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Heavy metals and their removal from water by adsorbents: A review

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ABSTRACT:

The present article reviews, heavy metals, technologies available for the removal of heavy metals from water. Various adsorbents, factors influencing adsorption of heavy metals, chemically treated adsorbents and their effect on rate of adsorption.

KEYWORDS: Heavy metals, adsorbents, adsorption.

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INTRODUCTION:

On earth water is very important for all living things including various microorganism and man. There are various sources of water. Rain is the main source of water, which is purest form of water. But during its downward journey it gets contaminated with various impurities and it becomes impure.This impure water is not suitable for many applications in industry and even for drinking also because its most of the properties get changed.Sometimes there is over use of water by some industries and human beings. Out of total water only 0.00192% water on the earth is useful for human intake.

To increase the awareness of the water in public in every year 22nd March is celebrated as

International World Water Day since 1993. This day attracts the attention of whole world on water scarcity, water management by communities, governments, individuals,organizations, irregularity in rain and forthcoming challenges if use of water will be not proper.

Quality of water is very important in whole world because it is directly affect the health.Various tests decide the quality of the water. Many Indian states are facing various problems related to water like proper quality of water, shortage of water resources, water pollution, unavailability of sufficient water, decrease in water tables level etc.

Various substances or pollutants are present in impure and polluted water. Out of various pollutants mainly heavy metals attract our attention because most of them are toxic and have adverse effects on living things and human beings when accumulated above their tolerance limit. If the contamination of heavy metals is above tolerance limit then they must be removed from water.Many processes have been used for the removal of heavy metals from waste waters, such as chemical precipitation, coagulation, solvent extraction, membrane separation, ion exchange and adsorption[1]. Adsorption, reverse osmosis and ion exchange methods can be used for dilute concentrations of the metals. But except adsorption above two are costly. So as alternative to reverse osmosis, ion exchange, membrane filtration, chemical precipitation etc. adsorption method using various adsorbents have been tested by various researchers. Heavy metal adsorption was studied on various adsorbents such as activated carbon, fly ash and bio adsorbents (adsorbents from plant and animal-origin materials, for example bark/tannin-rich materials, humus, peat moss, modified cotton and wool, chitin, chatoyant, seaweed, and biopolymers) [1].

Among the total water requirement very small amount of water is required for cooking and drinking. High amount of water is required for cleaning, flushing toilets, bathing etc. This high amount of water after its use remaining water we can say as waste water can be recycled for various purposes like landscaping, industry, irrigation, recharging ground water etc. This can save fresh water.

Out of the different types of pollutions waste water pollution is most important. The main sources of this pollution are domestic sewage and industrial effluents. Industrial effluents sometimes contain heavy metals and when this waste water is discharged into various water bodies these heavy metals affects the ecosystem including aquatic life and disturb their self-purification process. So it is very essential to treat this industrial waste water before discharging into water bodies to remove such heavy metals. Various researchers developed suitable methods to remove heavy metals from waste water or to reduce their concentration level.

By using various methods heavy metals are removed from waste water.Chemical, biological and physical methods are available for this purpose.Out of these chemical and physical methods or processes are major methods for treatment of waste water. The main disadvantages of these methods are disposal problems, high cost, electricity requirement and high chemical reagents requirement.

Generally, found heavy metals in industrial wastewater are Pb, Cr, Hg, As, Ni, Cu etc[2]. All they have different maximum permissible limit (MPL in mg L^{-1}), sources and adverse effects which are discussed below.

MPL (mg L^{-1})[1]:

Pb=0.05, Cr=0.05, Hg=0.1,As=0.06, Ni=0.1, Cu=2.0[1].

Sources:

Pb-Printing, Batteries, Lead paint industries.

Cr-Electroplating, Textile, Leather industries.

Hg-Thermometers, Pesticides, Batteries industries.

As-Ceramic, Dyes, Metallurgical industries.

Ni-Forging, Batteries, Electroplating industries.

Cu-PCB designing, Electroplating industries.

Adverse effects:

Pb-Headache, anemia, destruction in kidney

Cr- Ulcers, skin irritations, carcinogenic

Hg-Chest pain, children suffer from mental retardation, teratogenic effects

As- Cancer, diarrhoea, vomiting

Ni- Skin dermatitis, diarrhoea, vomiting,

Cu- Accumulation in the kidneys, gastrointestinal problems, carcinogenic.

Following are some important techniques which have been studied for the heavy metal removal from the industrial wastewater. But all they have certain advantages and disadvantages.

A. Reverse Osmosis:

Advantages: Pure effluent

Disadvantages: Expensive, High pressures

B. Evaporation:

Advantages: Pure effluent

Disadvantages: Generates sludge's, Expensive

C. Electrochemical:

Advantages: Metal recovery

Disadvantages: Expensive, For high concentrations

D. Ion exchange[3,4]:

Advantages: Metal recovery, Effective

Disadvantages: Sensitive to particles, Expensive

E. Chemical precipitation:

Advantages: Cheap, Simple

Disadvantages: Generates sludge, Difficult separations

F. Chemical oxidation/reduction:

Advantages: Mineralization

Disadvantages: Chemicals required

G. Electrodialysis[5]:

Advantages: Pure effluent

Disadvantages: Expensive, Formation of metal hydroxides which clog the membrane.

By considering all above facts adsorption technique seem to be suitable for the removal of heavy metals from the industrial wastewater.

Adsorption: The phenomenon of accumulation of chemical substances at the surface of a solid is called adsorption. Reverse of adsorption is called as desorption. Adsorption is very popular technique for heavy metal removal from wastewater. This technique is found superior as compared to all other techniques as it has following advantages,

    (i)   Very simple technique

    (ii)   Low cost

    (iii)   Less space required

    (iv)   Simple equipment

    (v)   Economical

    (vi)   Simple design

    (vii)   Possibility of metal recovery

    (viii) No chemical or biological sludge

    (ix)   Regeneration of adsorbent

(x)   Insensitivity to toxic pollutants

(xi)   Produce high quality treated water

(xii)   Cheap adsorbent

(xiii) Natural/eco-friendly adsorbents

(xiv)   Easy to operate

(xv)   High efficiency

There are two types of adsorption processes Chemical adsorption and Physical adsorption depending upon which type of force is involved during adsorption process.

Adsorbents: For heavy metals removal from industrial wastewater various adsorbents can be used. But they should be environmental friendly, abundantly and easily available and low cost. Waste materials or by-products from various industries[6], plant materials, other biological materials, various parts of living things, waste building materials etc. can be used as low cost adsorbents.

Literature survey shows that various researchers used various plant materials as cheap adsorbents for removal of heavy metals from wastewater. They are Coffee[7], Green tea, Algae, Jambhool, Potato husk, Jute, Sunnhemp[8], Ratrani leaf, Cashew nut shells, Coconut husk, Apple Pomace, Date tree leaves, Syzygium cumini, Tea waste, Ashoka leaf, Almond husk, Prosopis spicegera, Jute stick, Cassia Siamea etc. They can remove heavy metals like Pb, Cr,Co,Hg,As,Cd, Cu, Fe, Ni etc.from industrial waste water.

Not only plant materials but also other materials can also be used for this purpose like Hydroxides of aluminium and iron, activated carbon[9], bagasse, waste rubber, albumin, hair, feathers, wool, activated red mud, ores etc. But the total cost of process become comparatively high because few of them are costly.

Pretreatment of adsorbentswith acids or bases can increase the adsorption efficiency. Sulphuric acid, hydrochloric acid, nitric acid, phosphoric acid, sodium carbonate, calcium hydroxide, sodium hydroxide, Potassium hydroxide can be used for pretreatment of adsorbents. Although pretreatment of adsorbents enhances the adsorption efficiency but while using these adsorbents methods of pretreatment and the cost of chemicals used have to be considered for low cost adsorbents.

Various researchers reported that the heavy metals adsorption enhanced by using the pre-treatedadsorbents with bases and acids.Few examples are shown in Table no.1.

Table no.1.Percentage removal of Heavy Metals by untreated and treated adsorbents

Metal	Adsorbent	% Removal	Reference
Cr	Untreated Jambhool leaf powder	69.2	10
	HNO_3 treated Jambhool leaf powder	98.4	
Cu	Untreated Nerium Indicum	71	11
	HCl & NaOH treated Nerium Indicum	80	
	Untreated Cassia Siamea	42	
	HCl & NaOH treated Cassia Siamea	60	
Fe	Untreated Syzygium cumini	73.62	12
	HNO_3 treated Syzygium cumini	94.21	

Various factors play very important role in the adsorption process. Few of them are contact time, amount of adsorbent, pH, initial concentration[13] of metal ions, temperature etc. As contact time, temperature, amount of adsorbent increases generally adsorption of heavy metals increases. There isdecrease in the adsorption with increase in the initial concentration of metal ions. With the help of temperature factor enthalpy (ΔH), entropy (ΔS) and Gibbs free energy (ΔG)[14]can be determined. Their values are used for different conclusions.

This adsorption technique has various uses like removal of heavy metals from industrial waste water, separation of gas mixture, decolourisation, in chromatographic analysis, purification, recovery of dyes from solution, softening of hard water, clarification of sugar liquid, for impurities removal from crude oil, purification of air.

CONCLUSIONS:

Adsorption is a substitute technique to traditional techniques for the heavy metals removal from the wastewater. To enhance the adsorption, the pre-treated adsorbents with acid or base can be used. To make the adsorption process economical natural, eco-friendly, easily available, abundantly available, low cost plant materials as adsorbents can be used.For industry, irrigation, toilet flushing, landscaping, etc. instead of using fresh water the wastewater formed after adsorption process can be recycled and used.

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