

Removal of Heavy Metals from wastewater: A review

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ABSTRACT

This study reviews methods available to remove heavy metals from industrial wastewater which are useful to small scale industries, effects of some important heavy metals on human health, need for the removal of heavy metals from water resources. Adsorption as economical and convenient method for the removal of heavy metals. Various natural, easily available, low cost adsorbents, various factors which affects adsorption and applications of adsorption in various fields.

Keywords: Heavy metals, Adsorption, Industrial wastewater, Low cost materials.

1.INTRODUCTION

Freshwater resources like ponds, lakes, reservoirs, groundwater, streams and rivers etc. contain water of almost no salt content. They are used to supply water for agriculture, industries, drinking water and as food for fish and other sea animals. But many water resources contain wastes like heavy metals, fertilizers, sewage, decaying animal and vegetable matters and industrial pollutants and waste materials. All these have been proven to be very harmful to aquatic ecosystem.

Natural elements like heavy metals are globally-distributed pollutants. Due to increased use of metallic compounds almost in all fields like cosmetics, construction materials, medicines, processed foods, fuel sources the concentration of heavy metals is found above permissible limit in air, drinking water and soil which causes air, water and soil pollution. Metals have tendency to accumulate in certain parts of the human body in some selected tissues and may become toxic and harmful to life on earth and in water. It is very difficult for everyone to avoid exposure of these heavy metals from surrounding environment.

Industrial effluents mainly contain heavy metals like Arsenic, Silver, Copper, Chromium, Iron, Manganese, Mercury, Nickel, Cobalt, Lead, Zink, Cadmium, etc. These industries are mainly Fertilizer, Tanning, Paper, Printing, Plating, Paint, Mining, Insecticides and Pesticides, Photographic, Electronics etc. [1]

Some heavy metals like copper and iron are essential to life but other metals have no useful role in human and other living organisms.

Effects of heavy metals on human health

Heavy metals which are hazardous to humans are generally includes chromium, copper, lead, cadmium, mercury, zinc,iron, arsenic,cobalt,nickel etc.These metals are found naturally in the soil in trace amounts and in industrial waste water due to different chemical processes like washing,cleaning,precipitation,filtration,ion exchange etc.in trace amount or above the permissible limit which causes few problems.

Name of metal	Source of pollution	Effects
Chromium	Electroplating, tanning, dyeing, leather, textile industries.	Carcinogenic, liver damage,skin irritation,ulcer,edema. [2]
Copper	As contaminant in food especially shellfish, liver, mushroom, nuts, chocolate, PCB designing, electroplating industry.	Carcinogenic,Hemochromatosis , gastrointestinal problems,accumulation in the kidneys,brain, skin and heart. [3]
Lead	Glass, lead paint, printing, Batteries manufacturing industries.	Destruction in kidney, reproductive system, liver, brain and central nervous system, anemia, headache. [4]
Mercury	Paints, pulp and paper, oil refining, rubber processing and fertilizer industries [5] Batteries, thermometers, fluorescent light tubes and high intensity street lamps, pesticides,	Mercury is generally considered to be one of the most toxic metal found in the environment.It causes mental retardation, genetic defects, teratogenic effects. Mercury causes impairment of pulmonary function and kidney, chest pain [5] and dyspnoea.

	cosmetics, pharmaceuticals industries	
Iron	Engineering industries, Dissolution of rocks and minerals in water, sewage.	Haemochromatosis, stains laundry.
Arsenic	Ceramic, fertilizers, detergents, metallurgical, dyes, glasswares, pesticides industries.	Vomiting , diarrhea,black foot disease, cancer. [6]
Nickel	Silver refineries, electroplating industry, metal finishing and forging, batteries manufacturing, mining industries. [7]	Dermatitis, cancer of lungs, Acute poisoning of Ni (II) causes headache, dizziness, nausea vomiting, chest pain, extreme weakness.

Heavy metals not only affect human being but also affects on aquatic organisms.

Need for the removal of heavy metals:

Discharge of domestic, agricultural and industrial wastes in rivers,lakes and different water bodies causes water pollution.If pollutants are heavy metals then they causes above problems and heavy metals cannot be destroyed through biological degradation.Hence there is a need to remove the heavy metals from the waste water. So lot of research is going on to remove heavy metals from waste water. Due to the above toxicological effects of heavy metals on human beings and aquatic life it becomes very essential to treat these toxic heavy metals present in waste water effluents before they are discharged into freshwater bodies.

Methods for the removal of heavy metals:

Several methods are available for the treatment and removal of heavy metals. The commonly used methods for removal of heavy metals from aqueous streams and wastewater include solvent extraction, chemical precipitation, lime coagulation, reverse osmosis, ion exchange, adsorption, cementation, electro deposition etc. [8]

Metals are often toxic and dangerous, widely present in industrial and household wastewaters. Precipitation produces large quantities of solid sludge for disposal; the metal hydroxide sludge resulting from treatment of electroplating wastewater has been classified as a hazardous waste. These conventional methods are ineffective in the removal of low concentrations of heavy metals. Moreover, it is not possible to recover the heavy metals by the above mentioned methods.

Adsorption:

Accumulation of chemical substances at the surface of a solid is called adsorption. The process of removal of an adsorbed substance from the surface is known as desorption. The substance adsorbed on the surface of another substance is called an adsorbate. A substance which adsorbs another substance on its surface is called an adsorbent.

Adsorption is one of the most convenient technique for the removal of heavy metals from wastewater.

Due to regeneration of adsorbent, minimization of chemical and or biological sludge, high efficiency, possibility of metal recovery, [9] flexibility and simplicity of design, the process is suitable even when the metal ions are present in concentration as low as 1mg/L , [10]. insensitivity to toxic pollutants, low cost, easy to operate adsorption has been found to be superior technique as compared to the other methods for the removal of heavy metals from the wastewater. [11] first presented the use of activated carbon for the adsorption of heavy metals.

Types of Adsorption:

The attachment of atoms or molecules of adsorbate on the surface of solids and liquids may be through two types of forces, physical or chemical .Depending upon the types of forces involved in adsorption, it may be divided into two types, physical adsorption or physisorption and chemical adsorption or chemisorptions. [11]

In physical adsorption the forces of attraction between the particles of the adsorbate and the adsorbent are weak Van der Waals' forces. Physical adsorption is relatively weak because Van der Waals' forces are weak.

In chemical adsorption the forces of attraction between the adsorbate and the adsorbent are chemical bonds. It is slow process.

Adsorbents for metal removal:

Literature survey indicates that there are several chemical, biological and waste vegetable matters or substances that have been used by several researchers as adsorbents for the removal of heavy metals from the wastewater.

But to make the adsorption process economic adsorbent should be readily available, inexpensive and environmental friendly. So most of the researchers have been used adsorbent having low cost and which were abundant in nature or the materials which required little processing or was byproduct or waste material from another industry or which has lost its economic or further processing values. Such adsorbents are seaweed, orange peel, peanut skins, bamboo-pulp, dyed sawdust, algae, clay, zeolite, sawdust, flyash, maize or corn cob, modified cotton and wool, tea waste, dyed jute, groundnut shells, [11] coffee, green tea, date tree leaves, jambhool, potato husk, ashoka leaf powder, syzygium cumini, Jute and sun hemp, apple pomace, almond husk, prosopis spicegera, ratrani leaf powder, jute stick, cashew nut shells, cassia siamea, coconut husk, feathers, hairs, bagasse etc.)

Effect of pre-treatment of adsorbents on the adsorption of heavy metals also studied by some researchers and they found that the heavy metal adsorption increased by pretreating the adsorbents with acids like HNO_3 , H_2SO_4 and HCl and alkalis like NaOH . Some examples are 54.3 % Pb removed by Untreated Rice husk and 74.04 % Pb removed by Acid treated Rice husk, [12] 69.2 % Cr removed by Untreated Jambhool leaf powder and 98.4 % Cr removed by HNO_3 treated Jambhool leaf powder, [13] 73.62 % Fe removed by Untreated Syzygium cumini and 94.21 % Fe removed by HNO_3 treated Syzygium cumini [14] etc.

The adsorption is affected by several factors such as contact time, amount of adsorbent, temperature, concentration of adsorbate, pH of solution, etc. [11]

With increase in the amount of adsorbent the removal efficiency increases rapidly which may be attributed to the greater availability of the exchangeable sites or surface areas at higher concentration of the adsorbent. [15]

As contact time increases the adsorption increases up to certain extent and then it remains constant. [16]

The removal of heavy metals from wastewater by adsorption is dependent on the pH of solution.

The decrease in the adsorption capacity with increase in the concentration of metal ion may be attributed to the availability of smaller number of surface sites on the adsorbents for a relatively larger number of adsorbing species at higher concentration. [16]

With increase in temperature metal removal increases. This may be probably due to a decrease in the escaping tendency of the adsorbate species from the surface of the adsorbent. With the purpose of understanding the effect of temperature on adsorption process, thermodynamic parameters such as change in Gibbs free energy (ΔG), enthalpy (ΔH) and entropy (ΔS) should be determined. ΔH and ΔS can be calculated from the slope and intercept of van't Hoff, the plot $\ln K$ versus $1/T$. [17] The positive value of ΔH , indicating the process of metal adsorption is endothermic in nature. While the positive value of ΔS suggests an increase in disorder at the solid-liquid interface. [18]

Applications of adsorption

1. Removal of heavy metals from industrial wastewater
2. Removal of dyes from industrial wastewater [1]
3. Recovery of dyes from dilute solution [11]
4. Gas masks containing adsorbents to purify the air from poisonous gases and vapors. [19]
5. Removal of impurities from petroleum oils
6. Inactivation of bacteria toxin, hormone or a mineral or as antidote in case of poisoning
7. Removal of impurities from motor spirits
8. Purification of enzymes [19]
9. Clarification of sugar liquid
10. Separation of gas mixture
11. In chromatographic analysis
12. In softening of hard water [20]
13. In drying gases, decolourisation and purification [20]

2.CONCLUSION

Among all conventional and modern methods adsorption is a very good alternative for the removal of heavy metals from the industrial wastewater, other polluted water and solutions. It is economical and convenient method. [21] Heavy metal removal capacity of adsorbents can be increased by its pretreatment with alkali or acid. [21] Certain low cost materials which are abundant in nature or which required little processing or which are byproduct or waste material from another industry or which has lost its economic or further processing values and various plant materials can be used as adsorbents to make the adsorption process more economical. The heavy metals can be recovered by this method and the wastewater after this process can be recycled and used for various purposes like for landscaping, irrigation, for industrial processes, for recharging ground water to increase water level, for toilet flushing and for ecosystems. These are the additional advantages and benefits of this adsorption technique.

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