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Original Article

Effect of pH and Adsorbent dosage on the removal of Hexavalent chromium from its aqueous solution by activated carbon of pachygone ovata

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ABSTRACT

The activated carbon was prepared from the plant leaf pachygone ovata which was freely available. In order to increase the adsorption capacity, adsorbent was chemically modified by using sulphuric acid at moderate temperature. It was well proven that modification with mineral acids at moderate temperature could increase the porosity of the adsorbent. In this study chemically modified activated carbon was employed to evaluate their performance on the removal of Cr (VI) from their aqueous solution. The parameters influencing adsorptive capacity of adsorbent such as pH of the solution and adsorbent dose were analyzed. The optimum pH and adsorbent dose were identified.

Keywords: Activated carbon, hexavalent chromium, effect of pH, effect of adsorbent dosage

INTRODUCTION

Tremendous urbanization and rapid industrialization led high risky situation to the environment. Due to the anthropogenic activities all living organism lives under this critical conditions. Heavy metals pollution becomes threatening factor to the environment and most serious hilarious effect to the ecosystem. The heavy metals are raised to the environment by the effluents released from the industries like fertilizer and pesticide industry, mining and smelting of metalliferous, metallurgy, metal surface treating, electroplating, electrolysis, electro-osmosis, leatherworking, electric appliance manufacturing paint, solvent, pharmaceutics etc. The effluents from these industries mainly contains organic pollutants and metals like chromium, lead, cadmium, copper, iron, zinc, manganese, mercury and arsenic. Due to its great mobility, heavy metals are reached to the environment (1). The chromium contamination leads to liver damage, pulmonary congestion, edema, and causes skin irritation and ulcer formation. According to WHO, the acceptable limit of chromium present in drinking water in the range of 0.05 ppm higher than that may introduce various health effects (2).

There are numerous treatment methods are available they are mainly reduction, ion exchange, electrodialysis, electrochemical precipitation, evaporation, solvent extraction, reverse osmosis and chemical precipitation. Most of these methods suffer from the drawbacks such as high capital and operational costs or the disposal of the residual metal sludge (3). To overcome this difficulty we have to suggest effective and low cost treatment methods. Adsorption is one of the effective method for the removal of heavy metals. Generally the activated carbons are used as an adsorbent because of its large surface area, microporous character and chemical nature. Many reports are appeared to the reduction of concentration of chromium using various adsorbents they are tea residue (4), corn stalk (5), fruits (6), water chestnut (7) and olive stones.

The aim of the present study is to utilize ecofriendly low cost adsorbent to remove Cr (VI) from its aqueous solutions. The study extended to vary the adsorption parameters such as pH of aqueous solution, concentration of adsorbate, adsorbent dosage, contact time etc.

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MATERIALS AND METHODS

Adsorbent: The leaves of pachygone ovata leaves were obtained from the local area. The leaves collected were washed with distilled water to remove adhering sand, mud, dirt and other contaminant and then dried in the shadow for a week. The dried material was powdered by using the domestic mixer.

Modification of adsorbent: The dried plant materials were mixed in a 1:1 wt ratio with concentrated H_2SO_4 and allowed to soak for 24 hrs at room temperature. The samples were placed in muffle furnace and heated to 200ºC for 24 hrs. After this, the sample was allowed to cool back to room temperature. Then, the samples were washed with distilled water and soaked in 1% $NaHCO_3$ solution to remove remaining acid. The sample was then washed with distilled water until pH of the activated carbon reached 6 then dried at 105°C for 5 h. The activated carbon was introduced into mesh to obtain the approximate particle size 0.05 m.m. This fine powder was stored in an air-tight container for the further experiments.

Adsorbate: The stock solution of Cr (VI) was prepared by dissolving the weighed quantity of 0.283g of potassium dichromate. Experimental solution of various concentrations of Cr (VI) was prepared by diluting from the stock solution and the pH of metal solution was maintained by using 0.1N of NaOH and 0.1N of HCl.

Metal adsorption experiment: Batch adsorption experiments were carried out in conical flasks stirred with magnetic stirrer at different pH (2, 4, 6, 8 and 10) and for different adsorbent dosage (1, 2, 3, 4 and 5 g/l) with the metal concentration 50 mg/l. The samples were taken out at equilibrium time 180 min, centrifuged and then filtered. The concentration of Cr(VI) was analyzed by AAS.
The quantity of metal adsorbed at equilibrium was calculated by the following expression:

$$Q_E = \frac{(C_0 - C_E)V}{M}$$

where 'm' is the mass of adsorbent (mg), 'V' is the volume of the solution (L), 'C_o' is the initial concentration of metal ($mg.L^{-1}$), 'C_e' is the equilibrium metal concentration ($mg.L^{-1}$) and 'Q_e' is the metal quantity adsorbed at equilibrium (mg of Cr(VI) by adsorbent).

RESULTS AND DISCUSSIONS

Characterization of an activated carbon: The Functional group present in the activated carbon derived from pachygone ovata was identified by help of FT-IR image. The FT-IR image of an activated carbon was analyzed by Fourier transform infra-red spectrometer model Shimadzu. Fig 1 represents the FI-IR image of an activated carbon was represented as follows:

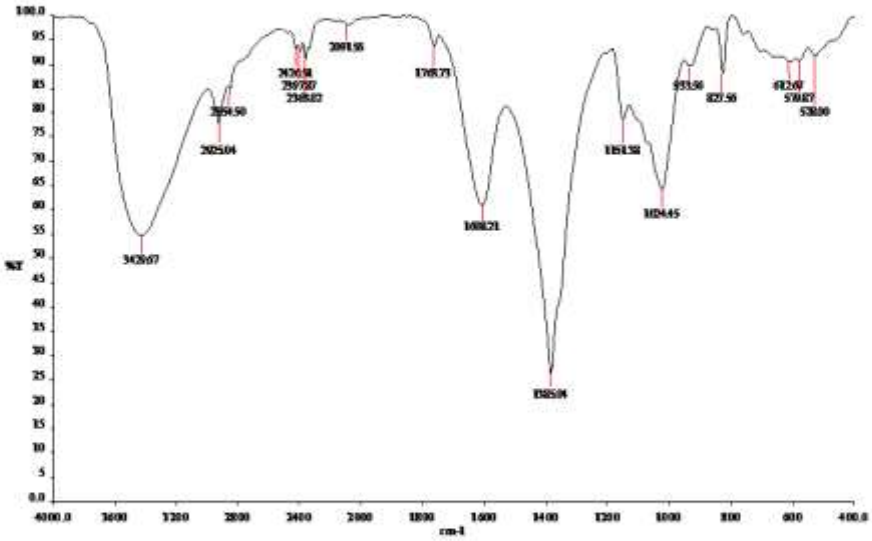

Fig 1: FT-IR spectra for activated carbon

The Fig 1 shows that the FT-IR spectra of chemically modified activated carbon before adsorption. The peak at 3429 cm^{-1} attributed to O-H stretching vibration of intra-molecular hydrogen bonding in water molecules the peak due to 2925 cm^{-1} and 2854 cm^{-1} are due to C-H stretching in Alkane and O-H stretching in carboxylic acid. Peak at 1608.4 cm^{-1} is observed due to the C=C stretching absorption band of ketone, aldehyde and carboxylic acids. The peak at 1151 cm^{-1} is due to the presence of C-H stretching of the ether group The peak at 1024 cm^{-1} is arise due to the –C-C- group. The peak at 1768 cm^{-1} represents the C=O stretching in anhydrides. The peaks at 612, 579 and 528 cm^{-1} represents the alkyl halides. The peak at 933 cm^{-1} indicates that the presence of O-H bending in the carboxylic acids. Band at 2091 cm^{-1} is due to the presence of –C= - C-H alkyne stretching.

Effect of pH:

The pH of an aqueous solution is an important parameter which controls the adsorption process. pH of the solution affects the metal ion species and the surface charge state of the adsorbent directly. The effect of pH was studied by varying pH 2 to 10 while keeping other parameters constant.

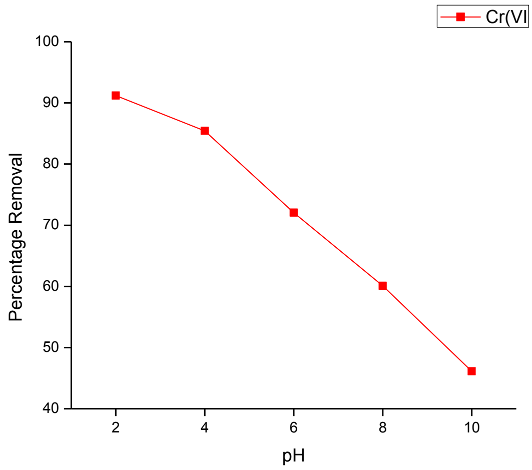

Fig 2: Effect of pH on the removal of Cr (VI) by an activated carbon

Fig 2 represents the effect of pH on the removal of Cr (VI) by an activated carbon. Fig 2 shows that the maximum removal was achieved at pH 2 where the percentage removal was 91.2 %. It was also observed that percentage removal was high at acidic pH and it starts decreasing as we move down the basic pH. At low pH, the metal solution present in their anionic forms such as CrO_4^{2-}, $Cr_2O_7^{2-}$ and $HCrO_4^-$ and the functional groups of the adsorbent become protonated which results in the strong electrostatic attraction between anions and cations. But at high pH deprotonation occurs, functional groups become negatively charged which repels negatively charged chromium. In addition the Coulombic force of electrostatic attraction and surface complexation play important roles in the elimination of Cr(VI) from aqueous solution. (8)(9)

Effect of adsorbent dosage: The study of adsorbent dosage was important because the adsorbent surface provides the active sites for the metal ions to adsorb. The effect of adsorbent dosage on the removal of metal by adsorbent was studied by varying the adsorbent dosage from 1g/l to 5 g/l while keeping other parameters constant. The fig 3 represents the effect of adsorbent dosage of on the removal Cr (VI). From Fig 3 it was found that the percentage removal was increases with increase of carbon dose from 1 g/l to 5 g/l and maximum percentage removal was observed at carbon dose 5 g/l where the percentage removal was 92.4 %. This pattern is due to the availability of active sites or surface area on the adsorbent increases with increase of adsorbent dosage facilitates the complexation of the Cr (VI) which inturn results in increase of percentage removal. (10)

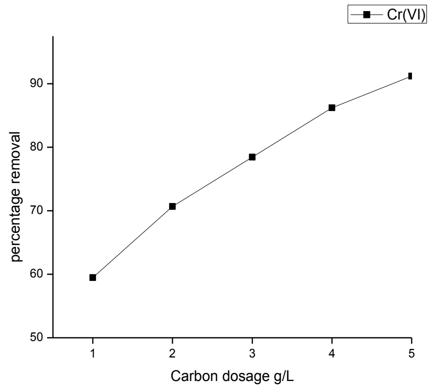

Fig 3: Effect of adsorbent dosage on the removal of Cr (VI) by an activated carbon

CONCLUSION

In this study, activated carbon was prepared from pachygone ovata leaves are used for the removal of chromium (VI) from its aqueous solution. Earlier chemical activation of leaves carried out by conc.H_2SO_4 at moderate temperature at 200°C which increases the porosity of the carbon. The activated carbon is seems to be suitable choice for the removal of chromium (VI) from its aqueous solution. pH of chromium (VI) solution plays an important role in adsorption process. The hydrogen ions produce the electrostatic attraction with the adsorbents. It is observed that optimum pH found to be at pH 2, where the maximum percentage removal is 91.2 %. It is determined as the optimum adsorbent dose is found at adsorbent mass 5 g/l. When we increase the adsorbent mass, the active sites or surface area provided by adsorbent is also increases so that we obtained the maximum yield at highest adsorbent mass. The removal of chromium was rapid at initial stages slowly reaches the equilibrium at contact time 180 min after that there is no remarkable change in the adsorption. On the whole, it is concluded that activated carbon prepared from the pachygone ovate leaf is suitable adsorbent for the removal of chromium from wastewater not only that it is also low cost and easily available.

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