Low Cost Adsorbent for Removal of Heavy Metal from Industrial Wastewater

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Abstract- *Heavy metal pollution is a major problem in the environment. The impact of toxic metal ions can be minimized by different technologies, viz., chemical precipitation, membrane filtration, oxidation, reverse osmosis, flotation and adsorption. But among them, adsorption was found to be very efficient and common due to the low concentration of metal uptake and economically feasible properties. Activated carbon has been frequently used as an adsorbent. Because of its extensive use in water and wastewater treatment industries, activated carbon becomes an expensive material. So there is a need of safe and economical method for elimination of heavy metal from wastewater.*

In this paper, various low cost adsorbents have been reviewed for the removal of heavy metal from wastewater. These adsorbents include the materials of natural origin, agricultural wastes and industrial by products.

Keywords- Adsorbent, agricultural waste, Heavy metal

I. INTRODUCTION

Heavy metals are elements which have atomic density more than 5. Some toxic heavy metals, such as lead, cadmium, nickel, cobalt, chromium, arsenic, iron and zinc, cause metal toxicity in living organisms. Heavy metals contaminations could exist in wastes of many industries, such as metal plating, mining operations, tanneries, chloralkali, radiator manufacturing, smelting and alloy industries, wood processing industries, petroleum refining industries, storage battery industries. The heavy metals present in the wastewater is persistent and non degradable in nature. Moreover, they are soluble in aquatic environment and thus can be easily absorbed by living cells. Thus, by entering the food chain, they can be bio accumulated and biomagnified in higher trophic levels also. The heavy metals, if absorbed above the permissible labels, could lead to serious health disorders. Therefore, it is obligatory to treat metal contaminated wastewater before discharging into the environment. Therefore, it is necessary to treat metal-contaminated wastewater before its discharge into the environment.

The conventional methods for heavy removal from wastewater includes chemical precipitation, chemical oxidation, ion exchange, membrane separation, reverse osmosis, electro dialysis etc. These methods are not very effective, are costly and require high energy input. They are associated with generation of toxic sludge, disposal of which is expensive and non ecofriendly in nature. Adsorption has emerged out to be better alternative treatment methods. It is said to be effective and economical because of its relatively low cost.

The adsorbent may be of mineral, organic or biological origin. It could be zeolites, industrial byproducts, agricultural waste, biomass and polymeric material. One of the conventional adsorbent, activated carbon has been extensively used but high cost effectiveness of activation processes of activated carbon limits its usage in wastewater treatment processes. The present research is in search for cost effective or low cost adsorbents of natural origin and their applicability in heavy metal removal from industrial wastewater.

II. EFFECT OF HEAVY METAL ON ECOSYSTEM

Toxic or heavy metals with their huge contribution to pollution pose a serious threat to the world. It stands out to be one of the major factors in world crisis. The food chain which is probably most essential for the maintenance of ecological balance is drastically affected by pollution caused due to toxic metals, as it causes bioaccumulation and biomagnifications, and also affects agriculture. Recent research activities exposed the fact that certain toxic metals have the potential to remain in the environment for a very long period of time which eventually leads to its bio accumulation to higher levels causing harm to human beings. The heavy metals, if absorbed above the permissible labels, could lead to serious health disorders.

Some of the negative impacts of heavy metals on plants include decrease of seed germination and lipid content by cadmium, decreased enzyme activity and plant growth by chromium, the inhibition of photosynthesis by copper and mercury, the reduction of seed germination by nickel and the reduction of chlorophyll production and plant growth by lead.

Heavy metal ions are toxic to both human beings and animals. The toxic metals cause physical discomfort and sometimes life threatening illness and irreversible damage to vital body system. The metals get bio accumulated in the aquatic environment and tend to biomagnified along the food chain. Thus, the organisms at higher tropic level are more susceptible to be affected by their toxicity. There are 20 metals which are almost persistent and cannot be degraded or destroyed. Mercury (Hg), lead (Pb), cadmium (Cd), chromium (Cr [VI]), Zinc (Zn), Arsenic (As), Nickel (Ni) etc., are toxic heavy metals from ecotoxicoligal point of view. Treating the industrial effluents contaminated with heavy metals within the industrial premises before being discharged is efficient way to remove heavy metals rather than treating high volumes of wastewater in a general sewage treatment plant. Thus it is advantageous to develop separate handling modal for removal of heavy metals from the industrial effluents.

III. ADSORPTION

Adsorption is one of the most efficient wastewater treatment technologies because of its low cost, simple operation and it does not produce a large amount of sludge. Adsorption is basically a mass transfer process by which a substance is transferred from the liquid phase to the surface of a solid, and becomes bound by physical and/or chemical interactions. It is a partition process in which few components of the liquid phase are relocated to the surface of the solid adsorbents. All adsorption methods are reliant on solid-liquid equilibrium and on mass transfer rates. The substance being adsorbed is the adsorbate and the adsorbing material is termed the adsorbent. The materials used as adsorbents must have high content of carbon or oxygen for efficient adsorption.
The main factors that impact the efficiency of adsorption are the following:

1. Surface area of the adsorbent material
2. Nature and concentration of adsorbate
3. pH of the solution
4. Temperature
5. Properties and dose of the sorbent
6. Contact time

Adsorbent: A material that has the ability to extract certain substances from gases, liquids, or solids by causing them to adhere to its surface without changing the physical properties of the adsorbent. Adsorbents are classified in two types

Natural Adsorbent: Natural adsorbents include charcoal, clays, clay minerals, zeolites, and ores. These natural materials are relatively cheap, abundant in supply and have significant potential for modification and ultimately enhance the adsorption capabilities.

Synthetic Adsorbent: Synthetic adsorbents are adsorbents prepared from Agricultural products and wastes, house hold wastes, Industrial wastes, sewage sludge and polymeric adsorbents. Each adsorbent has its own characteristics such as porosity, pore structure and nature of its adsorbing surfaces. Many waste materials used include fruit wastes, coconut shell, scrap tyres, bark and other tannin-rich materials, sawdust, rice husk, petroleum wastes, fertilizer wastes, fly ash, sugar industry wastes blast furnace slag, chitosan and seafood processing wastes, seaweed and algae, peat moss, clays, red mud, zeolites, sediment and soil, ore minerals etc.

IV. LOW COST ADSORBENT

The removal of heavy metals by using low cost adsorbent is found to be more encouraging in extended terms as there are several materials existing locally and profusely such as natural materials, agricultural wastes or industrial by-products which can be utilized as low-cost adsorbents.

Two main advantages of using low cost adsorbent are the re-use of a dumped waste in a useful purpose and the contribution to solving the problem of the solid waste sector by reducing the amount of waste that needs to be landfilled. For all these reasons adsorption using low cost or zero cost waste products can be considered a sustainable method of treatment of industrial wastewater.

An adsorbent should have high selectivity to facilitate quick separations, favourable transport and kinetic characteristics, thermal and chemical stability, mechanical strength, resistance to fouling, regeneration capacity and low solubility in the liquid in contact.

Low cost adsorbents can be classified either by their nature; organic/ inorganic, or by their availability; natural materials, agricultural/ industrial/ domestic wastes, or synthesized products.

Adsorption by Natural Materials

Zeolites

They are naturally occurring crystalline alumino silicates consisting of a skeleton of tetrahedral molecules, connected with each other by mutual oxygen atoms. Ion exchanging capacities of zeolites make them a suitable candidate for removal of heavy metals. Adsorption in zeolites is in fact a choosy and reversible packing of crystal cages, so

surface area is not a significant aspect. Zeolites consist of a wide variety of species such as clinoptilolite and chabazite. Among the different zeolites, clinoptilolite has been extensively studied and was shown to have high selectivity for metals like Pb (II), Cd (II), Zn (II) and cu (II). Several zeolites are modified during the past few years to increase their efficiency. Clinoptilolite was found to be more effectively removing heavy metals.

Clay

There are three main groups of clays: kaolinite, montmorillonite-smectite, and mica. The montmorillonite has the highest cation exchange capacity and its recent market price is found to be 20 times cheaper as compared to activated carbon. Their heavy metals removal capacity is less as compared to zeolites but their easy availability and economical properties give back their less efficiency. Efficiency for heavy metal removal by clay could be improved by modifying them to clay-polymer composites.

Peat moss

Abundant in nature and has a very high organic content. Its large surface area (≥ 200 m2/g) and high porosity makes it an effective agent for heavy metal removal from wastewater. It was observed that peat moss plays an important role in treatment of metal-bearing industrial effluents such as Cu2+ , Cd2+ , Zn2+ and Ni2+.

Chitosan

It is produced by alkaline N-deacetylation of chitin, is drawing an increased amount of research interest for its heavy metal removal capability due to chelating property. It can be made by treating shrimp and other crustacean shells with the alkali sodium hydroxide. Chitosan has been used for treatment of Hg2+, Cu2+, Ni2+, Zn2+, Cr6+, Cd2+, and Pb2+.

Adsorption by Agricultural Wastes

Use of agricultural by-products as adsorbents for heavy metal removal from industrial waste water has been increasing nowadays. Most of the studies were focused on plant wastes such as rice husk and neem bark, Black gram husk, Waste tea, Turkish coffee, Walnut shell etc. Some more adsorbents like papaya wood, maize leaf, teak leaf powder , coraindrum sativum , lalang (Imperata cylindrica) leaf powder, peanut hull pellets, sago waste, saltbush (Atriplex canescens) leaves, tree fern, grape stalk wastes, etc. are also studied in detail.

Chemically modified agricultural wastes have been found to have enhanced chelating efficiency. Wheat bran, a by-product of wheat milling industries proved to be a good adsorbent for removal of many types of heavy metal ions which eventually results in better efficiency of adsorption of copper ions as reported by O zer et al.

Orange peel has been used for Ni (II) removal from simulated wastewater. Similarly, Adsorption of divalent heavy metal ions particularly Cu2+, Zn2+, Co2+, Ni2+ and Pb2+ onto acid and alkali treated banana and orange peels was performed by Annadurai et al. in 2002. Activated Coconut shell carbon powder (ACSCP) and Activated charcoal powder (ACP) is used as adsorbent for removal of Lead from electrochemical industry effluent.

The benefits of using agricultural wastes for wastewater treatment include easy technique, needs modest processing, superior adsorption ability, and selective adsorption of heavy metal ions, economical, easy availability and easy regeneration but the use of untreated agricultural wastes as adsorbents can also fetch a number of problems such as small adsorption ability, elevated chemical oxygen demand (COD) and biological chemical demand (BOD) as well as total organic carbon (TOC) due to discharge of soluble organic compounds contained in the plant materials. The increase of the COD, BOD and TOC can cause diminution of dissolved oxygen (DO) content in water and can make threats to the aquatic life. Consequently, plant wastes require be modifying or treating ahead of being applied for the cleansing of heavy metals.

Adsorption by Industrial Wastes

Various industrial wastes have also got adsorption capacity and can be used for adsorbing heavy metals from wastewater. These industrial wastes are produced as a by-product and are used rarely for any purpose. These are easily available and very economical also. These industrial wastes are found to have good application as adsorbent. Industrial by-products such as fly ash, blast furnace sludge, waste slurry, lignin-a black liquor waste of paper industry, iron (III) hydroxide and red mud have been explored for their technical feasibility to remove toxic heavy metals from contaminated water.

Fly ash

Fly ash is a residue of the coal combustion process, could be a good substitute to the high cost activated coal and zeolite in sorption of heavy metals. Sorption capacity of fly ash is influenced by the fly ash origin and chemical treatment.

Blast Furnace sludge

Blast furnace slag is a by-product of steel manufacturing. Sludge is a waste of the electroplating industry, where metal ions in wastewater precipitates with calcium hydroxide forming the sludge. The sludge consists of insoluble metal hydroxides and other salts.

Black Liquor

Black liquor is a waste produced from paper industry, it contains lignin, which is a substance that has a potential to adsorb heavy metals in wastewater.

Cement kiln dust

Cement kiln dust (CKD) is another potential low cost adsorbent of heavy metals. CKD results from the combustion process of the raw material in cement production, and it is carried by the exhausted gases of the cement kiln to be captured by the air pollution control device of the kiln. CKD is a major source of air pollution; consequently, imposes health threats, especially diseases related to the respiratory system because it is a very fine dust. Handling CKD and dumping it in landfills is not always done in the proper way that prevents environmental pollution.

Advantages of Low cost adsorbent:

- Reuse of dumped waste in a useful purpose.
- The contribution to solving the problem of the solid waste sector by reducing the amount of waste that needs to be land filled.
- Low cost organic adsorbents can be fruitfully used for the removal of heavy metals with a concentration range of 20–60 mg/l.
- Easily available and regenerated.
- Needs modest processing and having easy technique for treatment.
- Cheep or having zero cost so it economical for small scale industries.
- They could be used on its natural state.

V. CONCLUSION

Adsorption is an efficient technique in heavy metal removal from wastewater at trace concentrations. The use of commercially activated carbons for wastewater treatment leads to increase in the cost of treatment, hence low cost adsorbent are the better option for removal of heavy metal from industrial wastewater. Low cost adsorbents are relatively cheap and easily available, can be easily modified, and show good adsorption capacity for wide number of pollutants. Low cost adsorbent derived from agricultural waste or natural products have been extensively investigated for heavy metal removal from contaminated wastewater. It has been found that after chemical or thermal modifications, agricultural waste exhibited tremendous heavy metal removal capability. Concentration of adsorbate, extent of surface modification and adsorbent characteristics are the factors responsible for metal adsorption capability. Cost effectiveness and technical applicability are the two important key factors for selecting effective low cost adsorbent for heavy metal removal.

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