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Removal of Heavy Metals from Waste Water by Adsorption: A Review

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ABSTRACT

Heavy metal-containing industrial effluents could be a major source of contamination, posing serious environmental risks. For a long time, removing heavy metals from wastewater has been a difficult task. Nickel, chromium, lead, zinc, arsenic, cadmium, selenium, and uranium are all heavy metals found in industrial wastewater. Chemical precipitation, ion exchange, reverse osmosis, electrodialysis, ultrafiltration, nanofiltration, coagulation, flocculation, and floatation are only a few of the successful heavy metal removal technologies investigated thus far. However, these approaches have a number of drawbacks, including a high reagent demand, unpredictability in metal ion removal, and the formation of toxic sludge, to name a few. Because the adsorption process is straightforward, cost-effective, and adaptable, it has become the most used approach for removing hazardous pollutants from wastewater. Many studies have employed adsorbents such as coal fly ash, rice husk ash, nano material, and conducting polymer to remove heavy metals such as Cr, Pb, Hg, Zn, Mn, and Cu from water. Adsorption has proven to be a great method for treating industrial waste effluents, with benefits such as low cost, availability, profitability, ease of operation, and efficiency. This paper reviews the use of various readily available natural materials as adsorbents of heavy metals from industrial wastewater.

Keywords: Adsorption, Heavy Metal.

I. INTRODUCTION -

Water pollution has become a big issue in recent years. Furthermore, both natural and human activities influence water, which is one of the most valuable resources for human, plant, and animal survival, as well as aquatic environments. The discharge of heavy metals directly into local water resources without sufficient treatment is rising day by day as a result of advances in industrial technology, posing a hazard to all environments and humans [1]. Heavy metal is one of the most biologically dangerous and deadly components of industrial effluent, thus keeping it under control is crucial. Because of their high toxicity to human health, heavy metal concentrations in wastewater are closely regulated [2]. Gene toxicity, neurotoxicity, hepatotoxicity, nephrotoxicity, kidney and lung damage, shortnessof breath, chest pain, skin dermatitis, gastrointestinal disorders, vomiting, diarrhoea, inhibition of oxidative enzyme activity, and an increase in blood pressure have all been linked to excessive heavy metal exposure in humans. Industries (refinery, mining, tannery, electroplating, fertilizers, textiles, dyes, etc.) have used traditional technologies (membrane filtration; solvent extraction, ion exchange, reverseosmosis, oxidation, chemical precipitation, etc.) to purify wastewater of heavy metals [3].The creation of dangerous chemical sludge, insufficient metal removal, low efficiency, and a high energy and reagentrequirement are all disadvantages of these processes. New cost-effective, safe, and toremove heavy metals from aqueous solutions, a variety of biomass-based adsorbents from biological (fungi, algae, yeast, and bacteria) and agricultural (rice husk, saw dust, banana peels, corn cob, orange peel, sawdust, sugarcane bagasse, and so on) sources have been used [4].Adsorption is the major techniques used for removal heavy metal termed as " adhesion of atoms, ions or molecules from a gas, liquid or dissolved solid to a surface". Adsorbate refers to the molecular species accumulates at the surface, while adsorbent refers to the medium on which the adsorption occurs. The processes can occur between any two-phase contact like liquid-liquid, gas-liquid, and liquid-solid interfaces. The main properties in determining cheap tools are being used to overcome the limitations of previous methodologies. adsorption equilibrium and rate qualities, which are needed for plant design, are the surface Characteristics and pore structure of adsorbents. Adsorption equilibrium is the most important thing when planning adsorption operations [5].

II. LITERATURE REVIEW:

1. Adsorbent -Activated carbon

K. Kadirvelu et al. carried the experiment on heavy metal removal from industrial wastewater. The adsorbent they used was **activated carbon** which is prepared from coirpith by a chemical activation method. The adsorption of toxic heavy metals namely: Hg(II), Pb(II), Cd(II), Ni(II), and Cu(II) was studied using synthetic solutions. They discovered that when the pH climbed from 2 to 6, the percent adsorption increased and stayed constant up to 10. The experimental findings from batch mode adsorption experiments revealed that coirpith carbon may be utilised to successfully remove metal ions from genuine industrial wastewaters. Ion exchange seems to be the mechanism of metal ion adsorption. Because coconut coirpith is a waste product from the coir processing industry, the resultant carbon is projected to be a cost-effective metal removal solution for water and wastewater [6]. Y. Orhan et al. carried out the batch studies in order to compare the metal ion adsorbed on **activated carbon** as adsorbent with agricultural waste as another adsorbent. Waste tea, Turkish coffee, tired coffee, nut and walnut shells were employed as adsorbents. Batch investigations were carried out at room temperature, as well as adsorption trials. Batch tests revealed that these adsorbents had a high potential for adsorption of AI (ll) metal ions.The results they obtained shows that agricultural wastes appear to be suitable for the removal of Cr (VI), Cd (II) and AI (III) from wastewater. Batch studies shown that the adsorption reaction can be described by the first order reversible reaction and the sorption equilibria data can be approximated to Freundlich isotherm [7].M. A. O. BADMUS et al. carried a project on " Removal of Lead Ion from Industrial Wastewaters by Activated Carbon Prepared from Periwinkle S (Typanotonus fuscatus) . Due to advancement in the technology the disc hells of large quantity of metallic waste into water or land dump sites .Lead is metal ion which is toxic to human society. Small amount of lead in human body for long period can lead to malfunctioning of organs and chronic disease. Various methods are there for removal of lead from water but using activated carbon prepared from periwinkle shells has advantage over other because of easy availability. The activated periwinkle shell carbon has high adsorption of lead as in term of easy availability. The Freundlich and Langmuir models is applicable and mechanism used in Adsorption is mainly chemisorption reactions [8].

2. Adsorbent-Saw dust

BULUT Yasemin et al. in their experiment they used **sawdust** as an adsorbent for remoavl of heavy metals.The effect of contact time, initial metal ion concentration and temperature on metal ions removal has been studied. In their experiment work they found equilibrium time of 60 minutes and the model that fits the kinetics are pseudo first-order, second-order and intraparticle diffusion models and isotherms can be described by Langmuir and freundlich isotherms. The mechanism which describes the adsorption was found to be ion exchange.The conclusion derived from their research work was adsorption of heavy metal ions depends on their initial concentrations, temperature and contact time [9].

3. Adsorbent- Sodium alginate

E.S. Abdel-Halim et al. carried out an adsorption experiment on heavy metal removal. The adsorbent they employed was acidified sodium alginate (ASA), which is made from commercial sodium alginate that undergoes a simple acidification process using alcoholic HCl solution to transform it into water insoluble substance (ASA). The ASA was employed to remove Zn (II) ions from their aqueous solutions, and the effects of pH, adsorbent dosage, agitation period, and adsorbate concentration on the adsorption of Zn (II) ions onto ASA were investigated. They discovered that the adsorption of Zn (II) ions onto ASA is pH-dependent, with maximal adsorption at pH 6 [10].

4. Adsorbent- Natural clay

Heba H et al. their main aim was to remove heavy metal ions using **natural clay** material. They performed batch experiment and the following conclusions have been made heavy metals like Ni(II), Zn(II) and Fe(II) can be adsorbed and thus removed in significant amounts using cheapest clay material (adsorbent) from aqueous solutions. In batch mode adsorption studies, removal of metal ion increased with the increase of amount of adsorbent. The increase in initial metal ion concentration increased the amount of metal uptake per unit weight of the adsorbent (mg/g). Whereas the extent of adsorption % decreased. The Langmuir model better represented the adsorption process than the Freundlich model. Kinetic modelling results showed that the pseudo second order kinetics equation was appropriate for the description of this type of adsorption and removal [11].

5. **Adsorbent- Rice hulls**

SUEMITSU ET AL. observed that **Rice hulls,** when coated with the reactive dye of Procion Red or Procion Yellow, was found to be highly effective for removal of many metal ions from aqueous solutions. The following results were obtained. The adsorption appears to be pH dependent. Throughout the adsorption studies, no dyestuff leakage from the substrate was detected, demonstrating that dyestuff binding with rice hulls was surprisingly strong not only at neutral to alkaline ph's but even at low ph's. After the batch experiment the adsorbent has been recovered by treating with dilute hydrochloric or nitric acid solution, and used repeatedly [12].

6. **Adsorbent- Apple residue**

Sung H. Lee et al. performed batch experiments in order to remove copper, lead and cadmium ions by **apple residues (AR)** as adsorbent. Batch experiments were used to investigate the effects of solution pH, ionic strength, ligands, and co-ions. Phosphorus (V) oxychloride was added to apple residues to improve their physicochemical qualities and considerably increase metal removal capability. The pH-dependent elimination of copper, lead, and cadmium by Apple residues (AR) was discovered. Phosphorus-treated apple residues (P-AR) have been found to be a good and inexpensive adsorbent for removing metals from aqueous solutions, especially at low [13].

7. Adsorbent- Tea leaves

S.S Ahluwalia et al. carried out batch experiment for removal of heavy metal ion removal. The adsorption used was tea leaves, to be an effective, low cost biosorbent. Removal of lead, zinc, iron and nickel from metal solution by dried biomass of **tea leaves** has been studied. Batch studies shows that the adsorption process fits Langmuir and Freundlich isotherms. The carboxyl group was shown to be involved in the binding of lead and iron, whereas the amine group was found to be involved in the binding of nickel and zinc, according to FTIR tests [14].

8. Adsorbent -Sugarcane bagasse

Lakkimsetty Nageswara Rao et al. in their experiment heavy metals are considered as major pollutants which are released from the many industries without any proper treatment to the river, sea and open land due to non biodegradable character of heavy metal will affect the human , animal and plants . In their study modified **sugarcane bagasse** has been used as adsorbent for Removal of copper and zinc due to its high ability of extracting and carried a batch experiment and conclude the optimum conditions for copper ion is pH =8, Contact time=2 hr , adsorbent dosage=0.6g, and initial concentration=100ppm while for zinc ion was pH=6, contact time=1hr, adsorbent dosage=1g and initial concentration=50ppm.The equilibrium was well fitted to Langmuir as well as the Freundlich isotherms .The Maximum adsorption capacity has found to be 25 mg/g and 19 mg/g for copper ion, 9.23 mg/g and 12.25 mg/g for zinc ion by using modified and unmodified sugarcane bagasse adsorbents and their results shows that adsorption of copper using Modified sugarcane bagasse has the maximum adsorption capacity [15].Tushar .C. Sarker et al. has done the experiment on removal of hazardous metal using **sugarcane bagasse**. Due to rapid industrialization and urbanization the production of hazardous metal has been increased and because of toxicity and non-biodegradable it is fatal to living begin. Tushar .C has used sugarcane bagasse as low cost adsorbent which are improved by applying a variety of modification .The adsorption potential of adsorbents depends on their chemical nature, as well as different physicochemical experimental conditions including the solution pH, initial concentration of the pollutant, adsorbent dosage, and the contact time of the system [16].Mohd Adib Mohammad Razi et al. has done the experiment on removal of heavy metal from textile industries. The wastewater from the textile industries has high amount of heavy metals removing of heavy metals, among them are ion exchange, membrane technologies and adsorption on activated carbon and concluded that **sugarcane bagasse** activated carbon was efficient adsorbent for the removal of metal ions. It has proven that the SBAC had performed 91 and 89% of metal removal (Fe and Zn respectively) due to the High surface area which provide many of the active sites for Adsorbing of metal ions [17].Belssing Amaka Ezenonuegbu et al. has done the experiment on removal of lead and nickel from using **sugarcane bagasse** and given his review due to the advancemets in the industrialization the excessive use of chemicals all over the world the has been increased .the sugarcane bagasse has been used as the adsorbent to remove the heavy metals from the untreated refinery effluent was conclude that optimum conditions for the removal of pb and Ni occurred at ph = 6.0 , temperature 30 , contact time 90 min and adsorbent dosage 0.5 g ,maximum adsorption capacity of pb and Ni were 1.61 and 123.4 mg/g . Therefore the sugarcane bagasse was confirmed to be an effective adsorbent for heavy metal ion withefficient recovery and regeneration performance [18].A O Akanni et al. has done research utilising raw Sugarcane Bagasse (SCB) adsorbent to extract Fe2+ ions from industrial effluent. The initial concentration of Fe2+ ions in industrial (galvanising) wastewater was evaluated first to estimate the removal effectiveness of SCB in adsorbing Fe2+ from wastewater, as well as the adsorbent's optimal circumstances (such as phase contact duration, rotation speed, and concentration dose). The results show that percentage removal of Fe2+ ions from aqueous solution was 95.11% with the raw sugarcane bagasse adsorbent. The sorption capacity decreases with increasing dosage concentration and phase contact time and the desorption studies demonstrated important data for the regeneration and recovery of both adsorbent and heavy metal ions [19].

9. Adsorbent – Activated teff straw

Mulu Berhe Desta has carried out the batch sorption experiment, the heavy metal like Pb , Cr, Cd and Cu used for colour pigment has been increased due to demands of clothing and apparel increase with the improving sense of fashion and lifestyle thus textiles are manufactured to meet the growing demands. **Activated teff Straw** has been used which is eco friendly, cost effective and the adsorption isotherms could well be fitted by the Langmuir model. The elimination percentage is greater than 80% of the initial concentration. Teff Straw has been evaluated as economically viable for the removal of metal ions from textile effluents due to its high adsorption capability [20].

10. Adsorbent- Eggshells , Green Coconut powder

Renu et al. has given review on removal of heavy metal using various adsorbents. The various potential of commercial and agricultural adsorbents for the removal of chromium, cadmium and Copper from wastewater few adsorbents that stand out for their maximum adsorption capacities are: graphene sand composite ,Composite of carbon nanotubes and activated alumina , **PEI functionalised eggshell** for Chromium, chitosan/TiO2 composite , chitoSan-coated ceramic alumina , α-ketoglutaric Acid-modified magnetic chitosan, electrospun Nanofibre membrane of PEO/chitosan , NaX Nanozeolite , **green coconut shell powder**, succinic anhydride modified olive stones for cadmium, green coconut shell powder,Paenibacillus polymyxa bacteria for copper. Conclude that the most adsorption well fitted by Langmuir and Freundlich [21].

11. Adsorbent- Sugarcane bagasse and eggshell

Charlene Harripersadth et al. has carried out the comparison and given the between the **eggshells** and the **sugarcane bagasse**, now days due to increasing in industrial activity and water usages has been increased and discharge of waste water disposals without proper treatment has also been increased .FTIR and XRD investigations were used to determine the surface characteristics of sugarcane bagasse and eggshells. Conclusion: Pb adsorption equilibrium was obtained in 25 minutes for eggshells and 30 minutes for bagasse, however Cd adsorption equilibrium took 60 minutes for both eggshells and bagasse. The maximum monolayer adsorption capacity of Pb and Cd removal using eggshells were found to be 277.78 and 13.62 mg/g, respectively. For bagasse, the maximum capacity was 31.45 mg/g for Pb and 19.49 mg/g for Cd and his study has shown that natural agricultural biomaterials such as eggshells and bagasse have a high efficiency and have the potential to be used as effective adsorbents [22].

12. Adsorbents – Various adsorbent are used for comparisons

Rajeev Arora et al. reviewed various adsorbents which can be used for heavy metal ions removal. The primary goal of his research is to efficiently identify the nanomaterials employed in the heavy metal adsorption process. The factors that impact the adsorption process, such as pH, contact duration, and so on, have also been examined. The conclusion that has been made is that the performance of nano material oxide and its composite is better than other adsorbents in terms of kinetics, contact time, pH value and high content of heavy metal contents in lesser time. It is also observed that high pressure drop in the adsorption column i.e. batch, continuous or packed bed column [23].Singh Kulbir et.al. has carried the Project of Removal of Heavy Metals by Adsorption using agricultural based Residue and given a review. The release of heavy metals into Environment without proper removal has led to health related disease and also harmful to both plants and animals. Various technique are available like ion-exchange, adsorption, Precipitation, Membrane Filtration and Co-Precipitation/adsorption, these techniques are expensive and materials used for removal are not easily available. By keeping all points agricultural based materials are used which is in expensive and easily available. It has potential adsorption of heavy metals, the adsorption capacity depends on type of the adsorbent used and nature of waste water used and effectiveness and efficiency depends on various experimental process such as adsorbent dosage Ph and temperature of the system [24].Dimple Lakherwal et al. reviewed various methods for heavy metal recovery from industrial waste water. The various methods used for heavy metal recovery are Chemical precipitation, Electrodialysis, Coagulation/ flocculation, Ultrafiltration, Reverse Osmosis and Adsorption.In her review paper she concluded that adsorption process has great potential for the elimination of heavy metals from Industrial wastewater using low cost adsorbents.Low cost adsorbents should be used to minimize cost and maximize heavy metal removal efficiency [25].

III. CONCLUSION -

This review looked at the origins of heavy metal ions as dangerous substances, as well as why they should be removed from our environment. Due of the high expense of existing removal processes, a search for low-cost, environmentally acceptable solutions is necessary. According to the findings of the literature review, adsorption is the most cost-effective and environmentally benign technology for removing heavy metals from both home and industrial wastewater. It is being used to remove harmful heavy metals from industrial effluents as an alternative to traditional approaches. It has a number of advantages, including low cost, high efficiency, minimal chemical/biological sludge, and biosorbent regeneration with the prospect of metal recovery. The adsorption method offers a lot of promise for removing heavy metals from industrial wastewater using low-cost adsorbents, according to an assessment of numerous heavy metal removal strategies and adsorbents. Batch adsorption experiments were utilised to report maximum adsorption capacities for specified pollutants in the majority of the investigations, confirming their application and selectivity. Adsorption is one of the most important metal absorption processes, having a variety of features that occur at the mineral-solute interface.

Various researchers have used desorption and regeneration tests to determine the application, recovery, and reuse of adsorbents in reported investigations. Many research have shown that chemical changes can improve the removal capabilities of various adsorbents, as mentioned in this article. As a result, the level of chemical treatment, activation, and modification of the adsorbent influences its adsorption capabilities. More research into low-cost adsorption processes is needed to encourage the usage of non-conventional adsorbents on a broad scale. To keep costs down and maximise heavy metal removal efficiency, low-cost adsorbents should be used.

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