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Methods for Removal of Heavy Metals from Industrial Waste Water

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Abstract:

Now a days, heavy metals is a serious problem because these heavy metals are discharged into water from various chemical industries. They are dangerous to all living organisms and necessary to eliminate to minimize the risk of uptake by plants, animal and human. Several methods are developed and extensively investigated for heavy metal removal. The innovative processes for treating industrial water waste that containing heavy metals which involving technologies for reduction of toxicity of metals. The innovative process for removal of heavy metals such as chemical precipitation, adsorption, ion exchange, membrane filtration, coagulation-flocculation and floatation. In this review paper, discuss about the methodologies for removal of heavy metals from water waste including, chemical precipitation, ion exchange, membrane filtration, coagulation-flocculation and electrodialysis with their advantages and limitations because of its low-cost, availability and eco-friendly nature.

Keywords: *Heavy Metals, Electrodialysis, Flocculation, Adsorption*

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Introduction

Heavy metals are refer to as metallic elements with high atomic weight and high density. Developed industries like fertilizer industry, metal processing, pulp-paper industry, mining activities, rubber-plastic industry, batteries etc. which is discharge heavy metals contaminated water into nearby water bodies. At low concentration, heavy metals are highly toxic and are carcinogenic but not biodegradable. By these heavy metals, cause serious threat to human life and to aquatic, vegetation cover. These heavy metals get absorbed and accumulated in human body that causes serious health disease such as cancer, damaging of nervous system, organ damage even death. Heavy metals are generally considered those whose density exceeds 5g per cubic centimeter. Most of these heavy metals are fall into this category are highly water soluble, well-known toxics and carcinogenic agents and most heavy metals are copper, Lead, Silver, Gold, Cadmium, Nickel, Mercury, Cobalt etc. Wood processing industries where a chromated copper-arsenate wood treatment produces arsenic containing wastes, inorganic pigment manufacturing producing pigments contain chromium compounds and cadmium sulfide; petroleum purifying generates conversion catalysts contaminated with nickel, vanadium, and chromium; and photographic operations producing film with high concentrations of silver and ferrocyanide. These generator produces a large quantity of water waste residues and mud that can be characterized as hazardous wastes requiring extensive waste treatment. If heavy metals are present in low amounts, then they are highly toxic in nature and removal of heavy metals from waste water have to be made as a subject to strict legislations.

For removal of heavy metals from waste water, efficient and effective methods are needed especially for chemical industries. The methods such as ion exchange, electrodialysis, flotation, membrane filtration etc.

Methods for Removal of Heavy Metals

Chemical Precipitation

It is an effective and most widely used method for removal of heavy metals from inorganic waste in industry. In this method, chemical react with heavy metals that is present in waste water and formation of insoluble precipitation. These precipitates are removed by using sedimentation technique and clear water is poured. Produce insoluble precipitates of heavy metals such as hydroxide, sulfide, carbonate and phosphate by conventional chemical precipitates. The mechanism of these process is based on to produce insoluble metal precipitation by reacting dissolved metals in solution and precipitant. Very fine particles are generated in this precipitant process and used the chemical precipitants, coagulants, and flocculation processes to increase their particle size to remove them as mud. In can be easily removed in case of metal precipitate and form solids and discharged the low metal concentration. In solution, removal percentage of metal ions may be removed to optimum by changing major parameters such as pH, temperature initial concentration, charge of the ions etc.

Coagulation and Flocculation

Coagulation is a process that uses coagulants and these coagulants are formed by the combination of insoluble particle and dissolved organic matter into large combinations and some coagulants such as aluminum sulphate (alum), magnesium chloride (MgCl2), polyaluminium chloride (PACL), and aluminum hydroxide oxides. Lead is removed form waste water in existence of other metals such as iron and zinc with aluminum sulphate, polyaluminum chloride, magnesium chloride. For removal of heavy metals, use of coagulant process that causes so many problems such as it increases heavy metal concentration in wastewater, large volume of sludge is produce and health problems. To eliminate these problems, use alternative coagulant must be considered such as chitosan, biopolymers.

Flocculation is widely used technique for removal of heavy metals from waste water. In this process, flocs bind with particles that forms the bridges in between which convert into large agglomerates or clumps and some flocculation such as sodium dodecyl sulphate, polyferric sulfate and polyacrylamide are used for treatment of waste water.

Ion Exchange

Ion exchange technique is widely used for treatment of removal of water in industry and it can attract soluble ions from liquid phase to solid phase. In this process, used only low cost materials and convenient operations and treating water with low concentration of heavy metals. In this process, most widely used anions and cations for removal of metal ions in the solution. Synthetic organic ion exchange resins are used for ion exchangers and can be used at low concentrated metal solution and this method is highly sensitive with pH of aqueous phase.

It can absorbs positively and negatively charged ions from an electrolyte solution because it are water soluble solid substance and release other ions with same charges into solution in an equivalent amount. In this solution, positively charged ions in cationic resins

such as hydrogen and sodium ions are exchanged with positively charged ions, such as nickel, copper and zinc ions. Similarly, the negative ions in the resins such as hydroxyl and chloride ions can be exchanged by the negatively charged ions such as chromate, sulfate, nitrate, cyanide and dissolved organic carbon.

Membrane Filtration

This process is capable of removing suspended solid, organic compounds and inorganic contaminants such as heavy metals. It can be retained that is depend on particle size and it contain various types of membrane filtration such ultrafiltration, nanofiltration and reverse osmosis can be employed for heavy metal removal from wastewater.

Ultrafiltration (UF): This type of method work at low pressures and removed dissolved and colloidal materials. It is two types technique, first one is Micellar enhanced ultrafiltration (MEUF) and second is polymer enhanced ultrafiltration (PEUF). MEUF is a physicochemical membrane separation technique in which there is addition of anionic surfactant in waste water. So that the monomers of anionic surfactant aggregate and they form micelles. Because of electrostatic force, heavy metals are trapped in outer part of micelle. In case of heavy metals are not trapped in outer part of micelle and remaining surfactant passes through the ultrafiltration membrane. MEUF contain several advantages such as it gives high flux, high removal and low cost and disadvantages such as it increases operating cost as well. PEUF uses water soluble polymer in waste water. If the size of these polymers is larger than molecular weight that retained in the membrane and cut off the membrane. PEUF helps for removal of small solute molecules which can nor remove by conventional UF.

Reverse Osmosis (RO): This process is derived by pressure. According to Mohsen-Nia et al. has removed Copper and Nickel from waste water that using disodium salt removed Cu and Ni from wastewater using disodium salt ethylenediaminetetraacetic acid (Na2EDTA). Increasing the chelated ion size of copper and nickel by addition of (Na2EDTA) and rejection efficiency has been increased up to 99.5%. But according to Ozaki et al. has used aromatic polyamide (ES20) ultralow membrane for removing copper, nickel and chromium from wastewater. Removal heavy metals was found greater than 95%.

Nanofiltration: Ranging pore size in between UF and RO in the nanofiltration that is the type of membrane filtration. Nanofiltration membranes are composed of synthetic polymers containing charged groups in which exist positively charged polyethylimine crosslinked polyimide nanofiltration membrane (PEI) that has good chemical, thermal and mechanical property. But is also contain one limitation that gives the rejection efficiency only for the multivalent cations. This membrane is modify for removal of heavy metals from waste water.

Electrodialysis

Electrodialysis is a membrane separation and by applying an electric potential, ionized species in solution are passed through an ion exchange membrane. This membrane are made up of thin sheets of plastic materials with either anionic or cationic characteristics. When solution is passed through cell membrane that containing ionic species, then anions migrate toward the anode and cations toward the cathode that crossing the anion exchange and cation-exchange membrane. It contain disadvantages that membrane replacement and corrosion process. Membrane using with higher ion exchange capacity that give result in better cell performance. At different concentration, effects of flow rate, temperature and voltage using two types of commercial membranes, using a laboratory ED cell, on lead removal.

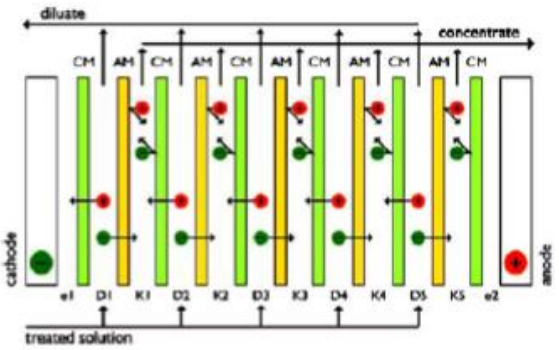

Figure: Electrodialysis Process

This process gave the result that increasing voltage and temperature improved cell performance and separation percentage decrease with increasing flow rate.

Flotation

Flotation method is well known method for removing of heavy metals. It contain several advantages such as selective metal ion recovery, low sludge generation and it provides high separation efficiency. According to Scorzelli et al. has been used sodium dodecylsulfate (SOS) as a collector and isopropanol and methyl isobutyl carbinol (MIBC) as a frother for cadmium removal from wastewater. But according to Polat and Erdogan, removal of copper, zinc and chromium from waste water by using ion flotation method. Ion floatation has several advantages such as less energy requirements, rapid operation, low concentration of metals, small space requirements, less operating cost.

Review of Literature

Orhan and Buyukgungor (1993), concluded Althat removal of Cr (VI), Cd (II) and Al (III) from waste water that are agricultural waste. Adsorption reaction can be described by first order reversible reaction and sorption equilibria data can be approximately to Freundlich isotherm.

Qaiser, Saleemi and Ahmad (2007), for chromium and lead, Ficus religiosa leaves powder was found to be a very good adsorbent. For both metals, it has good sorption capacity and capacity was 5.66 ± 0.43 mg g-1 for hexavalent chromium and 16.95 ± 0.75 mg g-1 capacity for lead. Sorption was dependent on pH and optimal pH was 4 and 1 for lead and chromium. For chromium, optimal temperature was 40ºC but 25ºC for lead. In case of lead, ion exchange between protons and metal cations but in case of hexavalent chromium, ion exchange between metal anions and hydroxyl ions.

Hsu, Peng and Lee (2009), stated that adsorption capacity increased with prolongation of reaction times and decreased as the particle size increased. For metal adsorption, optimum pH values were in range of 4~6. Phyllostachys pubescens was the most effective method in removing heavy metal ions from aqueous solutions in bamboo samples. By hot water extraction treatment, removal of heavy metals efficiency of raw bamboo can be greatly and easily improved. The removal of hot-water extracted bamboo waste was better than that of bark, exhausted coffee, and exhausted tea. The hot-water-extracted bamboo wastes may be potential alternative biosorbent to remove of heavy metals from industrial waste.

Dhabab (2011), in this paper, percentage of removal of heavy metal ions from waste water solution by using adsorption. With experimental conditions, amounts were between 50 to 94 ppm such as time contact, pH, initial concentration and weight of loading material. Heavy metal removal percentage was Pb2+ (94%), Zn2+ (72%), Cu2+ (65%), and Fe2+ (50%).

Salam, Reiad and ElShafei (2011), peanut husk charcoal, fly ash and natural zeolite are low-cost adsorbent that are effective for removal of copper and zinc ions from aqueous solutions. In this paper, uses batch method such as pH, contact time, adsorbent dose and metal concentration at an ambient temperature 27± 2 ºC. This optimum pH was used for adsorption of copper and zinc removal at 6-8. Copper and zinc ions were adsorbed onto adsorbents very rapidly within 2-3 h for Cu and Zn ions using different adsorbents.

Suryan and Ahluwalia (2012), dictated that heavy metals are removed by using biosorption technology in which living and dead biomass is used that find the major drawback of cost of growing a sufficient quantity of bacterial fungal or algal biomass. Adsorption of metal ions was affected by pH, adsorption was above 70% for all the metal ions covering a range of pH from 2 to 5.

Tanchuling, Resurreccion and Ong (2012), in this paper, discuss about the "Development and Testing of Coco-peat Filter Bed as Sorbent Material". After done studied on laboratory scale, observe that coca-peat is a viable material for sorption, due to its sorption capabilities, as well as its being locally-available, abundant and cheap.

Hegazi (2013), concluded that removal of heavy metals by using low cost adsorbents with a concentration range of 20-60mg/l. Rice husk material was effective for removal of Fe, Pb and Ni but fly ash was effective in removal of Cd and Cu. Percentage removal of heavy metals was dependent on dose of low cost adsorbent and adsorbent concentration. For heavy metal adsorption, optimum pH range is 6-70.

Malik, Lata and Singhal (2015), concluded that treatment of contaminated lead waste water by using adsorbent method. The maximum uptake capacity of adsorbent was observed at pH 4.5. The percentage adsorption as well as uptake capacity of adsorbent increased with decrease in pH. The percentage adsorption was found to be increase with increase in adsorbent dose but it decrease with increase in adsorbate concentration. Lead should be remove from aqueous solution by using MAV leaf powder that are very efficiently and thermodynamic parameters are supported by adsorption process. The adsorption process was exothermic and spontaneous at ambient and slightly higher temperatures.

Raouf and Raheim (2017), dictated that removal of heavy metals by using conventional technologies that contain sources and hazardous effects. It was established that improving the environmental pollution of heavy metals by adsorption is more beneficial than other methods. Mentioned the technologies for removal of heavy metals of agricultural waste.

Conclusion

Methodologies are play an important role for removal of heavy metals from waste water. Here, many methods are discuss such as chemical precipitation, flotation, ion exchange, electrodialysis and membrane filtration etc. All methods are contain some advantages and disadvantages. First is chemical precipitation which is simple and expensive and it has disadvantage such as production of sludge. This method is useful for concentration of heavy metals is high and low heavy

metal concentration is not effective. In coagulation-flocculation method contain advantage that is sludge settling and dewatering but disadvantages is high cost and large consumption of chemicals. In ion exchange method, advantages that there is no change in pH waste and excellent reliability but disadvantages is high membrane cost, requirement of resin fouling and resin regeneration. In methods, choice of method depend on initial metal concentration, capital investment, operational cost and environmental impact.

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