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Techniques to Remove Cadmium from Waste Water: A Short Overview

D Anitha[1], R Subha[2], O A Sridevi[3]
[1, 2,3]Assistant Professor, Department of Chemistry, Karpagam Institute of Technology, Coimbatore

Abstract: *Cadmium is a highly toxic element and stringent limits have been set for it in industrial wastewater as well as in drinking water. Therefore, an efficient and economic technique to remove cadmium from aqueous solution is essential. In this paper, some available techniques to remove cadmium from aqueous solution like adsorption, biological methods, electro coagulation, floatation and solvent extraction have been listed.*

Keywords: *Cadmium; Adsorption; Electro coagulation*

1. INTRODUCTION

Heavy metal pollution is of global concern as it affects the environment. Cadmium is one of the important water pollutants, emitted by smelting, metal plating, cadmium-nickel batteries, phosphate fertilizers, pigments, stabilizers and alloy industries [1]. Cadmium has been listed as a category-I carcinogen by the International Agency for Research on Cancer and as a Group-B1 carcinogen by the US Environment Protection Agency (EPA) [2]. Cadmium has been reported to cause renal disturbance, lung insufficiency, bone lesions and hypertension in humans [3].Overdoses of Cadmium cause spilling of proteins in the urine and disruption of potassium metabolism [3,4].

The World Health Organization, US Environmental Protection agency, and the EU Directive have set 0.005 mg/L as the maximum cadmium (II) concentration level in domestic water supplies [5].The US Environmental Protection agency has set 2 mg/L as the permissible discharge limit of Cadmium concentration to a wastewater body. Indian standard code IS 10500 has set the maximum permissible limit of Cd in effluents while discharging them to inland surface waters and public sewers as 2.0 and 1.0 mg/ L respectively. Moreover, IS 10500 has set the maximum permissible limit of Cd in drinking water as 0.003 mg/L [6].

In the present work, we have given an overview of some techniques like adsorption, biological methods, electro coagulation, floatation and solvent extraction used to remove cadmium from wastewater.

2. Techniques for Removal of Cadmium from Waste Water

2.1 Adsorption

Adsorption is the most effective and economic method because it is very inexpensive locally and naturally available material can be efficiently used for the removal of Cd from aqueous solution. The adsorption process offers flexibility in design and operation, and in many cases will produce a high-quality of treated effluent. Moreover, adsorption is sometimes reversible, by regenerating the adsorbents by a suitable desorption process [7].

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Yang Ding et al. (2012) used rice straw to remove Cd from large-scale effluent contaminated by heavy metals since it exhibited a short biosorption equilibrium time of 5 min, high biosorption capacity (13.9 mg g^{-1}) and high removal efficiency at a pH range of 2.0–6.0. [8]. Hongyu Wang et.al. (2015) developed a novel approach to prepare an engineered biochar from $KMnO_4$ treated hickorywood through slow pyrolysis. Batch sorption experiments showed strong sorption ability to Pb (II), Cu (II), and Cd (II) with maximum sorption capacities of 153.1, 34.2, and 28.1 mg/g, respectively. The removal of the metals was mainly through surface adsorption mechanisms involving both the surface MnOx particles and oxygen-containing groups [9].

Feng Zhang et al. (2015) investigated the efficiency and mechanisms of Cd removal by biochar pyrolyzed from water hyacinth (BC) at 250 550 ºC. BC450 out-performed the other BCs at varying Cd concentrations and can remove nearly 100% Cd from aqueous solution within 1 h at initial Cd 50 mg/L. The maximum Cd sorption capacity of BC450 was estimated to be 70.3 mg g_1 based on Langmuir model, which is prominent among a range of low-cost sorbents [10].

Jaehong Shimab et al. (2014) synthesized an environmentally benign alternative by combining corn cob silica with alginate and immobilized bacteria into beads for treating contaminated water. Beads containing corn cob silica decreased Cu concentrations by 84–88% and Cd by 83–87% within 24 h. Beads containing corn cob silica removed >97% of the Cu and >99% of the Cd, critical for reducing toxicity to the bacteria. Beads with the immobilized strain removed phenol when zeolite was used instead of corn cob silica, but beads with silica were more effective for Cu and Cd removal. Results show the potential of corn cob silica combined with alginate and immobilized bacteria for removing phenol and heavy metals from contaminated water [11].

Ihsanullah et al. (2015) reports a comprehensive study of the adsorption characteristics of cadmium(II) on modified structures of carbon nanotubes (CNTs), carbon nanofibres (CNFs), activated carbon (AC), and fly ash (FA).The optimum conditions of 2 h of contact time, pH 7, 50 mg adsorbent dosage and 150 rpm rotational speed were observed. The maximum adsorption capacities of the modified adsorbents were observed to be 2.02 mg/g, 1.98mg/g, 1.22 mg/g and 1.58mg/g, for CNTs, AC, CNFs and FA, as obtained from Langmuir isotherm models. It was determined that surface modification of the CNTs, CNFs, and AC enhanced their adsorption efficiency [12].

Taman R et al. (2015) prepared Copper oxide nano-particles with optimum solution pH for adsorption of both metals from aqueous solutions at 6. Adsorption was rapid and occurred within the first 20 min for both metals within different solution concentrations (250, 100, 50 and 25 mg/L). The kinetic of Cd^{2+} and Fe^{3+} adsorption onto copper oxide nano particles was well fitted by the pseudo second-order rate equation. The equilibrium adsorption data for Cd^{2+} was best fitted by the Langmuir adsorption isotherm model [13].

Dharmveer Singha et al. (2014) synthesized Citric acid coated magnetite nanoparticles (Fe_3O_4-Cit) for the removal of cadmium from aqueous solutions. The Cd (II) ions adsorption equilibrium on the Fe_3O_4-Cit were obtained by 35 min at the optimized pH 5. Kinetic study shows the Cd (II) adsorption on to Fe_3O_4-C it follow the pseudo-second order kinetic model with R_2 >0.997at 308K.The experimental data found to be suitable linearity with Langmuir isotherm having maximum adsorption capacity(qm) values in mg g−1 10.81, 11.45 and 12.56 at the 298K,303K and 308K, respectively[14].

2.2 Biological Methods

Various biological treatments, both aerobic and anaerobic can be used for heavy metal removal. Methods like activated sludge process, biofiltration, anaerobic digestion stabilization, biosorption have been used by various researchers for removal of chromium [15].

Fariba Mohsenzadeh et al. (2014) studied the removal of cadmium ions by three species of Trichoderma (T. asperellum, T. harzianum and T. tomentosum) under different pH (5, 7, 9) and different concentrations of Cd (1, 100, 200 ppm) in liquid media containing potato extract and dextrose. Above mentioned fungal strains were cultured in the Cd-polluted media and the remaining amount of metal ions in the media was measured after two months growth, using atomic absorption. All three fungal species were able to reduce the amount of Cd in the all three Ph. T. asperellum showed maximum removal efficiency of cadmium (76.17%), (10.75 mg/g, at fungal dry weight) [16].

2.3 Electro Coagulation

Electro coagulation is an effective method for the removal of cadmium from wastewater. It has simple and easily operated equipment with less use of chemical and less production of sludge.

Amir Hossein Mahvi et al. (2007) found electrocoagulation method as a reliable, safety, efficient and cost- effective method for removal of cadmium from industrial effluents, especially designed for pH = 10 and voltage = 40 v. It was shown that electro coagulation process achieves a fast and effective reduction of cadmium (more than 99%) present in industrial effluents [17].

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Umran Tezcan Un et al. (2015) studied the removal of cadmium (Cd), copper (Cu) and nickel (Ni) from a simulated wastewater by electro coagulation (EC) method using batch cylindrical iron reactor was investigated. The influences of various operational parameters such as initial pH (3, 5, 7), current density (30, 40, 50 mA/cm^2) and initial heavy metal concentration (10, 20, 30ppm) on removal efficiency were investigated. The removal efficiencies were significantly affected by the applied current density and pH. The experimental results indicated that after 90 minutes electro coagulation the highest Cd, Ni, Cu removal of 99.78%, 99.98%, 98.90% were achieved at the current density of 30 mA/cm^2 and pH of 7 using supporting electrolyte (0.05 M Na_2SO_4) respectively[18].

2.4 Floatation

A separation technique which has recently received a sharp increase in research activities is ion flotation. This technique has four important advantages for treating wastewaters: low energy consumption, small space requirements, small volume of sludge and acting selectively.

Mohammad Hossein Salmani et al. (2013) optimized parameters of ion flotation for cadmium removal in simulated wastewater at laboratory scale. It was obtained on the reaction between Cd^{2+} and sodium dodecylesulfate (SDS) collector followed by flotation with ethanol as frother. Test solution was prepared by combining the required amount of cadmium ion, SDS and necessary frother or sodium sulfate solution. All experiments were carried out in a flotation column at laboratory temperature (27°C), adjusted pH = 4 and 120 minutes. The best removal efficiency obtained at a collector-metal ratio of 3:1 in 60 min with flow rate of 150 mL/min was 84%. The maximum cadmium removal was 92.1% where ethanol was introduced at a concentration 0.4% to flotation column with above conditions [19].

2.5 Solvent Extraction

Solvent extraction is a powerful technique used to remove metal ions from aqueous solutions .The principle of solvent extraction is that when a metal ion solution is contacted with a solvent, the metal ion is distributed between the two phases

Nogueira and Delmas (1999) have proposed new solvent extraction flow sheet for removal of heavy metals from sulphate solutions. The investigation showed that organo phosphoric acid was the most efficient extractant. Under optimized conditions, it was possible to remove 99.7 % cadmium [20].

Conclusion

The present overview proves that though many techniques are available for cadmium removal adsorption is one of the most studied techniques. There is lack of information in literature for regeneration/reuse/safe disposal of loaded adsorbents. The engineering aspects for commercial applications of adsorbents have not been sufficiently studied.

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