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POTENTIAL OF PHYTOREMEDIATION IN REDUCING HEAVY METALS IN CONTAMINATED WATER: A REVIEW

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ABSTRACT

Industrialization has led to an increase of water contaminants in the form of heavy metals that pose significant risks to the environment and to human health and welfare. In the environment, heavy metal decreases fish population and biodiversity, causes surface degradation, and deteriorates the quality of groundwater and growth of vegetation. The conventional physiochemical technologies that are implemented to clean water contamination is often times lacking in performance while also being expensive and hazardous. Phytoremediation, the use of plants to reduce contaminants in a wide variety of environment, including water, have been hailed as an innovative new technology that is effective, green, and low cost. The aim of this article is to describe the potential of phytoremediation of water contaminated by heavy metal by first understanding the dangers of heavy metals to humans and the environment, then the application of phytoremediation and its mechanism and the advantages and disadvantages of this method of environmental remediation. Several studies have found that phytoremediation is an effective method of reducing heavy metal contaminated water but further study is still needed to optimize the process and overcome its limitation.

Key Words
Conservations, risks, environment, remediation

INTRODUCTION

Industrialization has led to an increase of water contaminants in the form of heavy metals. From a conservatism standpoint, heavy metals pose several significant risks such as decreasing fish population and biodiversity, environmental degradation, and deteriorating number of microbes, quality of groundwater, and growth of vegetation. From a medical standpoint, accumulation of heavy metal in humans can cause serious long-term diseases. While several different physiochemical technologies have been implemented to clean and contain these contaminants, most are expensive, hazardous, and do not result in accordance to the desired performance (Emiliani et al. 2020). Phytoremediation, a green and low-cost technology utilizing plants' natural ability to adsorb and accumulate heavy metal have been offered as a solution in place of conventional clean-up technologies. The aim of this article is to describe the potential of phytoremediation of water contaminated by heavy metal, by first understanding the dangers of heavy metals to humans and the environment, then the application of phytoremediation and its mechanism, and the advantages and disadvantages of this method of environmental remediation.

HEAVY METALS AND ITS EFFECTS ON HUMANS AND THE ENVIRONMENT

Environmental contaminant is one of the most, if not the most, important factor currently contributing to environmental degradation (Sakakibara 2011). This includes the occurrence of heavy metals commonly found in industrial wastewater (Emiliani et al. 2020). Heavy metals are generally defined as elements characterized by its metallic properties and an atomic number above 20 (Tangalu et al. 2011). Heavy metals contaminants commonly found in water include Cd, Cr, Cu, Hg, Zn, As, Ni, and Pb (Emiliani et al. 2020; Tangalu et al. 2011). While some of these are micronutrients essential to the growth of plants, several elements, such as Pb, Co, and Cd, are toxic and have no known biological function. These pollutants pose a significant risk to all living organisms as it cannot be biologically or chemically degraded, rather it has to be physically removed or altered into a non-toxic compound (Tangalu et al. 2011). Its inability to degrade causes accumulation of heavy metals in the bodies of organisms who ingest it.

As it accumulates, metal ions are transferred through the trophic chain, eventually reaching human beings, who are at risk of consuming food with high levels of heavy metal already accumulated through the chain. Previous research has shown that although heavy metal can enter the inside of the human body through several different mechanisms, such as direct intake, dermal contact, and inhalation (Liang et al. 2017 in Kanwar et al. 2020), the most common way is by ingesting contaminated food or water. This is especially true for populations of people living in areas with high anthropogenic pressure, as heavy metal contaminants are much more common there than in areas with lower amount of pressure (Sakakibara 2011).

Heavy metals are often lethal, and very toxic both in elemental and soluble form (Kanwar et al. 2020; Sakakibara 2011). It poses a risk to organisms even at very low concentration (Emiliani et al. 2020). One example of this is the naturally occurring element arsenic. Arsenic has been found to be highly toxic to man and other living organisms. Another example is lead, which is toxic in almost all living beings, including plants, animal, and microorganisms. In humans, it can cause health problem, often related to brain damage and retardation. The element mercury is a persistent environmental pollutant, alluding to its ability to accumulate in living organisms. Mercury poisoning is characterized by neurological and renal disturbances and due to its ability to pass the blood brain barrier, mercury also has an effect on the brain (Tangalu et al. 2011). Cadmium, another heavy metal, is adsorbed by animals through its gills and gastrointestinal pathway. It can be accumulated in the tissue, most notably those ones on its heart and kidneys. Cadmium will form bonds with proteins and produces semi-permanent metalation which contributes to the metal's long residence time (Nur 2013).

Another effect of ingesting heavy metals is decreasing levels of vitamin C and iron in the human body (commonly caused by the ingestion of arsenic, chromium, and lead). This decrease of essential nutrients in the human body can cause weaker immune system, functional disorders, disabilities, and malnutrition (Bansod et al. 2017 in Kanwar et al. 2020). Heavy metals are also at risk of attacking the central, nervous, gastrointestinal, immune, and reproductive system when accumulated over a long period of time (Turdean 2011; Gong et al. 2016 in Kanwar et al. 2020). As mentioned beforehand, it can cause brain retardation, blood poisoning, cancer, skin problems, disorders in the lung, and dysfunction in human DNAs. Exposure over long periods of time causes debilitating diseases such as Alzheimer's, Parkinson's, and collapse in skeletal muscle and brain and optic nerves (Kampa and Castanas 2008; Guillarte 2011 in Kanwar et al. 2020). In the environment, water contaminants, such as heavy metals, can negatively affect fish population and biodiversity (Emiliani et al. 2020). If heavy metals level exceeds the limit set by the World Health Organization, it can create toxic effects for soil and aquatic systems by deteriorating the quality of groundwater, agriculture friendly microorganism, and growth of vegetation (Vries et al. 2007; Popescu et al. 2009 in Kanwar et al. 2020).

PHYTOREMEDIATION APPLICATION AND MECHANISMS

Phytoremediation have been defined as a technology (Sakakibara 2011; Tangalu et al. 2011; Dal Corso 2019; Ali et al. 2020; Emiliani et al. 2020) or a technique (Kanwar et al. 2020) that utilizes different plants and / or microbes to adsorb and / or accumulate metals and in doing so remediate selected contaminants from large variety of sources, such as soil, sludge, sediments, wastewater, and groundwater (Dixit et al. 2016; Saha et al. 2017). Etymologically, phytoremediation originates from the Latin word *phyto* meaning "plant" and *remedium* meaning "to correct or remove an evil". According to Ali et al. (2020) and Emiliani et al. (2020), there are several features important in determining plants species that are efficient in removing pollutants. Plants used in phytoremediation have to be efficient in removing heavy metals with a mechanism that allow them to uptake and tolerate large amounts of heavy metals. Aside from its ability to remediate metals, plants chosen for this process should be abundant and easily accessible, native to the environment with a quick growth rate and high yield. It should not need any special culture conditions to maintain its low cost feature. Several external factors attributed to the environment, such as solar exposure, availability of nutrients, pH levels, and salinity can influence both the plants potential and growth.

According to Tangalu (2011), Caroline (2015), Kanwar (2020), and Ali et al. (2020) , the mechanism of phytoremediation consists of several different processes, which include phytoextraction, rhizofiltration, phytodegradation, phytostabilization, and phytovolatilization. According to Dixit, et al. (2015), phytoremediation mechanism also includes one additional process, which is phytofiltration. Caroline (2015) and Dixit (2015) describes phytoextraction as a process in which heavy metal is adsorb by the root of the plant and accumulated in its shoot (leaves and branches). Ali et al. (2020) and Tangalu et al. (2011) further expanded this concept by adding that plants that have undergone phytoextraction can then be harvested and burned in order to gain energy or to recycle material gained from the ash. Rhizofiltration is a mechanism in which contaminants surrounding the root are adsorb, precipitated, and sequestered in order to clean the wastewater (Tangalu et al. 2011). Phytodegradation is the metabolism or breakdown of heavy metal in plants through the use of different enzymes, such as dehalogenase and oxygenase. Phytostabilization is the ability of plants to excrete certain chemical compounds in order to immobilize heavy metal in the rhizosphere while phytovolatilization is a phytoremediation mechanism that happens when plant absorbs metals through the root and degrades it before releasing it to the air through its leaves (Caroline 2015). Tangalu et al. (2011) also adds that phytovolatilization occurs when plants adsorb water containing contaminants like heavy metals.

According to Tangalu et al. (2011), there are several factors that will affect the uptake of heavy metals through phytoremediation. The first is the plant species. It is important for the success of phytoremediation to select a species which can accumulate heavy metals while being able to produce large amounts of biomass. Plants' ability to uptake heavy metal in and of itself is divided into two different mechanisms. accumulators and excluders. Accumulators can survive with large concentration of contaminants in its tissue while excluders restrict the amount of heavy metal uptake it does. The second factor affecting the uptake of heavy metal is the properties of the medium. This includes characteristics of the environment such as the level of pH, amount of organic matter, and other chemical contents, such as phosphor. These environmental conditions, if not favorable, can limit the amount of heavy metal uptake by plants.

Several studies have been conducted in order to understand the effectiveness of phytoremediation. One study, conducted by Diliarosta (2018) focuses on the ability of Salvinia molesta to decrease the amount of lead in irrigation canals. The study found that after 144 hours, the amount of lead in the water had decreased 51,3% from 1,75 mg/l to 0,852 mg/l which concluded that Salvinia molesta can be used as an effective phytoremediation agent of lead (Pb). Another study conducted by Setiyono (2017) indicated that three different plant species, Eichornia crassipes, Salvinia cucullata, and Pistia stratiotes was also able to effectively absorb Cr in wastewater with no noticeable different between the three. Other studies done by Emiliani (2011), Sakakibara (2016), Saha (2020) Caroline (2015), and Suharto (2011) have shown that utilizing plants can be an effective solution to remediate heavy metals in water, although each plant species often have differing abilities in metal uptake, adsorption, and accumulation

ADVANTAGES AND LIMITATIONS OF PHYTOREMEDIATION

Phytoremediation have been studied extensively in recent times because it is hailed as a promising technology that is effective in its performance, cost-effective, environmentally friendly, and aesthetically pleasing (Sharma et al. 2014; Ali et al. 2013). Phytoremediation is also less disruptive than conventional physical and chemical technologies used for heavy metal clean up in water. A study conducted by Emilian et al. (2011), showed a large decrease of heavy metal levels in water, ranging from 77-95% decrease after treatment by *Salvina biloba.* Phytoremediation is possibly one of the cleanest and cheapest technology that can be implemented to remediate hazardous sites. It is estimated that the cost of utilizing phytoremediation as method of cleaning heavy metal is 60 to 80% cheaper than conventional methods and it does not need expensive equipment or specialized personnel. It is also applicable to large range of both environment and contaminants to remediate (Tangalu et al. 2011).

Although phytoremediation has shown to be an effective, cheap, and environmentally friendly method to reducing levels of heavy metal in water, it is still time consuming and takes larger amounts of time to clean a contaminated area by using phytoremediation techniques than to clean it with traditional technologies. Aside from that, the sucess of phytoremediation is also governed by multiple external factors, such as chemical characteristics of the medium, climactic condition, and concentration of the contaminant. It is also limited by the plant's internal factors, such as root depth and age.

Conclusion

Several studies have found that phytoremediation is effective at reducing heavy metal contamination in water while also being environmentally friendly, cost-effective, and aesthethically pleasing. Despite the obvious benefit that this particular method offers, it is still limited by factors, both external and internal to the plants. As such, it can be concluded that further studies should be conducted to fully understand the mechanisms of phytoremediation in order to optimize its performance and overcome external and internal limitations that might hinder its effectivity.

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