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Biological Methods for Heavy Metal Removal-A Review

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Abstract*— In the current era of globalization and rapid industrialization, the environmental issues are becoming more and more nuisance for human being. Efficient and effective methods for the removal of pollutants present in water is the need of the chemical industries. Heavy metals present in waste water and industrial effluent is major concern of environmental pollution. Most heavy metals are well-known toxic and carcinogenic agents and it represent a serious threat to the human population and the fauna and flora of the receiving water bodies. 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. Studies on biological methods are very important area of research with huge potential for research and applicability for removal of heavy metals. Various biological methods include trickling filter, biosorption, activated sludge process and various anaerobic methods. In this review paper attempt is done to summarize this research work, in order to study their effectiveness and the findings. Biological methods by using various low materials were found be very effective methods with the percentage removal above 90 percent..

***Index Terms*—Heavy Metals, Biological Methods, Biosorption.**

I. INTRODUCTION

Heavy metals present in waste water and industrial effluent is major concern of environmental pollution. Most heavy metals are well-known toxic and carcinogenic agents and it represent a serious threat to the human population and the fauna and flora of the receiving water bodies. Heavy metals have a great tendency to bio-accumulate and end up as permanent additions to the environment. Heavy metals are considered to be the following elements: Copper, Silver, Zinc, Cadmium, Gold, Mercury, Lead, Chromium, Iron, Nickel, Tin, Arsenic, Selenium, Molybdenum, Cobalt, Manganese, and Aluminum. Heavy metals like Zn, Cu, Ni, and Ar are known to have toxic effects at very low concentrations as well as very high concentration. The removal of heavy metals from waste water has recently become the subject of considerable interest owing to strict legislations. Industrial wastewater containing heavy metal should be treated before discharge to the water stream but its treatment is very costly. There are several techniques to remove heavy metals from wastewater such as filtration, electro coagulation etc but there is some limitation such as long treatment time. Various biological treatments, both aerobic and anaerobic can be used for heavy metal removal.

II. METHODS FOR HEAVY METAL REMOVAL

Following methods have been used by various researchers for removal of heavy metals.
A.Biosorption
B.By bacteria and microorganism
C.Activated sludge process
D.Biofilter
E.Anaerobic digestion
F.Stabilization Ponds
G.Others
The summery of the research on removal of heavy metal by these methods is presented in the next section.

A. Biosorption

Mane et. al. have used pretreated algal biomass to remove one of the heavy metal namely selenium(1).They used algae isolates Viz., Spirogyra sp and Nostoc commune for this experiment. They treated the biomass using chemical treatment and used it for selenium removal. Also they used live algae for the purpose and compared the results with the earlier treated biomass. They observed that the Spirogyra sp and Nostoc commune, when treated physically or chemically is able to remove selenium to considerable extent. They also observed that pretreatment of

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biomass with NaOH showed increase on biosorption of selenium by approximately in comparison with living biomass. Also the research indicated that acetic acid treatment significantly increased the biosorption of selenium. Wang and Chen have carried out survey of the biosorbents used for heavy metal removal(2). Their study emphasizes the potential of biomass in wastewater treatment application, especially heavy metal removal. They also found during the review that the biomass can be modified chemically or physically to increase the adsorption capacity. There is the trend of using hybrid technology using living cells. Many researchers have used immobilization technology for better results. Also the recycling and reuse of the material further optimizes the treatment cost and makes it more effective. The investigation on the ability of algae to eliminate a number of various heavy metals, particularly lead and cadmium in one metal solution system was done by Moustafa and Idris(3). They also tried to identify the limiting parameters for the metal removal process. They used the strain Chlorella vulgaris for its high tendency to remove heavy metals in two successive steps, the first is the adsorption on its surface followed by fixation. They observed that the algae was able to remove 60 percent lead and 65 percent cadmium. A review on the biosorption method for heavy metal removal was carried out by Das et.al(4). According to their study, though many methods are available for the removal of heavy metals, each one is having some disadvantages. The review gave better understanding of various biosorbents that can be used for the metal removal purpose. Many naturally available and cheap materials can be used for biosorption of metals. Now, the optimization aspect of biosorption is vastly studied and analyzed aspect of biosorption. It is aimed at mainly reuse and regeneration of the material. Biological sludge was immobilized into Ca-alginate beads via entrapment and biosorption of copper, zinc and chromium was carried out by Hai-suo et.al.(5). In the immobilized sludge the biosorption rate was lower owing to the polymer mass transfer resistance. Free pretreated activated sludge was found to have more removal rate. Biosorption process attained equilibrium in 20 hours and no further change in the metal ion concentration was observed. No significant effect of temperature on the biosorption process was observed for free biomass. For immobilized biomass, there was strong effect of temperature on the process for temperature change from 10 to 40 degree Celsius. The sorption process was well fitted in the Langmiur isotherm, indicating monolayer adsorption

B. By Bacteria and Microorganism

Illhan et.al has tried removal of chromium, lead and copper ions by microorganisms from industrial wastewater (6). They investigated the effect of pH, temperature, initial concentration on the metal removal. The optimumpH values were observed to be 2,3.5,4.5 respectively for these three metals. At the optimized conditions the biosorption values were found to be 88.66,100 and 44.94 mg/lrespectively for chromium, lead and copper ions . They concluded that Staphylococcus saprophytics was suitable mainly for lead and chromium. The removal of heavy metals by using native accumulator plant was tried by Chehregani et.al(7). The carried out the research in order to analyze the capacity of native accumulator plants to photo remediation of heavy metal. They used old waste pool of Pb for their study and collected the plants in the area. They analyzed the soils near the plants and chose the plant with maximum metal uptake for the study. They introduced the plants such as E. cheiradenia, R. lutea, S. excelsa, S. orientalis, C. oblonga and C. virgata. Isolation, identification and characterization of heavy metal resistant bacteria was studied by Raja et.al(8). They collected the wastewater samples across Madurai district. They isolated and characterized the bacteria and determined optimal growth conditions. They also determined the minimum inhibitory concentration (MIC) . The sewage isolates showed optimum growth at 30 °C and pH 7.0determined at 30^{o}C for 5 days. They observed that. the growth rate of the sewage bacteria in the presence of heavy metal was consistently slower than the control. Also bacteria imaged in liquid appeared to have smooth surfaces and apparently greater resolution of cell surface structures. Sharma et.al. have tried the biological removal of the zinc by using Aspergillus sp.(9). They developed the fungal strain in 100 ml conical flask. The initial pH was 5.6, and temperature of 30 degree Celsius. They conducted experiments using sugar concentrations of 10, 15 and 20g/l and at dilution rates of 0.08, 0.04 and 0.02 per hour. They observed that there was no significant increase in the specific zinc uptake with increase in sugar concentration. The specific zinc uptake was found to be 120mg/g of dry biomass at 10g/l sugar concentration. Jong and Parry removed heavy metals by sulfate reducing bacteria (SRB) in short-term bench scale up flow anaerobic packed bed reactor(10). 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.

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Pandey et.al. Carried out research on Biosorption characteristics of Aspergillus flavors in removal of Nickel from an aqueous solution (11). Their investigation dealt with effect of different level of Ni on the growth and biosorption efficacy of Aspergillus flavors. The mycelia growth of Aspergillus flavors 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 leach ate, 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 (12). 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, and 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 Immobilization or granulation of fungal biomass could be effectively used to improve metal uptake capacity. 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 (13). Their work included batch and column studies at various values of PH, contact time, dosages and initial 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. Suhasini et.al have carried out research on removal of heavy metal from aqueous solution using Schizosaccharomyces Pombo in free and alginate immobilized cells(14).They performed the batch studies by varying parameters such as pH, temperature and metal concentration. The optimum temperature was 25 degree Celsius and pH value of 4. The maximum removal of 73 percent was observed at the initial concentration of 100 ppm with inoculums concentration 1 %. Their investigation suggests than immobilization beads gave better metal removal than free beads.

C. Activated Sludge Process

Hasani et.al. used fixed activated sludge system for treatment of wastewater containing heavy metal compounds (chromium, lead and nickel(15).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. Mechanism of activated sludge process was studied by Pagnanelli et.al(16). They carried out studies on chemical mechanism of cadmium and lead removal by activated sludge process. They observed that the carboxylic and amino groups are two main groups responsible for the binding properties of the biomass. The metal plating effluent was treated by activated sludge remediation by Atkinson et.al(17). They collected waste activated sludge samples on weekly basis from drying beds on water treatment facilities for domestic waste. They also carried out desorption studies and estimated desorption efficiency. They concluded that the biosorption of heavy metals occurs in nonspecific fasion with preference to those metals, which are present in largest amount. They also found that sludge-bound metals can also be effectively desorbed using mineral acids .The behavior of six heavy metals in an activated sludge pilot plant under conditions of normal and elevated influent metal concentrations was studied by Rossin et.al(18). They observed that the greatest degree of heavy metal accumulation was for the sludge age of 12 days. Under steady state conditions of normal and elevated influent metal concentrations. heavy metal removal efficiencies were similar. Hasani et.al. have tried removal of heavy metals from industrial wastewater using fixed bed activated sludge process(19). They observed that chromium, lead and nickel removal efficiency in the fixed activated sludge at concentration of 1 mg/lit was is 84%, 75% and 80%, respectively, by increasing concentration of them to 5 mg/lit, the removal percentage increased to 90%,84% and 87%, respectively. According to their studies the removal heavy metals from wastewater was not just a biological operation, but at some stage pure adsorption takes place

D. Biofilter

Srivastava and Majumder have carried out review on treatment of heavy metals mainly nickel by using novel Biofiltration technique (20). 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

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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. Trickling filter was used for removal of heavy metals by Dermou et. al(21). They observed that the use of indigenous bacterial populations provides a certain advantage and ensures durability under various operating conditions. They operated the system in three different ways i.e. batch, continuous and sequencing batch reactor (SBR) with recirculation. The use of an attached growth system provides the necessary surface for the development of biofilm structures. Biofilms provide high biomass concentration per unit volume, while bacteria can remain in the reactor for unlimited time, thus allowing the bacteria better adjustment to the environmental conditions.

E. Anaerobic Digestion

Chemical and microbial removal methods for heavy metal removal by an aerobically digested sludge was tried by Tyagi et.al(22).They observed that the removal of metals increased with decreased sludge solid concentration and pH and also the microbial processes mixed culture gave 10% better solubilisation of metals than in single culture. According to their studies the cost of sludge treatment in terms of chemicals was found to be decreased by 80% in microbial leaching. The studies on the metal removal from an aerobically digested sludge by chemical treatment and microbial leaching processes in laboratory reactors were carried out by Ito et.al (23). The addition was ferric sulphate was done, which was the reason for. Acidification of the sludge and elution of heavy metals from the sludge. The investigation also showed that with an increase in the amount of iron added and decrease in the sludge concentration, the pH of the sludge decreased .They also observed that the Ferric iron eluted cadmium, copper and zinc effectively than sulphuric acid. They concluded that ferric iron played a role to acidify the sludge. It also oxidized metallic compounds in the sludge. This chemical method was found to be useful for the removal of heavy metals from aerobically digested sewage sludge.

F. Stabilization Ponds

Attached growth waste stabilization ponds were used for heavy metal removal by Polprasert, and Charnpratheep (24). They conducted experiments to investigate the performance of AGWSP units that received Cd and Cr shock loadings. According to the investigation the waste stabilization pond (WSP) units without attached-growth media had more concentrations of the applied heavy metals present in the effluents than waste stabilization ponds.

G. Others

A study on the effects of the heavy metals copper, lead, and zinc on biofilm and planktonic *Pseudomonas aeruginosa* was undertaken by Teitzel and Parsek(25). They examined the effects of the heavy metals copper, lead, and zinc on biofilm and plank tonic Pseudomonas aeruginosa. They used rotating biological contactor for the purpose of generating biofilm and free swimming cultures. The biofilms were observed to be 2-600 more resistant to heavy metals than free swimming cultures. They concluded that the extracellular polymeric substances that encase a biofilm may be responsible for protecting cells from heavy metal stress by binding the heavy metals and retarding their diffusion within the biofilm. Cr by chemical precipitation and by biological method.9. The treatment of tannery waste by using chemical and biological treatment was carried out by Abdulla et. al(26). They used the chemical precipitation method for chromium removal in the first stage removal and then they used biological method for removal of residual chromium from the supernant of chemical precipitation method. Their results showed that isolate S65 is the most efficient isolate where nearly 97% of chromium (VI) was removed over 4hrs period. They concluded that the combination between the chemical precipitation and the biological removal of chromium from tanning wastewater make it meet the environment safely.

III. CONCLUSION

Many investigators have tried various methods for removal of heavy metals from waste water. Biological methods are found to be effective for heavy metal removal. The presence of heavy metals in the form of complex on the biological mass is cause of concern. The recovery of heavy metals from this biomass is very important area of research. Biomass has been used effectively for the removal of heavy metals by researcher. Studies also show that the chemical and physically modified biomass has higher potential for removal of heavy metals than untreated

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biomass. The satisfactory removal of heavy metals like selenium, lead, cadmium, chromium, copper, nickel has been reported by various investigators. The key area of research in the heavy metal removal by biological methods is the recovery of heavy metals. The recovery and regeneration are the two important factors which can make the biological methods, a more attractive and economical alternative.

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