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A Review on Research for Cadmium Removal from Effluent

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Abstract*— Removal of heavy metals from the effluent is very important part of the research carried out in environmental field. Various methods tried by the researchers include adsorption, biological methods, electro coagulation, electro dialysis and various membrane separation techniques among others. In this review paper attempt is done to summarize this research work, in order to study their effectiveness and the findings. Adsorption by using various low cost adsorbents was found be very effective method with the percentage removal upto 99 percent while the biological methods were also effective with the removal percent more than 90 percent. Other methods like Electro dialysis, floatation, membrane separation and extraction were used effectively by various researchers. Adsorption was found to be the method used by many researchers with encouraging results. Each method has its own advantages and disadvantages. From the current review, adsorption seems to be the best alternative, provided that the effective regeneration method is established and employed.

***Index Terms*— Adsorption, Cadmium, Concentration, Effluent.**

I. INTRODUCTION

The pollution of water bodies because of heavy metals is widely studied area of investigation. The presence of heavy metals in many electroplating, pigment, alloy, fertilizer and chemical industries render importance to the heavy metal pollution. The cadmium is one of the important water pollutants, emitted from the sources such as smelting, metal plating, cadmium-nickel batteries, phosphate fertilizers, pigments, stabilizers, alloy industries. The cadmium concentration in these wastewater ranges from 0.01 to 3.2 mg/l.Cadmium is mainy used in batteries and electroplating industries. Out of the total cadmium emitted from the various industries, fifty percent of the cadmium is emitted by electroplating industries. The wastewater containing cadmium is disposed to the inland seawater. It is observed that the intake of cadmium by the crops increase the concentration in the food and subsequently in human bodies. When cadmium is present in human bodies above certain level it may cause liver damage, renal damage, hyper tension and anemia. In india the maximum permissible limit for cadmium concentration in drinking water is 0.01 mg/l.

II. VARIOUS METHODS USED FOR CADMIUM REMOVAL

Following methods are used predominantly for cadmium removal

A. Adsorption
B. Biological Methods
C. Electro coagulation and Electro dialysis
D. Floatation
E. Membrane Separations
F. Extraction

A. *Adsorption*

The study on cadmium removal by using fly ash was carried out by Visa and Duta (1). They studied the kinetics and thermodynamics of the process. They modified the surface characteristics of the fly ash by contacting it with alkaline solutions and the complexion agents for long time. Also they discussed the immobilization efficiency in connection with contact time, wastewater volume, adsorbent mass ratio and ions concentration. They also observed that the adsorption process follows the Langmuir and Freundlich mechanisms and pseudo second order kinetics. According to their experimental observations, moderate NaOH concentrations (2N) are enough for developing a substrate that, in optimized conditions brings about 97 % removal for cadmium and nickel ions in a large concentration range. Boparai et.al have tried the adsorption of cadmium ions on the nano zerovalent iron particles (2). They also studied thermodynamic and kinetic aspects of this process. They conducted the studies in the concentration range of 25-480 mg/l. They found that the adsorption in this case increases with the increase in

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temperature as with endothermic reactions. The adsorption process was observed to be second order. In this case the Freundlich and Temkin isotherms fitted the adsorption process. The adsorption on the surface was the rate determining step. Ulmanu et. al. have used low cost waste materials such as activated carbon, kaolin, bentonite, diatomite and waste materials such as compost, cellulose pulp waste and anaerobic sludge(3). According to the studies, the bentonite was found to be best adsorbent compared to others, showing 99 percentage removal of cadmium even in presence of copper. The equilibrium data fitted in the Freundlich and Langmuir isotherms for all the adsorbents. Maleki et al have carried out research on adsorption of cadmium on barley hull and barley hull ash (4). According to the studies, with pH, the removal efficiency increases. Their research showed that the maximum adsorption was about 95.8 percent for barley hull and 99.2 % and barley hull ash, respectively. The corresponding optimum pH, contact time and initial concentration were observed to be pH value of 9, contact time of 180 min and concentration value of 30 mg /l respectively. The process was found to follow second order kinetics. Yavuz et. al. have used calcite for removal of cadmium and lead from aqueous solution(5). They carried out batch experiments at room temperature. They used centrifugal separator for separation of calcite. It was observed that the adsorption followed Langmuir isotherm reasonably well. Natural calcite showed considerable removal of cadmium and hence can be used as low cost adsorbent for the removal of cadmium. The heavy metal removal from paint industry wastewater by using leca as an adsorbent was tried by Malakootian et.al.(6).They studied the ability of light expanded clay aggregate for removal of heavy metals. They observed that the removal efficiency was around 90 % for removal of cadmium. The optimum contact time was observed to be between 110 minutes to 130 minutes.Mousavi and Seyedi have carried out research on nickel and cadmium removal by using nettle ash as an adsorbent(7). They observed that the optimum pH required was 6. Also the the experimental data well fitted in the Langmuir isotherm equation with the monolayer adsorption capacity of 142.8 mg/g. The adsorption kinetics was found to follow pseudo second order kinetics. Kumar has carried out review on heavy metal removal from effluent by using various agricultural products and by products as adsorbents (8). His study reveals that many agricultural products such as waste tea, sawdust, nut shells etc. can be used effectively for cadmium removal. The modification of these materials increases their effectiveness considerably.

B. Biological Methods

The research on removal of cadmium by using various biological methods has been attempted by many researchers. Wang et.al. have used aerobic sulphur reduction pathway for precipitation of cadmium on cell surface(9). They engineered an aerobic sulphur reduction pathway for sulphide secretion. This sulphate was used for overproducing cysteine, which was converted to sulphide by cysteine desulfhydrase. With this pathway, the bacterium was developed, which was used to precipitate cadmium to cadmium sulfide. They infered that the system they used was not immediately practical mean for remediation of metal pollutant. There is a need to develop a more environmentally relevant organism. Mockaitis et.al. have carried out research on kinetic and metabolic implications of toxic effects of cadmium on anaerobic biomass (10). They performed experiments in a continuous fixed bed anaerobic bioreactor for treating synthetic wastewater. They studied the removal efficiency for organic matter for various influent concentrations of cadmium. They concluded that the anaerobic process was suitable for cadmium removal below 29.8 mg/l of cadmium concentration. Perez et. al. have developed the mathematical model for cadmium removal using sulphate reducing bacterium(11).They developed a model which when applied to a continuous process, predicted a maximum cadmium removal of 99.1%. Also it showed inhibitory effect at cadmium concentration above 190 mg/l.

Biological siliceous filter with active biomass was used for cadmium removal by Tilki and Shariat(12).They tried to determine cadmium adsorption isotopes by bacterial biomass, pH effect and biomass concentration. They also estimated the efficiency of siliceous containing column having adhered biomass to remove cadmium from water. Kaewsarn and Yu have used pretreated biomass for cadmium removal from aqueous solution (13). They found the maximum removal capacity of biomass was at pH value of 5 and it was 0.53 mmol/g. They also observed that the maximum of the adsorption took place in first 35 minutes. Inthorn et. al. have used filamentous cyanobacterium Tolypothrix tenuis for the removal of cadmium from aqueous solution(14).They observed that the cadmium removal equilibrated within 30 minutes and it was well described by Langmuir isotherm. They also studied the effect of other metals on the removal and observed that the removal was not affected by the presence of sodium, potassium, calcium and manganese ions.

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C. Electro coagulation and Electro dialysis

Many researchers have tried the electro coagulation as effective method for cadmium removal. Mahvi and Bazrafshan have used the electro coagulation process for cadmium electrode (15). They filled the tank with synthetic wastewater with different cadmium concentrations and they measured the amount of cadmium ion removal at pH 3, 7 and 10 and in electric potential range of 20, 30 and 40 volts. The initial concentration of cadmium affected the removal efficiency and for higher concentration of cadmium, higher electrical potential or more reaction time is needed. Also their study indicated that the final pH was higher than the initial pH. The increase in current density has positive effect on removal efficiency. Gering & Scam horn have used $CdCl_2$ and $CdSO_4$ as representative salts(16). They studied the parameters like current efficiency, stack resistance, and osmotic water transfer for electro dialysis. They obtained reasonably high current efficiencies for purification of cadmium laden water. Marder et. al. have tried the separation of cadmium by using electro dialysis cell with five compartments(17). They used platinum sheets as working electrodes in the outer compartments. Their results demonstrated that the removal of cadmium depends on the applied current density and was limited by the precipitation of cadmium on the cation-exchange membrane in the dilute central cell compartment.

D. Floatation

Kobayashi has used adsorbing particle floatation for removal of cadmium from wastewater (18). He carried out investigation on adsorbing particle floatation by using bentonite and a catholic surfactant. He observed that the addition of polyacryl amide increased the floatation efficiency. He found that it was possible to remove each metal separately by selecting the proper operating conditions.

E. Membrane Separation

Denizli et.al. have carried out investigation on use of membrane chromatography for removal of heavy metal from the aquatic solution(19). They observed that the adsorption rates were very high and the equilibrium was achieved within 10 minutes. They carried out the regeneration of the polyvinyl alcohol membranes by using dilute nitric acid. The heavy metal could be repeatedly adsorbed and stripped without significant losses. Ulewiz and Walkowiak have used the technique of ion floatation and transport through membranes for separation of zinc and cadmium ions from sulphate solution (20). They presented an experimental investigation on zinc (II) and cadmium (II) ions separation from aqueous sulfate solutions, containing equimolar mixture on both metal ions, by ion flotation (IF) and transport through polymer inclusion membrane (PIM) processes. They carried out ion floatation experiments for dilute aqueous solutions with an anionic surfactant (sodium dodecylbenzene sulfonate) and a cationic surfactant (hexadecylpyridinium chloride).They observed that with cationic surfactant, the floatation separation of cadmium to zinc grows as sulphate concentration increases. The rejection of cadmium salt in nanofiltration membranes was investigated by Ballet et.al.(21). They quantified the convective and diffusive parts of the transport. They presented an experimental investigation on zinc (II) and cadmium (II) ions separation from aqueous sulfate solutions, containing equimolar mixture on both metal ions, by ion flotation (IF) and transport through polymer inclusion membrane (PIM) processes. Ion floatation experiments were carried out for dilute aqueous solutions with an anionic surfactant (sodium dodecylbenzene sulfonate) and a cationic surfactant (hexadecylpyridinium chloride). It was that with cationic surfactant, the floatation separation of cadmium to zinc grows as sulphate concentration increases. Qdais and Moussa have carried out a comparative study on removal of heavy metals by membrane technology(22).They investigated the application of nanofiltration and reverse osmosis for the removal of heavy metals from the wastewater. According to their studies, reverse osmosis is more effective with the removal efficiency of 90 percent compaired to the nanofiltration which has the removal efficiency of 90 percent.

F. Extraction

Nogueira and Delmas have proposed new solvent extraction flow sheet for removal of heavy metals from sulphate solutions(23). According to the investigation carried out by them organ phosphoric acid was the most efficient extract ant. Under optimized conditions, it was possible to remove 99.7 percent cadmium.

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III. CONCLUSION

Many investigators have tried various methods for removal of cadmium from waste water. Many biological methods are found to be effective for cadmium removal. The presence of cadmium in the form of complex on the biological mass is cause of concern. The recovery of cadmium from this biomass is very important area of research. In case of adsorption also, regeneration of the adsorbent and recovery of the metal from the adsorbent is important area of research. Other methods such as electro coagulation, electro dialysis, floatation, membrane separation and extraction are also effective. The choice of a particular method for the removal of the metal depends on the concentration in the effluent, cost, and nature of effluent, percentage removal required and the availability of the equipment, material required. Adsorption seems to be the method that provides flexibility in terms of these parameters.

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