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Introduction

Water pollution caused due to addition of heavy metals resulting from the industrial activities is increasing tremendously and is a matter of global concern. Mining, mineral processing and metallurgical operations are generating e uents containing heavy metals. e heavy metals present in the wastewater is persistent and non degradable in nature. Moreover, they are soluble in aquatic environment and thus can be easily absorbed by living cells. us, by entering the food chain, they can be bioaccumulated and biomagni ed in higher trophic levels also. e heavy metals, if absorbed above the permissible labels, could lead to serious health disorders. In light of the facts, treatment of heavy metals containing industrial e uent becomes quite necessary before being discharged into the environment. e scientists and environmental engineers are therefore facing a tough task of cost e ective treatment of wastewater containing heavy metals. e conventional methods for heavy metal removal from wastewater includes chemical precipitation, chemical oxidation, ion exchange, membrane separation, reverse osmosis, electro dialysis etc. ese methods are not very e ective, are costly and require high energy input. ey are associated with generation of toxic sludge, disposal of which renders it expensive and

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us, the organisms at higher trophic level are more susceptible to be a ected by their toxicity. ere are 20 metals which are almost persistant and cannot be degraded or destroyed. Mercury (Hg), lead (Pb), cadmium (Cd), chromium (Cr [VI]), Zinc (Zn), Arsenic (As), Nickel (Ni) etc., are toxic heavy metals from ecotoxicoligal point of view. e table below shows Maximum Contaminant Level (MCL) standards for some heavy metals established by USEPA [5]. ese heavy metals can lead to serious e ects such as stunted growth, damage to vital organs, damage to brain, cancer and in some cases death also. Health hazard related to heavy metal toxicity are not new. Human diseases like minamata, itai itai, uorosis, Arsenicosis etc. are due to heavy metal ingestion above permissible levels. Treating the industrial e uents contaminated with heavy metals within the industrial premises before being discharged is e cient way to remove heavy metals rather than treating high volumes of wastewater in a general sewage treatment plant. us it is advantageous to develop separate handling modus operandi for removal of heavy metals from the industrial e uents. e current work focuses on study of natural coagulants as an e ective and economical alternative treatment process for heavy metal removal from industrial wastewater (Table 1)

Adsorption

As discussed earlier, adsorption has emerged as a e ective, economical and ecofriendly treatment technique. It is a process potent enough to ful ll water reuse obligation and high e uent standards in the industries. Adsorption is basically a mass transfer process by which a substance is transferred from the liquid phase to the surface of a solid, and becomes bound by physical and/or chemical interactions [5]. It is a partition process in which few components of the liquid phase are relocated to the surface of the solid adsorbents. All adsorption methods are reliant on solid-liquid equilibrium and on mass transfer rates. e adsorption procedure can be batch, semi-batch and continuous. At molecular level, adsorption is mainly due to attractive interfaces between a surface and the group being absorbed. Depending upon the types of intermolecular attractive forces adsorption could be of following types:

Physical adsorption

It is a general incident and occurs in any solid/liquid or solid/gas system. Physical adsorption is a process in which binding of adsorbate on the adsorbent surface is caused by van der Waals forces of attraction. e electronic structure of the atom or molecule is hardly disturbed upon physical adsorption. Van der Waals forces originate from the interactions between induced, permanent or transient electric dipoles. Physical adsorption can only be observed in the environment of low temperature and under appropriate conditions, gas phase molecules can form multilayer adsorption. Commercial adsorbents utilize physical adsorption for its surface binding.

Chemical adsorption

It is a kind of

and cu (II). Several zeolites are modi ed during the past few years to increase their e ciency. Clinoptilolite was found to be more e ectively removing heavy metals owing to its ion exchange capability, followed by pretreatment [5,7].

Clay

 ere are three main groups of clays: kaolinite, montmorillonite-smectite, and mica. e montmorillonite has the highest cation exchange capacity and its recent market price is found to be 20 times cheaper as compared to activated carbon. eir heavy metal removal capacity is less as compared to zeolites but their easy availability and economical properties give back their less e ciency. E ciency for heavy metal removal by clay could be improved by modifying them to clay-polymer composites [8-10].

Peat moss

Abundant in nature and has a very high organic content. Its large surface area (200 m^2/g) and high porosity makes it an e ective agent for heavy metal removal from wastewater. It was observed that peat moss plays an important role in treatment of metal-bearing industrial e uents such as Cu^{2+}, Cd^{2+}, Zn^{2+} and Ni^{2+} [11]. e adsorption capacity of sphagnum peat moss was found to be 132 mg/g of Cr^{6+} at a pH range of 1.5-3.0. e most striking bene t of this adsorbent in treatment is the easiness of the system, low cost, and the capability to acknowledge a wide variation of e uent composition [12].

Chitin: It is the second most abundant natural biopolymer followed by cellulose. Chitin is a long-chain polymer of a N-acetylglucosamine, a derivative of glucose. It is the main component of the cell walls of fungi, the exoskeletons of arthropods such as crustaceans (e.g., crabs, lobsters and

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