of plants or plant products to restore or stabilize contaminated sites, collectively known as phytoremediation, takes advantage of the natural abilities of plants to take up, accumulate, store, or degrade organic and inorganic substances. This technology is based upon the remarkable ability of plants to uptake concentrate, detoxify or metabolize different elements and compounds present in the environment around. Major target of the technology are heavy metals and organic pollutants (Ibbini *et al.*, 2009; Salt *et al.*, 1998) and contaminant removal from aquatic ecosystems (de Farias *et al.*, 2009; Kagalkar *et al.*, 2011). This technique offers an innovative way for contaminants removal such as metal contaminated sites can be cleaned by this technology. Different processes are involved using plants that tolerate and accumulate metals at high levels. Phytoextraction removes metals or organics from soils by accumulating them in the biomass of plants. Phytostabilization reduces the bioavailability of pollutants by immobilizing or binding them to the soil matrix, and phytovolatilization uses plants to take pollutants from the growth matrix(Arnold *et al.*, 2007; Edwards *et al.*, 2011) transform them and release them into the atmosphere (Peuke and Rennenberg, 2005a). Rhizofiltration involves the removal of pollutants from aqueous sources by plant roots (Ansari *et al.*, 2016; Vesely *et al.*, 2011). Phytodegradation, or phytotransformation, is the use of plants to uptake, store and degrade organic pollutants (Tiwari *et al.*, 2008). Global governments are establishing research and demonstration programs to use this potential (McIntyre, 2003). Pollutant removal is achieved by different actions of plants and their associated rhizosphere bacteria on contaminants. Removal of organic pollutants through plant-based clean-up involve direct uptake and accumulation of contaminants and subsequent metabolism in plant tissues, transpiration of volatile organic hydrocarbons through the leaves. Efficacy of phytoremediation largely depends on photosynthetic activity and growth rate of plants. The technique has also been proposed as an alternative to accelerate the removal and degradation of agro-industrial wastewater (Doty *et al.*, 2007).

Polluted soil and water resources affect pedosphere, hydrosphere, atmosphere, lithosphere and biosphere. A sustainable ecoremediation technology by using plant to remediate soil and water cleanup of large volumes of contaminated sites (Thakur *et al.*, 2016) by using green plants to remediate and rehabilitate municipal solid waste landfills and dumpsites, has emerged as a potential candidate (Nagendran *et al.*, 2006). Great efforts have been made in the last two decades to reduce pollution (Bandara *et al.*, 2011; Thijs *et al.*, 2016). One of the conventional clean up techniques that use plant to treat urban or rural domestic waste water is a safe method. Now most ornamental hydrophytes adapted to the wastewater well and were fairly efficient in scavenging BOD5 (biological oxygen demand 5 d), COD (chemical oxygen demand), TN (total nitrogen), TP (total phosphorus) and heavy metals (Cr, Pb, Cd) in the wastewater. However, the efficiency varied a lot for various species to different contaminants, *Iris pseudacorus* L. and *Acorusgramineus* so land were good choices for treatment of composite-polluted urban wastewater. On the other hand, interaction of different components in the wastewater might have certain effects on phytoremediation (Mahar *et al.*, 2016). This indicates that phytoextraction efficiency must be assessed by different approaches in order not to ignore any potential hazard and that an efficient phytoextraction scheme will have to take into account the different dynamics of the soil-plant system (Keller *et al.*, 2005).

More than 400 plant species have been identified to have potential for soil and water remediation. Environmental problems posed by municipal solid waste (MSW) are well documented. Scientifically designed landfills and/or open dumpsites are used to dispose MSW in many developed and developing countries. Rehabilitation of these facilities is needed due non-availability of land and need to reuse the dumpsite space especially in urban areas. A variety of options have been tried to achieve the goals of rehabilitation (Yadav *et al.*). The direct use of living green plants to degrade various environmental contaminants, including recalcitrant organic compounds or heavy metals is an easy way to remove toxicity. (Macek and Kas, 2000; Weishaar *et al.*, 2009). One of the burning problems of our industrial society is the high consumption of water and the high demand for clean drinking water. Numerous approaches have been taken to reduce water consumption, but in the long run it seems only possible to recycle waste water into high quality water. It seems timely to discuss alternative water remediation technologies that are fit for industrial as well as less developed countries to ensure a high quality of drinking water. To quantify the occurrence and the distribution of micro pollutants, to evaluate their effects, and to prevent them from passing through wastewater collection and treatment systems into rivers, lakes and ground water bodies represents an urgent task for applied environmental sciences in the coming years. Public acceptance of green technologies is generally higher than that of industrial processes (Lyubenova *et al.*, 2009).

Various modern tools and analytical devices have provided insight into the selection and optimization of remediation processes by various plant species. However, efficient hyperaccumulation by naturally occurring plants is also feasible and can be made practical by improving their nutritional and environmental requirements (Wan *et al.*, 2016). Thus phytoremediation of organics appears a very promising technology for the removal of contaminants from polluted soil (Ali *et al.*, 2003). Plants can transpire groundwater and lower the concentrations of organic contaminants in soils and groundwater. The evapo-transpirational activity of vegetation acts as a natural pump-and-treatment system (Karthikeyan and Kulakow, 2003).

Phytoremediation is a promising technology that uses higher plants to enhance biodegradation and is known to reduce groundwater contamination by at least three major mechanisms: plant uptake, phytovolatilization, and enhanced rhizosphere bioremediation (Chirakkara *et al.*, 2016). The presence of the trees, therefore, promotes direct volatilization into the atmosphere (Moreno-Jimenez *et al.*, 2009). Soil pollution, a very important environmental problem, has been attracting considerable public attention over the last decades (Gopalakrishnan *et al.*, 2009). Traditional physiochemical methods have been used to remove the organic pollutants from soils. However, the enormous costs and low efficiencies associated with these remediation technologies limit their availabilities and encouraging companies to ignore the problem (Doty *et al.*, 2007; Xie *et al.*, 2008b). The enormous growth of industrialization and the use of numerous aromatic compounds in dyestuffs, explosives, pesticides and pharmaceuticals have resulted in serious environmental pollution and have attracted considerable attention continuously over the last two decades (Aken *et al.*, 2011; Dordio *et al.*, 2009; Germaine *et al.*, 2006). Many aromatic hydrocarbons, nitroaromatic compounds, polycyclic aromatic hydrocarbons, polychlorinated biphenyls, diauxins and their derivatives are highly toxic, mutagenic and/or carcinogenic to natural microflora as well as to higher systems including humans (Agnello *et al.*, 2016). The mechanisms of phytoremediation mainly include the direct plant uptake of organic pollutants, degradation by plant-derived degradative enzymes, and stimulated biodegradation in plant rhizosphere regarded as an efficient technique to remove or degrade various pollutants in soils, water and sediments and its efficiency is close related to physicochemical properties of organic pollutants, environmental characteristics, and plant types. It is no doubt that soil amendments such as surfactants improves the solubilities and availabilities of organic pollutants in soils (Gao and Zhu, 2005). However, hydrophobic organic molecules such as PAHs, PCBs, PCDD/Fs, TNT and RDX are much less responsive to bioremediation strategies (Murakami *et al.*, 2009) than, for example, BTEX or LAS. PCDD/Fs and PCBs represent 3 prominent groups of persistent organic pollutants that share common chemical, toxicological and environmental properties(Antiochia *et al.*, 2007). Hydrocarbons can be used as fertilizers because microbes in the rhizosphere can degrade hydrocarbons to provide nutrient to plants. In general, degradation of total oil and grease was higher in planted than in unplanted soil but these involve a complex process (Merkl *et al.*, 2005a). In phytoremediation of petroleum-contaminated soils, one of the main traits is the root zone where enhanced petroleum degradation takes place. Root surface area in contaminated soil play a significant role to remove contamination (Merkl *et al.*, 2005b). In the process of PCBs removal, plants acted not only as a supporter of biodegradation, but also as an active participator in metabolism because they absorb and accumulate PCBs from the environment, and store the non-toxic metabolic products in their tissues. Roots also play an important role in degradation by the contained ecto enzymes, or indirectly through stimulating the activity of rhizospheric microbes (Liu and Chen, 2006; Xie *et al.*, 2008b) DDT and other persistent organic pollutants are difficult to remove from contaminated soils due to their hydrophobicity that's why it is accumulated in the environment having a wide range of adverse effects on non-target species as a result weathering occurs. The remediation of hydrocarbon will be possible to translocate hydrophobic chemicals across the root and through the shoot via an aqueous transpiration stream (Lunney *et al.*, 2004).2,4,6-Trinitrotoluene (TNT) is a potent mutagen, and a Group C human carcinogen that has been widely used to produce munitions and explosives. Areas i.e. weapon burning, and open explosion sites are heavily contaminated with TNT and plants are used to extract TNT from contaminated soil (Murakami *et al.*, 2009; Ramakrishna and Jailkhani, 2008). Conventional remediation activities in such sites are expensive and damaging to the ecosystem. Pentachlorophenol (PCP) is a persistent organic pollutant (POP) previously used as a timber treatment chemical to prevent sap stain and wood rot. For the last 50 years due to its mobile nature it has a tendency to leach and contaminate nearby environments (Mills *et al.*, 2006). The combined remediation mechanisms of volatilization and biodegradation in the vadose zone were used for naphthalene remediation in the areas where a tree-based phytoremediation system has been used that shows transport and biodegradation of naphthalene in the vadose zone and 90% of the naphthalene vapors were biodegraded aerobically within 5-10 cm above the water table during the summer months (Andersen *et al.*, 2008). Hairy root cultures were used to study the removal of 2,4-dichlorophenol (2,4-DCP), an industrial effluents that is highly toxic for human and aquatic life can be removed by hairy root cultures (Agostini *et al.*, 2003), PAH are carbonaceous materials that are associated with soil particles especially in coke oven sites and because of coating of PAH with soil their availability and release from these particles is very low and difficult. Plants can make it easy by phytoextraction. (Nam *et al.*, 2008). Pants are effective for the removal of total PAHs by 69% with parallel changes in soil taxonomy from particularly hydrophobic (initial sample) to moderately-strongly hydrophobic (planted) and hydrophilic to very hydrophilic (unplanted) after 12 months. The greatest reduction in soil hydrophobicity was observed in the unplanted, unfertilized treatments that had the buck exclusion rate of PAHs(Chekol *et al.*, 2004; Shimoda *et al.*, 2009). Ectomycorrhizal fungus Suillusbovinus, forming hydrophobic mycelium in soil that would easily enter into contact with hydrophobic pollutants, impedes rather than promotes PAH degradation (Joner *et al.*, 2006).

Similarly it is a viable approach to removing atrazine [2-chloro-4-(ethylamino)-6-(isopropylamino)-s-triazine] from contaminated water (Ma *et al.*, 2016). The presence of plants may contribute to hydrophobicity in contaminated soil (Cofield *et al.*, 2007). It was found that phytoremediation can be a good complement to intrinsic remediation in shallow aquifer sites contaminated with ethanol-blended gasoline spills (Corseuil and Moreno, 2001). Improvement of the hydrocarbon phytoremediation is a reasonable way to remove hydrocardon from soil (Jensen and Collins., 1985)as well as degradation of total petroleum hydrocarbons (TPH) (Hutchinson *et al.*, 2001). The concentration of 13 polycyclic aromatic hydrocarbons (PAHs) and their combined soil toxicity was determined on homogenized soil and on such soil subjected to a time-course phytoremediation (Joner *et al.*, 2006).

Ideal plants for phytoremediation

The plants which are fast growing, have high biomass, deep roots, are easy to harvest and can tolerate and accumulate a range of heavy metals in their ariel and harvestable parts are considered to be the ideal plants for phytoremediation (Bokhari *et al.*, 2016). However efficient hyperaccumulation by naturally accuring plants is also feasible and can be made practical by improving their nutritional and environmental requirement. Metal-hyperaccumulating plants, desirable for heavily polluted environments, can be developed by the introduction of novel traits into high biomass plants in a transgenic approach, which is a promising strategy for the development of effective phytoremediation technology. The plants were able to remove all the pollutants in wastewater and significant portions of substances (Ghaly *et al.*, 2005).The literature survey, however, indicate that so far we have not been able to find any plant that fulfill these criteria. In general plants express an incomplete set of remediating features. For example most of the metal hyperaccumulators are small and slow growing. The phytoremediation of metal-contaminated soils offers a low-cost method for soil remediation and some extracted metals may be recycled for value. Both the phytoextraction of metals and the phytovolatilization of Se or Hg by plants offer great promise for commercial development (Wiszniewska *et al.*, 2016). Natural metal hyperaccumulator phenotype is much more important than high-yield ability when using plants to remove metals from contaminated soils. The hypertolerance of metals is the key plant characteristic required for hyperaccumulation; vacuolar compartmentalization appears to be the source of hypertolerance of natural hyperaccumulator plants. Alternatively, soil Pb and Cr^{6+} may be inactivated in the soil by plants and soil amendments (phytostabilization). Little molecular understanding of plant activities critical to phytoremediation has been achieved, but recent progress in characterizing Fe, Cd and Zn uptake by Arabidopsis and yeast mutants indicates strategies for developing transgenic improved phytoremediation cultivars for commercial use (Chaney *et al.*, 1997). Conventional breeding and biotechnology are being used to correct these shortcomings by transferring desired traits from metal hyperaccumulator plants to selected high biomass producing nonaccumulator species (Lasat, 2002). On the other hand there is a need to know research background and the development of plants modified for remediation purposes, using genetic engineering and deeper understanding of plant cooperation with microorganisms is a need of time (Macek and Kas, 2000).

Soil depth is an important factor that affects the efficiency of phytoremediation. Remediation proceeded rapidly near the surface of the soil (0-20 cm) but the effect of vegetation relative to non-vegetated control only was significant in the lower soil depths. Contaminant dissipation in the 20-40 cm and 40-60 cm layers was not significantly different between vegetated and non-vegetated soil(Keller *et al.*, 2005). It is also verified that biodegradation of organic contaminants in soil may be enhanced by the presence of vegetation (Keller *et al.*, 2005). Metal concentrations in sediment increased with depth, indicating a gradual improvement of sediment quality. In contrast, dissolved metal concentrations were highest in top layers due to mobilization from oxyhydroxides and precipitation with sulfides in deeper layers. Mostly it was observed that water table lowering combined with organic matter decomposition led to immobilization due to sulfide formation(van Griethuysen *et al.*, 2005).The presence of a high level of OM (organic matter) and nutrients also increased aboveground biomass growth. This shows an encouraging basis for planning larger scale experiments to test the role of OM and nutrients and soil in improving phytoremediation(Arreghini *et al.*, 2006).

Climate change and land use may significantly influence metal cycling in dynamic river systems because temperature had a statistically significant effect on the mineralization rates (Greenwood *et al.*, 2007).The removal rate of all solvents is slower in winter, but the seasonal effect is most pronounced. Due to variation in metabolic pathways induced by plant and seasonal variation in available root-zone oxygen it is known that plant and seasonal effects are believed to be interdependent e.g. variation of sediment characteristics in a floodplain lake, including concentrations of dissolved organic carbon, acid volatile sulfide and trace metals have been studied by sampling period included a severe winter stream and a dramatic water level drop during summer was noticed that was due to seasonal variations (van Griethuysen *et al.*, 2005). Variation in transpiration also influenced species and seasonal effects on THF removal, but not the other more biodegradable solvents. A model based on a prediction of plant uptake of nonionic dissolved chemicals suggests that as much as 39% of the THF in solution could have been removed through plant transpiration (Balestrini *et al.*, 2005).

Crops play a major role in decreasing the contaminants from soil as well as degrading the pollutants such as crop mineral concentrations did increase uniformly as soil minerals concentration increasing, indicating that magnificence utilization of minerals does occur in agronomic species produced on mineral-enriched soils (Kratochvil *et al.*, 2006). Different experiments are done in different cropping systems under sub-tropical climatic regions to evaluate changes in organic carbon accumulation, chemical and microbiological properties of the soils (Manna and Singh, 2001). Waste water irrigation system is used to mobilize minerals and nutrient to soil as well as to remove pollutants from soil so this kind of decision support systems (DSS) can be time-efficient and cost-effective means for such long-term impact evaluations. Scientists are agreeing with actual long-term water use experiments on similar soils, such pre-validated tools could be efficient means for designing, local resource and target crop yield-specific appropriate water use plans for irrigated agricultural lands (Kaur *et al.*, 2007).

The use of *Vetiveria zizanioides* (vetiver) was studied to evaluate its efficiency for the remediation of soils contaminated by heavy metals. Vetiver plants were tested for Cr, Cu, Pb and Zn. Phytoextraction and bioremediation. The vetiver plant can be considered a quite good "hyperaccumulator" only for Pb and Zn. As for bioremediation experiments, the vetiver plant showed heavy metal uptake values significantly lower than those obtained with other biological substrates(Antiochia *et al.*, 2007). Among them, Thlaspi, Brassica, Sedum alfredii H., and Arabidopsis species have been mostly studied (Lone *et al.*, 2008). Phytoremediation is considered for managing Se in central California soils. The technology involves the use of plants in conjunction with microbial activity associated with the plants to extract, accumulate, and volatilize Se. Once absorbed by plant roots, than translocated to the shoot where it may be harvested and removed from the site (Banuelos, 2001). To prevent these unwanted side-effects, careful management of phytoremediation methods, therefore, seems necessary (Romkens *et al.*, 2002). Toxic heavy metals, metalloids and dilute concentrations of trace element are constantly released into the environment by different sources. The potential of constructed wetlands for use in remediating agricultural drainage water and industrial effluent, as well as concerns over their potential ecotoxicity is very important. Contaminants can be removed from large volumes of wastewater by constructed wetlands. In upland ecosystems, plants may be used to accumulate metals/metalloids in their harvestable biomass (phytoextraction). Plants can also convert and release certain metals/metalloids in a volatile form (phytovolatilization).

Genetic engineering has been used to develop plants with improved efficiencies for phytoextraction and phytovolatilization. For example, metal-hyperaccumulating plants and microbes with sole abilities to tolerate, accumulate, and detoxify metals and metalloids represent an important pool of unique genes that may possibly be transferred to fast-growing plant species for enhanced phytoremediation. There is also a need to develop new strategies to improve the acceptability of using genetically engineered plants for phytoremediation(LeDuc and Terry, 2005). Recent advances in biotechnology will play a gifted role in the development of new hyperaccumulators by transferring metal hyperaccumulating genes from low biomass wild varieties to the higher biomass producing cultivated species in the times to come(Lone *et al.*, 2008). Sites heavily polluted with organic contaminants require hyperaccumulators, which could be developed by genetic engineering approaches.

Percentage of work on different field of phytoremediationuptil the year of 2018

Pollution of the environment by metals and organic contaminants is an immovable worldwide problem, with cleanup costs running into billions of dollars using current engineering technologies.

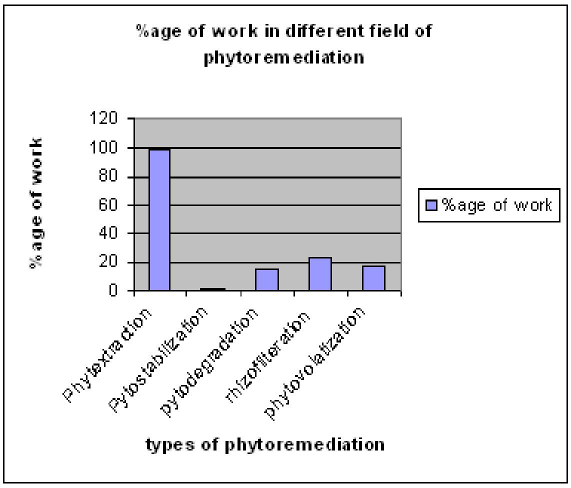

Fig. 1.

The availability of alternative, cheap and effective technologies would significantly improve the prospects of cleaning-up metal contaminated sites. Phytoremediation has been proposed as an economical and 'green' method of exploiting plants to extract or degrade the contaminants in the soil(Wan *et al.*, 2016). To date, the majority of phytoremediation efforts have been directed at jumping the biological biochemical and agronomic hurdles to deliver a working technology with negligible attention to the economic outlook other than simple estimates of the cost advantages of phytoremediation over other techniques(Angle and Linacre, 2005). It is accepted that phytoremediation is not a remediation technology which can be applied to all contaminated sites, or even the majority of them. The process is slow and can be metal specific. Phytoremediation is suggested as a viable technique when the following parameters are satisfied: the site is of low economic value, time constraints do not apply, a low cost solution is required the main metal pollution is with only one or two metals and confined to the surface layers, the labile pool is the most toxic form of the metal, metals and other contaminants are not found at phytotoxic levels; and when there is an infrastructure present to safely treat and dispose of the contaminated biomass which may be produced. These parameters apply tophytoremediation as a stand-alone technology (King *et al.*, 2006; Scholz and Hansmann, 2007). Overall there is an impact that there is a chance of uncertainty in results by using this technology and project cost is more than project demand so decision makers should change this overall impact because not only plants but genetically modified crops are also used to enhance this technique. Plant scientists who work on phytoremediation have therefore spent considerable efforts to enhance GSH levels in trees to increase their stress tolerance. Preliminary results from these trials show that the transgenic poplars are genetically stable and there are no indications so far of any impact on the environment. The transgenic trees have a higher capacity than wild-type trees for accumulating heavy metals, At present, the main concerns about the release of GMPs are their potential impact on the environment and their risks to human health, which are reflected both in past German legislation and in European directives (EC, 2001). The present discussion in Germany on the use of GMPs shows less concern for human health and focuses more on the potential impact on the environment in general and in particular on agriculture forms that are free of GMPs and subject to ecological management (SRU, 2004). Unfortunately these debates have largely slowed down or even halted the use of this environmentally friendly technology (Peuke and Rennenberg, 2005a). System of environmental remediation is beneficial in terms of lesser financial commitment by both the government and the inhabitants to its development and utilization especially when the peculiar economic condition of the majority of the inhabitants in this region is considered (Erakhrumen and Agbontalor, 2007). Phytoremediation of farmland has met resistance in several countries where it was tried due to farmers disliking growing a crop simply to throw it away, or preferring the use of chemical stabilisers. Many farmers demand to be paid to grow accumulator crops on their land (King *et al.*, 2006).

Countries working on phytoremediation

The problem of environmental pollution has assumed an unprecedented proportion in many parts of the world and different countries are working on this project to remove pollutants from the environment. Following is the list of countries working on phytoremediation. Nigeria, India, Germany, Columbia, China, Washington State Serbia, Saudi Arab, USA, California (Berkeley), Canada, Netherlands, Sweden, New Brunswick, Sydney, Denmark, Spain, Australia, Texas, England, New Zealand.

Advantage of phytoremediation

The use of plants to remediate polluted groundwater is becoming an attractive alternative to more expensive traditional techniques (Clinton *et al.*, 2004). In order to adequately assess the effectiveness of the phytoremediation treatment, a clear understanding of water-use habits by the selected plant species is essential (Singh, Labana *et al.* 2003). This technique is applicable to a broad range of organic and inorganic contaminants including many metals with limited alternative options. It can be performed with minimal environmental disturbance; topsoil is left in a usable condition and may be reclaimed for agricultural use; organic pollutants may be degraded to CO_2 and H_2O,removing environmental toxicity. Reduces the amount of waste to be landfilled (up to 95%), can be further utilized as bio-ore of heavy metals(Ijaz *et al.*, 2016; Luo *et al.*, 2016).Chance of contaminant via air and water is less; possibly less secondary air and/or water wastes are generated than with traditional methods. It does not require expensive equipment. It is cost-effective for large volumes of water having low concentrations of contaminants. Phytoremediation in combination with burning the resulting biomass to produce electricity and heat, could become a new environmentally friendly form of biotechnology(Peuke and Rennenberg, 2005a; Verma *et al.*, 2007). A plant-based bioremediation (phytoremediation) strategy has been developed from the breakdown products of the chemical warfare agent (Zakharova *et al.*, 2000).In large scale this technique can be used to store potential energy which can be utilized to generate thermal energy (Erakhrumen and Agbontalor, 2007).

Disadvantages of phytoremediation

Despite several advantages, phytoremediation has not yet become a commercially available technology. Progress in the field is hindered by lack of understanding of complex interactions in the rhizosphere and plant based mechanisms which allow metal translocation and accumulation in plants (Hooda, 2007). Many modern tools and analytical devices have provided insight into the selection and optimization of the remediation process by plant species. Phytoremediation uses wild or genetically modified plants (GMPs) to extract a wide range of heavy metals and organic pollutants from the soil. Initial experiments with transgenic plants have shown that they are indeedefficient in drawing metals from heavily contaminated soils (Peuke and Rennenberg, 2005a). Due in large part to its aesthetic appeal, this technology has gained increasing attention over the past 10 years. Phytoremediation advances with genetic engineering use different plant processes and mechanisms normally involved in the accumulation, complexation, volatilization, and degradation of organic and inorganic pollutants(Moreno-Jimenez *et al.*, 2009). Certain plants, called hyperaccumulators, are good candidates in phytoremediation, particularly for the removal of heavy metals. The rhizosphere provides a complex and dynamic microenvironment where microorganisms, in association with roots, form unique communities that have considerable potential for the detoxification of hazardous materials(Ma *et al.*, 2016). Phytoremediation efficiency of plants can be substantially improved using genetic engineering technologies (Cherian and Oliveira, 2005; Pilon-Smits and LeDuc, 2009; Tripathi *et al.*, 2016; Xie *et al.*, 2008a). Most scientific and commercial interestin phytoremediation now focuses on phytoextractionand phytodegradation, which use selected plant species grown on contaminatedsoils(Dietz and Schnoor, 2001). These are then harvested toremove the plants together with the pollutants that have accumulated in their tissues.Depending on the type of contamination the plants can either be disposed of orused in alternative processes, such as burningfor energy production.

In essence, phytoextraction removes pollutants from contaminated soils, concentrates the main biomass and further concentrates the pollutants by combustion. It is also possible to recover some metals from plant tissue (phytomining), which humans have done for centuries in the case of potassium (potash), and which may even become economically valuable (Meagher,2000;Liu and Chen, 2006).

Future of phytoremediation

Efforts should be geared towards conservationof the remaining and establishment of more plant species including other types of vegetation inthis ecological zone in such a way that will assist in exploitingthis technique of environmental pollution remediation.

It was suggested that phytoextraction and phytostabilization as the potential and alternative techniquess for soil reclamation (Mahar *et al.*, 2016). People are also working the stability of the transgene under field conditions and (b) the possibility of horizontal gene transfer to microorganisms in the rhizosphere.(Kawahigashi, 2009; Peuke and Rennenberg, 2005b).

Conclusion

It is concluded that phytoremediation can be viable and efficient when there is a small amount of metal in soil and hyper accumulator plant (specially equipped) also work even when a combination of metals are present in soil. This technology could be improved and used in terms of research and industry but there is a need to get better understanding of phytoremediation mechanism in terms of transporter proteins and metal tolerant protein from hyperaccumulater plants as well as plant proteomic and genomic side andgenetic modification. Botanist, molecular biologist, Geneticist and biochemist should improve the efficiency and the viability of phytoremediation as a competitive remediation technology by studying the whole mechanism of hyperaccumulator plants (King *et al.*, 2006).

Acknowledgement

The corresponding author acknowledges the all authors whose coordination helped in completing this review.

Abbreviations

EDGA (glycoletherdiamine tetra acetic acid) TNT(Tri Nitrotuolene) THF(Tetrahydrofuran) OM(Organic matter) DSS (decision support systems) MSW (municipal solid waste) BOD5 (biological oxygen demand 5 d) COD (chemical oxygen demand)TN (total nitrogen)TP (total phosphorus)PAHs(polycyclic aromatic hydrocarbons)PCBs(Poly cholinated biphenyls) PCDD/Fs (Polycholorodibenzo-p-dioxin, Polycholorodibenzo furans) RDX(hexahydro-1, 3, 5-trinitro-1, 3, 5-triazine) TPH(total petroleum hydrocarbons) GMPs(Genetically modified plants) GSH(Glutathione (substrate))

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