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A Review on Removal of Heavy Metals from Aqueous Solution using Low Cost Adsorbents

Amandeep Kaur | Renu Sharma | Tanuja Srivastava | Tejinderpal Singh | Deepshikha

Bhai Gurdas Institute of Engineering & Technology, Sangrur, Punjab, India.

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ABSTRACT

Heavy metals toxicity caused by industrial waste water and other natural sources has become a threat to environment and ecosystem for the past many decades. Very small concentration of metallic ions present in water increases health problems to living organisms. Although there are various conventional treatment methods such as chemical precipitation, ion exchange, coagulation, flocculation, electrochemical technique, adsorption and co-precipitation are available for removal of heavy metals from aqueous solution. A number of researchers paid their attention towards biosorption which involve highly effective and economical adsorption technique for removal of heavy metals using various inexpensive adsorbents such as agricultural waste material, waste by products of pharmaceutical fermentation, food processing, fruit waste and dead microbial biomass. The use of low cost adsorbents is highly preferable due to reduced cost of waste disposal and thus leads to environmental protection. In this review paper, a compiled scattered available research work related to use of various adsorbents for the removal of commonly occurring heavy metals have been reported.

General Terms

Adsorption

Keywords : *Biosorption, Heavy metals, Adsorbents, Adsorption.*

I. INTRODUCTION

Water is an important source of life, energy and thus is essential element to all living things on earth. The purest form of water is colorless, odorless and tasteless in nature. The level of contaminants has increased due to discharge of industrial effluents in aquatic ecosystems which pollute and contaminate water streams naturally [1]. Water pollution raises a great concern now a days due to rapid industrialization e.g. domestic water, sewage, alley metal mining operations, agricultural waste, fertilizers, feather industries and pesticides which have largely discharged various types of pollutants into environment and cause disorder into ecosystem. However millions of people worldwide are suffering from shortage of fresh and clean drinking water chemicals, paper, petroleum and primarily metal sectors cause about 97% of water contamination. Heavy metal pollution caused by industrial activities and technological development is posing significant threats to environment because of its toxicity, non biodegradability, bioaccumulation and persistent tendency through food chain.

Heavy metals refer to any elements with high atomic weights and high density. These metals are highly toxic even at low concentration.

They cause serious problem to human life and to aquatic, vegetation cover [2]. The heavy

metals get adsorbed and accumulated in human body causing serious health diseases such as cancer, damaging of nervous system, organ damage and even death. It also retards growth and development of living organisms.

Zn, Ni, Cu, Hg and many other heavy metals are generally found in industrial waste water effluents [3]. They all cause many health problems and environmental problems. Zinc cause paralysis and neurological problems [4]. Some other unwanted effects include dizziness, breathing problems, chest pain and many others. Nickel is other toxic metal known as environment pollutant. It is one of shiny metal so is commonly used in jewellery. chromium is other heavy toxic metal, presence of which beyond a limit disturb many biological functions of plants. Mercury causes Asthma and temporary respiratory problems. The harmful effects from various heavy metals have been described in the **Table 1.**

Table 1 Harmful health effects with intake heavy metals.

Heavy Metal	Health effect
Zinc	State of depression, increased thrist, complete or partial paralysis, neurological problem systems.
Copper	Liver kidney failure, anaemia, gastrointestiral bleeding, nausea, dizziness, respiratory problems.
Nickel	Nausea, coughing, carcinogenic dermatitis, chronic asthma
Iron	Stomach upset, ulcers, mental retardation, liver and brain damage

Hence, there is a need to treat heavy metal contaminated water before discharging it into environment. The objective of this review paper is to provide fundamental information and literature in adsorption of heavy metals from aqueous solution on various types of low cost adsorbents which include agricultural waste biomass, microbial, synthetic, natural and industrial waste by products etc which are also, sources of pollution.

II. METHODS FOR REMOVAL OF HEAVY METALS

Various techniques including precipitation, ion exchange, adsorption, filtration, electrodialysis, reverse osmosis etc. methods are available in literature for removal of heavy metals [5]. These methods are reliable but having certain disadvantages such as use of toxic reagents, high energy requirements, non selective, generation of toxic waste and also require large settling tanks for precipitation of voluminous sludges. Ion exchange method has advantage of allowing recovery of metallic ions, but it is expensive [6]. So, there is a need of safe and economical method for removal of toxic metals. For this purpose, adsorption process is one of the easiest, safest and cost effective processes [7]. This has therefore led to use of adsorbents which have been found significant popularity because of their lower production costs, abundance of their ingredients in nature, low cost of their regeneration and further that they can be simply discharged after expiration. Various low cost adsorbents used for removal of heavy metals are described below:-

2.1 Adsorption on Agricultural waste

Agricultural residues can be used as adsorbent material in removal of heavy metals as they are less costly, require little processing & possess good adsorption capacity [8]. Some of the agricultural waste adsorbents are discussed below:-

2.1.1. Rice straw

Rice straw is one of the agricultural waste materials used as low cost adsorbent material. Rice straw consists of cellulose (32-47%), hemicelluloses (19-27%), lignin [9] (24%). It is basically left residue in agricultural land during harvesting time which is burnt leading to emission visibility and even causes breathing problems. Rice straw serves as potential adsorbing material possessing efficient binding sites that are capable to remove toxic metals from waste effluents [10].

2.1.2. Wheat Bran

Wheat bran has been found good adsorbent for removal of heavy metal ions like Cu, Cd. It has been reported that wheat bran on treating with strong dehydrating agent like H2SO4 shows 5% adsorption efficiency for Cu ions, in 51.5mg/g in 30 min at pH value 5, whereas, it was found 12% for Ni ions [11,12]

2.1.3. Sugarcane baggase

It is a waste product obtained from sugar refining industry that has been tested as adsorbent material for heavy metal removal. It consists of cellulose, lignin and pentosan. The negative charge

of baggase makes it capable to absorb the postitively charged heavy metal ions. It has been reported that sugarcane baggase was found to be efficient adsorbent for removal of Cu and Ni heavy metals with greater adsorption efficiency about 87%-95% [13,14].

2.2 Adsorption on Industrial waste

There are different industrial waste materials that remove heavy metals from aqueous solution. These are quite easily available as by product of many industries. Various industrial adsorbents Such as fly ash, tea waste, saw dust is discussed as:-

2.2.1. Tea waste

Tea is second most used beverage in world after water so tea waste has gained much attention because it is good sorbent material in heavy metal removal such as Fe, Ni. The cell wall material of tea consists of cellulose, lignin carbohydrates that have hydroxyl, oxyl and phenolic groups and could be a good bio sorbent material for heavy metals. It shows 7.1% adsorption for removed of Cu metal [15]

2.2.2. Flyash

Flyash is one of residues produced in coal combustion that composed of fine particles that are driven out with flue gases. It is potentially used for water treatment process due to its chemical composition like silica, alumina, and ferric oxide. It is major air pollutant and water pollutant that disturb ecological balance & causes environmental hazards [16]. It has been reported that flyash is one of industrial waste that serves as better adsorbent for removal of Cu with 70% adsorption efficiency & removal of Ni with 68% adsorption efficiency [17].

2.2.3. Saw dust

Saw dust is by-product obtained from wood industry. It contains many organic compounds like cellulose, lignin and hemicelluloses along with polyphenolic groups that bind heavy metal. Saw dust of fir and popular wood show maximum adsorption capacity as compared with untreated saw dust. On treating with NaOH, saw dust of fir and poplar woods shows maximum uptake of Cu^{+2}, Zn^{+2} metalions. Saw dust was tested as adsorbent material for removal of Cu^{+2} and Zn^{+2} metal ions [18].

2.3 Adsorption on Natural Materials

2.3.1. Peat Moss

It is complex organic substance which is obtained from residue of sphagnum moss & other water logged plants when partially decomposed. Peat moss was found to be one of effective natural adsorbent for heavy metals. Peat moss play vital role in removal of heavy metals from industrial waste water like Zinc, copper [19], chromium. It has been notified by researchers that maximum adsorption efficiency was observed with Peat moss for Cd and Cu it was 39.8mg/g & 1.2mg/g [20].

2.3.1. Banana Peel

Fruit peels like orange peel and banana peel are capable in adsorption of heavy metals as their cell walls are rich in polysaccharides that mainly composed of cellulose and pectin compounds which get ionized on alkaline treatment & generate negative charges which bind metal cations [21]. Annadurai et al., (2003) reported that cellulose based fruit peels like banana and orange peels are (acid and alkali treated) are adsorbent material in adsorption of Cu^{+2}, Zn^{+2}, $Co^{+2,}$ Pb^{+2} and Ni^{+2}. Banana peel exhibits maximum adsorption capacity for heavy metal removal in comparison to orange peel [22].

2.4 Biosorbents

Biosorbents are quite advantageous because of its high effectiveness in heavy metal removal. These can be derived from following sources:

2.4.1. Algae Biosorbent

Algae are one of the autotrophic organisms that has been tested and used as biosorbent material to adsorb toxic heavy metals. Its low cost easy availability with more metal sorption capacity makes it more beneficial biosorbent. It has been reported that with use of spirogyra sp. of algae 14% removal efficiency was observed for lead [23]. Celekli et al., (2010) observed that spirulina platensis showed 7% removal efficiency for copper metal ion [24].

2.4.2. Bacteria Biosorbent

Bacteria are one of the other categories that have been used as biosorbent material because of its size, ability to grow under controlled conditions [25]. Many bacterial species have been tested for heavy metal removal as they have excellent sorption capacity because of their surface to volume ratio and their active chemosorption sites [26]. The removal efficiency for Cu metal ion was found to be 32.5% with Enterobactor species and

17.87% with Arthrobacter sp. of bacteria [27]. For the removal of nickel metal ion E. coli has been tried out with removal efficiency of 6.9% [28].

2.4.3. Fungal Biosorbents

The fungal kingdom is very diverse, with species growing as unicellular yeasts and or branching hyphae that produce a remorbable array of spores and other reproduction structures. The shape and integrity of gungus is dependent upon mechanical strength of cell wall. The fungal cell wall can make up 30% or more of dry weight of gungus. Fungi can be grown easily and produces large biomass. It shows good metal binding property because of presence of cell wall material in large a quantity Alkali treated biomass of Aspergillus niger was used to remove Cd^{2+}, Cu^{2+}, Zn^{2+}, Ni^{2+} with uptake capacity of upto 10% of its weight [29]. About 4% of Cr (VI) has been removed by using fungi pencillium purpurogenum [30]

III. CONCLUSION

A review of various low cost adsorbents presented in this paper shows effectiveness and potential of adsorption process by using low cost adsorbents derived from agro-industrial, dead microorganisms, fermentation. food processing and municipal wastes etc. The use of waste materials as low cost adsorbents for removing various pollutants from aqueous solution presents many features especially their contrilution in reduction of cost for waste disposal, therefore contributing to environmental protection. The adsorption capacity is dependent on the type of adsorbent used and nature of aqueous solution treated. Although amount of available literature data on use of low cost adsorbents in water treatment is increasing at tremendous pace, there are still several gaps which need to be filled.

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