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Removal of mercury from aqueous solution- Review on current status and development

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ABSTRACT: Environmental pollution due to heavy metals like mercury is of serious concern throughout the world. Due to anthropogenic activities, the concentration of mercury has increased in the environment. Though many methods are available for mercury removal, adsorption is considered as simple, economical and versatile method. In this paper the efficiency of mercury removal from aqueous solution using agricultural waste, polymers and nano material were reviewed.

Keywords: Heavy metal; Modification; Adsorption; Isotherm

1. INTRODUCTION

Heavy metals are abundant in our drinking water, air and soil because they are present in every area of modern consumerism like construction materials, cosmetics, medicines, processed foods and personal care products [1]. Natural inputs of mercury to the environment are related to weathering of mercuriferous area, the degassing from surface water and from the earth's crust through volcanic eruptions, naturally caused forest fires, and biogenic emissions [2]. Mercury is a pervasive contaminant that is highly toxic and is readily accumulated by organisms [3,4]. Mercury may enter a human body by inhalation of mercury vapor as Hg⁰, drinking water as inorganic mercury, Hg²⁺, and/or by the consumption of fish and fish products as methyl mercury, CH₃Hg⁺ in the diet [5,6]. In small quantities, certain heavy metals are nutritionally essentially for a healthy life, but in large amounts they may cause acute or chronic toxicity (poisoning). The absorption of this hazardous substance into the bloodstream, distribution to the entire tissues and bioaccumulation in the receptive sites leads to adverse effects, such as potent neurotoxicity, blood vessel congestion and kidney damages [7].

Various methods exist for the removal of mercury from water which include chemical precipitation/ coagulation, membrane technology, electrolytic reduction, ion exchange and adsorption [8, 9]. Among various available methods for the removal of Hg, adsorption has been shown to be an economically feasible and easily applicable alternative using various adsorbents [10-12]. The other methods are not to be effective and least possible for treatment of mercury from water. More number of studies on mercury removal has been reported in the literature. In the present work, we have reviewed the recent articles on the mercury removal from aqueous solution by considering the effect of various parameters such as pH, temperature, metal ion concentration, contact time, and

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adsorbent dosage on mercury uptake. These factors are of the utmost significance, as any change in these parameters may considerably change the mercury removal efficiency of an adsorbent.

2. GENERAL OBSERVATIONS

Most of the studies have been performed in batch mode operation. Synthetic stock solutions were prepared by dissolving mercury compounds (mercury nitrate, mercury chloride etc) for adsorption studies. Adsorption and kinetic plots were noted. Few authors have performed thermodynamic and column studies also.

2.1 Effect of temperature

Temperature plays a significant role in the uptake of mercury ion from the surface at ambient temperatures. Depending upon the adsorption mechanism, the rate may either increase or decrease with temperature^[13]. Xincheng et al., observed a significant decline in adsorption with increasing temperature indicating that the process is endothermic^[18]. Rajamohan, observed an increase in mercury adsorption capacity with increase in temperature indicating the process to be exothermic^[20].

2.2 Effect of pH

Adsorption of mercury is very sensitive to the pH. The adsorption capacities were found to be low at low pH values and increased with increase in pH. The mechanism of adsorption can be explained based on pH. The mercury ions were bound to the adsorbent surfaces mainly by the process of the ion exchange and physico-chemical adsorption as the ionic mobility plays an important role. The mobility of ions and rate of interactions between oppositely charged ions and adsorbent surfaces are more pronounced in dilute solutions. Anurudhin et al observed the percentage removal to increase gradually with increasing pH and reach an optimum value of 6. The solution pH affects the surface charge of the adsorbent, the degree of ionization and the speciation of the surface functional group^[16].

2.3 Effect of Contact time and initial metal ion concentration

The initial concentration of metal ions provides an important driving force to overcome all mass transfer resistances of the metal ion between the aqueous and solid phases^[28]. Equilibrium time is one of the important parameters for selecting a wastewater treatment system^[29]. Equilibrium concentration increases with increase in adsorbate concentration due to saturation of sorption sites on the adsorbent^[26]. Anirudhan et al carried out adsorption experiments at concentrations from 25 to 100 mg/L and found an increase in adsorption of metal ion with increase in contact time of 3 hr^[16]. Syed and Ganesan indicate that the increase in initial concentration of Hg(II) ions resulted in a reduction in the percentage removal using Eucalyptus globules bark as adsorbent. It was observed that, the percentage removal of Hg (II) ions decreases exponentially with the increase in the initial concentration of Hg(II) ions. This may be due to reduction in immediate solute adsorption, owing to the lack of available active sites on the adsorbents surface compared to the relatively large number of active sites required for high initial concentration of Hg (II) ions^[25].

2.4 Effect of Adsorbent Dose

Dosage of adsorbent is a key parameter to control both availability and accessibility of adsorption sites^[30]. Adsorption has been found increasing with the increase in dose of adsorbent. But with the higher dose of adsorbent in the solution, the mobility of the ion reduces and there results a decrease in the rate of adsorption. Syed and Ganesan found an increase in removal of Hg (II) with increase in dose of adsorbent due to increase in availability of active sites^[25].

2.5 Adsorption and Kinetics equilibrium

The equilibrium relationships between adsorbent and adsorbate are best explained by adsorption isotherms^[31]. Several equilibrium isotherm models were employed in order to study the nature of adsorption process. These include two parameter isotherms such as the Langmuir, Freundlich, Temkin, Dubinin-Radushkevich and three parameter isotherms such as the Sips and Redlich Peterson respectively.

The adsorption kinetics is significant in the treatment of wastewater, as it provides valuable insights into the reaction pathways and rate of reactions^[32]. These models include the pseudo-first order, pseudo-second order, Elovich, intraparticle diffusion and Baughman's plot. The adsorption capacities, isotherm and kinetics of various adsorbents were given in Table 1.

Conclusion

The present review has established that adsorption offers a great opportunity for a cheap and highly effective process for the removal of mercury (II) ions from aqueous solution. Experimental parameters like temperature, solution pH, metal ion concentration, adsorbent dose, contact time and adsorption kinetics influence adsorption process. On the basis of evidences presented in this review there exist a significant potential for future research in utilizing the adsorbent in industries, agriculture as well as for domestic purpose.

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Table 1 Removal of mercury from aqueous solution using agro waste, polymers and nano material from selected literature.

Adsorbent	Activation	Q_{\max}^{-1} (mg g ⁻¹)	pH	Isotherm model	Kinetics studied	Reference
Wal nut	Zinc chloride	151.51	2	L,F, Langergren	Pseudo first order, Second order	Zabihi et al. (2009) [14]
Bio masslichen (<i>Xanthoparmelia conspersa</i>)	Un Modified	82.5	6	L,F	Pseudo first order, Pseudo second order	MustafaTuzen et al. (2009)[15]
Coconut buttons	Acid activation(H ₂ SO ₄)	41.83	7	L,F	Pseudo first order, ,Second order	Anirudhan et al. (2011) [16]
Bamboo Leaf Triton X-100 Modified SDS Modified	Surfactant modification	27.1 28.1 31.05	8	L,F,Temkin Langergren	Pseudo first order, Second order, Elovich	Dilip Kumar Mondal et al. (2013) [17]
Coconut	H ₂ O ₂	5.236		L,F, Langergren	First order, Second, order, Pseudo second order	Xincheng et al. (2013) [18]
Pistachio shell	Un Modified	2.299	6	L,F	Second order	Zahar Aghajani et al.(2014) [19]
Pistachio Hulls	Acid activation(HCl)	113.64	7		Pseudo second order, Intra particle diffusion	Rajamohan et al. (2014) [20]
Polyaniline/ cellulose acetate composite	Chemical polymerization	280.11	5	L	Pseudo first order, Second order	Renjie Li et al .(2014)[21]
Polymer	polystyrene coated CoFe ₂ O ₄ modified with 2-(3-(2-aminoethylthio)propylthio)ethanamine (AEPE-PS-MPs)	-	7-8	-	Pseudo first,order, Second order	Kunawoot Jainae et al. (2014)[22]
Pine Cone	chemically activated by H ₃ PO ₄ and then modified with 2,6-diaminopyridine.	384.62 mg/g	1.5	L,F	Pseudo first, order, second order	Mokhtari et al. (2015)[23]
Manganese chloride nanoparticle	Sol gel	311	6	L,F	Pseudo first order, Second order, Intra-particle diffusion	Arshadi et al. (2015)[24]
<i>Eucalyptus globules</i> bark	Acid activation (HNO ₃)	4.014	7	L,F	First order, Intra particle diffusion	Syed Meera et al. (2015) [25]
Bio mass S. glaucescens G. corticata,	Un Modified	147.05 -4.71	5 7	L,F	First,Second order	AkbarEsmacili et al. (2015) [26]
Graphite	Hummer modification	181.8	7	L,F, Henry, Dubinin- Radshkevich,	Pseudo first Second,order, Elovich,Bangham	Limei Cui et al. (2015)[27]

L,Langmuir;F,Friendlich