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Research Article

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Removal of Pb(II) ions from aqueous solutions using activated carbon prepared from plant *Glycosmis mauritiana*

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ABSTRACT

The present work illustrates the adsorption of lead from aqueous solutions on Glycosmis mauritiana carbon (GMC) was investigated to assess the possible use as a low cost adsorbent for the removal of lead from waste water. The influence of various factors such as initial concentration, amount of adsorbent, solution pH, particle size of the adsorbent, and temperature on the adsorption capacity has been studied. The percentage removal of lead was observed to decrease with increase in the initial concentration of lead. The adsorption of lead decrease with increase in temperature indicates the exothermic nature of the reaction. The pH value of lead adsorption onto the GMC was found to be 6.0. The results indicated that the activated carbon prepared by sulphuric acid activation (GMC-2) could be used effectively for adsorption of lead (II) ions from aqueous solution. The characterization of the activated carbon prepared was measured to evaluate its high quality.

Keywords: Activated carbon, adsorption, lead (II) ions, Heavy metals.

INTRODUCTION

In wastewater, most of the heavy metals present in a reduced state, which it can infer from the lower redox potentials. The exposure of heavy metals at trace level is to be a risk for human beings. In common, there are more than 600 organic and inorganic pollutants have been reported in water along with biological pollutants[1]. Lead play a wide application in the manufacturing of lining for chemical baths and storage vessel's batteries, circuit boards, chemical transmission pipes, electrical components and radiation shielding. Polyvinyl chloride used as a chemical stabilizer. Lead continues to use extensively in rolled and extruded products in the construction industry. In recent years the use of lead sheeting has found increased in the building industry[2]. Lead also has a variety of other uses including the manufacture of pigments, water repellents, dyes, varnishes, resins, automotive parts, explosives, paper coatings, crystal vessels, ammunition, ceramic glazes, jewellery, toys, ceramics glass industries[3], rubber, plastics and in analytical applications. Tetraethyl lead and tetramethyl lead were widely used as an additive fuel in motor vehicles. Heavy metal pollutants have a unique property accumulation along the food chain and it cause detrimental and deleterious effects on human health, including reduced growth and development, it causes cancer and in extreme cases it leads to death for both children and adults. Many studies reported that it daily use of lead affects the human directly includes development of neurodegenerative, cardiovascular, renal and reproductive effects. Regular inclusion of lead causes hypertension, anaemia, renal impairment, toxicity to the reproductive organs and immunotoxicity. At high levels of Pb(II) ions exposure leads to attacks the central nervous system to cause convulsions and coma. Thus, it is necessary to reduce or eliminate heavy metals into the environment and discharge into surface water.

Numerous methods have developed for removing heavy metal treatment. Electrochemical reduction[4] Adsorption[5] Chemical Precipitation[6], ion exchange[7] membrane filtration, reverse osmosis[8], ion exchange[9], solvent extraction, flocculation, membrane separation, electrolysis[10], photochemical reactions[11], activated sludge[12], magnetic separation[13], electroplating are the some of the traditional methods used for the heavy metal treatment. However, some of these techniques are economically impossible and are slender to meet present disposal of toxic elements in the environments.

An adsorption is a well established and one of the successful methods for removing toxic metal, organic pollutants and dyes from the aquatic medium in the industrial effluents[14]. In search of adsorbents, the many researchers show a rapid growth in the development of low cost, effective, alternative adsorbents for treatment of water and recycling of wastewater using adsorption process. Due to its simplicity, mechanical stability, treatment cost in an economical approach and as eco-friendly techniques activated carbon is widely used commercially in worldwide. Adsorption is a purely a surface phenomenon and mass transfer process by which its transfer ions from the liquid phase to the surface of a solid and becomes bound by physical and or chemical interactions[15]. Various functional groups like alcohol, aldehydes, ketones, carboxylic, ether, phenolic make these adsorbents effective towards metal binding and make the material as attractive for removing of heavy metals[16].

Removal of Pb(II) aqueous solution by adsorption using various conventional adsorbent like kaolinite[17] natural biosorbent (cocoa pod husk, watermelon rind, rose petals waste, cortex orange waste[18-21], modified adsorbent (pine cone powder (KOH), Orange peel (NaOH and $CaCl_2$)[22,23], coffee residue treated with phosphoric acid and zinc chloride[24], formaldehyde treated onion skin, chemically treated rubber leaf powder, functionalized coconut active charcoal [25-27] have reported to remove toxic lead from wastewater. In this study, the activated carbon prepared from GMC modified with activating agent sulphuric acid. The chemical activation consists of more advantages compared to physical activation. Sulphuric acid helps to develop the porosity of carbon and improve the pore development of carbon structure and increases the yield of the carbon [28].

EXPERIMENTAL SECTION

Preparation of adsorbents

The plant chosen for the preparation of activated carbon is G*lycosmis mauritiana.* Chemically activated carbon can be prepared by dipping the plant material into sulphuric acid(50%). The plant material soaked in different chemical were kept for 24 hours, at the end of the 24 hours the soaked materials were removed and dried in oven at 110°C for 4 hours. The dried samples are made to activate in a muffle furnace at 600°C for 3 hours in the absence of air. The activated samples were cooled and washed with distilled water until the pH of washed water become 7. The activated samples are then crushed, sieved named as GMC-2 used for further characteristics work.

Preparation of Metal stock solution:

All chemicals used in this study were analytical grade. A Stock solution of lead was prepared by dissolving required quantity of $Pb(NO_3)_2$ in double distilled water. Different concentrations of lead (II) ions were prepared by diluting $1000 mgL^{-1}$ of the stock solution in double distilled water. Acid and base solutions (0.1mol. HCl and 1mol. NaOH) were used for pH adjustments.

Characterization of adsorbents

In order to characterize the surface structure of activated charcoal HRSEM in F E I Quanta FEG 200 ZEISS analysis was carried out. The surface functional group involved in metal adsorption, the unadsorbed GMC-2, lead (II) ions adsorbed in GMC-2 were analyzed using FTIR spectra of the samples were recorded in the range of 4000–400 cm^{-1} shimadzu spectrometer.

Adsorption studies

Adsorption experiments were carried out by agitating the adsorbent in 50 ml of adsorbate solution of desired concentration and pH at room temperature in a shaker. The samples were withdrawn from the shaker at predetermined time intervals and centrifuged. The supernatant metal solution is titrated against EDTA solution. The pH of solutions was adjusted using dilute 0.1 mol. HCl and NaOH solutions.

Batch adsorption studies

The adsorption of metal ion on GMC carbon was investigated by batch methods to study the maximum adsorption of a metal ion and its equilibrium condition. An attempt has been made to optimize the process parameters viz., metal concentration, pH of the solution and adsorbent concentration for the adsorption of the metal. All experiments were carried out by adding 50 mL of metal solution and adsorbent in an Erlenmeyer flask and made for constant stirring for 210 min. At the end of the each experiment, the solution was filtered and the filtrate was titrated with standard EDTA solution.

$\% \text{ Adsorption} = (C_0 - C_e) / C_0 \times 100$

Where, C_0 is the initial concentration of adsorbate (mg/L), C_e is adsorbate concentration (mg/L);

The effect of particle sizes on removal of Pb(II) was studied by agitating 50 ml of 100 mg L^{-1} of Pb(II) solutions with 200 mg of adsorbent of particle size 53-500μ for a period of 210 min. The effect of adsorbent dose on removal of Pb(II) was studied by agitating 50 ml of 100 mg L^{-1} solution of Pb(II) containing different doses of adsorbent (100–500 mg) for a period of 210 min. The effect of pH on Pb(II) removal was studied by using 50 ml of 100 mg L^{-1} solutions of Pb(II), adjusted to initial pH 3 to 7 and agitating with 200 mg of adsorbent for 210 min. The effect of temperature on Pb(II) removal was studied by using 50 ml of 100 mg L^{-1} solutions of Pb(II), with different temperature 35-55°C and agitated with 200 mg of adsorbent for 210 min.

RESULTS AND DISCUSSION

Characterization of adsorbent

SEM: The surface morphology of the GMC-2 and lead (II) ion adsorbed GMC-2 can be analyzed by using scanning electron microscope. GMC-2 treatment with sulphuric acid has led to irregular shapes and pores on its surface indicates that the adsorbent. These pores and cavities provide a large exposed surface area for the adsorption of metal ions. After the metal adsorption, the porous surface on the GMC-2 gets filled showing adherence of metal ions on the surface shown in figure-1.

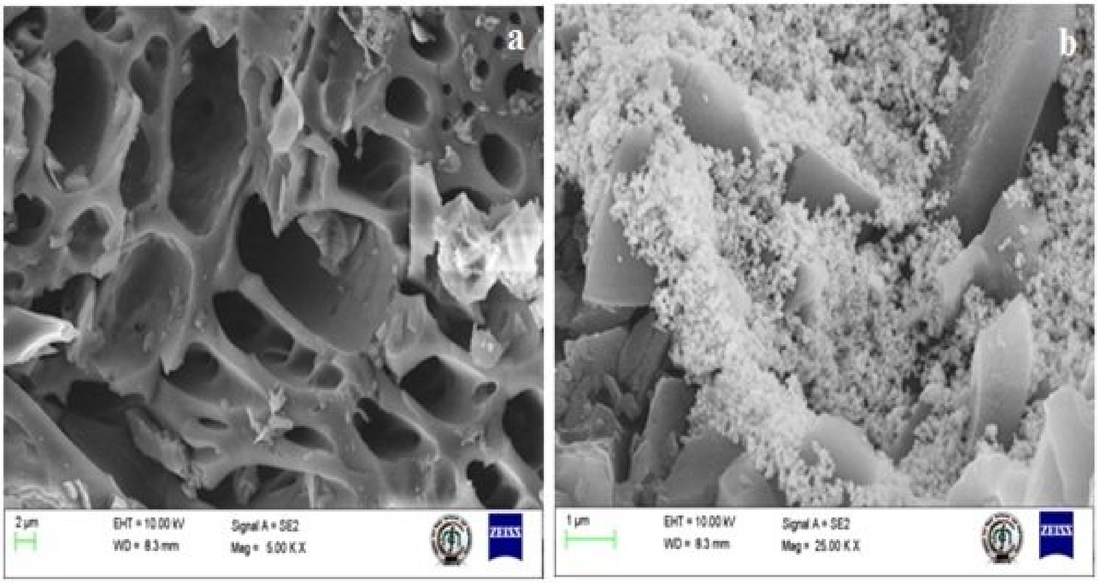

Figure-1. SEM of (a) GMC-2 and (b) Lead (II) ion adsorbed GMC-2

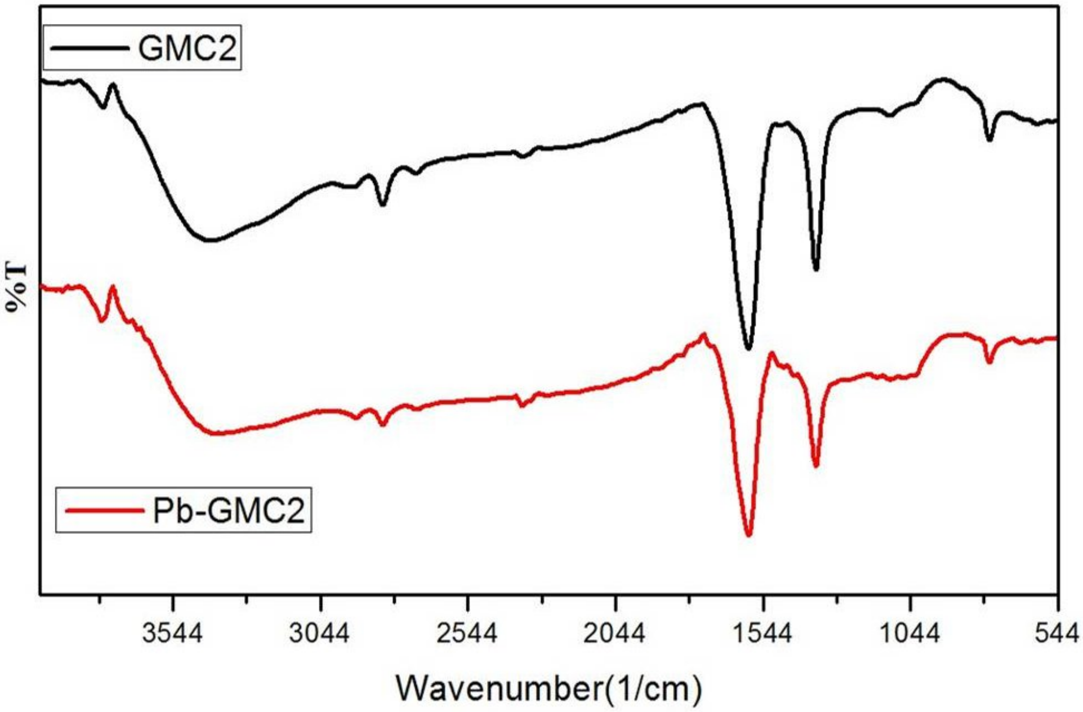

Figure-2. FTIR spectrum of GMC-2 and Lead (II) ion adsorbed GMC-2

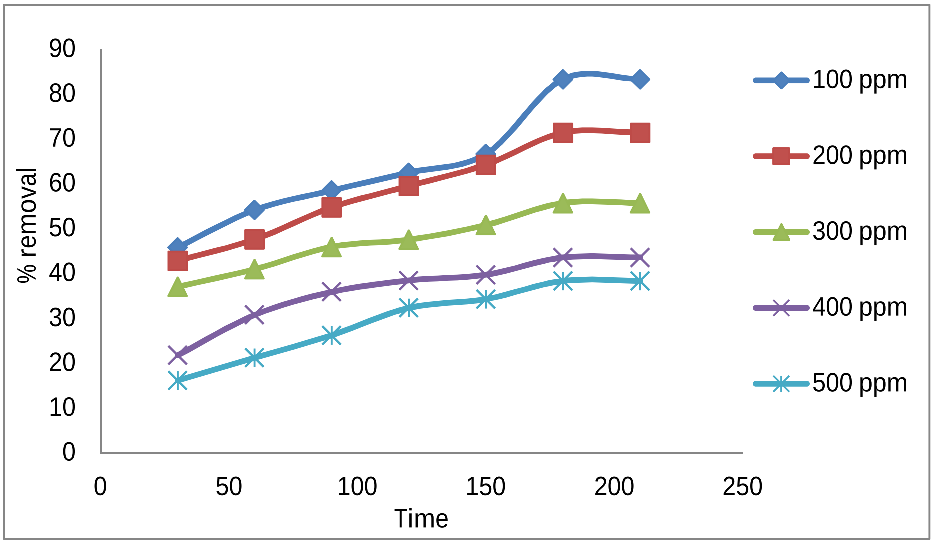

Figure-3. Effect of initial concentration on removal of Pb(II) from aqueous solution
Conditions: Size of adsorbent=53µ; adsorbent dose=200mg; pH=6; temperature=32±2ºC.

Spectroscopic studies: The functional groups present in the active sites of an adsorbent are examined using FTIR spectroscopy. The functional groups present in the surface of the adsorbent are attributable for attracting the metal ion present in the solution. The functional present in GMC-2 and lead (II) ion adsorbed GMC-2 shown in figure-2. The figure illustrates that peaks obtained in the range of 3780cm^{-1} reveals the acidic hydroxyl group present in the surface and the peaks at 3620-2500 cm^{-1} shows the presence of O-H groups present in the adsorbent. The peaks observed at 2857-2686 cm^{-1} indicates the presence of –CH and –CO groups and the peaks obtained at 1585-1624 cm^{-1} shows the presence of the N-H group as primary amines and –C-C group. The peaks at 1370-1350 cm^{-1} indicates the presence of CH groups on the surface of the GMC-2. The -C-Cl group of alkyl halide present in the range of peaks obtained from 850-550 cm^{-1}. The lead (II) ions adsorbed GMC-2 shows a similar FTIR spectrum as that obtained with an unloaded adsorbent, except that the bands had shifted to higher or lower values as shown in figure-2. The shifting of band due to the Pb(II) adsorption. Thus, the FTIR analysis revealed that the functional group like –OH, C-H bending, and C=O, COO-, O-H groups were mainly responsible for the adsorption.

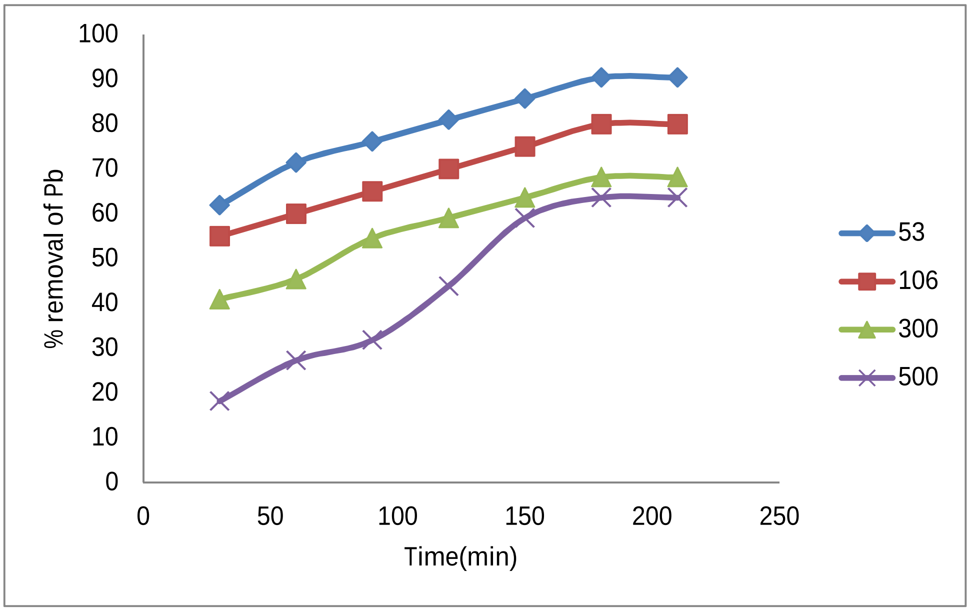

Figure-4. Effect of Size of adsorbent on removal of Pb(II) from aqueous solution
Conditions: Pb(II)=100mg/l; adsorbent dose=200mg; pH=6; temperature=32±2°C.

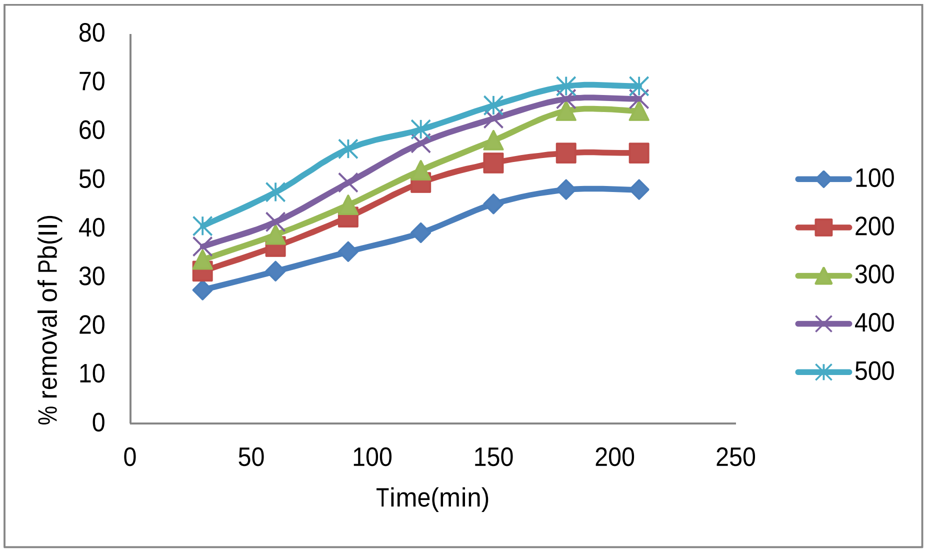

Figure-5. Effect of concentration of adsorbent on removal of Pb(II) from aqueous solution
Conditions: Pb(II)=100mg/l; Size of adsorbent=53µ; pH=6; temperature=32±2°C.

Effect of initial concentration of metal: The adsorption process on effect of initial concentration (100-500mg/L) on the percent removal of Pb(II) ions is shown in Figure-3.The results reveals as the increase in concentration of metal ion found to be a decrement in percent adsorption of Pb(II) ions and the uptake capacity of metal found to be increased with increase in initial concentration. The number of lead ions available at lower concentration of the solution is found to less as compared to the available sites on the adsorbent. However, at higher concentrations, the metal ions are greater than the available adsorption sites are saturated and thus, the percentage removal of lead ions depends on the initial concentration[32]. The maximum percentage removal (83.33%) of Pb(II) ions was achieved at 100 mg/L of lead solution.

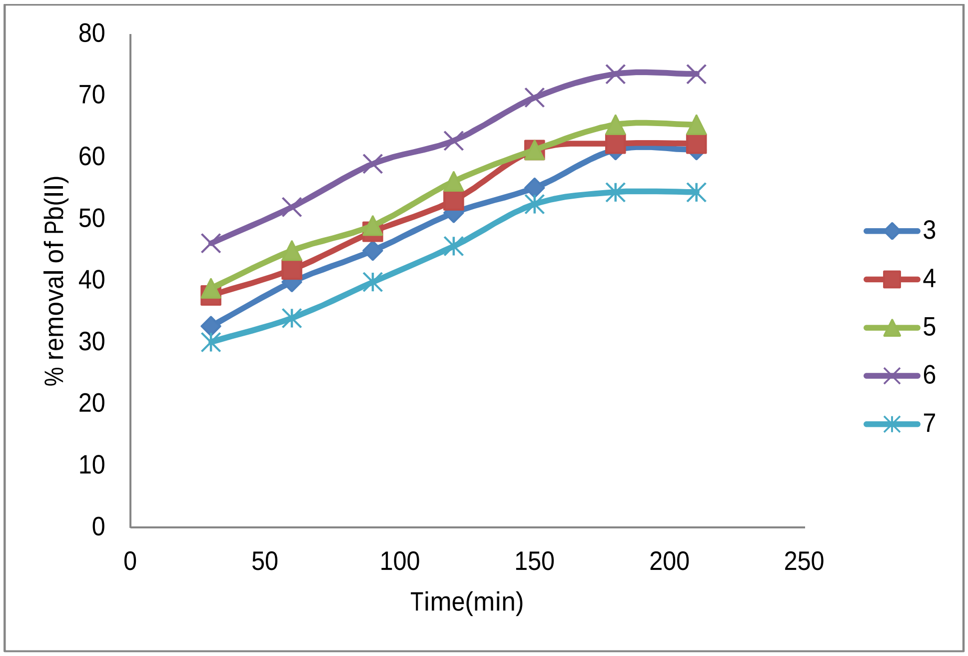

Figure-6: Effect of pH on removal of Pb(II) from aqueous solution
Conditions: Pb(II)=100mg/l; adsorbent dose=200mg; Size of adsorbent=53µ; temperature=32±2°C.

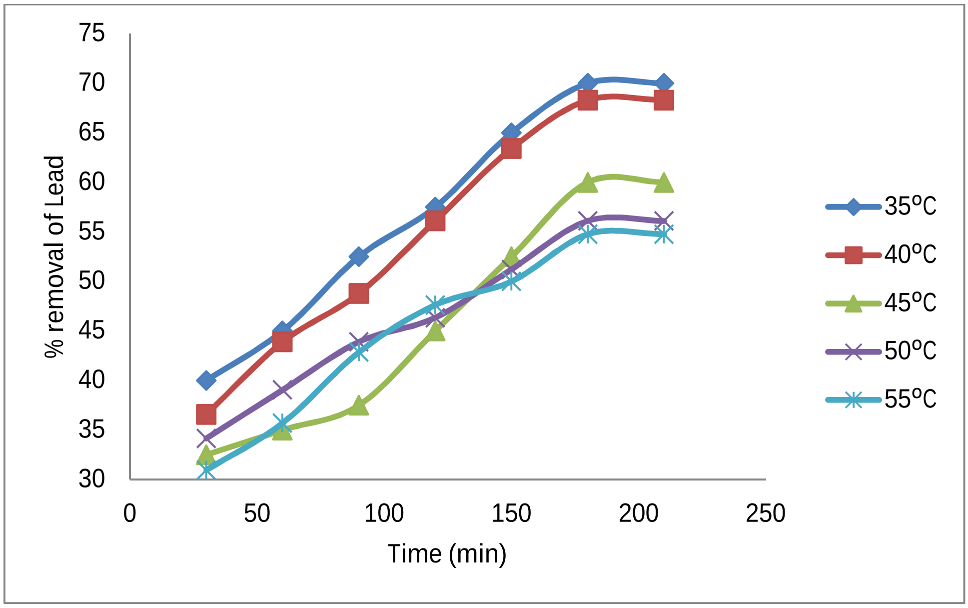

Figure-7. Effect of temperature on removal of Pb(II) from aqueous solution
Conditions: Pb(II)=100mg/l; adsorbent dose=200mg; pH=6; Size of adsorbent=53µ.

Effect of particle size: Adsorption is a process of surface controlled phenomenon. The percent removal of Pb(II) decreased with increasing adsorbent particle size as shown in figure-4. The higher adsorption occurred in smaller adsorbent particle size is attributed due to the smaller particles give large surface areas offers a comparatively larger and more accessible surface area and hence, there was an increase of adsorption is found as the size of the particle gets decreased. Thus, the adsorption equilibrium of lead found to be 90.47% at180 min with size 53µ and increasing the adsorbent particle size to 500μ leads to decrease of percent removal by 63.63%. For optimum condition, low particle size (53μ) was used for further experiments.

Effect of adsorbent concentration: The adsorbent dose is another important parameter that influences the adsorption of metal ions onto the GMC-2. The experiments were carried out under the conditions by varying the adsorbent dosage from 100mg to 500mg. It will be seen that the removal efficiency towards Pb(II) ions increased as the adsorbent dosage increased is presented in Figure-5. The factor is that adsorption sites remain unsaturated during the adsorption reaction. This is due to the dosage of the adsorbent is increased; there is a less proportionate increase in adsorption resulting from the lower adsorptive capacity utilization of the adsorbent. As adsorbent dose increased, there will be a more and more surface area will be available which increases active sites for binding of metal ions and thus exchangeable sites [29].

Effect of solution pH: The pH of the solution has a significant impact on the uptake of heavy metals, since it determines the surface charge of the adsorbent, the degree of ionization and speciation of the adsorbate. The optimum pH for the removal of Pb(II) ions from the solution with initial lead concentration of 100mg/L was observed that the percent removal of Pb(II) ions found to be increased with increasing pH 3-6 further increment of pH cause decline in adsorption displayed in figure-6. This is because at low pH, the active sites get protonated and thus the protonated H^+ ion competes with Pb(II) ions for the adsorption reaching the binding sites of the adsorbent caused by the repulsive forces. At high pH, the concentration of H^+ decreases hence they do not involve in metal ion on adsorption sites. The surface of the adsorbent with negative charge attracts positive charge of the metal ion easily towards its binding sites. At pH 7, a decrease of adsorption of Pb(II) ions was observed due to the formation of lead hydroxide [31]. The presence of Hydroxide species lowers the adsorption process onto adsorbent. Hence, the further experiments were conduct at optimal pH 6.

Effect of temperature: The effect of temperature on the removal of metal ions using GMC-2 was investigated at different temperatures (35–55°C). On increasing temperature, the removal efficiency of metal ion decreased as the solution temperature was increasing from 35 to 55°C as shown in figure-7. The decrease in percentage may be due to desorption caused by an increase in the available thermal energy. At the high temperature higher mobility of the adsorbate is induced causing desorption. This result shows the nature of the adsorption processes is mainly due to the decrease in surface activity, suggesting that adsorption between Pb(II) ion and GMC-2 is an exothermic process. The maximum adsorption of metal ions by the GMC-2 was obtained at 35°C shows that the adsorption of metal ions onto the GMC-2 is highly dependent on the temperature[30].

CONCLUSION

The present study shows that activated carbon prepared from chemically modified GMC-2 found to be an effective adsorbent for the removal of lead from aqueous solution. The adsorption process is a function of the concentration of adsorbent, pH, temperature and the size of the adsorbent. The maximum equilibrium was achieved practically in 180 min further increment there is no significant increase in adsorption. The FTIR analysis of GMC-2 showed that different functional groups are involved in the adsorption of the Pb(II) ions and there is no appearance of any new functional group after adsorption of lead prove to adsorption occur through physically.The results may be very useful for designing an economically cheap treatment process for the removal of Pb(II) from waste water from chemical industries.

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