Scientific Journal of Impact Factor (SJIF): 4.72

e-ISSN (O): 2348-4470
p-ISSN (P): 2348-6406

International Journal of Advance Engineering and Research Development

Volume 4, Issue 4, April -2017

Removal of Heavy Metals using Adsorption Process- A Review

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Abstract *— This paper reviews methods available for the removal of metals from industrial wastewater that are beneficial for small scale industries, Effects of metals on human health and Conventional methods for removal of heavy metals. The literature review shows that various low cost natural materials are used as adsorbents for removal of metals from aqueous solutions and industrial wastewater and applications of adsorption process.*

Keywords*- Metals, Adsorption, Low cost Natural Materials, Industrial wastewater*

I. INTRODUCTION

Water is the principal need of life on earth, and is an essential component for all forms of lives, from micro-organism to man [1]. Water pollution due to toxic metals has been a major cause of concern for environmental Engineers [3]. Man's activities through industrialization, urbanization, technological development and agriculture, discharge heavy metals into the environment; this has become a matter of global concern over the past few decades because the presence of heavy metal ions in high concentration in the environment is detrimental to life. Natural elements like heavy metals are globally-distributed pollutants. [2] 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 [2]. Many industries discharge wastewater containing toxic materials into rivers without adequate treatment. Most of the heavy metals discharged into the wastewater are found toxic and carcinogenic and cause a serious threat to the human health. [4] Metals can be distinguished from other toxic pollutants, since they are non-biodegradable and can accumulate in living tissues, thus becoming concentrated throughout the food chain. [3]

Effects of Metals on Human Health

Metals are toxic in nature and are dangerous for human consumption. These metals are found in various sources mainly industrial wastewater due to various processes carried out in the industries. They have serious effects on human health as they escape in the environment and pose a serious hazard. These metals can cause some serious health disorders like muscular dystrophy, cancer, Neurological disorders like Alzheimer's disease, Parkinson's disease. These metals not only cause harm to human health but also affect the aquatic life. Hence removal of these metals from wastewater is very essential before they are discharged in the water bodies.

II. CONVENTIONAL METHODS FOR TREATMENT AND REMOVAL OF METALS

Solvent extraction is a method for separating a substance from one or more others by using a solvent. It relies on variations in the solubilities of different compounds in different substances. In most cases, the substance to be extracted, which may be a solid, a liquid or a gas, is dissolved in a liquid, along with other substances, and a liquid solvent is used for the extraction — this is sometimes called liquid-liquid extraction. The technique may also be applied to solid materials that contain compounds that need to be extracted. This method is widely used in industry, and in the laboratory for refining, isolating and purifying a variety of useful compounds.

Chemical precipitation in water and wastewater treatment is the change in form of materials dissolved in water into solid particles. Chemical precipitation is used to remove ionic constituents from water by the addition of counter-ions to reduce the solubility. It is used primarily for the removal of metallic cations, but also for removal of anions such as fluoride, cyanide, and phosphate, as well as organic molecules such as the precipitation of phenols and aromatic amines by enzymes and detergents and oily emulsions by barium chloride.

Coagulation and flocculation are an essential part of drinking water treatment as well as wastewater treatment. Coagulation is the chemical reaction which occurs when a chemical or coagulant is added to the water. The coagulant encourages the colloidal material in the water to join into small aggregates called "flocs". Suspended matter is then attracted to these flocs. Flocculation is a slow gentle mixing of the water to encourage the flocs to form and grow to a size which will easily settle out. [4]

Reverse osmosis (RO) is a water purification technology that uses a semipermeable membrane to remove ions, molecules, and larger particles from drinking water. In reverse osmosis, an applied pressure is used to overcome osmotic pressure, a colligative property, that is driven by chemical potential differences of the solvent, a thermodynamic parameter. Reverse osmosis can remove many types of dissolved and suspended species from water, including bacteria, and is used in both industrial processes and the production of potable water. The result is that the solute is retained on the pressurized side of the membrane and the pure solvent can pass to the other side.

Ultrafiltration is a variety of membrane filtration in which forces like pressure or concentration gradients lead to a separation through a semipermeable membrane. Suspended solids and solutes of high molecular weight are retained in the so-called retentate, while water and low molecular weight solutes pass through the membrane in the permeate (filtrate). Ultrafiltration (UF) technology uses a membrane barrier to exclude particles as small as 0.01 microns, including bacteria, viruses and colloids. Advantages of UF compared to conventional treatment such as clarifiers and media filters, are its high tolerance to feed water quality upsets, absolute barrier and improved water quality.

These conventional methods are not effective in the removal of heavy metals as these processes produce a large amount of metallic sludge which also needs further disposal. Hence the recovery of metals using the above methods becomes difficult.

Adsorption is the phenomenon of accumulation of large number of molecular species at the surface of liquid or solid phase in comparison to the bulk. The process of adsorption arises due to presence of unbalanced or residual forces at the surface of liquid or solid phase. These unbalanced residual forces have tendency to attract and retain the molecular species with which it meets the surface. Adsorption is essentially a surface phenomenon. Adsorption process involves two components Adsorbent and Adsorbate. Adsorbent is the substance on the surface of which adsorption takes place. Adsorbate is the substance which is being adsorbed on the surface of adsorbent. Adsorbate gets adsorbed. Forces of attraction exist between adsorbate and adsorbent. These forces of attraction can be due to Vander Waal forces of attraction which are weak forces or due to chemical bond which are strong forces of attraction. Based on type of forces of attraction existing between adsorbate and adsorbent, adsorption can be classified into two types: Physical Adsorption or Chemical Adsorption.

Adsorption is a simple and cost effective technique and hence it is widely used for wastewater treatment. It is affected by factors like Contact time, Adsorbent Loading, Temperature, Concentration of Adsorbate, pH of solution etc. Adsorption is one of the most convenient technique for the removal of heavy metals from wastewater [2] having advantages over the conventional methods because of its simple design and sludge free environment. [3] Literature survey shows that various low cost natural adsorbents have been used to remove metal from wastewater. Some of them are listed as follows:

Adsorbent used	Metal removed	Reference
Corn Corb	Cu2+, Cr(VI), Ni(II)	[5], [13], [16]
Rice Husk	Ni(II), Pb2+, Zn2+	[6], [10]
Oil Palm, Coconut shell	Ni(II), Pb(II), Cr(IV),	[7]
Orange peel	Cr, Cd, Co	[8]
Prosopis Juliflora Leaf Powder	Cu(II)	[9]
Jambhool Leaf Powder	Cr(VI)	[11]
Pistachio Shells	Zn(II)	[12]
Tea Leaves	Pb, Fe, Zn, Ni	[14]
Saffron Leaves	Cu, Pb, Cd	[15]
Sugarcane Bagasse	Cu2+	[17]
Albizia Lebbeck stem	Cr(VI)	[18]
Walnut Shell	Cu(II), Cr(VI)	[19]

Experimental work is carried out by preparation of activated carbon from low cost natural adsorbents. This is done by pre-treatment of adsorbents either by using base solutions or mineral acid solutions. Research reveals that pre-treatment of adsorbents enhance the metal adsorption capacity of the adsorbent. [1]. **Sureshkumar Halnor and Milind Ubale (2013)** Studied the adsorption of Fe(II) using nitric acid treated Prosopis Juliflora Leaf powder. They reported 88%

removal of metal from industrial wastewater using a very low amount of adsorbent. **Sureshkumar Halnor et. al. (2013)** Studied the adsorption of Cu(II) using nitric acid treated Prosopis Juliflora Leaf powder. They reported 89% removal of metal from industrial wastewater using a very low amount of adsorbent.

APPLICATIONS

Adsorption has different uses like
1) Removal of heavy metals from industrial wastewater
2) Removal of impurities from petroleum oils [1]
3) Separation of gas mixture [1]
4) Chromatographic analysis [1]
5) Softening of hard water [2]
6) Adsorption indicators
7) Clarification of sugar [2]
8) Paint industry
9) Froth floatation method used for concentration of sulphide ores is based on adsorption
10) Decolourization and Purification [2]

CONCLUSION

Among all conventional methods, adsorption is a very good alternative for the removal of heavy metals from the industrial wastewater. It is economical and convenient method [2]. Certain low cost materials which are abundant in nature can be used as adsorbents to make the adsorption process more economical. Adsorption capacity can be enhanced by pre-treatment of adsorbent. The literature review showed that the adsorption capacity of the adsorbents depends on the size of the adsorbent, contact time, initial concentration of the adsorbate, temperature and pH. Hence low cost adsorbents should be used to minimize cost inefficiency and increase metal removal efficiency. [4]

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