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Review

Biological approaches to tackle heavy metal pollution: A survey of literature

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A B S T R A C T

Pollution by heavy metals has been identified as a global threat since the inception of industrial revolution. Heavy metal contamination induces serious health and environmental hazards due to its toxic nature. Remediation of heavy metals by conventional methods is uneconomical and generates a large quantity of secondary wastes. On the other hand, biological agents such as plants, microorganisms etc. offer easy and eco-friendly ways for metal removal; hence, considered as efficient and alternative tools for metal removal. Bioremediation involves adsorption, reduction or removal of contaminants from the environment through biological resources (both microorganisms and plants). The heavy metal remediation properties of microorganisms stem from their self defense mechanisms such as enzyme secretion, cellular morphological changes etc. These defence mechanisms comprise the active involvement of microbial enzymes such as oxidoreductases, oxygenases etc, which influence the rates of bioremediation. Further, immobilization techniques are improving the practice at industrial scales. This article summarizes the various strategies inherent in the biological sorption and remediation of heavy metals.

Contents

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1. Introduction

Recent years have evinced an unparalleled population growth and an accelerated pace of industrialization in line with it. Although, the quality of human life has substantially improved over the years, it is inevitable not to ignore that these developmental activities have taken place at the cost of the quality of our environment. During the last century, mining, electroplating, smelting, fertilizer, pesticides, tanneries, paper and electronic industries have accounted for the release of large amounts of heavy metals and petroleum hydrocarbons into the natural ecosystem, which has been reported to have disrupted the physiological functions in biological systems (Taiwo et al., 2016; Arivalagan et al., 2014). Environmental contamination can also occur through leaching of heavy metals, metal corrosion, atmospheric deposition, sediment resuspension to soil and ground water and metal evaporation from the water resources (Weerasundara et al., 2017; Francová et al., 2017). Hence, sediments constitute the major phase of contamination by metals in the aquatic systems (Nagajyoti et al., 2010). Among the pollutants, the hazardous heavy metals such as Arsenic (As), Cadmium (Cd), Lead (Pb), Copper (Cu), Chromium (Cr), Nickel (Ni), Zinc (Zn), Aluminum (Al) and Manganese (Mn) have known to be the major threats to the environment (Ullah et al., 2015; Dhanarani et al., 2016; Karthik et al., 2017a). These heavy metals impart serious health issues both to humans and ecosystems (Zeraatkar et al., 2016; Chen et al., 2015; Ullah et al., 2015). Source of various heavy metals are listed in Table 1.

The heavy metal pollutants can enter into the environment through natural and anthropogenic ways and can be deposited in soils, water bodies or in the air (Kuppusamy et al., 2017; Chen et al., 2015). Humus, the organic material present in the soil (which also makes the soil look green) has a high affinity for the heavy metal cations and extracts them from the water that passes through the soil. Roots of crops and other plants pick up these elements along with water and pass on to plants and then plants to animals. Heavy metals are also retained in the soil by adsorption on mineral particles present in the soil and precipitation reactions (Manafi et al., 2012). In water, particles with the adsorbed heavy metals settle to the bottom and the sediments may accumulate over them (Kang and So, 2016). If organisms consume these particles, the heavy metals enter the food web, thereby magnifying the after effect. While in the food chain, the heavy metals, which are generally non-biodegradable, get accumulated to result in multiple health hazards such as damage of lung, kidney, liver, pancreas and nervous disorders (Arivalagan et al., 2014; Kumar et al., 2017). For instance, accumulation of Cr(VI) and its reduced counterpart Cr(III) in the cells has been known to result in DNA damage. Similar adverse health effects have been reported for other heavy metals and hence, U.S. Environmental Protection Agency (EPA) and World Health Organization (WHO) have set a maximum permissible limit for every heavy metal in various systems (Kumar et al., 2017).

Earlier, methods such as chemical precipitation, coagulation, flocculation, filtration, reverse osmosis, ion exchange, membrane process, biosorption, aerobic and anaerobic microbial degradation (Kuppusamy et al., 2017; Carolin et al., 2017), have been extensively explored for their effectiveness in the removal of metals from different environmental media. Among these mechanisms, biosorption is considered as an innovative technology and remedial

Table 1
Sources of heavy metal contamination.

S. No	Sources	Heavy metals	Severity	References
1	Industrial waste: Mining, pharmaceutical, textile, petrochemical and oil spills and E-waste	Zn, Ni, Cu, Cr, Pb, Cd, Mn	High	Schaider et al., 2014; Mwinyihija, 2010
2	Air-borne sources: Stack, vehicular and fugitive emissions.	As, Cd, Pb	Wide area distribution-Severe	Wuana and Okieimen, 2011
3	Fertilizers	Co, Cu, Fe, Mn, Mo, Ni, Zn	Average	Roberts, 2014
4	Pesticides	Cu, Hg, Mn, Pb, and Zn	Low	Tchounwou et al., 2012
5	Sewage Sludge	As, Cd, Cr, Cu, Pb, Hg, Ni, Se, Mo, Zn, Tl and Sb	Low to average	Shamuyarira and Gumbo, 2014