Cadmium Toxicity On Human Health And Removal From Water Environment Following Latest Technology- A Review

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ABSTRACT
Cadmium contamination has been reported from many parts of World since last few years. This review is compiled to summarize the cadmium toxicity on human health and technologies currently being investigated to remove cadmium from water environment. This paper will describe some safe technologies for cadmium removal. Various ways of cadmium removal are: Precipitation, Cementation, Membrane separation technique, Ion exchange technique, Solvent extraction technique, Adsorption techniques, Floatation, Cathodic reduction, Electro coagulation and Electrodialysis technique, Biological methods. The choice of method for the cadmium removal depends on the concentration in the water and its nature, cost, percentage removal required.

Key Words: Cadmium, Health, Hazard, Removal technology

INTRODUCTION

Cadmium (symbol Cd and atomic number 48) naturally occurs in the earth's crust (0.1-0.5 ppm) but is not found in Free State while it occurs in air, water, soil as well as in tissues of plants and animals. Cadmium is present mainly in ores of zinc, copper or lead, the extraction and processing of which releases large amount of cadmium into the atmosphere, hydrosphere and soil thus contaminates the environment. The best known cadmium mineral is greenockite, cadmium sulfide (77.6% Cd). Other minerals are otavite, cadmium carbonate (61.5% Cd) and pure cadmium oxide (87.5% Cd). It is toxic, nonessential, non-degradable and therefore persistent and classified as a human carcinogen by the North Carolina National Toxicology Program[1].

CADMIUM TOXICITY IN HUMAN

As per guidelines for Drinking-water Quality, published in 1984, 0.005 mg/litre was recommended for cadmium in drinking-water and value was lowered to 0.003 mg/litre in the 1993 guidelines, based on the Provisional tolerable weekly intake (PTWI) set by JECFA[2]. Cd is also a highly toxic metal that can interrupt a number of biological systems, generally at doses that are much lower than most toxic metals [3]. Cadmium toxicity depends on path, quantity, and rate of exposure.

Cd absorbed by inhalation or ingestion can cause irreversible damage to several vital organs; the main organ of toxic effect in the human is the kidney[4]. Cadmium enters the kidney in form of cadmium-metallothionein (Cd-MT) which is filtrated in the glomerulus, consequently reabsorbed in the proximal tubulus, after that it remains in the tubulus cells. The quantity of cadmium in the kidney tubulus cells raise during every person's life span[14]. Various studies[5,6] showed that high urinary excretion, not only of low molecular weight proteins, but also of larger proteins such as albumin were interpreted as a sign of a primary glomerular damage caused by cadmium. According to Jarup *et al.*[7], a urinary excretion of 2.5 micrograms cadmium per gram creatinine reproduces a renal tubular damage degree of 4%.

Cadmium interacts with numerous aspects of liver function. According to Hyder *et al.*[8] environmental cadmium exposure was associated with hepatic necroinflammation, non-alcoholic fatty liver disease and non-alcoholic steatohepatitis in men, and hepatic necroinflammation in women. Molecular mechanisms responsible for the hepatotoxicity of cadmium involve oxidative stress, disturbance of the antioxidant defense system and the generation of reactive oxygen species[9].

Toxic effects of Cd on the bones became clear with the epidemic of the Itai-Itai disease in the Cd-polluted area of Toyama, Japan, after World War II. A severe osteomalacia along with multiple bone fractures and renal dysfunction was observed in Itai-Itai disease patients[10]. Women have higher cadmium body burden than men, reflected as elevated concentrations of cadmium in blood, urine and kidney cortex[11]. According to Choudhury *et al.* [12], women are at greater risk of developing cadmium toxicity than are men. Nordberg *et al.*[13] reported that bone mineral density was decreased in Chinese farmers exposed to Cd from contaminated rice for more than 20 yr. An increased risk of bone fractures with increasing Cd levels in urine has been reported [14]. Environmental Cd exposure may be related with increased risk of dental caries in deciduous teeth of children[15].

According to Falcon *et al.*[16] pregnant women exposed to environmental Cd might have an adverse effect in perinatal period, e.g. fetal growth retardation, low birth weight, birth deformities and premature. Cadmium may cause of pregnancy loss via effects on endocrine pathways or via the promotion of oxidative stress, which has been related to adverse reproductive health[17]. Cadmium has shown toxic effects on ovary [18] as well as on estrogenic activity[19]. Nagata *et al.*[20] reported that testosterone was positively associated with cadmium in postmenopausal women.

Further, cadmium may contribute to disease processes by disrupting the balance of oxidative stress[21]. There are also reports suggesting anemia and eosinophilia have been associated with cadmium intoxication[22].

REMOVAL FROM WATER ENVIRONMENT FOLLOWING LATEST TECHNOLOGY:

There are different physical and chemical methods used to treat water containing Cd(II). The common methods for cadmium remediation in water include:

1. Precipitation
2. Cementation
3. Membrane separation technique
4. Ion exchange technique
5. Solvent extraction technique
6. Adsorption techniques
7. Floatation
8. Cathodic reduction
9. Electro coagulation and Electrodialysis technique
10. Biological methods

1. Precipitation

This is a widely used technology for the removal of cadmium from water. It can be removed from inorganic effluent by using chemical precipitation. The most common method used is precipitation as hydroxide which is pH sensitive. The mechanism is given in equation 1.

$M^{2+} + 2(OH)^{-} \leftrightarrow M(OH)_2\downarrow$ (1)

where:

M^{2+} ..... dissolved metal ion

OH^{-} ..... precipitant

$M(OH)_2$ ..... insoluble metal hydroxide

The process involves the alteration of dissolved contaminants into insoluble solids, thereby help the contaminant's subsequent elimination from the liquid by physical methods, such as clarification and filtration. In a precipitation process, coagulants and flocculants are used to raise particle size through aggregation. Usually, heavy metals in water are precipitated by adding sodium hydroxide or lime during neutralization. The simple precipitation of metals as insoluble hydroxides, carbonates, or sulfides is used in about 75% of electroplating facilities to treat wastewater (Karthikeyan *et al.*, 1996)[23].

2. Cementation

One of the most powerful techniques for removing heavy metals from wastewater is Cementation. Process consists of displacing the toxic metal ions from the waste solution by a more active nontoxic metal, represented by equation 2.

$M + Cd^{2+} = M^{2+} + Cd$ (2)

The cementation process may successfully applied to recover Cd^{2+} spiked into an industrial wastewater sample[63].

3. Membrane separation technique

Liquid membrane process includes a dispersed emulsion together with organic membrane and aqueous internal phase in a continuous external phase (W/O/W). A comparative study on removal of heavy metals by membrane technology was carried out by Qdais and Moussa[24].

4. Ion exchange technique

It may be defined as the exchange of ions between the substrate and surrounding medium. Cadmium(II) adsorption from aqueous sulphate medium on Lewatit TP260 cationic (di-Na^+) ion exchange resin was studied by Alguacil[25]. A study by Pehlivan and Altun[26] revealed that a gel resin containing sulfonate groups (Dowex 50W) was efficient for removal of Cd^{2+} and amount of sorbed metal ion was 4.7 meq/g dry resin where as the sorption capacity of the Amberlite IR-120 resin for Cd was 3.3 meq/g[27].

5. Solvent extraction technique

Solvent extraction is one of the techniques for recovering /separating metal ions from aqueous solution. When a metal ion solution makes contact with a solvent, the metal ion is distributed between the two phases. Liquid-liquid extraction from aqueous media with specific extractants is also useful for cadmium separation[28,29].

6. Adsorption techniques

Another efficient method for the removal of heavy metals from contaminated water is Adsorption. Different types of adsorbents, including clays, zeolites, agricultural waste biomass, metal oxides, fly ash and sewage sludge, activated carbon have been used for removal of cadmium[30].

7. Floatation

Flotation as an adsorptive separation technique has received a sharp increase for cadmium removal in research activities. According to Salmani *et al.*[31] the application of ion flotation for cadmium ions removal from aqueous dilute solutions was efficient and very sensitive to the ionic strength.

8. Cathodic reduction

Another technique for removing heavy metals from wastewater is Cathodic reduction. Sulaymon *et al.*[32] investigated the performance of a novel pilot scale, fixed bed flow-through cell, consisting of a cathode formed by a bundle of stainless steel tubes for the removal of cadmium.

9. Electro coagulation and Electrodialysis technique

Electro coagulation and Ectrodialysis technique for the cadmium riches wastewater treatment is widely used now a day. Application of electrodialysis technique for the treatment of a synthetic wastewater containing approximately 0.0089 mol L^{-1} cadmium was studied by Marder *et al.*[33] using a five-compartment electrodialysis cell and their results demonstrated that the removal of cadmium depended on the applied current density.

10. Biological methods

Biological methods are one of the most popular processes and found to be effective for removing cadmium from water. Biological methods are found to be effective for heavy metal removal. Science long the heavy metal removal by biosorption has gained momentum. Research by Farzin[34] was capable to remove Cd, by biological removal using fungi with 94.47% efficiency. The investigation on the ability of algae for removal of heavy metals, particularly cadmium was done by Moustafa and Idris[35]. Green algae like *Chlorella emersonii*[36], *Ascophyllum sargassum*[37] and red algae like *Ceramium virgatum*[38] has the potential to remove cadmium from waste water. Biomass of the blue green alga *Anabaena sphaericais* is an efficient biosorbent for the removal of Cd(II) from aqueous solutions [39].

CONCLUSION

1. Cadmium (II) is one of the most toxic ions hazardous to living organism and toxicity depends on path, quantity, and rate of exposure.
2. The recovery of cadmium from contaminated water is very important area of research. Many investigators have tried various methods for removal of cadmium. This paper describes several technologies that may be safe and easily used for cadmium removal in our country.
3. The choice of a particular method for the cadmium removal depends on the concentration in the water and its nature, cost, percentage removal required.

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