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Biodegradation of heavy Metals by Microorganism and their role in Controlling Environmental Pollution.

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ABSTRACT

Rapid Industrialization and urbanization have increased the environmental pollution. The continuous release of the industrial effluent directly into environment causes various changes in physical, chemical and biological property of soil and water, which directly effects its biodiversity. Pollution caused by heavy metals has increased the attention worldwide as they arenon-biodegradable in nature, highly toxic. The increasing metal concentration have contaminated the land, water and air. The concentration of heavy metals increases due to various activities performed by humans, which enter into the cells of plants, animal sand get biomagnified. The xenobiotic nature various heavy metals lead to life threaten diseases in humans, plants and animals. Many microorganisms have the ability to degrade potent heavy metal such as cadmium, mercury, lead, arsenic, chromium, cobalt, zinc. Several bacterial species, algae, and fungi have the ability to degrade the complex heavy metals. Microorganism convert the complex form into simple form of heavy metals which decreases its toxicity.The present study gives details about the role of microorganism in degradation of heavy metal sand their role in controlling environmental pollution.

KEYWORDS: Microorganism, Heavy metals, Microbial degradation, Biosportion, bioremediation

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1. INTRODUCTION

Due to rapid industrialization anduse of natural resources, there has been an increase in the discharge of industrial effluent in to the environment, which has led to the accumulation of heavy metals into soil and water. In order to make the environment free from pollution, contaminated water bodies and soil is needed to be free from heavy metals and trace elements. Several techniques are used to remove the heavy metals, which includes reverse osmosis, membrane technology, evaporation, chemical precipitation, oxidation or reduction, filtration, ion exchange and many more (1). Heavy metal contamination is the excessive deposition of toxic heavy metals in the soil and water majorly done by human activities. Heavy metals include some significant metals which has biological toxicity, such as mercury (Hg), cadmium (Cd), lead (Pb), chromium (Cr) and arsenic (As), such as zinc (Zn), copper (Cu), nickel (Ni), stannum (Sn), vanadium (V) etc[1]. There are several conventional methods which are used to remediate heavy metals from the contaminated site are stabilization and excavation. These technologies can control the contamination but cannot permanently eliminate heavy metals from the environment remove. However, they have cost-effectiveness limitations; they do generate the hazardous by-products or inefficiency. Some biological methods have potential solve these drawbacks as they are easy to operate, they do not produce secondary pollution. Heavy metals are toxic at low concentration[1]. Today environmental pollution is a major problem because of toxic waste has led to disturbance in the biological, chemical and physical properties of water as well as of soil. The process of Biodegradation is the one of the way to overcome this problem as it is the process of breaking down of organic compounds, it leads to the bioaccumulation, and biotransformation of inorganic compounds into environmental which makes them ecofriendly[2].

2. HEAVY METALS

As the degree of toxicity, arsenic, cadmium, chromium, lead, and mercury ranks high among the priority metals that have public health significance. These elements are considered toxicants that induce multiple organ damage, even when exposure is at low level. They also act as human carcinogens according to the U.S. Environmental ProtectionAgency, and the International Agency for Research on Cancer[3].

2.1 Types of heavy metals

2.1.1 Arsenic

Arsenic is a ubiquitous element that is detected at low concentrations in environment. The inorganic form of arsenic includes trivalent and pentavalent. Arsenic enter into environment with the help of natural calamities such as volcanos, soil eruption etc. Arsenic is being used in manufacturing industries, which are engaged in production of herbicides, fungicides, wood preservatives and many more. Arsenic is widely exposed to humans as it contaminates the water. The person who are involved in industries producing arsenic are highly exposed to arsenic. Several human effects are observed due to arsenic. Several health effects such as cardiovascular, dermatological, neurological, and several respiratory problems are observed. It is also found that arsenic have high rate for cancers of kidney, bladder, skin and liver[3].

2.1.2 Cadmium

Cadmium is a heavy metal, which is widely distributed across the earth's crust. Cadmium is used majorly in industries. It is used in production of alloys, batteries etc. the route of exposure of cadmium are via inhalation of smoke, taking cadmium contaminated food, workplace contaminated with cadmium. Cadmium shows sever effect in lungs and in gastrointestinal tract, which cause fatal effect when inhaled or ingested[3].

2.1.3 Chromium

Chromium is found in nature in form of ore such as ferrochromite. It enters into various water bodies and land through release of effluents by the industries involved in production and processing of chromium. Humans are exposed to chromium annually via chromium containingcompounds in the workplace. Health effects are also caused by chromium when inhaled it causes irritation in nose and also cause nose ulcers. High dose of chromium lead to severe respiratory, cardiovascular, gastrointestinal effects, which can also lead to death[3].

2.1.4 Lead

Lead is naturally occurring metal present in very less amount. It occurs naturally due to several anthropogenic activities like burning, mining and manufacturing of fossil fuels.it is also used in industrially, agriculturally as well as domestically. The exposure of lead occurs due to inhalation of lead contaminated dust, by ingestion of various contaminated food and

water. Lead poisoning causes fatal effect on central nervous system.it also causes abnormalities in offspring, decreases the birth rate and preterm delivery[3].

2.1.5 Mercury

Mercury is a heavy metal, which occurs in liquid form at room temperature and releases as mercury vapour in environment. Both humans as well as animals are exposed to vapour of mercury in form of inorganic mercurous (Hg^{+}), mercuric (Hg^{+2}), and also in organic mercury compounds. Humans are exposed to mercury due to accidents, medical practices, several industrial and agricultural operation and dental care. As mercury is magnified in higher organisms its exposure becomes high due to food consumption mercury also acts as carcinogenic compound[3].

2.2Characteristics of heavy metals

2.2.1 Widely distributed

Due to urbanization heavy metals contamination is widely distributed across the world. It is problem of every country in the world. According to world's top ten environmental event, two events have related to heavy metal contamination[4].

2.2.2 Highly latent

As Heavy metals are colourless and odourless, so it is difficult to recognize. As environmental tolerance and environmental conditions changes, heavy metals in the soil is activated and cause serious ecologicaldamage[4].

2.2.3 Irreversibility and remediation hardness

In case of air and water pollution, the pollution problem can be overcome by dilution andself-purification. Although it is difficult to use dilution or self-purification techniques toeliminate heavy metal from soil. Some soils contaminated by heavy metals takes one or two hundred years to be remediated. Therefore, heavy metal contamination needs relative long time for remediation cycle[4].

2.3 Sources of heavy metals

The environment become contaminated by heavy metals because (i) the rates of generation cycle of metals generated via manmade methods are more rapid than natural ones, (ii) they are transferred from original site to several other environmental locations where

exposure rate increases (iii) the rate of at which the concentrated heavy metals are discarded is high. There are various anthropogenic sources, which are described here under:

2.3.1 Fertilizers

Fertilizers are widely used in agriculture as to grow and complete the lifecycle plants require macro elements [N,P,K,S,Ca and Mg] as well as microelements [Cu,Co,Fe and Mn]. A huge amount of fertilizers is added to soil in order to increase its fertility. Several elements are there which acts as potent toxic elements to soil[5].

2.3.2 Pesticides

Pesticides are sprayed in field in order to eliminate the pests which causes damage to crop. Several lead arsenate and arsenic containing compounds are used as pesticides to control pests. Several elements such as Cu,Cr, Hg,and Mn are used in pesticides[5].

2.3.3 *Biosolids and manure*

Livestock manures, composts, and municipal sewage sludge have numerous application as biosolids which leads to accumulation of heavy metals such as Cr,Hg,Pb,Ni,Se,Mo and As in soil. the waste produced from poultry, cattle, pig are commonly used as manures in agriculture. This manure produced from animal contain high concentration of heavy metals, which ultimately increases the concentration in soil[5].

2.3.4 Waste water

Wastewater is common practice carried out throughout the world.it is estimated that around 20 million hectare of land is irrigated with wastewater. The concentration of metals is relatively low in wastewater but continuous use of wastewater for irrigation increases the concentration of metal n soil[5].

2.3.5 Metal mining and waste from industries

The extraction of metal from ores if done in many countries. During process of mining heavy and large particle get accumulated at the bottom and are drained out directly into natural resources which contaminates the area with accumulation of heavy metals. The industries involved in manufacturing and processing of heavy metals discharge its effluent either in soil, water or in air. Due to this discharge the concentration of metals, get increased in soil, water and in air[5].

2.3.5 Air borne sources

The emission of metals by air, steam, gas or vapour is included in air borne sources of heavy metals. The metals like As,Cd and Pb are volatile when processed at high temperature.

The smoke released from chimneys of the industries and other fires eventually are deposited on land or sea[5].

3. MICROBIAL BIODEGRADATION

Biodegradation is defined as the reduction in complexity of the compound under biologically catalysed reaction, biodegradation is the process by which complex organic substances are converted into simple compounds by microorganisms and the process of formation of simple compound by microbes is called "mineralization"6. Many microorganisms are involved in degradation of heavy metals. Some are discussed here under:

3.1 Bacterial degradation

The degradation of environmental pollutants by is done by different bacteria.Several bacteria feed exclusively on hydrocarbons Bacteria which degrade hydrocarbons are named as hydrocarbon-degrading bacteria. Biodegradation of hydrocarbons can occur under aerobic and anaerobic conditions.*Bacillus, Corynebacterium, Staphylococcus, Streptococcus, Shigella, Alcaligenes, Acinetobacter, Escherichia, Klebsiella* and*Enterobacter, Bacillus* are reported as hydrocarbon degrading bacteria. Mainly soil borne bacterium are able to degrade hydrocarbon. Organism are usually gram negative bacteria. Although many bacteria are able to metabolize organic pollutants, but a single bacterium does notpossess the enzymatic capability to degrade all organic compounds in contaminated soil. Hence Mixed microbial communities have high biodegradative potential. Manyorganisms such as *Pseudomonas, Burkholderia, Ralstonia, Achromobacter, Sphingomonas* and *Comamonas.* are able to transform PCBs under anaerobic condition. Several organisms such as *Bacillus, Staphylococcus* and *Stenotrophomonas to* degrade dichlorodiphenyltrichloroethane (DDT) [6].

3.2 PGPR and PGPB degradation

Plant growth promoting rhizobacteria (bacteria that live on and near the roots of plants), and plant growth promoting bacteria are able to degrade the toxic organic compounds in contaminated soil and have potential for improving phytoremediation. An important class of bacteria is *Pseudomonas* spp., which have PGPR activity and hydrocarbon degrading capacity[6].

3.3 Fungal degradation

Fungi plays an important part in degradation because, like bacteria, they metabolizedissolved organic matter and fungi are principal organisms responsible for the

decomposition ofcarbon in the biosphere. Fungi can grow in low moisture areas and in lowpH solutions, which aids them in the breakdown of organic matter.fungi possess extracellular multienzyme complexes, they are most efficient, especially in breaking downthe natural polymeric compounds. With the help of their hyphal systems they are able to colonize and penetrate the substrates which helps in transport and redistribute nutrients withintheir mycelium. Mycorrhiza shows symbiotic relationship with the roots ofa vascular plant. Fungi posse degradative capabilities that have implications for the recycling of recalcitrant polymers (e.g. Lignin) and for the elimination of hazardous wastes from the environment[6].

3.4 Yeasts degradation

Several yeasts utilize aromatic compounds as growth substrates, Some species such as the soil yeast *Trichosporon cutaneum* uptake aromatic substrates such as phenol. aliphatic hydrocarbons which occurs in crude oil and petroleum products is degraded by yeasts. The n-alkanes are the most widely and readily utilized hydrocarbons, assubstrates for microfungi such as *Candida lipolytica, C. tropicalis, Rhodoturularubra,* and *Aureobasidion* (*Trichosporon*)*pullulans*. *Rhodotorula aurantiaca* and *C. ernobii* were found able to degrade diesel oil. Yeasts are also known for playing an important role in the removal of toxic heavy metals. Yeasts are capable of accumulating heavy metals such as copper, nickel, Cobalt, Cadmium and Magnesium as compared to bacteria[6].

3.5 Algal degradation

Algae and protozoa are also capable of degrading heavy metals. An alga, *Prototheca zopfi* utilizes crude oil and a mixed hydrocarbon substrate and exhibited extensive degradation of n-alkanes and isoalkanes as well as aromatic hydrocarbons. several cyanobacteria, green algae, red alga, brown alga, and diatoms oxidize naphthalene. Some fresh algae such as*Chlorella vulgaris, Scenedesmus platydiscus, S. quadricauda* and *S. capricornutum* are capable of utilizing and degrading PAHs[6].

4. BIOSORPTION OF HEAVY METALS

Biosorption describes the removal of heavy metals by the passive binding to non-living biomass from an aqueous solution. The removal mechanism is not metabolically controlled There are many types of biosorbents which includes bacteria, fungi, yeasts, and algae. these biosorbents remove various pollutants, but these are not yetfully understood. For example, the extracellular polymeric substances (EPS) of microorganism plays a role in metal

biosorption. Many chemical and functional groups can attract the pollutants, which depends on the choice of biosorbents[7]. The different biosorbents are described here under:

4.1 Bacteria

Bacteria are a major group found in soil and water, and as symbionts of other organisms. Bacteria can be found in a wide variety of shapes, which include cocci (such as Streptococcus), rods (such as Bacillus), spiral (such as Rhodospirillum) and filamentous (such as Sphaerotilus). The bacterial cell wall made up of peptidoglycan (poly- N-acetylglucosamine and N-acetylmuramic acid), which is located immediately outside of the cytoplasmic membrane. Peptidoglycan is responsible for the rigidity of the bacterial cell wall, and ultimately the cell shape. The bacterial cell wall is the first component that comes into contact with metal ions/dyes, where the solutes canbe deposited on the surface or within the cell wall structure. The chemical functional present on the bacterial cell wall, including carboxyl, phosphonate, amine and hydroxyl groups play vital roles in biosorption[7].

4.2 Fungi

Fungal cell walls and their components have a major role in biosorption and also take up suspended metal particulates and colloids. Their plays important roles are as decomposers of organic material, also acts as pathogens and shows symbiotic relationship with animals and plants, and as spoilage organisms of natural and synthetic materials. White rot fungi are highly specialized groups of organisms, which have the ability to remove mixed pollutants from environment[7].

4.5 Algae

Algae act as biosorbents due to its high sorption capacity. The difference between Rhodophyta, Chromophyta and Chlorophyta mainly occur in the cell wall, where sorption takes place. Brown algae are more efficient as biosorbents due the cell walls. The cell walls of brown algae generally contain three components1) cellulose, the structural support 2) alginicacid, and 3) sulphated polysaccharides. The carboxyl and sulphate are the predominant activegroups in this kind of algae. The carboxylic groups are generally the most abundant acidic functional group inthe brown algae. The adsorption capacity of the algae is directly related to the presence of these sites on thealginate polymer, which itself comprises a significant component up to 40% of the dry weight, of the dried seaweed biomass[7].

5. BIOREMEDIATION OF HEAVY METALS

Bioremediation is the process by which stimulation of microbes is done to rapidly degrade the hazardous organic pollutants. biological remediation process either precipitate or immobilize inorganic pollutants such as heavy metals. Stimulation of microorganisms is achieved by the addition of growth substances, nutrients, terminal electron acceptor or donors or some combination that enhances the degradation and biotransformation of pollutants[2].Microorganisms, food, and nutrients essential components needed for bioremediation. Aerobic as well anaerobic organisms are involved in bioremediation such as *Pseudomonas, Sphingomonas, Rhodococcus and Mycobacterium* (aerobic bacteria) degrade pesticides and hydrocarbons, both alkanes and polyromantic compounds. Anaerobic[2].

5.1 Microbialremediation

In Microbial remediation, some microorganisms are used to perform the absorption, precipitation, oxidation and reduction of heavy metals in the soil[5].Microbial remediation uses microorganisms to either degrade organic contaminants or to bind heavy metals in more inert and less bioavailable forms. Microorganisms break down contaminants by using them as food source or metabolizing them with a food source. Aerobic processes require an oxygen source, and the end products typically are carbon dioxide, water salts. Anaerobic processes are conducted in the absence of oxygen, and the productsincludes methane, hydrogen gas, sulfides, elemental sulfur and di- nitrogen gas[8].

5.2 Phytoremediation

Soil is contaminated by heavy metals. The plants have the certainhyper-accumulation ability for the contaminants which get accumulated mainly in the root or above the root. Use of plant in remediation to remove heavy metal is new technology. More than 400 species of such plants have been found in the world, and most of them belong to Cruciferae, including the genus Brassica, Alyssums, and Thlaspi that are suitable plants with strong ability for heavy metal accumulation and tolerance[5].

5.3 Mycoremediation

Fungi secrete amino acids,organic acids and other metabolites to dissolve heavy metals and the mineral containing heavy metals[5].

6. CONCLUSION

Today, it has become very important to maintain the nonrenewable sources present on earth. Microorganism plays a very important role in maintaining the global cycles and in decreasing the adverse effect caused in environment due to discharge of heavy metals. The process by which organism helps in elimination of heavy metals from environment by making them more simple from complex is term as biodegradation.

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