Advantages and disadvantages of phytoremediation: A concise review

Hossein Farraji[1,2], Nastaein Q. Zaman[1,3], Ramlah M. Tajuddin[4], Hamed Faraji[5]

[1]School of Civil Engineering, Engineering Campus, UniversitiSains Malaysia, 14300 NibongTebal, Penang, Malaysia
[2]Institute of Standard and Industrial Research of Iran (ISIRI), 91375-344, Mashhad, KhorasanRazawi, Iran
[3]Solid Waste Management Cluster, Engineering Campus, UniversitiSains Malaysia, 14300 NibongTebal, Penang, Malaysia
[4]Faculty of Civil Engineering, niversitiTechnologi Mara (UiTM), 40450 Shah Alam, Selangor DarulEhsan, Malaysia
[5]Faculty of microbiology, Research and Science Center ,Azad University of Jahrom, Iran

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Corresponding Author:
Hossein Farraji
E–mail: faraji6211@gmail.com

ABSTRACT

Treatment of wastewater and decontamination of terrestrial environment is the growing concern of scientists. Traditional treatment methods are not cost effective or suitable and in some cases cause additional environmental hazardous impacts. Finding a sustainable, cost effective green method for cleaning the environment is a merge case of researchers worldwide. Phytoremediation as a plant base treatment is going to utilize as one of suitable and recognized treatment methods for a wide range of anthropogenic pollutions. There are many discussions on applicability, economically feasibility and efficiency of this method. This review will discuss on advantages and disadvantages on phytoremediation to give a clear picture to researchers of environmental science.

1. Introduction

Traditional treatment method for cleaning environment contain serious problem such as switching a problem to another environmental crisis, non-sustainable, non-cost effective, highly limited in applicability, unable to conjunction with other treatments or in situ application and several environmental foot print. On the other hand, metallic elements (ME) are not subject to sustainable removal by the current commercial treatment method. Furthermore, several new types of wastewater such as health care, pharmacology and hospital wastewater which contains numerous pollutants with no available recognized traditional treatment method are going to be a major part of civilization and overpopulation impact on environment. In these types of wastewater two aspects of health care and pollutant removal are concern of researches. Additionally, many of pollutant could not be treated in wastewater treatment plants (Ferreira et al. 2016). Consequently, there is a critical requirement for a treatment technique with low cost (Yasin et al. 2015), environmentally friendly (Parise 2016), suitable for a wide range and concentration (Olivares 2013) of multiple pollutants (Tripathi et al. 2015), capable for combination treatment methods (Mojiri et al. 2016), in situ treatment method (Cheng et al. 2015) and easy large-scale applicability (Willscher et al. 2013), generally applied in conjunction with other cleanup approaches (Guo et al. 2014), or augmentation such as adsorbents (Mojiri et al. 2016), nutrients, organic amendments (Park et al. 2011) for effectively gaining with current environmental pollution. Phytoremediation as a new treatment method for environmental pollution socially expected to gain all current crises in higher efficiency and lower environmental impact as well as economically feasible. This emerging green technology, have been gained many serious anthropogenic pollution. Fair assessment required for disadvantages which related to this method. Even specifying it for a specific waste treatment such as municipal wastewater (McGee 2016) may give the solution key for concentration on advantages vs. the highlighting disadvantages. This review presents a fair comparison between drawbacks and merits of phytoremediation to give a clear picture for future studies.

2. Advantages

This technology is suitable for sites with shallow contaminants (Schnoor et al. 1995).They indicate that full-scale and pilot studies are going to demonstrate the promise and drawbacks of plant application for remediating hazardous waste in terrestrial and sediments. List of 16 applied project worldwide presented by (Schnoor et al. 1995). Table 1 shows numerous of current pilot and full-scale phytoremediation projects. This will reasonably be confirmed for a scientific technique which applied in practical experiences so brilliant lab scale results of researches, as well as high applicability of the aforementioned results, will give a clear picture from a sustainable environmental treatment method. The results of these studies will open new visions in commercialization of phytoremediation. Aquatic media have been presented high quality and effective responses for phytoremediation especially for organic contamination. Numbers of full-scale studies carried out such as treatment of swine wastewater by *Eichhornia crassipes* (Chien et al. 2015) and (Quinn et al. 2001) deep root hybrid *Populus* sp. for groundwater treatment. The efficiency of full scale phytoremediation in natural condition significantly lower than lab-scale researches meanwhile, advantages of this treatment method cause concerning high attention and requests for future environmental cleaning strategies (Gomes et al. 2013).

Table 1 Some implemented pilot scale phytoremediation project worldwide

Plant species	Pollutants	Location	Specification	Reference
Typha latifolia	Lignite and pyrolysis	Germany	4 years subsurface flow Constructed Wetland	Kuschk et al. 2003
Pteris vittata	Arsenic	USA	1900 L day^{-1} and total 60,000 L drinking water	Elless et al. 2005
Phragmites australis	Nutrients and Organic Pollution	UK	4.8m^3 daily on a piggery farm constructed wetland	Sun et al. 2006
Persicaria spp., *Ludwigia peploides, Myriophyllum papillosum, Juncus usitatus Bolboschoenus medianus Typha domingensis*	Pesticide	Australia	Ponded wetland contain plant and open ponds in Cotton farm	Rose et al. 2006
Paulownia tomentosa	Metallic elements	Italy	3months project 50 pots contain 6 kg soil	Doumett et al. 2008
Phragmites australis	Organic pollutants	Germany	Remediation research in regionally contaminated aquifers	Mareike Braeckevelt et al. 2008
Freshwater algae	Nutrients (N, P)	USA	270 days operation in 4 years+ harvesting algae	Mulbry and Kondrad, 2008
Phragmites australis Typha latifolia	Metallic elements	Taiwan	River water in 3 pilot CW with 180x50x50 cm diameters	Yeh et al. 2009
Paulownia Tomentosa	Metallic elements	Italy	30 days tartrate and glutamate influence	Doumett et al. 2010
Phragmites australis	Organic pollutants	Germany	24 month treatment + Ferric oxide and charcoal augmenting	Seeger and Kuschk 2011
Phragmites australis	Organic pollutants	Germany	Remediation research in regionally contaminated aquifers, One year period	M Braeckevelt et al. 2011
Phragmites australis Typha latifolia	Organic pollutants	USA	Tree pilot CW with 35m^2 Daily flow rates 1m^3	Ranieri et al. 2013
Cyperus alopecuroides	Nutrients Turbidity	India	Tanning process effluent in 300 liter Subsurface flow CW in 4 month try	Devi and Jayakumar 2014
Alternathera philoxeroides	Dye	India	96 h degradation for sulfonated textile dye	Rane et al. 2015
Paspalum vaginatum Sw. *P.Vaginatum + Spartium junceum* L., *P.Vaginatum + Tamarix gallica* L.	Metallic elements	Italy	Compost amendment phytoremediation for dredged marine sediment	Doni et al. 2015

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2. Cost effective

The cost of phytoremediation is highly variable and there a high correlation between cost of phyto-treatment and contaminant concentration, types, properties of soil and/water, site circumstances and importance of pollutant as a hazardous effect in the food chain. Anyway, phytoremediation is the most cost effective treatment methods with high social acceptance worldwide. Table 2 shows the cost of treatment for different applicable method with concentrating on main expenses (Raskin and Ensley 2000).
Based on the report of (Mulbry and Kondrad 2008) phytoremediation of nutrients in dairy wastewater ($11 per kg N) are well below the traditional treatment method. Phytoremediation of soil toxic metals could be recognized as unique low cost treatment in compare with traditional methods. The cost of decontamination will be increase about 7 times, when metallic elements combined with organic pollutants (Lasat 2000). Ligand application such as glutamate influence cause increasing phytoremediation (through the 30 days) to more than 87500-180000 $ in 1 ha at 50 m mol kg $^{-1}$ (Doumett et al. 2010). It indicates that augmentation or amendment process through the phytoremediation technique may contribute higher efficiency, but it should be investigated as the cost of augmentation and related environmental impacts (Römkens et al. 2002). Thus the market of phytoremediation highly depends on the managing the responses of cost effective methods in environmental protection condition. The largest market of phytoremediation belongs to organic contaminant removal from groundwater in the USA. Through the future trading, estimating of (Glass 1999) about 005 in comparison with 2000 indicate that > 300% increasing in phytoremediation market. He predicts that $235- 370 million for the market value of phytoremediation in 2005. Meanwhile, review of (Pilon-Smits 2005) showed that real market of this green technology was $100-150 million in the world. Increasing the price of metals and materials among the production process in manufacturing system and environmental protection regulars may contribute as decreasing pollutants in case and volume. On the other hand, phytoextraction and phytomining as two attractive soil decontamination could not reach to commercial specification, as an applied treatment method (Robinson et al. 2015) subsequently of their very long requirement time and low efficiencies. The most attractive aspect of phytoremediation belongs to wastewater treatment and future of this application may change the policy of municipal wastewater treatment in the world (McGee 2016).

Table 2 Soil treatment cost

Treatment types	Estimated cost ($/ton)	Extra expenses /Factor
Phytoremediation	5-40	Monitoring
Electrokinetics	20-200	Monitoring
Chemical treatment	100-500	Contaminant recycling
Landfilling	100-500	Transport excavation and monitoring
Vitrification	75-425	Monitoring (long-term)

3. Disadvantages

Any disability, failure unknown response may divert as contribute a factor to plant species and it also may cause increasing disadvantages of phytoremediation. Literature indicates that contamination concentration, toxicity and bioavailability and Plant choice and stress tolerance are the main disadvantages of phytoremediation such as following tips:

- Accumulation of pollutant in fruit and other edible parts of crop and vegetables.
- So far growing of phytoremediator plants (hyperaccumulators)
- Low biomass production in phytoremediators, so several planting and harvesting required for decontamination (Pilipović 2008)
- Generally, specific selective unique accumulation of one metallic element in hyperaccumulator (Xi et al. 2008)
- Environmental pollution caused by chelate–enhanced phytoremediation (Melo et al. 2008; Munn et al. 2008; Nam et al. 2008; Römkens et al. 2002)
- Very slow and seasonally effective treatment method (Chintakovid et al. 2008)
- Handling and disposing contaminated plants through the phytoremediation is the major foot print of this green technology (Ahalya et al. 2003; Ghosh and Singh 2005; Lasat 2000)
- Mobilization of radionuclides through the translocation in plants (Popa et al. 2008)
- Not applicable for all compounds (Trapp and Karlson, 2001)
- Dissolved contaminant in groundwater are not suitable case for aquatic phytoremediation (Van Den Bos 2002)

4. Discussion on drawbacks of phytoremediation

Disadvantages of phytoremediation could be categorized in 1)physiological properties and limitation of plant species 2) wrong application and planning the process of treatment 3) low efficiency or wake of phytomanagment 4) low concentration of necessary macro / micro nutrients in polluted media 5) interaction of multi contaminations 6) climate condition and adaptation of plant species in polluted areas. Plant species contain genetically properties and specification that characterized them in specific categories such as indicators, low tolerance, highly tolerant and finally hyperaccumulator species. In most cases hyperaccumulator plant species act as extractor of unique metallic elements. More than 400 plant species recognized as hyperaccumulator in plant families which *Brassicaseae* contain the highest numbers of hyperaccumulator plant species (Ghosh and Singh 2005). The art of proper application of these capable phytoremediators should be optimized by more investigation, such as multicultural planting system (Zhao et al. 2002) or combination microbes and plant species as omics tools (Bell et al. 2014) method for gaining higher efficiency in multi element polluted environment. Table 3 shows numbers of super hyperaccumulator plant species with the highest accumulation of metallic elements capacity (Lasat 2000).

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Table 3 Shows numbers of hyperaccumulator plant species

Plant species	Metal	Leaf content(ppm)
Thlaspi caerolenscens	Zn:Cd	39,6000:1,800
Ipomea alpine	Cu	12,300
Haumaniastrum robertii	Co	10,200
Astragalus racemosus	Se	14,900
Sebertia acuminate	Ni	25%by wt dried sap

The other aspect of disadvantages depends on plant selection for phytoremediation by following recognized methods:

- Screening nominated plant to find capable plant species
- Application of well-known hyperaccumulator species
- High biomass production, crop plant species
- Transgenic engineered plant species
- Seeking a polluted environment for naturally grown and adapted plant species

Plant species screening is a common method to find new accumulator or hyperaccumulator plant species (Kaimi et al. 2007). This method only will present capable plant species for specific pollutants and more investigating are required to characterizing toxic concentrating or dosages of pollutants for selected plant and other junction ability among the different pollutants (Chehregani et al. 2009).

Hyperaccumulators are professional accumulators of metallic elements and their presence in a heavy metal contaminated environment will give an effective opportunity for sustainable decontamination of metallic elements as non-degradable anthropogenic pollutants. Professional technique should be applied in proper method to gain designed goals. Preparing a suitable growing environment such as natural growing in nature may contribute to better results.

Crop plant species compensate their low accumulation of pollutants with high biomass production. Most of crop plants which applied in contaminated areas are *Brassica junca*, *Helianthus annuus*, *Zea mays*, *Brassica napus* (Vamerali et al. 2010). The main objective after decontamination issue with crop plants is managing high volume loaded contaminants plant biomass. Planning energy consuming (Pandey et al. 2016) or in precious contaminant case agromining (van der Ent et al. 2015), risk assessment in edible parts for human and livestock (Yang et al. 2009), should be considered in treatment process planning.

Transgenic plant species may have not a perfect social acceptance for edible crop production nevertheless, for preparing capable plant for cleaning environment from toxic metallic elements such as Mercury (Rugh et al. 1998), Cadmium (Das et al. 2016) and Arsenic (Fig. 1) (Chen et al. 2013). Cost of engineering process and cloning transgenic plants may contribute to the low attraction of this high-tech system in environmental cleaning (Bennett et al. 2003).

Naturally grown plants in polluted environment which may be hyperaccumulator, tolerant, semi-tolerant, low accumulator or adapted common plant species, arethe best candidate for phytoremediation in aquatic or terrestrial environment. Visiting polluted sites highly recommended (Farraji 2014) for finding capable plant species and familiarity with natural growing condition of these plants. Naturally grown hyperaccumulator plant species for Nickel (*Phyllanthus bolgooyi*) reported at Malaysia (van der Ent et al. 2013) and Manganese (*Phytolacca acinosa Roxb*) at China (Xue et al. 2004) (Fig. 2).

Fig. 1 Wild type (WT) and transgenic (L9 & L11) *Arabidopsis thaliana* applied for arsenic hyperaccumulation

Fig. 2 Nnaturally grown hyperaccumulator plant species for metal nickel (*Phyllanthus bolgooyi*) at Malaysia (left) and Manganese (*Phytolacca acinosa Roxb*) at China (right)

5. Conclusion

Phytoremediation as merging green technology is going to convert as a developed treatment method for decontamination or pollutant removal from the human environment. Advantages and disadvantages of this technique partly depend on limitation on plants as main leading organisms through the treatment process, meanwhile most of disadvantages related to proper application of this ecofriendly environment cleaning method. In other word, both efficiency ad advantages of phytoremediation highly related to suitable operation of treatment process. Combination with other treatment method as polishing or post treatment process, crop plant application for faster pollutants removal, transgenic engineered plant species with professional ability in pollutant removal as well as suitable application of hyperaccumulator plants species will lead future researches to presenting a clear picture for advantages of this cost effective method. Furthermore, eligibility of phytoremediation for municipal wastewater have been highly confirmed for future vision in wastewater treatment. Cost efficiency of phytoremediation, optimizing process of treatment and best combination junction with other treatment methods in phytoremediation hasn't been fully addressed and may consider as future studies objectives. To sum it up, phytoremediation as specific technique is a tool for scientific researches and the same as all technologies contain the pros and cons, thus efficiency of this technique highly depends on proper selection and suitable application with comfortable augmentation and amendments.

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