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Department of Civil Engineering
(Civil Engineering UG Program is NBA accredited for 3 Years up to 2023)

SYNOPISIS

a. Title: Lead heavy metal removal from aqueous medium using modified activated carbon and biochar

b. Name of the college and Department: Civil Engineering Department, Nitte Meenakshi Institute of Technology

c. Name of the Students & Guide(s) (with email id and cell no. if any)

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d. Keywords: Lead heavy metal, adsorbents, surface properties, aqueous medium

e. Introduction/background:

Pollution by heavy metals is currently of great concern. The presence of heavy metals in wastewater has been increasing with the growth of industries e.g., electroplating industry, batteries, mining industry, rayon industry, metal rinse processes etc., The most popular heavy metals are lead (Pb), zinc (Zn), mercury (Hg), nickel (Ni), cadmium (Cd), copper (Cu), chromium (Cr), and arsenic (As). Heavy metals are actively involved in the rise of numerous diseases, including diabetes, Alzheimer's disease, and different forms of cancer. Some heavy metals such as Cu, Zn, and Ni are essential micronutrients for plants but are toxic to organisms at high concentrations. The higher toxicity of these elements, if ingested may influence the normal human function of the body parts and pose serious health hazards like cancer. There are many methods identified for the removal of heavy metals from contaminated aqueous, soil, and air media. The most popular method to treat heavy metal-containing wastewater is chemical precipitation that uses alkaline solutions to raise the solution pH to allow the formation of heavy metal hydroxide precipitate followed by filtration or other solid/liquid separation processes. Although the chemical precipitation method is quite effective for heavy metal removal, the resultant heavy metal sludge is classified as hazardous solid waste and needs to be adequately treated.

As per the recent UNICEF and non-profit Pure Earth's report (July 30, 2020), around 800 million children are poisoned by lead. India accounts for 275,561,163 of these children. Lead exposure

during childhood is linked to several issues, including mental health and behavioral problems, including an increase in crime and violence. A leading contributor to lead exposure is informal and sub-standard recycling of lead-acid batteries. Lead-based industries, including mining, paints and pigments discharge its waste content into the streams and thereby increasing the percentage of lead in water bodies. Common methods for lead removal from effluents include coagulation, flocculation, sedimentation, filtration, ion exchange, and adsorption. Adsorption technology is an efficient method for removing lead from various sources. With its high surface area and affinity for heavy metals, adsorbents such as activated carbon or zeolites can effectively capture and immobilize lead ions from water or air.

f. Objectives:

In our study, lead removal efficiency by ecofriendly adsorbents is studied. The motivation of the current study stems from the fact that there is abundance of coconut shell as an agricultural waste. There is no adequate facility to manage such type of waste. On the other hand, coconut-shell activated carbon and biochar has been successfully tested for contaminants removal in soil, water and air media. While many studies have established that adsorption of heavy metals is possible using coconut-shell based activated carbon, no proper adsorption mechanisms have been elucidated to understand the same. The current study fills that research gap by evaluating the surface physicochemical properties of coconut shell activated carbon and correlating the properties with adsorption. Studies are underway to get more details on lead adsorption in water. The specific objectives are as below:

- Comparative adsorption study between untreated activated carbon (AC) and biochar (BC), acid treated AC and BC, and base treated AC and BC.
- Studying the efficiency of adsorption by varying time parameters for the obtained optimum dosage.
- Characterization of chemically treated coconut shell carbon by SEM analysis.

g. Methodology:

Preparation of AC and BC samples: the adsorbents passing through 2 mm sieve were washed using distilled water and oven dried at 100 $^{\circ}$C for 24 h and stored in air-tight containers until further use.

Acid and base treatment was carried out on adsorbents by dipping both the adsorbents in 1M NaOH and 1N H_2SO_4 solution for 48 hours and kept in oven drying for 24 hours.

An initial Pb^{2+} concentration of 50 mg L^{-1} and optimum carbon material dosage (5 g/500 mL) were used to study adsorption study. Acid modified AC was found as the best adsorbent with removal capacity of around 95 %. Further batch isotherm and kinetic studies were conducted to understand the adsorption mechanism. Qe was determined at time intervals of 5 min, 30 min, 1 h, 6 h, 12 h and 24 h. Pseudo-first order, pseudo-second-order, and intra-particle diffusion, were used to fit

experimental data (Guo et al., 2012; Qiu et al., 2009; Reguyal et al., 2017; Tosun, 2012; Zhu et al., 2017). Pb^{2+} adsorption isotherms were determined by conducting batch adsorption study at different initial Pb^{2+} concentrations varying from 15 to 1000 mg L^{-1} (15, 35, 50, 125, 300, 600 and 1200 mg L^{-1}) with optimum dosage (5 g/500 mL) of carbon material. Equilibrium concentration (Ce) was measured after shaking each carbon material and Pb^{2+} mixture for predetermined equilibrium time (24 h). Non-linear forms of isotherm models, Langmuir, and Freundlich were used to simulate experimental data (Essandoh et al., 2017; Foo and Hameed, 2010; Reguyal et al., 2017).

The reported values in the adsorption experiments represent the average of triplicate study results. Non-linear equations were solved using the Origin Version 8.5 software program developed by Origin Lab in the USA. The determination of isotherm and kinetic parameters involved minimizing the Chi-square (χ^2) function (Eq. A10) (Foo and Hameed, 2010; Guo et al., 2012). To assess the goodness of fit between the experimental data and the isotherm and kinetic models, the coefficient of determination, R^2, was employed.

h. Results and conclusion:

The study has shown that acid-treated AC can be effectively used to remove lead heavy metal from water. The isotherm study exhibited type 3 adsorption. Type 3 adsorption is usually adsorbed in macroporous adsorbents. Further, acid treatment might have improved the porous structure of the AC which might have contributed overall increase in adsorption efficiency. Kinetic studies proved that adsorption happens over a period of time which might be due to the chemisorption of lead facilitated by surface functional groups on the surface. EDS analysis confirmed carbonization of AC surface and possible introduction of active sites and porous structure which might have contributed to better removal of lead by AAC.

i. Innovation of the project:

Development of low-cost eco-friendly adsorbent for lead heavy metal removal from water.

j. Scope of future work

Future work involves understanding the adsorption capacities by co-correlating with the characteristics of the adsorbent. Characterization results of SEM, BET, and FTIR analysis will provide an in-depth idea of the nature of adsorption and aid in developing an optimized surface for the efficient removal of lead heavy metal. Likewise, future study can involve studying a range of pollutants involving emerging contaminants that can be mitigated using cost-effective and eco-friendly adsorbents.