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Mini Review

Biosorption of Heavy Metals: A Mini Review

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Abstract

Heavy metal bearing effluents may be considered a major source of contamination causing serious environmental problems. Removal of these heavy metals from industrial wastewater is therefore imperative. Conventional techniques are quite expensive and not too efficient. Biosorption of heavy metals from wastewater using different types of biosorbents has appeared as an efficient and low-cost technique. Hence, series of extensive studies are required in this area.

Keywords: Biosorption; Metals; Technique

Introduction

Water covers about three quarter of the earth surface, making it the most abundant liquid on earth with a massive volume of about 1.5 x 10^{18} metric tons. It is known as blue gold, lifeline on earth and one of the most priceless gifts of nature. The quantity of water on earth is about three hundred times larger than the mass of the entire atmosphere [1]. Ninety seven percent of this volume is salty water contained within the seas and oceans. However, animals require fresh water for consumption while humans require freshwater for domestic and industrial activities, with fresh water making up just 3% of the total amount of water on earth. Much of this 3% of freshwater are locked up as icebergs or deep groundwater. Less than 1% of the earth's water exists as accessible freshwater available for human use [2]. Thus, despite the massive amounts of available water, freshwater sources are scarce with the limited sources of freshwater under high use. Significant resources and efforts will be required to find new sources of freshwater [3]. Natural water is never entirely 100% pure as it contains traces of other substances which bestow on it physical, chemical and bacteriological properties.

One of the major challenges facing developing countries is low/no capacity to manage the huge amount of waste generated regularly through different anthropogenic activities. More challenging is the indiscriminate disposal of these wastes into the environment with the aquatic system acting as endpoint. This often renders the water resources almost useless for both primary and/or secondary use [4]. Contamination of water bodies with heavy metals is now a global challenge due to fact that they are persistent in nature, biocummulate, toxic at low concentration and are non-biodegradable. Hence, there is a need to remove them from industrial effluents. Some of the conventional techniques that have been used for heavy metals removal include chemical precipitation, membrane filtration, ion exchange, reverse osmosis, electrochemical methods, solvent extraction and coagulation. However, these techniques may show one or more technical and/or economical disadvantages such as high energy demand, high cost of reagents, long processing time, high sensitivity to operational conditions, sludge generation and low efficiency at high metal concentration. Therefore, there is a need to develop low-cost and ecofriendly techniques like adsorption [5].

Definition of terms

- Heavy metals are metals with specific gravity greater than 5.0 g/cm^3.
- Adsorption is the transfer of molecules, ions or atoms from one phase (solid, liquid or gas) to another phase (liquid or solid). It differs from absorption being a surface phenomenon while absorption is a bulk phenomenon.

- Biosorption is the ability of biological materials to accumulate ions, atoms or molecules from wastewater or aqueous solutions through physico-chemical pathways of uptake.
- Biosorbent is a biological material on which adsorption is taking place.
- Sorbate/adsorbate is a material which is adsorbed.

Sources of heavy metal pollution

- **Cadmium:** ceramics, fertilizer, fungicides, mining, plastics.
- **Lead:** pipes, paints, mining, burning of fossil fuels, canned foods, batteries
- **Mercury:** batteries, mining, dental fillings, vaccines, fish, paint.
- **Nickel:** diesel exhaust, foods, batteries, electroplating, pigments
- **Arsenic:** pesticides, herbicides, smelting, semiconductors, rock sedimentation
- **Copper:** leather processing, pesticides, fungicides, volcanic eruption, mining
- **Chromium:** leather tanning, steel production, textile industries, electroplating.
- **Bismuth:** byproduct of copper and lead mining, paints.

Regulatory discharge limits for wastewater containing heavy metals

Different regulatory agencies have set maximum values for heavy metals in industrial effluent before discharge into the water bodies. The table below shows the world health guideline for drinking water and health effect of the metals.

Constituents	Health effects	WHO Permissible limit for drinking water
Antimony	Increased in blood cholesterol; decrease in blood glucose	0.005 mg/l
Arsenic	Skin damage; circulatory system problems; increased risk of cancer, bone marrow depression	0.01 mg/l
Cadmium	Hypertension, carcinogenic, teratogenic, mutagenic, liver and kidney damage, Itai-Itai disease and weight loss	0.003 mg/l
Chromium	Chronic toxicity (above 5mg/l), bleeding of the gastrointestinal tract, ulcers of the skin and mucus membrane	0.05 mg/l
Copper	Short term: exposure: gastrointestinal distress. Long term: exposure: liver or kidney damage. Wilson's disease causes the body to retain copper that can lead to brain and liver damage. Neurotoxicity, acute toxicity, dizziness, diarrhea	2.0 mg/l
Iron	Essential nutrient, no proven health hazard	No guideline value
Lead	Blood level value above 100ppb can inhibit haem synthesis; irritation, mental retardation, brain damage, tumour producing, encephalopathy, seizures, loss of appetite	0.01 mg/l
Manganese	Neurotoxin at high level	0.1 mg/l
Mercury	Mental disturbances, gingivitis, haematological changes, insomnia, chest pain, dysponoea, haemoptysis, impairment of pulmonary function, abortion and foetal malnutrition, Minamata disease is well known for mercury's bio-enhancement and toxicity. Corrosive to skin, eyes, muscles	0.001 mg/l
Molybdenum	Some evidence of carcinogenicity	0.07 mg/l
Nickel	Carcinogenic, affects reproductive health, chronic bronchitis, reduced ling function, lung cancer	0.02 mg/l
Selenium	Depression of growth, liver pathology, manifest in nails, hair and liver	0.01 mg/l
Silver	Argiria (discolouration of hair and skin)	No guideline value
Uranium	Effects on kidney, nephropathy, destruction of kidney cells	1.4mg/l
Zinc	Short term "metal-fume fever", gastrointestinal distress	3mg/l

Table: Health effects of heavy metals and WHO guidelines for drinking water (2008).

Advantages of biosorption

The following are the potential advantages of biosorption over other conventional techniques for heavy metals removal from wastewater:

- Availability of vast/large number of low-cost biomaterials;
- Fast kinetics that ensure short processing time for large volume of waste;
- Almost no sludge generation;
- Low energy demand;
- Low consumption of expensive chemicals;
- Relatively high efficiency at low and high metal concentration;
- Relatively low capital demand due to availability of low cost biomaterials;
- High possibility of regenerating and re-using biosorbents;
- Suitable for almost all metals with high recovery;
- Metals can be removed in the presence of another ion.

Factors affecting biosorption

- Temperature
- pH
- Nature of biosorbent
- Initial metal ion concentration
- Time
- Agitation time
- Presence of other ions
- Surface area of biosorbent
- Biosorbent dosage

Mechanism(S) of biosorption

Biosorption involves binding of atoms, ions or molecules to materials of biological origin which involves a passive or physicochemical uptake of the chemical specie to a biomass, independent of metabolism. The mechanism(s) involved in biosorption are difficult to identify.

Biosorption, metal sequestration can occur via:

- Adsorption (ionic, chemical and physical)
- Ion exchange
- Complexation/coordination
- Precipitation

Potential biosorbents

- **Keratinous materials:** Feathers, fur, hair etc
- **Bacteria:**
- **Gram-negative bacteria:** *Escherichia coli, Pseudomonas aeruginosa*
- **Gram-positive bacteria:** *Bacillus subtilis, Micrococcus luteus*
- **Cyanobacteria:** *Ananaena sp, Synechocystis sp*
- **Algae:**
- **Seaweed (macro-algae):** *Ecklonia Maxima, Lesonia flavicans, Sargassum* seaweed
- **Micro-algae:** *Chamydomonas sp*
- **Red sea weed:** *Porphyra sp*
- **Fungi:**
- **Mold:** *Spinellus fusiger*, *Aspergillus oryzae*
- **Mushrooms:** *Agaricus bisporus, Russula brevipes*
- **Yeast:** *Saccharomyces cerevisiae, Candida albicans*
- **Agricultural waste:**
- **Shells:** Coconut shell, palm karnel shell, groundnut shell
- **Husk/Bran/Straws:** Rice husk, wheat bran
- **Aquatic waste:** Snail shell, fish bones
- **Others:** Fruit/vegetable wastes
- **Industrial waste:** Activated sludges, fermentation wastes
- **Plant residues:** Sawdust, dried weeds
- **Other:** Chitosan, chitin, cellulose based materials.

Conclusion

This work highlighted the toxic effect of heavy metals and the need to develop an eco-friendly technique like biosorption. Conventional techniques are expensive and not as efficient as biosorption. From this work, it is obvious that biosorption is an eco-friendly and economical technique for heavy metal removal. Potential adsorbents include keratinous materials, bacteria, fungi, algae, agricultural waste, industrial wastes and plant residue. Hence, there is a need to carry out more extensive work with these biosorbents.

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