Adaptive Strategies In Bacteria To Survive Under Heavy Metal Stress

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Introduction

Environmental microbiology is an area of growing interest both to microbiologists and to the general public. The expansion of industry has resulted in a significant rise in the release of industrial wastes containing heavy metals into environment, primarily affecting soil and water. Several heavy metals such as arsenic, chromium, cadmium,copper,mercury,nickel, lead,selenium, silver, zinc exhibit toxicity even at minimal concentration. These are not only cytotoxic, but also possess carcinogenic and mutagenic properties. However, the uncontrolled discharge of these toxic heavy metals into soil and water is a significant health concern worldwide because these metals cannot degrade into non toxic forms, resulting in a negative effect on ecosystem. To create a healthier environment for humans, contaminated water bodies and land must undergo remediation to eliminate heavy metals and trace elements from these areas. Numerous methods exist for eliminating these heavy metals, such as chemical precipitation, oxidation or reduction, filtration, ion-exchange, reverse osmosis, membrane technology, evaporation, electrochemical treatment, and also slow depletion of heavy metals takes place through leaching, plant uptake, erosion, and deflation. However, the efficiency of these methods become ineffective when the concentration of heavy metals drops below 100 mg/L (Ahluwalia et al., 2007). Aa many of the waste metals are soluble in water, so physical separation methods cannot effectively separate them (Hussein et al., 2004).Alternately, employing biological methods like biosorption and/or bioaccumulation for removal of heavy metals may be an attractive alternative to physico-chemical methods (Kapoor et al., 1995). Utilizing microorganisms and plants for remediation purposes is thus a possible solution for heavy metal pollution since it includes sustainable remediation technologies to rectify and restore the natural condition of soil.

Some of the adaptive strategies used by different bacteria against heavy metal toxicity are:

Morphological changes

When Bacterial is exposed to unfavourable environmental conditions, like extreme acidity or alkalinity, suboptimal temperatures, and toxic inorganic or organic pollutants, induce stress responses that necessitate the morphological inclusions to enhance bioremediation augmentations. On exposure to heavy metals bacteria undergoes observable changes in morphology as confirmed by SEM micrographs of bacteria CR48 grown at 10 nM Co addition revealed that the cells were oval shaped and 3–5 times larger than control cells (0.92–1.2 9 0.6–0.7 µm), while they became elongated on exposure to 10 µM. Further addition (400 µM) produced long rods some of which showed a bulge at one end (Antony et al., 2011).

Active transport or efflux mechanism

Active transport or efflux system is a primary and mostfrequently attributedresistance/adaptive mechanism in bacteria for heavy metal acquisition. This system facilitates the systematic movement of of heavy metal ions across the cytoplasmic membrane utilizing either ATP hydrolysis or an electrochemical gradient. Efflux mechanism serves as a fundamental defence against toxicity of heavy metals causing a decreased accumulation potentials and concentration for cellular detoxification purposes. The efficiency of efflux pump systems is integral to bacterial cell physiology, viability, pathogenicity, and virulence profiles.

Mechanism of EPS metal sorption

Bio-sorption operates as a surface phenomenon, independent of microbial metabolism. The primary mechanism of exopolysaccharide or intact microbial cell (alive or dead) mediated biosorption is the interaction of positively charged metal ions with negatively charged EPS and cell surfaces. The presence of abundant active and ionisable functional groups, along with non-carbohydrate components likeacetamido group of chitins, structural polysaccharides found in fungi, and various group such as amine, sulfhydral and carboxyl in proteins, phosphodiester (techoic acid), phosphate, hydroxyl groups in polysaccharide imparts overall negative charge on the polymer.This characteristic property aids in the binding to toxic heavy metals subsequently reducing their toxicity within the ecosystem.

Siderophores

Siderophores, which are low-molecular-weight chelating agents (200–2000 Da) are synthesized by bacteria, fungi, and plants to facilitate uptake of iron (Hider and Kong, 2010). The observation that certain siderophoresare produced in response to toxic metals suggests that these chelators may play a potential role in bacterial heavy metal tolerance. In Gram-negative bacteria, toxic metals enter the periplasm mostly by diffusion across the porins. When, metals bind to siderophores in the extracellular environment reduces the free metal concentration, probably by impacting diffusionand consequently their toxicity. Growth assays showed that Pseudomonas aeruginosa strains capable of producing pyoverdine and pyochelin appeared to be more resistant to metal toxicity than a siderophore non-producing strain (Braud et al., 2010).

Biotransformation

Biotransformation plays a crucial role in the adaptive evolution of bacterial bioremediation by converting highly toxic metal ions into less toxic forms aiding in the detoxification process.The process of biotransformation can be intracellular or extracellular for effective toxicity elimination and bioremediation strategy. It was reported that Pb (II) adsorption by Lysinibacillus fusiformis KMNTT-10 indicating the detoxifying by biotransformation to lesser soluble PbS (Mathivanan et al., 2018).

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