الجامعة المستنصرية
كلية العلوم
قسم علوم الحياة/ المرحلة الثالثة
مادة بيئة الاحياء المجهرية/الدراسة المسائية والصباحية

Microorganisms and Metal Pollutants

Metal pollution is a global concern. The levels of metals in all environments, including air, water, and soil, are increasing, in some cases to toxic levels, with contributions from a wide variety of industrial and domestic sources .For example, anthropogenic emissions of lead, cadmium, vanadium, and zinc exceed those from natural sources by up to 100-fold.

Metal-contaminated environments pose serious health and ecological risks. Metals such as aluminum, antimony, arsenic, cadmium, lead, mercury, and silver cause conditions including heart disease, liver damage, cancer, neurological and cardiovascular disease, central nervous system damage, encephalopathy, hypophosphatemia, and sensory disturbances.

Microbial activity in the sediment converted elemental mercury into the highly toxic and bioavailable methylmercury. Which accumulated in fish. Lead is a second metal of concern because lead poisoning of children is common and leads to retardation and semi-permanent brain damage. Because metal availability is strongly dependent on environmental components, such as pH, redox, and organic content, there is often a discrepancy between the total and bioavailable amount of a metal present. In environmental samples, and a bioavailable metal is generally soluble and not sorbed to colloids on soil surfaces.

Metals cannot be degraded through any physical, chemical or biological means, including microorganisms. However, microorganisms can alter the bioavailability of metals and their potential toxicity by changing the valence state of specific metals through oxidation or reduction.

Metals defined

There are three classes of metals: metals, metalloids, and heavy metals. Metals, in general, are a class of chemical elements that form lustrous solids that are good conductors of heat and electricity. However, not all metals fit this definition; for example, mercury is a liquid. Elements such as arsenic, boron, germanium, and tellurium are generally considered metalloids or semimetals in that their properties are intermediate between those of metals and those of nonmetals. Heavy metals are defined in a number of ways based on cationichydroxide formation, a specific gravity greater than 5 g/ml, complex formation, hard–soft acids and bases, and, more recently, association with eutrophication and environmental toxicity.

As a result of the complexity of the chemical definitions, metals have also been categorized into three additional classes on the basis of their biological functions and effects:

1) The essential metals with known biological functions.

2) The toxic metals and metalloids.

3) The nonessential metals with no known biological effects.

The following metals are currently known to have essential functions in microorganisms: Na, K, Mg ,Ca, V,Mn, Fe , Co , Ni , Cu ,Zn, Mo ,and W . Chromium is also thought to be essential, although this is still in dispute. Metals such as Na, K, Mg, and Ca are required by all organisms. Tungsten (W), on the other hand, appears to be essential only in hyperthermophilic bacteria, such as Pyrococcus furiosus , found in hydrothermal vents . Tungstate is thought to replace molybdate in these environments.

In general, essential metals are required for enzyme catalysis, molecule transport, protein structure, charge neutralization, and the control of osmotic pressure. The toxic metals include those with no known biological function. These include Ag, Cd, Sn, Au,Hg,Tl,Pd, Al, and metalloids Ge, As , Sb ,and Se. Metals are predominantly present as cationic species, and metalloids are predominantly present as anionic species.

Metal bioavailability in the environment:

Metal in the environment can be divided into two classes

1- Bioavailable (soluble, nonsorbed and mobile).

2- Nonbioavailable (precipitated, complexed, Sorbed and nonmobile).

Soils usually exhibit higher concentrations of metals than waters because metals are more likely to accumulate in soil versus being diluted or carried elsewhere in water, and soils are composed of minerals which can naturally contain high concentrations of metals.

Soil organic matter contains both humic and non humic substances , Humic substances contain a variety of organic functional groups that are able to interact with metals. These functional groups include carboxyl, carbonyl, phenyl, hydroxyl, amino, imidazole, sulfhydryl, and sulfonic groups. Metals complexed with humic substances are generally not bioavailable and therefore are less toxic to biological systems.

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Metal toxicity effects on the Microbial Cell:

Due to ionic interactions, metals bind to many cellular ligands and displace essential metals from their normal binding sites. For example

- Cadmium can replace zinc in the cell.
- Metals also disrupt proteins by binding to sulfhydryl groups
- disrupt nucleic acids by binding to phosphate or hydroxyl groups. As a result protein and DNA.

These metal–microbe interactions result in decreased growth, abnormal morphological changes, and inhibition of biochemical processes in individual cells. The toxic effects of metals can be seen on a community level as well.

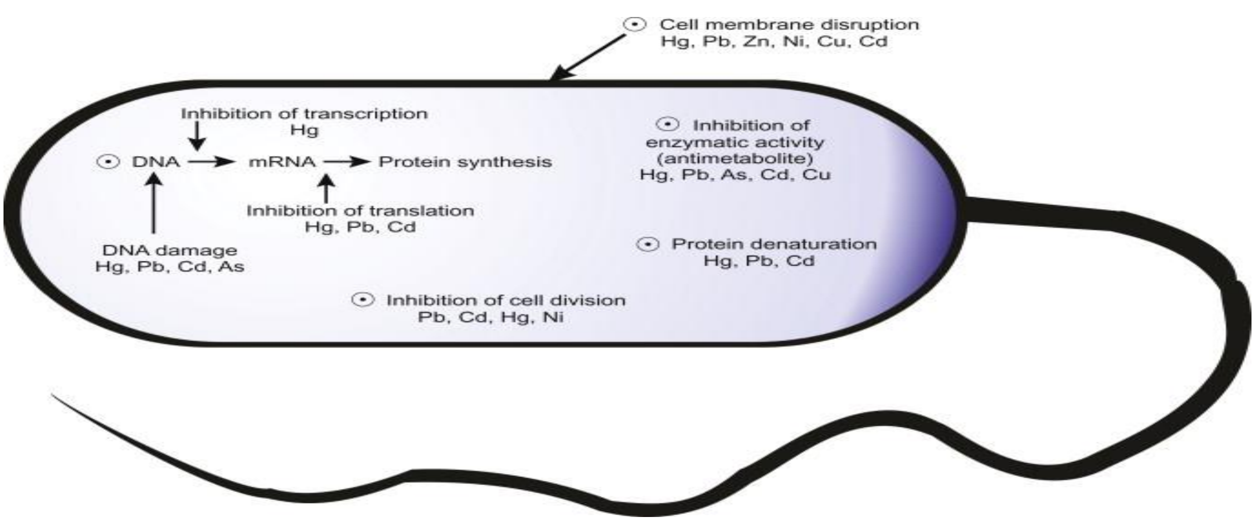

Figure: Metal toxicity effects on the Microbial Cell

Mechanisms of Microbial Metal Resistance and Detoxification

Microorganisms are believed to have evolved metal resistance because of

- Their exposure to toxic metals on early Earth.
- Anthropogenic contamination of the environment with metals.

Microorganisms have evolved ingenious mechanisms of metal resistance and detoxification in response to metals in the environment. Many of the resistance determinants are encoded on the chromosome but some are encoded on mobile genetic elements such as plasmids and transposons.

Microbial metal resistance mechanisms:

1. Volatilization 2. EPS sequestration 3. Efflux pumps 4. Precipitation as metal salts 5. Outer membrane or cell wall binding 6. Reduction 7. Biosurfactant complexation

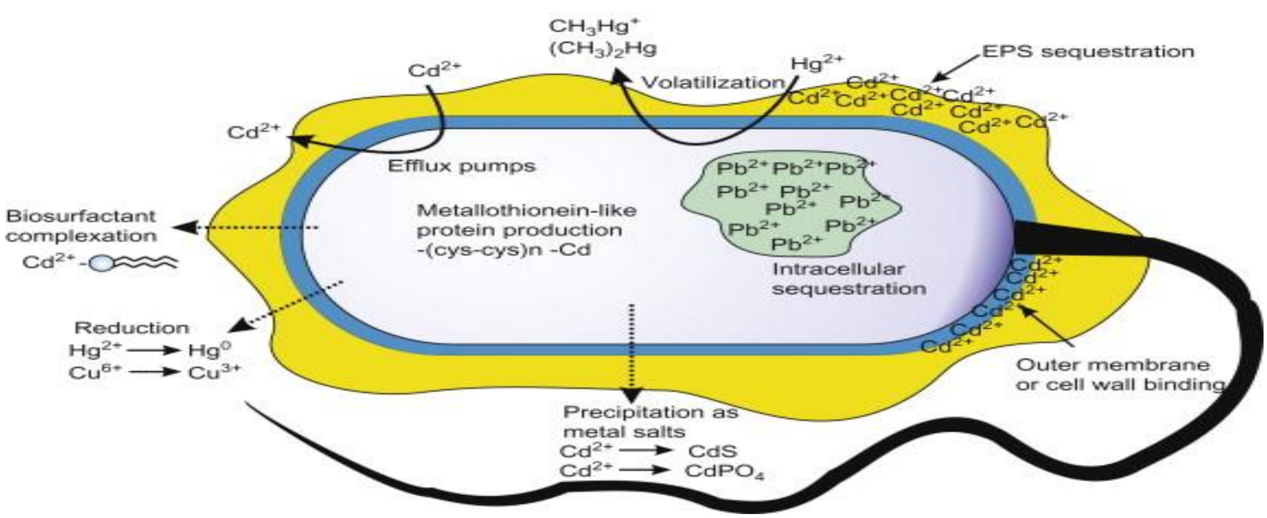

Figure: Microbial metal resistance mechanisms