# A Study of Heavy Metal Removal by Adsorption

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*Abstract*— Environmental pollution has become a cause for great concern as it is increasing day by day. The presence of heavy metals in the environment is one of the major concerns because of its toxicity and threat to human life and environment. The increasing contamination of urban and industrial wastewaters by toxic metal ions causes significant environmental pollution. This results in the pollution of water whereby the quality of water deteriorates, affecting aquatic ecosystems. Pollutants can also seep down and affect the groundwater deposits. These inorganic micro-pollutants are of considerable concern because they are non-biodegradable, highly toxic and have a probable carcinogenic effect. Adsorption of heavy metals is by far the most effective and widely used technique for the removal of heavy metals from effluents. Low cost. Non-conventional materials are used nowadays for the effective removal of heavy metals.

***Key words:*** Adsorption, Heavy Metals, Kinetics

## I. Introduction

Heavy metals are very toxic in nature and harmful to the environment. Rapid industrialization and increase in population are responsible for the inclusion of heavy metals in the environment. These metals are found well above the tolerance limit many times in the aquatic environment. Metal ions are non-biodegradable in the nature and therefore their intakes are toxic at certain levels. Heavy metals are important toxicants known to exert adverse effects in humans and animals, given sufficient exposure and accumulation in the body. This has a great concern both at personal and public health risk. Heavy metals are also known to interact with the essential trace minerals at the level of absorption and also during the metabolism. The adverse effects of the absorbed and accumulated heavy metals include neurological, reproductive, renal and hematological systems. Anodic Stripping Voltammetry can be used for the evaluation of the levels of toxic heavy metals such as lead, cadmium, mercury etc. Cadmium is a metallic element used in plastics manufacture as a heat stabilizer and as a pigment constituent. It is a carcinogen and a toxin. Hexavalent Chromium is a constituent of inorganic pigments. It is carcinogenic and corrosive on living tissue. Lead is a metallic element used in plastics manufacture as a heat stabilizer and in inorganic pigments for opacity. It is a cumulative toxin. Mercury is a metallic element used in inorganic pigments. It is a neurotoxin. Various technologies employed to remove toxic metals include ion exchange, reverse osmosis, chemical precipitation, and electro floatation. These methods are costly and are not affordable in the developing countries like India. In wastewater treatment, the process of adsorption has an edge over other methods, due to its simplicity. Activated carbon is commonly used as an adsorbent. However, it is much expensive and suffers losses during regeneration. Therefore, low cost and non-conventional adsorbent materials such as sawdust, neem leaves, water hyacinth etc are tried by various researchers in recent times.

## II. Adsorption Process

Adsorption is a process in which certain adsorbates are selectively transferred from the fluid phase to the surface of insoluble, rigid particles suspended in a vessel or packed in a column. It is actually the accumulation of atoms or molecules on the surface of a material. This process creates a film of the adsorbate (the molecules or atoms being accumulated) on the adsorbent's surface. Adsorption is present in many natural, physical, biological, and chemical systems and is widely used in industrial applications. Similar to surface tension, adsorption is a consequence of surface energy.

## III. Adsorbents and Their Properties

Most industrial adsorbents fall into one of three classes: Oxygen-containing compounds – Are typically hydrophilic and polar, including materials such as silica gel and zeolites. Carbon-based compounds – Are typically hydrophobic and non-polar, including materials such as activated carbon and graphite.

Adsorbents are used usually in the form of spherical pellets, rods, moldings or monoliths with hydrodynamic diameters between 0.5 and 10 mm. They must have high abrasion resistance, high thermal stability and small pore diameters, which results in higher exposed surface area and hence high surface capacity for adsorption. The adsorbents must also have a distinct pore structure which enables fast transport of the gaseous vapors. The commonly used adsorbents are activated carbon, zeolites and silica gel. Activated carbon which is a highly porous, amorphous solid consisting of microcrystallites with a graphite lattice, usually prepared in small pellets or a powder. It is the most widely used adsorbent. Its usefulness derives mainly from its large micropore and mesopore volumes and the resulting high surface area.

Activated carbon can be manufactured from carbonaceous material, including coal (bituminous, subbituminous, and lignite), peat, wood, or nutshells (i.e. coconut). The manufacturing process consists of two phases, carbonization and activation. The carbonization process includes drying and then heating to separate by-products, including tars and other hydrocarbons, from the raw material, as well as to drive off any gases generated. The carbonization process is completed by heating the material at 400–600 °C in an oxygen-deficient atmosphere that cannot support combustion. The carbonized particles are “activated” by exposing them to an oxidizing agent, usually steam or carbon dioxide at high temperature. This agent burns off the pore blocking structures created during the carbonization phase and so they develop a porous, three-dimensional graphite lattice structure. Activated carbon is used for adsorption of organic substances and non-polar adsorbates and it is also usually used for waste gas (and waste water) treatment.

Silica gel is another adsorbent which is chemically inert, nontoxic, polar and dimensionally stable (< 400 °C) amorphous form of $SiO_2$. It is prepared by the reaction between sodium silicate and sulfuric acid, which is followed by a series of after-treatment processes such as aging, pickling, etc. These after treatment methods results in various pore size distributions. Silica is used for adsorption of heavy (polar) hydrocarbons from natural gas.

Zeolites are natural or synthetic crystalline aluminosilicates which have a repeating pore network and release water at high temperature.

In addition to these major adsorbents, various other adsorbents which are cheap and naturally available are used in recent times. Eg : Sawdust. Neem leaves, water hyacinth etc.

## IV. Adsorption Kinetics

Kinetics of adsorption, describing the solute uptake rate, which in turn governs the contact time of adsorption process is one of the important characteristics defining the efficiency of adsorption.

The Freundlich isotherm is employed for the adsorption of metal ions on the adsorbents. It is represented as

$$\text{Log } q_c = \log K = 1/n \log C_e$$

Where $q_c$ is the amount of metal ion adsorbed per gram of adsorbent (mg/g),$C_v$ is the equilibrium concentration of metal ion in solution and K and n are constants incorporating all factors affecting the adsorption capacity and intensity of adsorption respectively.

## V. Atomic Absorption Spectrophotometeric Method (AAS Method) for Heavy Metal Detection

Atomic absorption spectrometry (AAS) is an analytical technique that measures the concentrations of elements. Atomic absorption is so sensitive that it can measure down to parts per billion of a gram in a sample. The technique makes use of the wavelengths of light specifically absorbed by an element. Atoms of different elements absorb characteristic wavelengths of light. Analyzing sample to see if it contains a particular element means using light from that element.

In AAS, the sample is atomised – i.e. converted into ground state free atoms in the vapour state – and a beam of electromagnetic radiation emitted from excited heavy metal atoms are passed through the vaporized sample. Some of the radiation is absorbed by the heavy metal atoms in the sample. The greater the number of atoms there is in the vapour, the more radiation is absorbed. The amount of light absorbed is proportional to the number of heavy metal atoms.

A calibration curve is constructed by running several samples of known heavy metal concentration under the same conditions as the unknown. The amount the standard absorbs is compared with the calibration curve and this enables the calculation of the heavy metal concentration in the unknown sample.

## VI. Heavy Metal Removal by Adsorption

Industrial effluents may contain pollutants like heavy metals, phenols, oil, grease etc. Foreign materials which contaminate the water supplies may be harmful to life because of their toxicity and the reduction of normal oxygen level of water. The toxic effects of heavy metals include kidney and lever troubles, hypertension and carcinogenic effects. Most of the treatment processes for removal of heavy metals such as precipitation, ion exchange, reverse osmosis, solvent extraction etc is very expensive. Adsorption process is very simple and cleans in its operation and can be used for the efficient removal of heavy metals.

Effluents containing heavy metals are mixed with adsorbents either in batch adsorption process or column adsorption process. In batch adsorption process, the solution containing heavy metals were taken in beakers. Adsorbents are mixed in the solution and paddles were allowed to rotate inside the beakers for a predetermined period. Solution containing heavy metals can also be mixed with the adsorbents by shaking in a shaker for a predetermined period using mechanical shaker.

In column studies, glass columns are packed with adsorbents. Effluent containing heavy metals is taken in an overhead tank and allowed to pass through the glass column with adsorbents. The water after passing through the glass column is tested for heavy metals.

The percentage removal of various heavy metals like lead, copper, chromium and nickel at various time intervals are shown in figure 1[2].

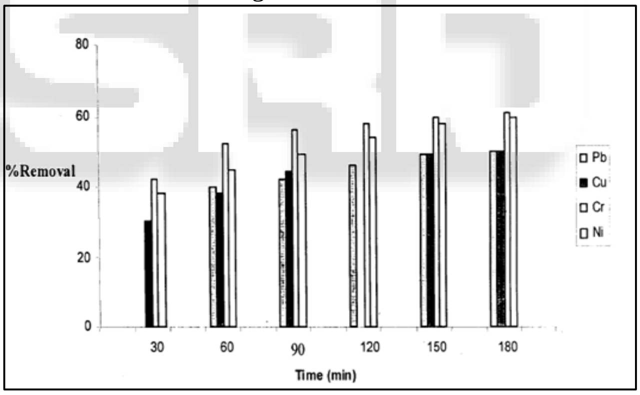


Fig. 1: Percentage removal of different heavy metals by adsorption

## VII. Summary and Conclusion

Heavy metals can be removed effectively by adsorption process. The percentage of adsorption of heavy metals normally depend upon the particle size of adsorbents, quantity of adsorbent, contact time and ph of effluent solution. The percentage removal of heavy metals increases with time of contact time initially reaching a maximum value and then decreases. Increases with increase in initial concentration. Increases with decrease in size of particle Increases with quantity of adsorbent, Varies slightly with pH reaching maximum around pH 4-5.

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