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Remediation of Heavy Metals

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Abstract—*Soil is highly contaminated with heavy metals due to increase in industrial activity, excessive use of fertilizers and pesticides, mining activity, improper disposal of e-waste, and spilling of petrochemicals. It is important to remediate heavy metals from soil to improve agricultural areas. The contaminated soil is affecting ecosystems, degrading the quality of ground water, which in turn affect plants, animals and human health. Soil is majorly contaminated with metals such as cadmium, zinc, copper, arsenic and lead. Remediation of soil can be through various physical methods such as soil washing or soil vapour extraction; chemical methods such as chemical extraction; thermal methods and electrokinetics. But most of the methods have their own drawbacks, first of all they are not able to remediate the soil completely and also they leave behind certain products which are toxic for the environment. Another method for remediation is bioremediation, which include mycoremediation, phytoremediation and bioaugmentation. As microorganisms and plants have a major and natural role in degradation of pollutants present in the environment, bioremediation serves as an eco-friendly, inexpensive and effective method for soil remediation, but it is time consuming. Remediation of soil is imperative to ensure a healthy and secured environment for plants, animals and human beings. Many governmental and non-governmental organizations are putting sincere efforts to combat this problem. Large number of research projects are running at national and international level to develop new and effective technologies for remediation of soil.*

Keywords: *remediation, soil, heavy metals, bioremediation, contaminants, physical method*

1. INTRODUCTION

Remediation can be defined as the removal of metal contaminants or pollutants from contaminated soil, surface water, and ground water. Nowadays there is an increase in environmental contamination with heavy metals due to increased industrial activities, mining, smelting, fertilizers, and pesticides[1]. Heavy metals are immutable in nature and persist in the environment for a long time, they cannot be eliminated completely and can only be changed from one oxidation stage to other non-harming stage[1]. Subsequently these heavy metals enter the food chain and accumulate and as a result affect human and animal health. To combat these problems, various remediation technologies like chemical remediation, biological remediation and physical remediation were developed. However, these methods have some drawbacks in completely remediating the metal contaminants and also leave some toxic compounds behind which have more detrimental affects. Biological remediation is one method which uses the natural capability of plants and microorganisms without any release of toxic compounds[2].

Table 1: Metals as pollutants

Metals	Amount in soil (ppm)	Permissible level (ppm)
Arsenic (As)	3-12	39
Cadmium (Cd)	0. 1-10	0. 8
Lead (Pb)	10-70	85
Copper (cu)	1-50	36
Nickel Ni)	0. 5-50	10
Zinc (Zn)	9-12. 5	15

Reference: [3] Tchounwou, P., Yedjou C., Patlolla A., and Sutton D., "Heavy Metals Toxicity and the Environment", *Molecular,clinical and environmental toxicology,* 101, August 2014, pp. 133-164.

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Table 2. Impact of Metals on Humans

Metals	Humans
Cadmium	Toxic to the kidney, cause bone de mineralization, impair lung function
Copper	Gastrointestinal distress, vomiting, abdominal pain, pulmonary fibrosis, and increased vascularity of the nasal mucosa
Zinc	Causes damage to the pancreas, disturb the protein metabolism, causes arteriosclerosis, skin irritations, nausea and anaemia.
Lead	Increased chance of illnessduring pregnancy, harm toa foetus, high blood pressure, digestive issue, nerve disorders, memory and concentration problems, muscle and joint pain.

Reference: [5] Bernard, A., "Cadmium & its adverse effects on human health", *Indian Journal of Medical Research*, 128, October 2008, pp. 567-64.
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Table 3: Impact of Metals on Animals

Metals	Animals
Cadmium	High blood pressure, iron-poor blood, liver disease and nerve or brain damage.
Copper	Damage to immune system. Impaired cell-mediated and humoral-mediated immune function have been observed in mice
Zinc	Decrease in weight gain and milk production, lameness.
Lead	Affects the CNS of animals and inhibits their ability to synthesise RBCs.Birds may lose their ability to fly, experience severe weight loss, and eventually die.

Reference: [7] Neathery,M.W, and Miller,W.J, "Metabolism and Toxicity of Cadmium, Mercury, and Lead in Animals: A Review", *Journal of Dairy Science*, 98, 4, April 2015, pp. 2075-2832.

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Table 4: Impact of Metals on Plants

Metals	Plants
Cadmium	Can alter the uptake of minerals by plants, chlorosis, leaf roll, stunting, affect on plasma membrane permeability
Copper	Leaves becomes dark green, then turn white as chlorophyll fails to enable proper photosynthesis, damage to the roots of plants resulting in slow growth or death of plant
Zinc	Necrosis of old leaves, elicits wilting, biomass decline.
Lead	Inhibition of growth, interference with cell division and with water absorption and balance, and reduction of photosynthesis

Reference: [9] Cakmak, I., and Marschner, H., "Increase in Membrane Permeability and Exudation in Roots of Zinc Deficient Plants", *Journal of Plant Physiology*, 132, April 1988, pp. 356-351.
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2. SOURCES OF METAL CONTAMINATION

Some of the metals found in the environment and their sources of contamination are:

Lead. Automobile exhaust, paint, lead smelters, water from lead pipes and solder, incinerator ash, mining wastes, utilities, lead-acid battery manufacturers and recyclers and lead solder in cans. Since hot water can leach lead from solder, using hot tap for filling the kettle and cooking may result in a high intake of lead even when there is no lead plumbing[11, 12].

Cadmium. Cadmium products, electric and electronic waste, plastic industries, recycling of cadmium-plated steel scrap, electroplating, sewage, manufacture and application of phosphate fertilizers, natural sources, non-ferrous metal mining, smelting and refining, iron & steel production, fossil fuel combustion, incineration and disposal of municipal waste[13, 14].

Zinc. Mining, smelting, refining operations, coal and waste combustion, automobile emissions, garbage incineration, steel processing and natural breakdown of zinc ore deposits. Inappropriate disposal of zinc-containing wastes from electric utilities and metal manufacturing industrie may result in high amounts of zinc in soil. Concentrated sources of zinc in water include mine drainage, rainwater in urban areas, industrial and municipal wastes. Diluted and widely distributed sources of zinc comprise of breaking down of most rocks and certain minerals over time, releasing zinc to groundwater or surface water [15, 16].

Copper. Natural sources include erosion of natural deposits, windblown dust, forest fires, decaying vegetation and sea spray. Sources that arise due to human activities, include mining, coal-fired power stations, wood production, metal production, sewage treatment processes, phosphate fertilizer production, waste incinerators, combustion of fossil fuels, corrosion of household plumbing systems and from the application of agricultural chemicals. Cigarette smoke also contains small amounts of copper[17, 18].

3. METHODS FOR REMEDIATION OF METALS

There are various Physical and chemical methods for remediation.

Physical methods

Physical methods include methods such as Soil washing in which soil is washed using a wash solution (generally water). The soluble impurities get dissolved in wash solution and soil is separated out. Wash solution and soil fractions get separated out on the basis of gravity setting[17]. This method is widely used for removing contaminants such as metals and other inorganic pollutants soluble in water. Metal contaminants which can be removed by this method include cadmium, chromium, lead, and zinc. The effectiveness of this method can be improved by using chelating agents (such as Disodium

EDTA and Sodium metabisulfite), leaching agent, surfactants, changing the pH of the solution. One of the major disadvantage of this technique is that soil has to be taken to the treatment plant and also complete excavation for treatment and then refilling the land with the treated soil is a costly as well as time consuming task[18]. Other physical method is Soil vapour extraction . In this method pipes, vaccum blowers and extraction wells are lodged in to soil and volatile and semi-volatile metal impurities are removed through these pipes and get collected in these wells. The technique is beneficial since, it can be used for large volume of soil and also it is inexpensive.

Chemical methods

Chemical methods include chemical extraction in which soil is treated with oxidizing agents such as ozone, hydrogen peroxide, chlorine dioxide which convert the hazardous substances into less toxic ones. These chemicals are sprayed on soil and allowed to react with contaminants present in the soil. The chemical components used in this method, alter the naturally composition of soil which is a major problem[22].

Thermal methods

Other methods used for soil remediation include thermal methods in which high temperature is used for remediation of volatile contaminants such as mercury[21]. It is a ex-situ method for soil remediation. It requires a shorter time period[4].

Electrokinetics

Electrokinetics is another remediation method which uses electric charge. It is used for remediation of charged contaminants such as metal from soil[22].

Bioremediation

Bioremediation is remediation using biological organisms such as bacteria(Bioaugmentation), Fungi(mycoremediation), plants(phytoremediation). Bioremediation is a method in which an organism can be used alone or is used in association with some other organisms for better remediation[15]. Phytoremediation is an advancing technology in which contaminated metals are remediated by plant and get accumulated in any part of plant or volatile metals are volatilised in environment. It is a growing technology as microbes and plants have natural remediation properties it is an eco-friendly and cost effective method . But one of the major disadvantage of this method is that it is very time consuming.

4. CONCLUSION

Increased concentration of metal in the soil has adversely affected the plants, animals and human life. It is a necessity to remediate soil for a healthy ecosystem. Bioremediation has turned up as a advance and effective technology to achieve this objective but its drawback has created the need to look up for a better alternative. A large number of governmental and non-governmental organizations are working in this direction. Many research projects are also running worldwide to find a better solution.

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