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Research For Removal Of Nickel From Waste Water - A Review

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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, electrocoagulation, electrodialysis and various membrane seperation techniques among others. In this review paper attempt is done to summerize 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 encouraging results Other methods like Electrodialysis, floatation, membrane seperation were used effectively by various researchers. Adsorption was found to be the method used by many reasearcher with encouraging results. Each method has its own advantages and disadvantages. Various biological methods using various types of biological materials includes conventional activated sludge process, biofiltration, anaerobic treatments,biosorption. Biological methods were found to be effective methods with scope for further research in this field in terms of cost effectiveness and regeneration

Index Terms—**Nickel, biological methods, adsorption**

I. INTRODUCTION

The source of nickel pollution is industrial processes such as connecter, lead frame, Tableware, electroplating, plastics manufacturing, metal finishing, nickel-cadmium batteries, fertilizers, pigments, mining and metallurgical operations. Severe health problems such as damage to lungs, kidneys, gastrointestinal distress, e.g., nausea, vomiting, diarrhea, pulmonary fibrosis, renal edema, and skin dermatitis are caused because of the injestion of nickel in higher concentration through water. It is also a known carcinogen. Therefore, it is necessary to develop effective and inexpensive methods to remove and/or recover nickel. Conventional methods for the removal of Ni(II) from wastewaters include chemical precipitation, activated carbon adsorption, ion-exchange, chemical reduction,flocculation, filtration, evaporation, solvent extraction, biosorption, reverse osmosis, electrodialysis. The Ni(II) concentration in wastewater has been reported up to 130 mg/ L. It can approach 2-900 mg/ L in plating rinse, which is known to be one of the major toxic pollutants. In the present study various methods used by researchers to remove nickel from wastewater have been reoprted and summerized.

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II. METHODS FOR NICKEL REMOVAL

A.Adsorption
B.Ion Exchange
B.Biological Methods
C.Electrocoagulations and Electrodialysis
D.Floatation
E. Coagulation and Flocculation
F. Membrane Seperation

In the following section the review of each methos is presented.

A. Adsorption

Hema Krishna et.al. used the powder of mosambi fruit peelings (PMFP) as an inexpensive and efficient adsorbent for Ni (II) removal from aqueous solutions(1). They studied parameters such as the initial metal ion concentration, pH, agitation time, adsorbent doseges and particle size in batch tests. The optimum values of initial metal ion concentration, pH , agitation time, adsorbent dose and particle size were observed to be 50 mg/l , 4,90 min,125 mg/50 ml and 0.6 mm respectively. They also observed that the adsorption process follows Langmuir and Freundlich adsorption isotherm models.The adsorption of Nickel (II) on Maioze cob has been studied by Muthusamy et. al(2)**.** They used atomic absorption spectroscopy for metal estimation.They studied Parameters like heavy metal concentration, adsorbent dose, contact time and agitation speed. Adsorption equilibrium were described by using Langmuir and Freundlich isotherms. According to their investigation Maize cob, a waste material, has good potential as an adsorbent to remove toxic heavy metal like nickel from industrial waste water. A review on Removal of heavy metal ions from wastewater by chemically modified plant wastes as adsorbents was carried out by Ngah and Hanafiah(3).In this review, an extensive list of plant wastes as adsorbents including rice husks, spent grain, sawdust, sugarcane bagasse, fruit wastes, weeds and others has been compiled. Some of the treated adsorbents show good adsorption capacities for Cd, Cu, Pb, Zn and Ni. According to their review, Chemical modified plant waste improved the adsorption capacity of adsorbents probably due to higher number of active binding sites after modification, better ion-exchange properties and formation of new functional groups that favours metal uptake. The bagasse fly ash, an industrial solid waste of sugar industry, was used for the removal of cadmium and nickel from wastewater by Gupta et.al(4). According to the research carried out by them, the removal of as much as 90% removal of cadmium and nickel is possible in about 60 and 80 min, respectively, under the batch test conditions. They also studied the effect of various operating variables, viz., solution pH, adsorbent dose, adsorbate concentration, temperature, particle size, etc., on the removal of cadmium and nickel. Maximum adsorption of cadmium and nickel occurred at a concentration of 14 and 12 mg/l and at a pH value of 6.0 and 6.5, respectively. A dose of 10 g /l of adsorbent was sufficient for the optimum removal of both the metal ions. The adsorption data followed the Langmuir model better then the Freundlich model. Also the adsorption of both the metal ions increased with increasing temperature indicating endothermic nature of the adsorption process. They suggested that the removal of the two metal ions takes place by a partial diffusion mechanism.

Dwairi and Al-Rawajfeh carried out investigation on the application of Khulays activated clay (bentonite) to remove nickel from wastewater(5). They investigated the removal characteristics of nickel ions from wastewater using Khulays activated bentonite under various operating variables like shaking time, solution pH, clay dosage and initial metal concentration. The results showed that the sorption of nickel ions on Saudi activated clay was relatively fast and the equilibrium was reached after 40 min. According to their investigation,increasing the initial nickel concentration decreased nickel removal percentage due to the saturation of clay with nickel ions. They observed that the adsorption of nickel increased from 70 to 100 % with an increase in solution pH from 2.0 to 9.0. The adsorption isotherm data were well fitted with both the linearized Langmuir and Freundlich models. Nickel adsorption onto Saudi activated bentonite was well represented by the pseudo-second-order kinetic model.

The study carried out by Gouda et.al. was focused on coconut leaves as an alternative adsorbent for the removal of Ni(II) from wastewater(6). The batch experiments conducted at at room temperature 27^0C showed that the adsorption process is affected by various parameters such as contact time, solution pH, adsorbent dose and initial concentration. The maximum removal efficiency of Ni(II) was 93.18% for 2.0g/50ml of coconut leaves at pH 8.0 in optimum time of 4 hours. Also the data was tested for the Langmuir and Freundlich equations. The data fitted well to both Langmuir and Freundlich isotherms. The adsorption kinetics were best described by the pseudo second order model.

Samarghandi et.al. studied the removal of divalent nickel from aqueous solutions on modified holly sawdust(7).Results of their investigation showed that the removal efficiency increased by increasing pH and decreased with initial nickel divalent concentration. Experimental equilibrium and kinetics data were fitted by Langmuir and Freundlich isotherms and pseudo-first-order and pseudo-second-order kinetics models, respectively. The obtained maximum adsorption capacity was 22.47 mg/g at a pH value of 7. According to their study, sawdust was found to be a better adsorbent for the removal of divalent nickel as compared to many other low cost and commercially available adsorbents. The results showed that the modified holly sawdust can be used for the treatment of aqueous solutions containing nickel as a low cost adsorbent.

Removal of cadmium, lead and nickel from industrial wastewaters has been investigated by Kamali using teawaste as a natural adsorbent(8). He performed research on bench scale by using different amounts of adsorbents in solutions with 5 different concentrations of each metal and also in a mixed combination. Besides, he also investigated the effect of various amounts of teawaste used in adsorption efficiency experiments. He observed that 1.5 g teawaste can treat nickel solution of 5 mg/L concentration with an efficiency of not more that 85.7%. Teawaste is a cheep material so its utilizing in industrial wastewater treatment plants would be convenient. The study also revealed that it is possible to increase the treatment efficiency by pretreatment with some chemicals such as acids, bases and detergents. Removal of nickel from wastewater using an agricultural adsorbent was tried by Moodley et. al.(9). In their study, they investigated the adsorption capacity of a low-cost adsorbent (pine sawdust) by treating wastewater containing nickel (II) and other heavy metal ions. They observed that Langmuir and Freundlich adsorption isotherms fitted well to experimental data.As a result, the highest adsorption capacity was attained at the combined effect of low adsorbent dose, high pH and high initial concentration.

Mostaedi et. al. Carried out invesigation to study the removal of nickel and cadmium from aqueoua solution using perlite(10). They observed that by using 8 g/l of perilite and otimum pH of 6 the percentage removal was 93 percent. They also observed that Freundlich isotherm fitted better than the Langmuir. They also evaluated the experimental data terms of kinetic characteristics of adsorption and found that the adsorption process for both metal ions follows well pseudo-second-order kinetics. The research studies on the removal of nickel(II) using chemically activated pouteria sapota seed and commercially available carbon were carried out by Rani et.al(11). They used sulphuric acid treated Pouteria sapota seeds carbon for removal nickel from aqueous solution. They also carried out desorption studies to study the regeneration aspect. By batch mode studies, it was observed that the removal increases with time and attains equilibrium at 3rd hour and 4th hour with the removal percentage of 80 . The percentage removal reached a maximum at pH 3. The optimum carbon dosage obtained was 100mg/100mL .Their Regeneration studies found that 0.01N of HCl is required to recover 79% the adsorbent.

B. Ion Exchange

Kumar et.al.carrird out research on the removal of nickel from aqueous solutions under different experimental conditions using a Ceralite IR 120 cationic exchange resin (CXR) as an adsorbent by batch adsorption techniques(12). Batch studies indicated that the percent adsorption decreased with increasing initial concentration of Ni^{2+} . Maximum Ni^{2+} removal was observed near a pH of 5.0. The adsorption process also obeyed the Langmuir and Freundlich adsorption isotherms. The monolayer adsorption capacity was found to be 28.57 mg/g. Dave et. al. Investigated the removal of nickel from eletroplating wastewater by weakly basic chelating anion exchange resins(13). They studied Effect of initial metal ion concentration, resin dose and pH on exchange capacities of ion exchange resins in a batch method. They infered that adsorption process was pH sensitive and showed maximumphenol removal at the pH values of 4 to 6 or an initial nickel concentration of 05-30 mg L-1 and with resin dose 25-700 mg/l. They observed that The uptake of Nickel by the ion exchange resins was reversible and thus has good potential for the removal/recovery of nickel from plating waste effluent contain nickel in the form of anion exchange.

C. Biological Methods

Srivastava and Majumder have carried out review on treatment of heavy metals mainly nickel by using novel Biofiltration technique(14). They discussed the various parameters of the biofiltration processes, their mechanism for heavy metals removal along with the kinetics of biofilters and its modeling aspects. They concluded that there is a high possibility for effective application of biofilters for removal of toxic heavy metals from contaminated water in large scale. The success in microbial cloning technique may improve the removal efficiency and hence the reduction in treatment cost. Pandety et.al have carried out investigation on the removal of Ni(II) by the fresh biomass (FBM) and chemically treated leached biomass (LBM) of Calotropis procera(15). Their work included batch and column studies at various values of PH , contact time , dosages and intial concentration. They observed that the biosorption processes fits the Freundlich model. They were able to remove 85% Ni at the optimum PH value of 3 and equilibrium adsorption time of 30 minutes. Hasani et.al. used fixed activated sludge system for treatment of wastewater containing heavy metal compounds (chromium, lead and nickel)(16).They carried out studies related to compatibility and performance of fixed activated sludge reactor(FAS). They observed that COD removal efficiency in the FAS is about 96% and the acclimation time for microorganisms is short. During investigation they observed that chromium, lead and nickel removal efficiency in the fixed activated sludge at concentration of 1 mg/lit was 84%, 75% and 80%, respectively, by increasing concentration of them to 5 mg/lit, the removal percentage increased to 90%,84% and 87%, respectively.

Jong and Parry removed heavy metals by sulfate reducing bacteria (SRB) in short-term bench scale upflow anaerobic packed bed reactor(17). They filled reactor with silica sand and employed mixed population of sulfate-reducing bacteria (SRB). The activity of SRB increased the water pH from 4.5 to 7.0, and enhanced the removal of sulfate and metals in comparison to controls not inoculated with SRB. Metal removal efficiencies of more than 97.5% for Cu, Zn and Ni, and more than 82% for Fe were achieved in the column experiments.Pandey et.al. carried out research on Biosorption characteristics of Aspergillus flavus in removalof Nickel from an aqueous solution(18). Their investigation dealt with effect of different level of Ni on the growth and biosorption efficacy of Aspergillus flavus. The mycelial growth of Aspergillus flavus was found till 10 mg/L. It was observed that the *A. flavus* has tolerance to accumulate with high level of Ni, as it showed growth up to 10 mg/L Therefore, bio-removal carried out by this fungus could serve as an economical mean of treating leachate, effluent and the polluted water areas charged with toxic metallic ions.

Hanif and Bhatti carried bioremediation of nickel from wastewater using immobilized Phanerochaete chyrsosporium biomass(19). They assessed Ni (II) remediation potential of live immobilized Phanerochaete chyrsosporium from aqueous solutions as well as from real hazardous effluents also studied the parameters like pH, dose, initial metal concentration, time, temperature etc. on bioremediation potential of Phanerochaete chyrsosporium in batch system. For regeneration of metal capacity of Phanerochaete chyrsosporium sulphuric acid (0.1 M) was found to be the best desorbing agent. They concluded that Immoblization or granulation of fungal biomass could be effectively used to improve metal uptake capacity.

D. Electrodialysis and Electrocoagulation

The work carried out by Kundra et. al. focused on treatment of waste water from Indian chemical process industries containing primarily heavy metal ions(20). The process makes use of titanium as a working electrode, which is stable, energy efficient and can treat variety of effluents. In their work they made an attempt to present a detailed view of the widely adopted treatment methods and possible clean alternative to the conventional removal processes. This technique can also be employed for other heavy metal ions, viz; Cr, Cd, Hg, etc.

The performance of electrocoagulation with aluminum electrodes for simultaneous removal of nickel, copper, zinc and chromium from synthetic aqueous aliquot solutions and actual electroplating wastewater was studied by Dermentzis et.al(21). Their investigation revealed that best removal capacity for all studied metals was achieved in the pH range 4 to8. Mixed solutions containing the same concentrations of all metals i.e. 75, 150 and 300 mg/L were tested. Three metals i.e. nickel, copper, zinc showed similer removal rates.They were completely removed in 20, 40 and 50 minutes respectively, while for the corresponding complete removal of chromium 40, 60 and 80 minutes were needed. Increased current density accelerated the electrocoagulation process, however, on cost of higher energy consumption. The experimentation on electrotreatment of a high strength industrial lead frame nickel-plating waste-water was carried out with newly designed electrodeposition reactor by Chen et.al(22).They circulated electrolyte rapidly past the anode and cathode at a higher flow rate, allowing for improvements in efficiency and recovery, and then nickel electrodeposited on the surface of cathode. They observed that that the pH decreased during the electrotreatment. The reason, they found for this was the production of H^+ on the anode surface, and the lower current density was accompanied with the higher current efficiency. In this study, the optimum pH value was found in the range of 2-2.5.

E. Floatation

Nickel removal by using floatation method was carried out by Turtureanu et.al.(23).They used floatation with cationic collectors (octadecilamine) for nickel removal. They also determined the optimum seperation parameters. The parameters like pH of Ni(II) solutions, molar ratio octadecilamine:Ni(II), air flow rate, flotation time, temperature and initial concentration of metal ions in sample. The removal upto 98 pecent was possible with optimal conditions mainly at pH greater than 10. Mahne, and. Pinfold have investigated the precipitate floatation for nickel removal from dilute solution.(24). They observed that the removal increases with increasing the temperature between 21 degree celcius to 40 degree celcius. The pH range required is 8 to 11.

A simple tecnic based on the sorption of Ni^{2+} ions from aqueous solutions onto limestone (LS) fines, followed by flotation with oleic acid (HOL) surfactant was used by Y. Hannachi and A. Hannachi(25). They studied different parameters (namely: solution pH, sorbent,surfactant and nickel concentrations, shaking times, ionic strength, temperature and the presence of foreign ions) influencing the sorptive-flotation process . They were able to remove nearly 99% of Ni^{2+} ions from aqueous solutions at pH 7 after shaking for 5 min and at room temperature (~25°C).

F. Coagulation and Flocculation

Amuda et.al. have removed trace metals from industrial wastewater by coagulation/flocculation process(26) They examined the effectiveness of the polymer addition to coagulation process for removal of nickel and other heavy metals.. They conducted experiments using the standard Jar test procedure to determine the performance of both ferric chloride and organic polymer (a non-ionic polyacrylamide) individually and ferric chloride-polymer combination. They found that it was possible to remove the metals in considerable amount. Mansoorian et. al. have carried out the investigation on practicle application of electrocoagulation for removal of nickel from aqueous solution by oron rod electrodes(27). They observed that by increasing pH, nickel removal efficiency for each concentration has increased, as much as 99.9% and 99.8% for 500 and 5 mg l^{-1} concentrations respectively.

G. Membrane Seperation

Borbely and Nagy have tried complexation-ultrfiltration method for nickel removal(28) . They used complexation enhanced ultrfiltration method with polymer sulphone membranes with different cut offs and complxating agents. They concluded that bottleneck of the process was regeration. Gajda and Bogacki have investigated tghe removal of heavy metals by using polymer inclusive membrane(29). This method was found to be useless for nickel but very effective for zinc

III. Conclusion

Many investigators have tried various methods for removal of nickel from waste water. Many biological methods are found to be effective for nickel removal. The recovery of nickel 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 electrocoagulation, electrodialysis, floatation and membrane seperation are also effective. The choice of a perticuler method for the removal of the metal depends on the concentration in the effluent, cost, nature of effluent, percentage removal required and the availability of the equipment, material required. Various biological methods with wide variety of choices in terms of contacting pattern and materials is still very interesting area of research with the potential for optimization of cost by adopting suitable regeneration and recovery methods.

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