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Phytoremediation: Environmental-Friendly Clean up Method

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Abstract: This review presents how green plants tolerate with heavy metal as for as environment cleaning up technology together with exploited species in the previous studies, thus making it more viable for present utilization. Phytoremediation has becoming a buzz word nowadays. It reflects the high public concern towards environmental cleanup technique due to its low cost, environmental-friendly approach and absolutely plant based technology used to decontaminate heavy metal pollution recently. This increasing of environmental awareness emerged from the disposal of industrial waste increased critically without a proper treatment, which caused environmental disasters. The high cost of conventional technologies used in remediate the polluted sites recently had primarily driving force behind the search to develop new alternative technology, which is called phytoremediation. Despites of its feasibility and great potential as a viable approach in cleanup polluted environment, phytoremediation is yet become commercially available technology.

Key words: Plant Based Technology · Alternate Remediating Technology · Plant Potential · Detoxification

INTRODUCTION

Nowadays, mankind has dominated industrial and agricultural landscapes development. The rapid increases of population together with fast industrialization growth have caused serious environmental problems, especially on dumping toxic waste materials, such as heavy metals into water and soils. Singh and his co-workers [1] reported that over the decades, annual worldwide release of heavy metals reached almost 20,000 metric tons per year. This phenomenon has reached to a promising toxic level due to the consequences of anthropogenic activities and urbanization in the past few years back [2]. These pollutants are continuously released into the terrestrial environment by natural resources also human activities [3]. Heavy metals are essentially non-biodegradable substances, thus its mobilization caused the spread of toxic contaminants into the environment. Plus, there have been reported that accidental release or disposal also contributed to the spreading of contaminants in certain areas nearby [4]. Heavy metals are identified as elements with an atomic density greater than 6 g cm^{-3}, which are one of the most occurred persistent pollutants in water [5]. These waste materials have a tendency to accumulate along the food chains, thus causing health and toxicity problems for the human and environment. They have been known to pose several problems and expected to be increased in the environment recently.

There has been reported that in United States of America (USA), at least 60,000 contaminated brown fields with heavy metals need reclamation [6]. According to the European Environmental Agency (EEA), more than 80,000 contaminated sites have been remediated in the last 30 years and another 240,000 sites need to be in reclamation [7]. In Republic of China, its one-sixth of arable land has been polluted by heavy metals and more than 40 % has been degraded due to erosion and desertification [8]. Severe pollution cases have been reported in India,

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Pakistan and Bangladesh, where their industrial units have dumped out the untreated chemical wastes in the surface drain irresponsibly [9].United States Environmental Protection Agency (EPA) reported that the bill for clean up thousands of polluted environment in 2004 cost as much as $250 billion. The amount is increasing year by year, thus has driven researchers to develop economic cleaning method. In order to maintain good quality of water body and keep them free from contamination, continuous efforts have been made to develop technologies that are easy to use, sustainable and environmental friendly feasible. Thus, for over the last decades, the awareness to protect and sustain the environment from pollution has increased. Societies realized that during the race for development and prosperity, both failed to protect the environment.

A lot of positive steps were taken over by the world to counterbalance the development and compromise the integrity of environment. They implemented stringent governmental regulation, forced government and private agencies to manage their hazardous waste properly. The heavy metals cleanup is a very challenging job with respect to high cost and respectively technical complexity [10]. Physicochemical approaches have been widely used for remedying polluted environment, especially in small scale sites. This approach is referred to heavy metal removal mechanisms include sedimentation, flocculation, complexation, microbial activity and uptake [11]. While the classic and common physicochemical for metal remediation in water, especially for drinking water include precipitation, ion exchange and reverse osmosis process. Reported that activated carbon adsorption remains the most powerful technology available treatment for wastewater and industrial effluents polluted with heavy metals ions around the world [12]. Furthermore, microfiltration and sedimentation techniques are also being used as an environment contamination cleanup process [13]. Based on Raskin *et al.* [14] and McGrath *et al.* [15], they discovered that the physicochemical approaches have its side effects as such potentially creates secondary pollution problems. Therefore, there is a need for researchers to come out with a new development of a cost-effective, efficient and environmental friendly of remediation methods in decontaminating the heavy metals pollution.

Instead of the used of conventional remediation technologies in cleaning up the vast majority of polluted sites, researchers came out with ideas of using plants to remove or decontaminate the affected areas. The concept of using plant to remediate contaminated environment has actually been implemented for the past 300 years is called phytoremediation [16]. Green plants have an enormous ability to uptake minerals, nutrient and ion from ground through their root systems. Based on previous study, Amin and co-workers [17] agreed that phytoremediation is an energy efficient, cost-effective, aesthetically pleasing technique done by plant naturally in remediating polluted sites around the world. They believed to be able to uptake pollutants from environment and accomplish the detoxification process by various mechanisms. These features allowed herbaceous and woody plants to be utilized as an alternative remediation technique for site polluted with heavy metals. Around 1990's, phytoremediation technology emerged to be a relatively recent technology with mostly conducted research study [18]. Previous studies visualized that phytoremediation approach may be a suitable and satisfactory treatment to measure heavy metals rate and its bioavailability in contaminated areas [19]. This paper provides a review of phytoremediation technology, its applications and limitations, as a potential remediate approach to be commercialized into field scale in future.

The Concept of Phytoremediation: Since early 1990's, phytoremediation technology has been introduced as considerably alternative used to remediate the toxic contaminated sites around the world. From the beginning, hazardous and toxicity contaminants were spread in soils and mobilized into the groundwater. Unlike other organic matters, heavy metals are essentially in non-biodegradable form and accumulate in the environment. Phytoremediation techniques required the uses of remarkable plant ability to filter, adsorb and saturate the contaminants by using their roots system in soils. Plants also capable in metabolizing various molecules in their tissues and this ability appear to be compromise approach for the removal of organic and inorganic pollutants from the environment [20]. Thus, this green based technology has been reported to be an effective, non-intrusive, aesthetically pleasing and socially accepted technique to clean up hazardous contaminants and remediate polluted environment [21-23]. The concept of phytoremediation was suggested by Chaney [24], where he reported that plants are used to clean up or remediate contaminated sites in several ways, such as removing pollutants from soils, water or air by breaking down organic or inorganic substances. Phytoremediation process also benefits in degrade, contain and stabilize, or filter the hazardous metals occurred in the environment. Earlier, farmers have been rotating their crops plantation as an application of phytoremediation for centuries, in term of preventing the potentially hazardous substances buildup in the soil. Thus, it also enriched the nitrogen in the soils to make it available to other plants. This plant based technology requires just one basic technique, where green plants take up the pollutants through their roots system and either being store in the roots, stems, or leaves (phyto-extraction), volatized into the air (phytovolatization), metabolized by plant itself (phyto degradation), or any combination of the above (Figure 1).

Important Principles Mechanisms in Phytoremediation

Extraction: Contaminants such as organic or inorganic heavy metal substances entered the environment through its mobilization from anthropogenic activities. They were also accumulated with soil particles happened to be dangerous and hazardous towards plants, animals which consumed plants and human being. As their natural ability, certain plants able to tolerate with contaminants by accumulate them onto and inside its root system. Plants' root system provides enormous surface areas that enable pollutants which has attached and accumulated together with water and nutrients, to be adsorb onto the roots and also absorb through the root system [26]. Contaminants accumulated inside the plants' body parts will be transformed into various extents, depending on the specific compounds, environmental conditions and plants genotypes involved [27]. Naturally in some plant, they can release special enzymes from their roots that aid in further breaking down hazardous substances [28]. This kind of mechanism helps in alleviating pollutant substances and rendering them to be less harmful to the environment, especially towards crops and animals as shown in Figure 2.

Containment: Instead of extracting and stabilizing harmful heavy metal substances present in the environment, green plant-based technology also prevent the continuity of contaminants' leaching out to the surroundings by using the mechanism found in plant roots system. Their roots system takes up and absorbs mobilized contaminants in the surrounding, thus accumulate them in several parts of the plants without inhibiting their growth. Referring to Baker and Brook [29] and Baker *et al.* [30] they claimed that there are several plants species have developed the ability to accumulate massive amounts of indigenous metal substances in their tissues without exhibiting symptoms of toxicity. Toxic substances in the soils also can be immobilized by plants' exudates. This type of mechanism helps to retain contaminants immobilization in the remediate environment, plus inhibit the plant growth in the same time (Figure 3). Polluted sites with heavy metals contaminants usually cannot be clean up totally, but required to harvest the plants after they all saturated with the hazardous substances for disposal.

Degradation: In term of using plants to remediate polluted sites, public should be noticed that plant itself have special ability to break down or degrade contaminants, using natural mechanisms within their body parts.

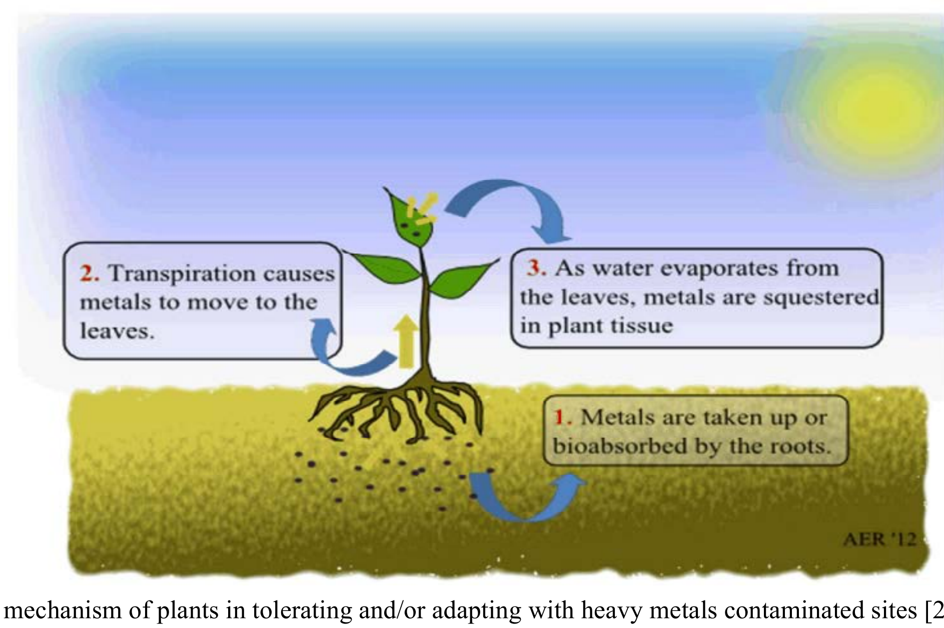

Fig. 1: Basic mechanism of plants in tolerating and/or adapting with heavy metals contaminated sites [25].

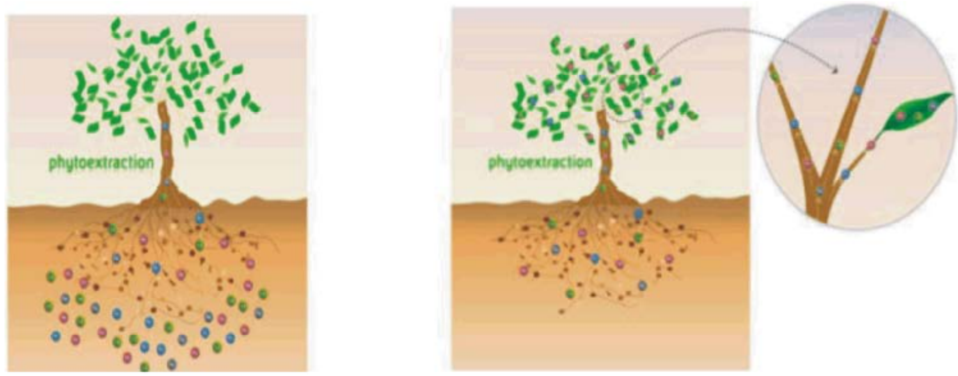

Fig. 2: Plant accumulated contaminants and extracted them into render harmless substances in the environment.

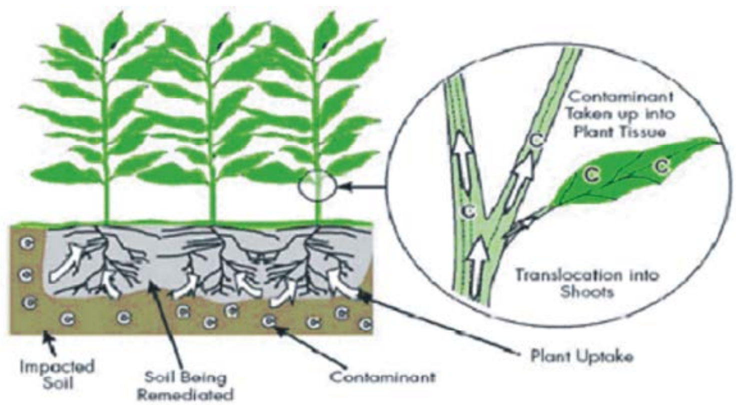

Fig. 3: Heavy metals pollutants uptake mechanism. Plants absorb metals form soils and translocate them into shoots and other plants' tissues.

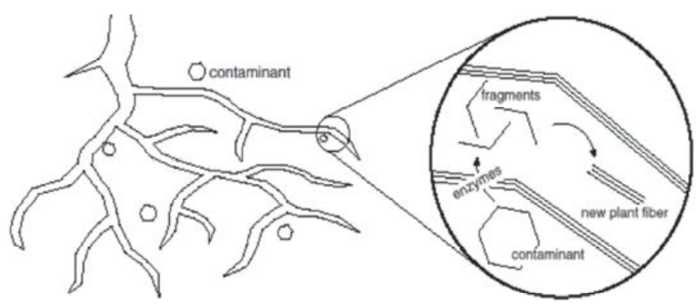

Fig. 4: Break down mechanism of contaminants in plants' root system.

Despites of detoxifying contaminant substances in the environment, plants have special enzymes which help them to break down the pollutants into simpler molecules to enhance their growth. Enzymes in plants help to catalyze and accelerate chemical reactions, thus destruct toxic substances into fragments (Figure 4).

Application of Phytoremediation Technology–Plants Exploitation: Several different types of phytoremediation are now being used commercially to clean up polluted sites, mostly still in a small scale application. Phytoremediation approaches mainly classified based on five main clean up techniques, such as phytoextraction, phytostabilization, phytovolatilization, phytodegradation and rhizofiltration [31-33]. All these techniques are initialized by root uptakes in the soil or growth medium, due to the presence of contaminant substances in the environment. Most of the findings reported that metal accumulated by plants were mostly distributed in their root tissues.

Table 1: List of some hyper accumulators/accumulators plants.

	Metals								
Plant species	Pb	Hg	Cu	Cd	As	Cr	Ni	Zn	Mn
Brasicca sp.	[35][36]	[35]	[35][36]	[35][36]	[37]	[35] [36]	[35]	[35] [36]	[35]
Alyssum sp.				[38]			[35][39]		
Thlaspi sp.	[35][40]			[35][41]			[35][40]	[35][40][41]	
Elshotzia sp.		[42]							
Azolla sp.	[35]		[35][43]	[44]		[35]	[35]	[45]	[35]
Helianthus sp.	[35]		[46]	[35]		[35]	[35]	[35][47]	
Arabidopsis sp.				[48][49]				[49]	
Eichhornia sp.	[35]	[35]	[35][50]	[35][50]		[50]		[35]	
Amaranthus sp.	[51]						[51]		
Pteris sp.					[52]				

Today, there is an increasing demand to use contaminated sites for phytoremediation and non-food biomass production. Despites of using crops and food biomass production in the previous research on phytoremediation, we should have a critical and deep consideration in exploiting the use weeds as to clean up polluted area. Previous studies reported that agricultural crops, flowering plants and aquatic macrophyte were mostly introduced to polluted environments as decontaminating organisms for remediating the sites. In the last two decades, several plants have been identified as highly effective in absorbing and accumulating various toxic elements occurred in the environment [34]. Currently, there has been more than 500 species identified and reported suits for heavy metal accumulators and some of them are presented in Table 1.

CONCLUSION

There have been a lot of conducted research in exploiting green plants as to as decontaminating hazardous substances occurred in the environment. Previous studies revealed that many of plants species have developed various type of mechanisms that helps them to tolerate and resists metal stress, thus accumulate pollutants into their body parts. Green plants have shown a variety of strategies in response to heavy metals in nature, thus, they have been identified as natural and low cost technology used to remediate polluted environment by their extracting mechanism. This paper reviewed more than one mechanism used by plants to detoxify contaminated fields, thus helps human being to reclaim the sites for other agriculture activities. There are also recorded that wide variety of green plants have been introduced to remediate polluted sites around the world and believed that there is still more possible species to be exploited, by looking for the suitable plants species which can uptake the contaminant. Fortunately, it has gained glorious popularities from the rediscovery of the vast potential of plants to do effective jobs at low cost in term of decontaminating polluted sites. Hence, phytoremediation technology is still seems to be a prosperous way to remediate environment contaminated with heavy metals nowadays rather than applying the conventional method used recently.

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