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Review Article

Microbial Remediation & Control of Bioaccumulation of Heavy Metals

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Abstract

Heavy metals are included among leading global pollutants and they get bioaccumulated at different trophic levels of ecosystem and their concentration and associated risk to them of vast range harmful health side effects increases along with the rise of trophic level, not only in humans but also in other forms of life. But microbial remediation can play significant role in biodegradation of bioaccumulation of heavy metals. In this regard, either the addition of suitable microbial strains likes Pseudomonas, Staphylococcus, *E. coli* etc. in ecosystem or their transgenic forms have been found quite useful and further investigations are also required to facilitate not only to developed regions but also to developing global zones.

Keywords: Heavy metals; ecosystem, microbial remediation; bioaccumulation; biodegradation.

INTRODUCTION

In current era, one of the most harmful contaminants of ecosystem are heavy metals (Ali *et al.*, 2019) which induce diverse health risks either directly or indirectly in biota (Ali and Khan, 2018). Some frequently reported heavy metals are Fe, Co, Cu, Mn, Mo, Se, Zn, Sr, Cd, Hg, Pb and As which mainly enter in food chains from exposure of industrial effluents and other of wastes and quite low amount of them, can cause toxicity (Dai *et al.*, 2016). As the level of bioaccumulation is directly proportional to trophic level, that's why; during their transfer from lower to higher trophic levels the possibilities of injurious effects rises (Aprile & Bellis, 2020). The sources of heavy metals are of two types: natural and anthropogenic. Anthropogenic sources mainly influence over natural sources (Hembrom *et al.*, 2020). Because heavy metals cannot be decomposed and transfer from lower to higher trophic levels in ecosystem (Kahlon *et al.*, 2018), (Ali and Khan, 2019). Moreover, the rapid worldwide modern developments have brought about a serious danger to natural environment due to heavy metals. Rapid industrialization and urbanization, along with increased consumption of a lot of manures and pesticides, causing addition of poisonous substances like heavy metals in soil, air and water (Rodriguesa *et al.*, 2017). Aquatic environments are usually exposed to heavy metals contamination at first due to broad spectrum natural processes and anthropogenic activities than air and soil (Elbeshti *et al.*, 2020), (Sung and Park, 2018).

Transmission of Heavy Metals in Food Chain

The primary sources of heavy metals exposure in the soil are atmospheric accumulation, animals' manure, clean water contamination or malfunctioning sewage system, metalloid-pesticides, phosphate-based fertilizers and sludge- based amendments and herbicides (Elgallal *et al.*, 2016), (Woldetsadik *et al.*, 2017), (El-Kady *et al.*, 2018). Similarly, humans come in contact to harmful heavy metals in an ecosystem through various ways including inhalation, ingestion (both food and drinking water) and dermal adsorption and its frequency is higher in developing countries (Eqani *et al.*, 2016) due to lack of proper agricultural and industrial waste disposal systems and such poor practice may cause addition of toxic heavy metals and also other forms of water, soil and air pollution. As an outcome, bioaccumulation of heavy metals occurs in human food chain (Table 1) and eventually causes ailments in humans (Ali *et al.*, 2019). The frequently reported health issues due to heavy metals exposure are as follows (Table 2):

Table 1: Major affected dietary sources

Dietary Sources	Heavy Metals Found	Reference (s)
Vegetables	Mn, Cd, Cu	Manzoor *et al.*, 2018; Sung *et al.*, 2018; Zhou *et al.*, 2016; Chetan *et al.*, 2015
Fish	Zn, Cu, Cr, Ni, Cd, Pb	Bawuro *et al.*, 2018; Ali and Khan, 2018
Egg	Mn, Fe, Zn, Cr, Pb, Cd	Gutierrez *et al.*, 2018; Frossard *et al.*, 2021; Shawahna *et al.*, 2020; Leibler *et al.*, 2018
Milk	Pb, Cd	Singh *et al.*, 2020;Salah *et al.*, 2013; Meshref *et al.*, 2014; Kambli *et al.*, 2019
Chicken	Pb, Cd, Zn, Cu, Ni	Wang *et al.*, 2019; Hakeem *et al.*, 2020; Abbas *et al.*, 2019
Fruits	Cr, Ni, Mn, Zn, Cu	Zahir Ur Rehman *et al.*, 2018; Gupta *et al.*, 2018
Drinking water	Zn, Ba, Pb, Ni, Cr, Cu, Cd, Mo	Mohammadi *et al.*, 2019, Aslam *et al.*, 2021

Table 2: Common health issues due to bioaccumulation of heavy metals

Heavy Metals	Possible Health Side Effects	Reference (s)
Pb	Disturbance in nervous, cardiovascular and reproductive systems, carcinogenic and often cause abdominal pain.	IARC, 2018; Zhang and Reynolds, 2019; Pandey *et al.*, 2017; Javed and Usmani, 2016; Zhou *et al.*, 2016; Islam *et al.*, 2017; El-Kady *et al.*, 2018; Carocci *et al.*, 2016
Cd	Cancerous, osteoporosis, renal and cardiovascular disorders, DNA damage and genetic impairment causing.	Zhang and Reynolds, 2019; Pandey *et al.*, 2017; Javed and Usmani, 2016; Zhou *et al.*, 2016; Islam *et al.*, 2017; El-Kady *et al.*, 2018; Carocci *et al.*, 2016; Fatima *et al.*, 2019
As	Causative agent of dermal, reproductive, neurological, hematological, developmental, respiratory, gastrointestinal, renal, hepatic, cardiovascular disorders, cancer and gene mutations.	Zhou *et al.*, 2016; Islam *et al.*, 2017; El-Kady *et al.*, 2018; Chikkanna *et al.*, 2019
Ni	Lung fibrosis, lung and nasal cancer, cardiovascular and kidney diseases causing and extremely poisonous heavy metal having allergic impacts. It often reported to cause headache, fatigue and dizziness	Pandey *et al.*, 2017; Genchi *et al.*, 2020; Javed *et al.*, 2020
Cu	Acute gastrointestinal inflammation and hepatic damage and toxicity stimulation.	Javed and Usmani, 2016; Zhou, *et al.*, 2016; Taylor *et al.*, 2020; Javed *et al.*, 2019
Hg	Damage Hair, blood and interference in metabolism and causative agents of cardiac issues.	Ali and Khan, 2018; Mergler, 2021
Zn	Disturbs functions of liver, spleen, kidney, stomach, pancreas, lungs and of immune system.	Zhou, *et al.*, 2016; Elshama *et al.*, 2018

Microbial control for bioaccumulation of heavy metals

The current era is of global industrialization, so heavy metals are gradually accumulating in rising concentration in soil due to their improper handling in major regions of the world (Taylor *et al.*, 2020). But the utilization of microorganisms for reduction in percentage of heavy metals in soil is significant and in this regard, not only suitable microbial strains can be added to the soil but also potent transgenic plants can be prepared for better fixation of heavy metals and to obtain environmental and commercial advantages (Elshama *et al.*, 2018) e.g., affectively zinc degrading microbial strains have been explored yet (Taylor *et al.*, 2020) and *Escherichia coli* are found ideal for the treatment and to restore the various standard physical parameters of heavy metals containing to wastewater and soil (Elshama *et al.*, 2018). Microorganisms have incredible capacity to eliminate dissolvable and insoluble types of xenobiotics, like pesticides and heavy metals, to less poisonous or non-harmful compounds (Su *et al.*, 2014). Microbial remediation is characterized as the utilization of microorganisms to accomplish the ingestion, oxidation, precipitation and reduction in concentration of heavy metals in the dirt or in water bodies (Aburas, 2016). To improve the heavy metal particles' adsorption properties of microbial cells are under investigation since recent past (Li and Tao, 2015) and in the light of last few years' reported data following microbial strains (Table 3) have been found useful for degradation of bioaccumulated heavy metals.

Table 3: Heavy metals control by microbial remediation

Heavy Metal	Microbial Consumers	Reference (s)
Zn	Pseudomonas, Bacillus, Staphylococcus, *Streptomyces rochei*	Taylor *et al.*, 2020; Hamdan *et al.*, 2021
Cu	Pseudomonas, Bacillus, Staphylococcus, *E. coli*, *Streptomyces rochei*	Taylor *et al.*, 2020; Wang *et al.*, 2019 Hamdan *et al.*, 2021
Hg	Pseudomonas, Bacillus, Staphylococcus	Taylor *et al.*, 2020
Cd	Pseudomonas, Bacillus, Staphylococcus, *Streptomyces rochei*	Taylor *et al.*, 2020; Hamdan *et al.*, 2021
Pb	Pseudomonas, Bacillus, Staphylococcus, *Streptomyces rochei*	Taylor *et al.*, 2020; Hamdan *et al.*, 2021
Ni	Pseudomonas, Bacillus, Staphylococcus, *Streptomyces rochei*	Taylor *et al.*, 2020; Hamdan *et al.*, 2021
Cr	Pseudomonas, Bacillus, Staphylococcus, *Streptomyces rochei*	Taylor *et al.*, 2020; Hamdan *et al.*, 2021
Mn	*Streptomyces rochei*	Hamdan *et al.*, 2021
Fe	*Streptomyces rochei*, rhizobacteria	Hamdan *et al.*, 2021, Huo *et al.*, 2021

CONCLUSION

Thus regular ecological estimation and control is required to monitor concentration of heavy metals (Su *et al.*, 2014) to ensure safety of human health from the harmful impacts of heavy metals and in this regard, the human food chain should be continually observed for bioaccumulation and biomagnifications of heavy metals. However, non-destructive examining techniques and utilization of ecological biomarkers should be selected to avoid destruction of biota (Aburas, 2016) to equally facilitate all regions of the world.

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