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Removing Metal Ions From Aqueous Solutions Through Biosorption

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ABSTRACT

Biosorption is a biotechnological breakthrough that provides an efficient, low-cost approach for detoxifying water of toxic metals. As so, it is illustrative of a common method for making use of less expensive biological alternatives for the same effect. One of the most important parts of modern environmental and bioresource technologies is biosorption. Due to their high surface to volume ratio, abundant availability, quick kinetics of adsorption and desorption, and low cost, the use of microorganisms (such as bacteria, algae, yeasts, and fungus) as biosorbents for heavy metal removal is attracting increasing attention. This review of the literature centres on different biosorbents, different biosorption methods, and different variables that impact biosorption ability. Biosorption, as a technique with potential to compete with standard industrial techniques, has also been examined critically.

Keywords: Biosorption, Heavy metals, Environment, Lead, Cadmium, Chromium

I. INTRODUCTION

One of the most pressing issues facing the planet today is the pollution caused by heavy metals. Table 1 details the origins of various material ions and the harm they can do to living things. This metal ion is not biodegradable and stays in the environment forever. Consequently, it is critical to preserve public health by removing heavy metal ions from wastewater. Heavy metal concentrations are often caused by industrial effluents, which can originate from a wide variety of sources, including pipe corrosion, waste dumping, electroplating, electrolysis, electro-osmosis, mining, surface finishing, energy and fuel production, fertiliser and pesticide production, leather processing, metal surface treating, photography, aerospace and atomic energy installations, and so on. Thus, heavy metals in effluent streams must be removed and recovered if environmental safety is to be ensured. Physical, chemical, and biological processes are the most common ways of precipitating metal ions out of water. Heavy metal ions are often removed from aqueous wastes using tried-and-true methods such chemical precipitation, lime coagulation, solvent extraction, membrane filtration, reverse osmosis, ion exchange, and adsorption. Traditional techniques of metal removal have their own advantages and disadvantages due to the specifics of each procedure (incomplete metal removal, high reagent and energy requirements, generation of toxic sludge or other waste products). When the concentration of heavy metals in aqueous effluents is more than the allowed value (less than 1 mg/L), most of these approaches are either unsuccessful or uneconomical because of the high expense involved in removing the metals. Cost-effective alternative technologies are increasingly being used because to rising environmental consciousness and stricter legislative restrictions on effluents.

Biosorption occurs rapidly and is characterised by the non-growing biomass/adsorbents sequestering metals passively. Some of the benefits it offers over more traditional methods are as follows: (low cost; high efficiency; minimization of chemical and or biological sludge; no additional nutrient requirement; regeneration of biosorbent; and possibility of metal recovery). An inorganic substance (the sorbent or biosorbent; adsorbent; biological material) and a liquid (the solvent, often water) containing a dissolved component to be adsorbed are required for the biosorption process to take place (adsorbate, metal). Because the adsorbent has a greater affinity for the adsorbate species, the latter is drawn to it and bonded there by several methods. Until equilibrium is reached between the quantity of adsorbate species bound to the solid and the amount still in solution, the process will continue. The adsorbate is partitioned between the solid and liquid phases based on the adsorbent's affinity for the adsorbate. Although the biosorption method, which employs microorganisms for the purpose of removing and recovering heavy metals from aqueous solutions, has been around for a while, it has only recently emerged as a low-cost, potentially useful technique. Metal ions undergo physico-chemical interactions with the cellular compounds of living organisms, leading to their absorption. This has led to a lot of research over the past two decades into the possibility of using biomaterial for the absorption of heavy metals.

II. BIOSORPTION – A DEEPER INSIGHT

An example of a biological physico-chemical process, biosorption involves the uptake of a target species (such as metal ions or dyes) by a living substance (such as plant biomass or microbes) (Gadd, 2009). The biosorbent (e.g., plants, bacteria, fungus) is a solid component of the biosorption process, and the liquid component, the sorbate, is typically an aqueous solution containing the metal ions. Biosorbents including algae, bacteria, fungus, and plants are frequently employed to detoxify water supplies that have been contaminated with toxic metals. A biological sorbent's cell wall is its primary biosorption location. Functional groups such as hydroxyl (found in alcohols and carbohydrates), carboxyl (found in fatty acids, proteins, and organic acids), amino (found in proteins and nucleic acids), ester (found in lipids), sulfhydryl (found in cysteine (amino acid) and proteins), and carbonyl (can be terminal such as in lysine) all contribute to the biosorption process and may be able to biosorb heavy metals (found in DNA, RNA and tissue plasminogen activator). Titration, infrared spectroscopy (IR), raman spectroscopy, X-ray photoelectron spectroscopy (XPS), energy-dispersive X-ray spectroscopy (EDS), and X-ray absorption fine structure spectroscopy are just some of the analytical techniques that can be used to study and analyse the functional groups of a biosorbent that contribute in the removal of a specific metal.

Biosorption capacity value and equilibrium time for the biosorption process are used to assess the feasibility of biosorption of a metal ion by a biosorbent. The following formula can be used to determine a substance's biosorption capacity:

$$q_e = (C_0 - C_e)\ V/W$$

Where C0 and Ce are the starting and equilibrium concentrations of metal ions in mg/L, V is the volume of metal ion solution in L, and W is the quantity of biosorbent material dosage employed, qe is the biosorption capacity (in mg of metal/g of biosorbent) (in g). More heavy metal ions can be bioabsorbed by a biosorbent with a greater biosorption capability. When the media's pH and temperature are just right, biosorption capacity can increase to its maximum. Although the biosorption capacity may be improved by adjusting the pH and temperature as well as other parameters (such as the contact time between the biosorbent and the metal ion solution and the amount of biosorbent used), these two variables have the greatest impact. The biosorption ability of a biosorbent is crucial when selecting one for the removal of a certain metal ion. Biosorbents with a greater biosorption capacity are preferable since they can potentially biosorb more sorbate, whereas biosorbents with a lower biosorption capacity will need to be replaced sooner rather than later. But other factors, such as the biosorbent's reusability and the speed with which it may biosorb target species in relation to its removal effectiveness, should be taken into account as well.

III. BIOSORPTION OF SELECTED HEAVY METALS

- **Biosorption of lead**

The transition metal lead is quite dense. Discharged lead (II) ions in the environment are estimated to have concentrations between 5-66 mg/L from the battery sector, 0.02-2.5 mg/L from the mining industry, and 125-150 mg/L from the oil business. The effects of lead on both plants and animals are well-documented. Anemia, brain damage, mental deficiency, renal damage, encephalopathy, anorexia, cognitive impairment, behavioural difficulties, and vomiting are only few of the illnesses it causes in people. Some enzymes and biomolecules include thio, oxo, or phosphate groups, and lead(II) ions have a strong affinity for them. Lead bioaccumulates in humans when it binds to those enzymes, altering cellular membrane permeability and potentially affecting haemoglobin formation and organ function (its half-time is over 20 years). It is crucial, therefore, to treat wastewater for lead before releasing it into the environment. Studies comparing the biosorption capacities of several biosorbents for the elimination of lead (II) ions from aqueous solutions are reported in Table 1 below

Table 1: Comparison Between Biosorption Capacity Of Different Biosorbents For Removal Of Lead(Ii) Ions From Aqueous Media

Biosorbent	Biosorbent Type	Maximum Biosorption Capacity (mg/g)

Pokeweed (untreated)	Plant	13.19
Pokeweed (treated with nitric acid)	Plant	14.51
Durian tree sawdust	Plant	20.37
Olive tree pruning (untreated)	Plant	27.05
Coconut coir	Plant	37.04
Oil palm empty fruit bunch	Plant	37.59
Peanut shells	Plant	39
Cyclosorus interruptus	Plant (Fern)	46.25
Olive tree pruning (treated with sulphuric acid)	Plant	65.62
Olive tree pruning (treated with nitric acid)	Plant	85.09
Olive tree pruning (treated with sodium hydroxide)	Plant	121.06
Anabaena sphaerica	Algae	121.95

- **Biosorption of chromium**

In a heavy metal, chromium is typically found in aquatic environments as the trivalent and hexavalent forms, and it is poisonous, carcinogenic, mutagenic, and teratogenic. Due to its high mobility and solubility in an aqueous environment, hexavalent chromium is one of the most pervasive contaminants in both surface water and groundwater. It is also approximately 500 times more hazardous than trivalent chromium. Allergies, breathing problems, a compromised immune system, and damage to the kidneys, liver, and stomach are all possible outcomes in people. Chromium is mostly obtained via the following manufacturing processes: electroplating, textile and metal finishing, iron and steel foundries, inorganic chemical plants, and tanneries. Removing chromium from wastewater is a crucial step for industry before dumping it into the environment. Selected studies comparing the biosorption ability of various biosorbents for the removal of various chromium forms from aqueous solutions are reported in Table 2.

Table 2: Comparison between Biosorption Capacities of Different Biosorbents for Removal of Chromium Ions from Aqueous Media

Biosorbent	Biosorbent Type	Chromium Sorbate	Maximum Biosorption Capacity (mg/g)
Opuntia ectodermis	Plant	Cr(VI)	16.4
Opuntia cladodes	Plant	Cr(VI)	18.5
Portulaca Oleracea	Plant	Cr(VI)	54.95
Spirulina sp.	Algae	Cr(VI)	90.91
Pleutrotus sajor-caju	Fungi	Cr(VI)	122.36
Ganoderma lucidum	Fungi	Cr(VI)	127.28
Agaricus bitorquis	Fungi	Cr(VI)	127.92
Pleutrotus sajor-caju	Fungi	Cr(III)	141.88
Ganoderma lucidum	Fungi	Cr(III)	149.58
Agaricus bitorquis	Fungi	Cr(III)	152.74
Chlorella vulgaris	Algae	Cr(VI)	161.41
Watermelon rind	Plant	Cr(III)	172.6
Aspergillus flavus	Fungi	Cr(III)	257
Cupressus lusitanica bark	Plant	Cr(VI)	305.4

- **Biosorption of cadmium**

Photosynthetic plants and fish collect cadmium and subsequently transfer it to people. Cadmium can lead to anaemia by competing with iron for binding sites on cysteine, glutamate, histidine, and aspartate. Hepatotoxicity results from cadmium's compound formation with cysteine-rich proteins such metallothionein in the liver; nephrotoxicity results from the metal's accumulation in the kidneys due to circulation and transport. Electroplating, smelting, paint pigments, batteries, fertilisers, mining, and alloy production are all major contributors to cadmium pollution. Table 3 displays a comparison of the biosorption ability of the various biosorbents tested for the elimination of cadmium ions.

Table 3: Comparison Between Biosorption Capacity Of Different Biosorbents For Removal Of Cadmium (Ii) From Aqueous Media

Biosorbent	Biosorbent Type	Maximum Biosorption Capacity (mg/g)
Ulva lactuca	Algae	29.1
Streptomyces rimosus	Bacteria	64.9
Saccharomyces cerevisiae	Fungi	68.78
Aloe vera waste	Plant	104.2
Anabaena sphaerica	Algae	111.1
Klebsiella sp.	Bacteria	170.4

IV. CONCLUSION

Heavy metal ions are discussed in this research for their origins as well as the reasons why they must be eliminated from the environment. It may be costly to remove waste using traditional means, therefore it's imperative that we find alternate ways to do it, preferably ones that don't harm the environment. Based on the research shown above, it is clear that biosorption is the best option for removing heavy metals from both municipal and industrial wastewater since it is both cost-effective and gentle on the environment. When it comes to cleaning up industrial wastewater, this technique is proving to be a viable alternative to the tried-and-true ways of the past. It has a number of advantages, including as low cost, high efficiency, reduced chemical and biological sludge, and the ability to regenerate biosorbent while potentially recovering metals. Since biosorption techniques are non-hazardous and may be used for a long time, they can be a practical alternative to conventional industrial techniques for removing heavy metals. Algae, bacteria, fungus, and plants are just few of the many biosorbent materials that may be employed. Physical adsorption, ion exchange, complexation, precipitation, and transport through cells are all possible biosorption processes.

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