Journal of Hazardous Materials 318 (2016) 587–599

Contents lists available at ScienceDirect

Journal of Hazardous Materials

journal homepage: www.elsevier.com/locate/jhazmat

Review

Comprehensive review on phytotechnology: Heavy metals removal by diverse aquatic plants species from wastewater

Shahabaldin Rezania[a,b,*], Shazwin Mat Taib[b,*], Mohd Fadhil Md Din[a,b], Farrah Aini Dahalan[c], Hesam Kamyab[a,b]

[a] Centre for Environmental Sustainability and Water Security (IPASA), Research Institute for Environmental Sustainability, Block C07, Level 2, Universiti Teknologi Malaysia, 81310 Johor Bahru, Malaysia
[b] Department of Environmental Engineering, Faculty of Civil Engineering, Universiti Teknologi Malaysia (UTM), 81310 Johor, Malaysia
[c] Water Research Group, The School of Environmental Engineering, Universiti Malaysia Perlis (UniMAP), Kompleks Pengajian Jejawi 3, 02600 Arau, Perlis, Malaysia

HIGHLIGHTS

- This review outlined heavy metal removal from water by different aquatic plants species.
- Phytoremediation is a cost effective and green wastewater remediation method.
- Phytofiltration (rhizofiltration) is the sole method for heavy metal uptake from water.
- Free floating aquatic plants are more efficient than submerged and emergent plants.

ARTICLE INFO

Article history:
Received 2 June 2016
Received in revised form 19 July 2016
Accepted 22 July 2016
Available online 25 July 2016

Keywords:
Phytoremediation
Phytofiltration
Heavy metal uptake
Aquatic plants
Submerge and emergent plants

ABSTRACT

Environmental pollution specifically water pollution is alarming both in the developed and developing countries. Heavy metal contamination of water resources is a critical issue which adversely affects humans, plants and animals. Phytoremediation is a cost-effective remediation technology which able to treat heavy metal polluted sites. This environmental friendly method has been successfully implemented in constructed wetland (CWs) which is able to restore the aquatic biosystem naturally. Nowadays, many aquatic plant species are being investigated to determine their potential and effectiveness for phytoremediation application, especially high growth rate plants i.e. macrophytes. Based on the findings, phytofiltration (rhizofiltration) is the sole method which defined as heavy metals removal from water by aquatic plants. Due to specific morphology and higher growth rate, free-floating plants were more efficient to uptake heavy metals in comparison with submerged and emergent plants. In this review, the potential of wide range of aquatic plant species with main focus on four well known species (hyperaccumulators): *Pistia stratiotes*, *Eicchornia* spp., *Lemna* spp. and *Salvinia* spp. was investigated. Moreover, we discussed about the history, methods and future prospects in phytoremediation of heavy metals by aquatic plants comprehensively.

Contents

* Corresponding authors at: Department of Environmental Engineering, Faculty of Civil Engineering, Universiti Teknologi Malaysia (UTM), 81310 Johor, Malaysia.
E-mail addresses: shahab_rezania89@yahoo.com (S. Rezania), shazwin@utm.my (S.M. Taib).

http://dx.doi.org/10.1016/j.jhazmat.2016.07.053
0304-3894/© 2016 Published by Elsevier B.V.

1. Introduction

As global population is increasing, the challenge of providing water security for communities in 2050 will be greater in future. Towards 2030, it is anticipated that securing clean water for human needs is demanding as there is huge pressure on limited natural freshwater sources globally [1]. Population growth due to rapid industrialization has resulted in the increase of wastewater discharge into the environment. In the past few decades, developed countries have decided to change in environmental policies and reducing of these pollution [2]. To achieve higher efficiency especially in urban areas, improvement and modification of established conventional water and wastewater treatment techniques is essential. Hence, this improvement should be based on updated water and wastewater regulations [3]. In this matter, several regulations were set by the governments which limited industrial activity regarding to discharging heavy metal pollution into the environment [4].

Wastewater is defined as the discharged water from any municipal or industrial source [5]. Inorganic chemicals such as heavy metals, cyanide, toxic organics, nitrogen, phosphorous, phenols, suspended solids, color and turbidity can be found in untreated wastewater which usually originated from residential and industrial sources. Various environmental and economic problems can be generated by these elements [6]. Most environmental pollutants have destructive effects on soil and water quality, plant and animal nutrition, as well as human health [7]. Significantly, metal contamination is a vital health hazard which leads to environmental concern because metals are not naturally biodegradable unlike organic pollutants and many metals can transfer across trophic levels and accumulate in the biota persistently [8,9].

Nowadays, considerable attention goes to heavy metal contamination of soils due to its high vulnerability. Application of biological processes for bioremediating the contaminated/polluted sites is a challenging task because heavy metals cannot be degraded and hence persist in the soil [10,11]. Regarding to the soil contamination, grain size distributions, interstitial pore spaces, effective grain sizes, degrees of irregularity and the coefficient of permeability are effective parameters which influencing the treatment performance [12].

Human health's as well as aquatic organisms can be affected by heavy-metals pollution in aqueous ecosystems. Also for providing sufficient source for drinking water heavy metals have be treated for safety [13]. Heavy metals contamination can be occurred directly or indirectly into water bodies which named as main hazardous contamination. Heavy metals are often found in agriculture as components of pesticides, herbicides as well as applied in industrial manufacture as raw materials or auxiliary materials [14].

Usual discharged heavy metals in waters are As, Pb, Hg, Cd, Cr, Cu, Ni and Zn. The researchers tried to develop coefficient bioremediation techniques due to critical issue of heavy metals existence in wastewaters [15]. Recently, numerous approaches have been studied for the development of cheaper and more effective technologies, both to decrease the amount of wastewater produced and to improve the quality of the treated effluent [16]. Conventional remediation techniques such as coagulation–flocculation, oxidation, chemical precipitation, ion-exchange, adsorption, membrane filtration, with flotation ozone/hydrogen peroxide, photocatalytic degradation and electrochemical methods to remediate heavy metals which named physico-chemical technologies has been used in many studies widely. These methods have negative affect to environment and are expensive [17,18].

As demonstrated by Fu and Wang [19], to remove heavy metals from wastewater, several physical, chemical and biological treatment methods have been developed. The prevailing purification technologies used to remove the contaminants are too costly and sometimes non-eco-friendly. Therefore, the research is oriented towards low cost and eco-friendly technology to assess the long-term impact of urban pollution on environment quality which named as phytoremediation [20].

2. Phytoremediation as a green technology

Bioremediation is a "treatment that uses naturally occurring organisms to break down hazardous substances into less toxic or non-toxic substances" which included bioaccumulation, biosorption and phytoremediation [21]. Phytoremediation (phyto meaning plant and remedium meaning to clean) is a natural and direct use of green plants to uptake/absorption of the pollutants through roots and translocation to the upper part of the plant [22]. Organic and/or inorganic pollutants (metals, pesticides, persistent organic pollutants) can be removed from contaminated soil, sludge, sediments and water [23,24]. In remediation of contaminated soil and water, a wide range of plant species are used [22].

As indicated by Valipour and Ahn [12], plant species used for phytoremediation should be possibly native and have a quick growth rate, extensive root system, high biomass yield, various habitats adaptation, high tolerance and the ability to accumulate the pollutants in the aboveground parts. Some environmental factors like temperature, pH, solar radiation and water salinity can influence the plant growth and its performance in phytoremediation. The importance of these parameters are related to size, weight and growth rate of aquatic plants. Nutrient availability also affects the growth and performance of aquatic plants [25]. Although, Parmar and Singh [26] showed the long removal time is a disadvantages of phytoremediation which can be solved by a combination of more than one phytoremediation techniques.

2.1. Phytoremediation mechanism and techniques

In the last two decades, using plants for metal removal which called Phyto-technologies has attracted more attention [27]. In these methods, the plants (hyper-accumulator) used for the phytoremediation and metal mostly accumulated in the shoot in comparison with the root [28]. In comparison to non-accumulator