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Review

Heavy Metal Pollution – Current threat to Environment

Dipanwita Das [1,*], Debargha Chakraborty [2]

1 Asst. Professor, Department of Environmental Science, Amity University, Kolkata, West Bengal

2 Former Research Scholar, Department of Environmental Science, University of Kalyani, Nadia, West Bengal.

*Corresponding author: ddas@kol.amity.edu

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Abstract: The release of toxic effluents from a variety of sources into the environment has become a major worldwide concern. One of the main ingredients in these undesirable industrial effluents is heavy metals. Although heavy metals are naturally occurring components of the earth's crust, human activity has significantly changed the geochemical cycles and biological balance of these elements. Heavy metals are mostly found in the effluent of certain sectors, including electroplating, paints, plastics, tanneries, and batteries. The government and other public sectors are developing strategies and putting various techniques into practice to properly mitigate the pollution caused by heavy metals. Conventional methods of extracting metals are often expensive and dangerous due to the potential for producing toxic byproducts. Additionally, those methods of treatment (which are primarily chemical and physical and include reverse osmosis, chemical precipitation, ion exchange, and evaporative recovery).

Keywords: Heavy metal; Pollution; Environment; Remediation; Bioremediation

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1. Introduction

"Heavy metal" is a general collective term for a group of metals and metalloids with an atomic density greater than 4000 kg m^{-3} or 5 times that of water and which are natural components of the earth's crust [1]. Although some of them act as essential trace elements for living organisms, in higher concentrations they can cause serious poisoning [2]. The most toxic forms of these metals in their ionic species are the most stable oxidation states, such as Cd^{2+}, Pb^{2+}, Hg^{2+}, Ag^{+} and As^{3+}, where they react with body biomolecules to form very stable bio-toxic compounds that are difficult to isolate [3]. In recent decades, biosphere pollution has increased significantly due to the release of chemicals and heavy metals such as cadmium (Cd), nickel (Ni), zinc (Zn), lead (Pb), copper (Cu) and mercury (Hg), etc.

This is because of various factors such as mining, smelting, manufacturing, use of pesticides and agricultural fertilizers, municipal wastes, traffic emissions, industrial effluents, and industrial chemicals. In most major cities, the issue of hazardous metal-induced environmental contamination is starting to become a concern. The introduction of hazardous heavy metals into the environment can result in biomagnification, bioaccumulation, and geo-accumulation. Heavy metal pollution of the environment is a global problem. It is peculiar to certain regions of the bio-geosphere and exists everywhere, albeit to varying degrees.

Pollution with heavy metal ions such as mercury, lead and copper has become an important risk factor due to their possible toxic effects [4]. For example, risks of Hg (II) exposure may include adverse effects on the central nervous system, lungs, kidney function and chromosomes [5]. Pb (II), on the other hand, can bioaccumulate through the food chain, while long-term inhalation of Cu (II) mist is said to increase the risk of lung cancer [4]. Numerous organic and inorganic compounds, heavy metals, especially pollute the environment. Living organisms cannot quickly prepare and adapt to the sudden and huge environmental load caused by various toxic substances, and therefore the accumulation of certain elements, especially toxic heavy metals, can cause unwanted changes in the biosphere, the consequences of which are unpredictable [6].Over the past decade, many countries have spent billions of dollars to clean up contaminated groundwater and soil.

2. Physico-Chemical Methods of Heavy Metal Removal from Environment

Ion exchange, chemical precipitation, and electrochemical removal are examples of conventional treatment methods that can be used to remove heavy metals from inorganic wastewater. Chemical precipitation is the method most frequently used in industry to remove heavy metals from solutions; approximately 75% of electroplating facilities treat their wastewaters with precipitation treatment, which can involve the use of hydroxide, carbonate, sulfide, or some combination of these treatments. Hydroxide treatment is the most widely utilized precipitation method because of its convenience of use, affordability of precipitant (lime), and simplicity of automatic pH control.

Gopalratnam *et al.* found 80% Zn, Cu, and Pb removal and up to 96.2% oil removal from industrial wastewater using a combined hydroxide precipitation and air flotation system [7]. Lime and limestone are the most commonly used precipitants due to their availability and affordability in most countries [8]. However, chemical precipitation requires large amounts of chemicals to reduce metals to acceptable levels for disposal. Other disadvantages include its excessive sludge formation requiring additional treatment, slow metal deposition, poor settling, fine metal aggregation, and long-term environmental effects of sludge disposal [8].

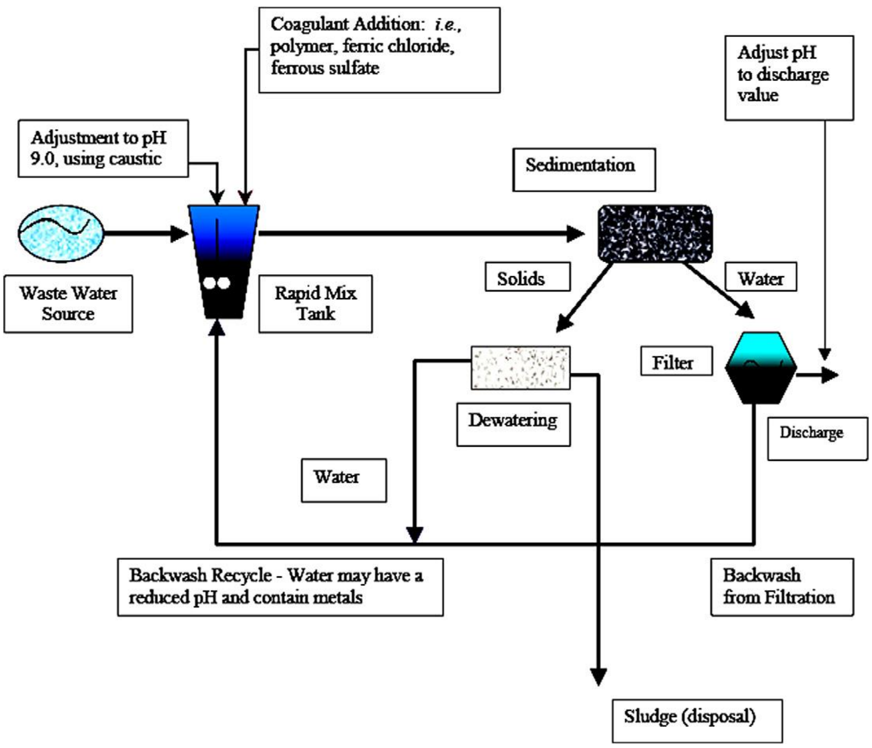

Figure 1 Processes of a conventional metals precipitation treatment plant.

Heavy metals have been shown to be removed from solutions via flocculation and coagulation. The neutralization of the particle charges is referred to as coagulation. Slow mixing is used in flocculation to encourage the destabilized particles to clump together. One new technique for treating water that has been effectively used to treat a variety of wastewaters is electrocoagulation. It has been used to treat heavy metal-laden wastewater, potable water and urban wastewater [9]. Using a surfactant to make a non-surface active substance surface active and generate a product that is removed by bubbling a gas through the bulk solution to form foam is the basis for flotation. There has been extensive research on the removal of heavy metals using foam flotation techniques.

Heavy metals can be effectively removed from waste waters via ion exchange. The removal of heavy metals is achieved through a reversible chemical reaction in which the ions in wastewater exchange places with those on the resin. Liquid ion exchange has been the subject of recent study concerning the removal of heavy metals from plating wastes. This method's drawback is that it cannot handle concentrated metal solutions since the wastewater's organics and other particles readily contaminate the matrix. In addition, ion exchange is very sensitive to the pH of the solution and is not selective. One obvious drawback was the possibility of corrosion turning into a major impediment, requiring frequent electrode replacements.

A solution containing the dissolved metallic ions comes into contact with a more active metal, such as iron, during the cementation process, which replaces metals. Thus, the process of cementation involves the spontaneous electrochemical reduction of an ionized metal in solution.to the elemental metallic state, followed by the oxidation of a metal serving as a substitute (iron, for example).

The process of complexation entails the use of a chelating or complexing agent to create a complex chemical. By creating a complex ion that lacks the chemical interactions of the removed ion—that is, by becoming bound up or complexed—sequestration entails removing a metal ion from solution. These techniques do, however, have a number of drawbacks, including a high reagent demand, erratic metal ion removal, the production of toxic sludge, etc.

The adsorption process has emerged as the most popular technique for eliminating hazardous pollutants from wastewater due to its ease of use, affordability, efficacy, and versatility. When a gas or liquid solute builds up on the surface of a solid or liquid (adsorbent), a molecular or atomic film is formed (the adsorbate). This process is known as adsorption. The most popular adsorbent on the market is activated carbon. Typically manufactured in small pellets or powder form, it is an amorphous solid with high porosity that is composed of micro crystallites with a graphite lattice. Numerous harmful metals are capable of being eliminated. Activated carbon clay minerals, biomaterials, industrial solid wastes, and zeolites are a few commonly utilized adsorbents for the adsorption of metal ions [10, 11].

3. Biological Methods for Heavy Metal Removal

The majority of conventional heavy metal removal methods are expensive and have insufficient efficiency at low metal concentrations, especially in the 1-100 mg/l range [12]. The disposal of the toxic sludges produced by some of these processes adds to the challenge of making treatment operations technologically and economically feasible. The hunt for more efficient ways to sequester metal has been prompted by these limitations. This option presents sorbents for biological techniques [13]. It was determinedly necessary to create an inexpensive, environmentally friendly method of eliminating contaminants, especially heavy metals. Therefore, by promoting the microbial and associated biota (flora and fauna) within the ecosystem to degrade, accumulate, and/or remove the pollutants from the designated areas, researchers propose a workable strategy to expedite the process of decay and removal of heavy metals. Therefore, bioremediation presents a compelling substitute. Phytoremediation, bioventing, bioleaching, l and farming, bioreactor, composting, bioaugmentation, rhizo-filtration, and bio-stimulation are a few methods associated with bioremediation.

Algae has also been used for removal of heavy metals from wastewaters and for concentration of valuable metals from dilute solutions Mane *et al*., have used pre-treated algal biomass to remove one of the heavy metal namely selenium [14]. For this investigation, they employed algae isolates from Viz., Spirogyra sp., and the Nostoc community. They discovered that selenium may be significantly removed from the Spirogyra sp. and Nostoc population through physical or chemical treatment. Additionally, they saw that, as compared to living biomass, pre-treatment of biomass with NaOH increased selenium biosorption.

An investigation on the bio-sorbents utilized for heavy metal removal was conducted by Wang and Chen [15] Their research highlights biomass's potential for heavy metal reduction in wastewater treatment applications.

Various macrophytes (spermatophytes, pteridophytes, mosses) have also been described as efficient collectors of heavy metals. Their ability to over accumulate heavy metals makes them interesting candidates for research, especially in the treatment of industrial wastewater and sewage [16, 17]. Aravind *et al*.,reported that the addition of the heavy metal Zn in a Cd-containing growth medium reduced Cd accumulation in *Ceratophyllum demersum*, indicating the existence of metal-metal interactions (Zn and Cd) [18]. *Azolla*, a free-floating, fast-growing, nitrogen-fixing pteridophyte, appears to be an excellent candidate for the removal, removal and solubilization of heavy metals in polluted aquatic ecosystems [19].

4. Microbes in Heavy Metal Removal

Microorganisms are nature's original recyclers, transforming toxic organic substances into harmless products, often carbon dioxide and water. Interest in microbial biodegradation of pollutants has increased in recent years as humanity strives to find sustainable ways to clean up polluted environments transform or accumulate a huge number of compounds, including hydrocarbons (such as petroleum), polychlorinated biphenyls (PCBs), polyaromatic hydrocarbons (PAHs), heterocyclic compounds (such as pyridine or quinoline), drugs, radionuclides and metals. Various microorganisms such as bacteria, fungi, algae and yeasts are usually used to control metal pollution through bioremediation, because they have the potential to internally accumulate various heavy metals [20]. Ashok *et al.*, confirmed that different bacterial strains were used to remove heavy metals from the aquatic environment [21]. Hanjun *et al.*, also reported bio-removal of cadmium from aquatic environment using endophytic bacterial bacillus species [22]. Many studies have shown that several species of bacteria were able to remove metals from the aquatic environment [23]. Recently, Basha and Rajganesh isolated four heavy metal resistant bacterial strains namely Escherichia coli, Salmonella typhi, Bacillus licheniformis and Pseudomonas fluorescein from textile industry wastewater used for bioremediation of heavy metals from textile dye waste [24].

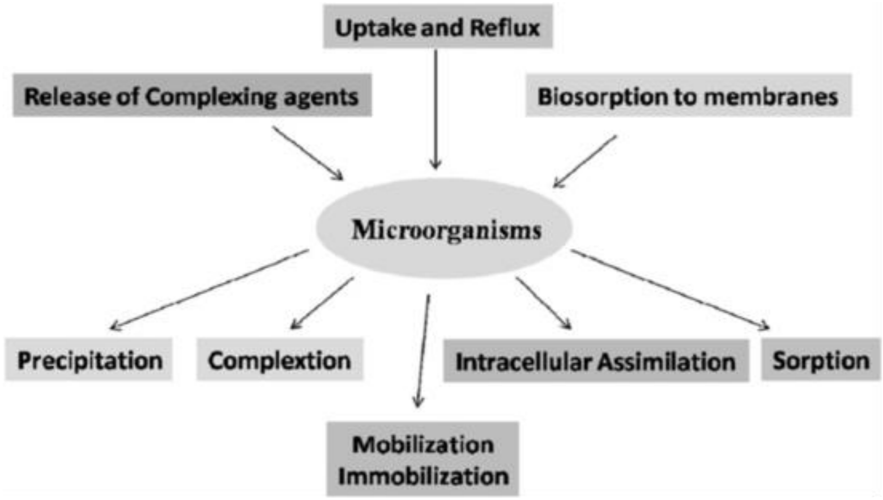

Figure 2 Metal-processing features adopted by microbes to be utilized in metal bioremediation processes.

5. Conclusions

Significant growth in agriculture, industry and technological growth, in addition to popu lation growth, has caused environmental degradation all over the world. Rapidly growing citi es, increasing traffic on roads, increasing energy consumption and waste production, as well a s the lack of strict compliance with environmental requirements increase the release of polluta nts into the air, water and soil. Microbial bioremediation is gaining attention as an important method to reduce metal pollution due to its low cost and high efficiency. Microbial metal bior emediation is an ecological, cost-effective and efficient strategy. To combat heavy metal pollut ion. Advances in the understanding of metal-microbe interactions have provided impetus to u se technology to develop more efficient microbes with greater potential for metal accumulatio n and/or detoxification to minimize heavy metal bioavailability and biotoxicity. Thus, biorem ediation has been introduced as a unique management method to control heavy metal polluti on, which is one of the major upcoming global problems in the current era of industrial boom.

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