Removal of mercury (II) from aqueous solution using various activated carbons: A short review

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ABSTRACT
Mercury has fundamental importance for human life and health but it is potentially toxic as well like all other heavy metals. United State Environmental Protection Agency has set its Mg^{2+} permissible limits as 0.01 mg/L in industrial effluents. These limits suggest more stringent requirement for the removal of mercury from aqueous environment, which necessitated the development of innovative and cost-effective technique. The research carried out for copper removal has been summarized in the current review paper.

Keywords: Heavy metal; Mercury**;** Adsorption; Isotherm

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1. INTRODUCTION

Most of the toxic heavy metals have been discharged in to the environment as industrial wastes, causing serious soil and water pollution[1]. At least 20 metals are classified as toxic and half of these are emitted into the environment in quantities that pose risks to human health[2]. The main way that people are exposed to mercury is by eating fish and shellfish that have high levels of methyl mercury, a highly toxic form of mercury, in their tissues. A less common way people are exposed to mercury is breathing mercury vapor. Mercury is a neurotoxin[3].

Mercury is considered by WHO as one of the top ten chemicals or groups of chemicals of major public health concern. Exposure to mercury – even small amounts – may cause serious health problems, and is a threat to the development of the child *in utero* and early in life. Mercury may have toxic effects on the nervous, digestive and immune systems, and on lungs, kidneys, skin and eyes[4].

In the present review we have summarized the recent development in preparation of activated carbon and analyzed the Mercury (II) removal with respect to effect of various parameters, removal efficiencies, kinetics of the solute uptake, modeling approach and isothermal studies.

2. Various adsorbents used for copper removal

Zhiyuan Liu et al (2020) was reported, adsorption of Hg (II) in an aqueous solution by activated carbon prepared from rice husk using KOH activation, the influences of contact time, initial concentration of Hg (II), adsorbent dosage, pH, and ionic strength on mercury ion removal was investigated. The Langmuir model was most suitable for the adsorption isotherm of RHAC, and its maximum adsorption capacity for Hg (II) was 55.87 mg/g. RHAC still had a high removal capacity for Hg (II) after five regeneration cycles.

Zhiyuan Liu et al (2020) were reported, preparation, characterization and application of activated carbon from corn cob by KOH activation for removal of Hg (II) from aqueous solution. The effects of adsorbent dosage, adsorption time, pH and initial Hg (II) concentration on mercury ion removal rate were studied. The specific surface area of this material is 1054.2 $m^2\ g^{-1}$. The Langmuir and Freundlich adsorption models were used to verify the adsorption isotherms. The adsorption isotherms were simulated well by the Langmuir model, which implied that it is a monolayer adsorption process. The kinetic data conformed to the pseudo-second-order model, which implied that the predominant process is chemisorption.

Tekin Şahan et al (2018) were reported, the adsorption of mercury (II) from aqueous media by a new adsorbent, 3-mercaptopropyl trimethoxysilane-modified bentonite (B-SH), and the optimization of adsorption parameters was investigated in this study. B-SH was used as a novel sorbent for mercury (II) adsorption, and the analysis of adsorption conditions was performed by response surface methodology (RSM). The characterization of B-SH was executed using Brunauer, Emmett and Teller (BET), Fourier Transform Infrared (FTIR) Spectroscopy, Energy-dispersive X-ray spectroscopy (EDX), and X-ray diffraction (XRD) analyses. The most important parameters for Hg (II) adsorption were initial pH, initial mercury (II) concentration (C_o), temperature (T (°C)), and adsorbent dosage (g). The RSM results showed that the optimal adsorption conditions yielding the best response were 6.17, 36.95 mg/L, 37.28 °C, and 0.19 g, for pH, C_o, T (°C), and adsorbent dosage, respectively. At optimum adsorption conditions obtained by program, the maximum adsorption capacities and the adsorption yield were 19.30 mg/g and 99.23%, respectively[13].

Shuangyou Bao et al (2017), A novel hybrid material was fabricated using mercaptoamine-functionalised silica-coated

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magnetic nano particles (MAF-SCMNPs) and was effective in the extraction and recovery of mercury and lead ions from wastewater. The properties of this new magnetic material were explored using various characterization and analysis methods. Adsorbent amounts, pH levels and initial concentrations were optimised to improve removal efficiency. Sorption likely occurred by chelation through the amine group and ion exchange between heavy metal ions and thiol functional groups on the nano adsorbent surface. The equilibrium was attained within 120 min, and the adsorption kinetics showed pseudo-second-order ($R^2 > 0.99$). The mercury and lead adsorption isotherms were in agreement with the Freundlich model, displaying maximum adsorption capacities of 355 and 292 mg/g, respectively. The maximum adsorptions took place at pH 5–6 and 6–7 for Hg (II) and Pb (II), respectively. The maximum adsorptions were observed at 10 mg and 12 mg adsorbent quantities for Hg (II) and Pb(II), respectively[12].

Mojtaba Hadavifar et al (2016) were reported functionalization of multi-walled carbon nanotubes can be carried out by introducing amino and thiol functional groups onto the nanotube sidewalls. This functionalized multi-walled carbon nanotubes can be used as a new type of efficient metal ions adsorbent from aqueous solutions. In this study, batch and column adsorption experiments were carried to evaluate the adsorption capacities of single and binary system mercury and cadmium. In the single system, the maximum adsorption capacity of 204.64 and 61.10 mg/g were obtained for mercury and cadmium, respectively, while for binary systems, the values of 35.89 and 14.09 mg/g were achieved for mercury and cadmium, respectively. Column breakthrough curves were obtained and described by Yan and Thomas models. The bigger Thomas rate constant (k_{Th}) (120.77 ml/min/mg for Cd(II) and 9.44 ml/min/mg for Hg(II)) indicated that the intensity of adsorption of Cd(II) onto thiolated MWCNTs was higher compared to Hg(II). However, the value of maximum adsorption capacity (q_e) for Hg(II) (39.75 mg/g) was bigger than that of Cd(II) (9.72 mg/g) in continuous system[11].

Andrea. J. Santana et al (2016) were study aims to investigate powders obtained from the peel of the fruit of *Pachira aquatica* Aubl, in it’s *in natura* and/or acidified form, as an adsorbent for the removal of mercury ions in aqueous solution. The materials were characterized by Fourier transform infrared spectroscopy and thermogravimetric analysis. The infrared spectra showed bands corresponding to the axial deformation of carbonyls from carboxylic acids, the most important functional group responsible for fixing the metal species to the adsorbent material. The thermograms displayed mass losses related to the decomposition of three major components, i.e., hemicellulose, cellulose, and lignin. The adsorption process was evaluated using cold-vapor atomic fluorescence spectrometry (CV AFS) and cold-vapor atomic absorption spectrometry (CV AAS). Three isotherm models were employed. The adsorption isotherm model, Langmuir-Freundlich, best represented the

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adsorption process, and the maximum adsorption capacity was predicted to be 0.71 and 0.58 mg g^{-1} at 25 °C in nature and acidified, respectively. Adsorption efficiencies were further tested on real aqueous wastewater samples, and removal of Hg (II) was recorded as 69.6 % for biomass acidified and 76.3 % for biomass in nature[14].

Anirudhan et al (2015) a novel adsorbent, 2-mercaptobenzamide modified itaconic acid-grafted-magnetite nanocellulose composite [P(MB-IA)-g-MNCC] was synthesized for adsorbing mercury(II) [Hg(II)] ions selectively from aqueous solutions. Fourier transforms infrared spectroscopy, X-ray diffraction, scanning electron microscopy and thermogravimetric studies were performed to characterize the adsorbent. The optimum pH for Hg (II) adsorption was found to be 8.0, and the adsorption attained equilibrium within 60 min[9].

Yifeng Huang et al (2015) studied with the concentration and removal of mercury (II) from wastewater by polymer-enhanced ultra filtration (PEUF) using poly vinyl amine as the mercury-binding polymer. A mercury removal as high as 99% was obtained, which was otherwise impossible to achieve with conventional ultra filtration. Over the feed mercury concentration range tested (0–50 ppm), the PVAm dosage used did not affect the mercury rejection considerably, while water flux was reduced significantly at a higher dosage of PVAm[10].

M. MadhavaRao et al (2007) has prepared activated carbon from agricultural by-products/waste as *Ceiba pentandra* hulls, *Phaseolus aureus* hulls and *Cicer arietinum* waste. The prepared adsorbents ACCPH, ACPAH and ACCAW had removal capacities of 25.88 mg/g, 23.66 mg/g and 22.88 mg/g, respectively, at an initial Hg (II) concentration of 40 mg/L[5].

Ajay Kumar Meena et al (2004), have report, Treated granular activated carbon, weathered coal, and treated sawdust showed 99.9 per cent, 99.8 per cent, and 99.7 per cent adsorptive removal of mercury under optimised conditions of pH 6 and dosage 8 g/l (0.8 g/100 ml) for 3 mg/l mercury aqueous solution in 48 h, respectively. The adsorption is pH-dependent and the maximum adsorption occurs at pH 6 [15].

D.M. Manohar et al (2002) have reported 2-mercaptobenzimidazole-clay used for removal of Hg (II) from aqueous media. The adsorption of Hg (II) increased with increasing pH and reached a plateau value in the pH range 4.0–8.0. The removal of Hg (II) was found to be >99% at an initial concentration of 50 mg/l. Mercury (II) uptake was found to increase with ionic strength and temperature. Further, the adsorption of Hg (II) increased with increasing adsorbent dose and decrease with adsorbent particle size. Sorption data analysis was carried out using Langmuir and modified Langmuir isotherms for the uptake of metal ion in an initial concentration range of 50–1000 mg/l[6].

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Irene Wagner-Döbler et al (2000) the enzymatic reduction of Hg (II) to water insoluble Hg (II) by mercury resistant bacteria has been used for removal of mercury from wastewater in technical scale. Pure cultures of seven mercury resistant strains of *Pseudomonas* were immobilized on carrier material inside a 700 L packed bed bioreactor. Neutralized chloralkali electrolysis wastewater with a mercury concentration of 3−10 mg/L was continuously fed into the bioreactor (0.7 m^3/h up to1.2 m^3/h). A mercury retention efficiency of 97% was obtained within 10 h of inoculation of the bioreactor. At optimum performance, bioreactor outflow concentrations were below 50 μg Hg/L, which fulfill the discharge limit for industrial wastewater[8].

H. von Canstein et al (1999) have reported a mercury-resistant bacterial strain which is able to reduce ionic mercury to metallic mercury was used to remediate in laboratory columns mercury-containing wastewater produced during electrolytic production of chlorine. Factory effluents from several chloralkali plants in Europe were analyzed, and these effluents contained total mercury concentrations between 1.6 and 7.6 mg/liter and high chloride concentrations (up to 25 g/liter) and had pH values which were either acidic (pH 2.4) or alkaline (pH 13.0). A mercury-resistant bacterial strain, *Pseudomonas putida* Spi3, was isolated from polluted river sediments. Biofilms of *P. putida* Spi3 were grown on porous carrier material in laboratory column bioreactors[7].

Conclusion

It is concluded from the above literature survey that the adsorption using activated carbons is a valuable tool for analyzing aqueous mercury (II) solution. It is simple, effective, and economical methods of water treatment.

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