



## **ADSORPTION STUDIES FOR THE REMOVAL OF Cr(VI) ION FROM AQUEOUS SOLUTION**

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### **ABSTRACT**

*The adsorption characteristics of Cr(VI) in the form of  $Cr_2O_7^{2-}$  ion from aqueous solution onto synthetic exchanger Amberlite IRA 400(Cl) resin was studied from UV – visible spectrophotometric measurement using DPC at 580nm. The efficiency of the adsorbent was judged from the variation of the % adsorption with (i) contact time, (ii) adsorbent dose and (iii) initial metal ion concentration. For the optimum adsorbent dose, the highest % adsorption was found to be 99.92% at 30ppm metal ion concentration.*

**Keywords:** adsorption, adsorbent, metal ion

### **INTRODUCTION**

Chromium exists usually in both trivalent and hexavalent forms in aqueous systems. The two-oxidation states of chromium have different chemical, biological and environmental characteristics (WHO, 1988). Cr(III) is relatively insoluble and required by microorganisms in small quantities as an essential trace metal nutrient (Katz and Salem, 1994), while Cr(VI) is of great concern because of its toxicity. Cr(VI) has been reported to be a primary contaminant to humans, animals, plants and microorganisms and it is known to be carcinogenic (Cieslak-Golonka, 1995; Raji and Anirudhan, 1998). Chromium is used in a variety of industrial applications; hence, large quantities of chromium are discharged into the environment. For this reason, increased attention is being focused on the development of technical know-how for its removal from metal bearing effluents before being discharged into water bodies and natural streams.

O'Dwyer and Hodnett (1995) developed a technique for the recovery of chromium from tannery effluents based on the use of redox-adsorption approach in which they demonstrated that the adsorption process followed the Langmuir model. However, the rate of chromium(VI) adsorption after its reduction to chromium(III) was interfered by the presence of  $Na^+$  ions.

### **MATERIALS AND METHODS**

#### **Preparation of Stock Solution and Regeneration of the Exchanger**

A 1000ppm Cr(VI) solution was prepared by dissolving 5.6575g of  $K_2Cr_2O_7$  AnalaR grade in a  $1.0dm^3$  volumetric flask using distilled deionised water (El-Nemr, *et al.*, 2008) and with serial dilution a 10ppm Cr(VI) test solution was prepared.

The Amberlite IRA 400(Cl) resin was regenerated as reported by Ibrahim (2007) and stored in a plastic container for subsequent use as required.

### **Static Adsorption Studies**

$100cm^3$  of the 10ppm Cr(VI) test solution was added into a beaker containing 5g of the regenerated resin at room temperature, i.e.  $30 \pm 2^\circ C$ .  $10cm^3$  fractions of the adsorption mixture were taken using a syringe (Alexander, *et al.*, 1978) after every 15min. for a period of 1hr 30min and the residual Cr(VI) content, i.e. the variation in concentration of Cr(VI) in the test solution, were analysed using Cecil CE7400 UV-Visible spectrophotometer using 1,5 – diphenylcarbazide (DPC) in an acidic medium at 580nm (Mendham, *et al.*, 2006).

The effect of adsorbent dosage was investigated by repeating the experiment using 10, 15 and 20g of the resin with the same volume and concentration of the test solution. While effect of variation in initial metal ion concentration was studied with the adsorbent dose having highest Cr(VI) adsorption with metal concentration varying from 10 to 40ppm.

### **RESULTS AND DISCUSSION**

In static equilibrium adsorption, the same solution remains in contact with a given quantity of adsorbent. As the amount of ion adsorbed on the resin increases and its concentration in solution decreases, the driving force for adsorption decreases with time accompanied by a reduction in the adsorption capacity. The adsorption process continues however, till equilibrium between the solute concentration in solution, and the solute adsorbed per unit weight of adsorbent, is reached. This equilibrium established is static in character, as it does not change further with time. The static equilibrium behaviour is characteristic of the nature of the adsorbent, the adsorbate, the solvent and the working temperature (Rajagopal and Kapoor, 2001).

#### **1,5 – Diphenylcarbazide Test**

In dilute mineral acid solution diphenylcarbazide produces a soluble violet colour, which is a characteristic test for chromium.

During the reaction chromate is reduced to chromium (III), and diphenylcarbazone is formed; these reaction products in turn produce a complex with the characteristic violet colour whose absorbance can be monitored by the use of UV - Visible spectrophotometer (Svehla, 2006).

**Effect of Contact Time**

The results of the contact time investigations are shown in Figures 1 and 2 for the different weights of the resin, in which Fig. 1 shows the variation of the amount of metal ion remaining in the test solution. The percent adsorption of the metal ion as calculated

from the relation  $\left(\frac{C_o - C_t}{C_o} \times 100\right)$ , were  $C_o$  and  $C_t$

are the initial metal ion concentration and the metal ion concentration at the various time respectively, was found to increase rapidly in the initial stage (i.e. the first 15min.) and levels off as equilibrium is established after about 45min (Fig. 2). An interesting feature of the result is that almost in all cases with exception of the 5g adsorbent dose, over 90% adsorption has been reached at equilibrium.

**Effect of Adsorbent Dose**

Fig. 3 reveals how changes in the adsorbent dose affects percent adsorption (i.e. amount of Cr(VI) ion removed by the resin) of the Cr(VI) ion having an initial concentration of 10ppm. The observed increase in the % adsorption with increase in adsorbent dose may be attributed to the fact the number of available adsorption sites increases by increasing the adsorbent dose. However, the adsorption density (q) i.e. the amount of Cr(VI) ion adsorbed per unit mass( $mg\ g^{-1}$ ) of the adsorbent, calculated from the relation

$$q = \frac{(C_o - C_t) \times V}{w}$$

Bhattacharya, *et al.* (2008);

Wang and Lin (2008), was found to decrease with

increase in adsorbent dose. This can simply be due to increase in unsaturation of adsorption sites or particle interaction, such as aggregation which results as sorbent concentration increases, thereby leading to decrease in total surface area of the adsorbent (Shukla, *et al.*, 2002).

**Effect of Variation of Initial Metal ion Concentration**

The efficiency of the adsorbent for the removal of the Cr(VI) ion as judged by the % adsorption was found to increase at the beginning with increase in metal ion concentration however, after reaching a maximum at 30ppm it decrease with further increase in the concentration of the metal ion (Figs. 4 and 5) for a fixed adsorbent dose and contact time of 15min. This observed phenomenon can be explained by the fact that the adsorbent has a limited number of active (exchangeable) sites, which become saturated above a certain concentration. Also increase of the initial metal ion concentration results in a decrease in the initial rate of external diffusion and increase in the intraparticle diffusion rate (El- Nemr *et al.*, 2008). Similarly, the involvement of high energy sites in the adsorption process at low concentration and the subsequent use of low energy sites at high metal ion concentration may be linked to the decrease in % adsorption observed at high concentrations (Bhattacharya, *et al.*, 2008; Kadirvelu and Namasivayam, 2003; Zouboulis, *et al.*, 2002).

**CONCLUSION**

This study indicated the efficiency of the adsorbent in the removal of the common industrial pollutant using the adsorption technique which by far is most versatile when compared to other methods, especially from the fact the spent adsorbent can be regenerated for further use.

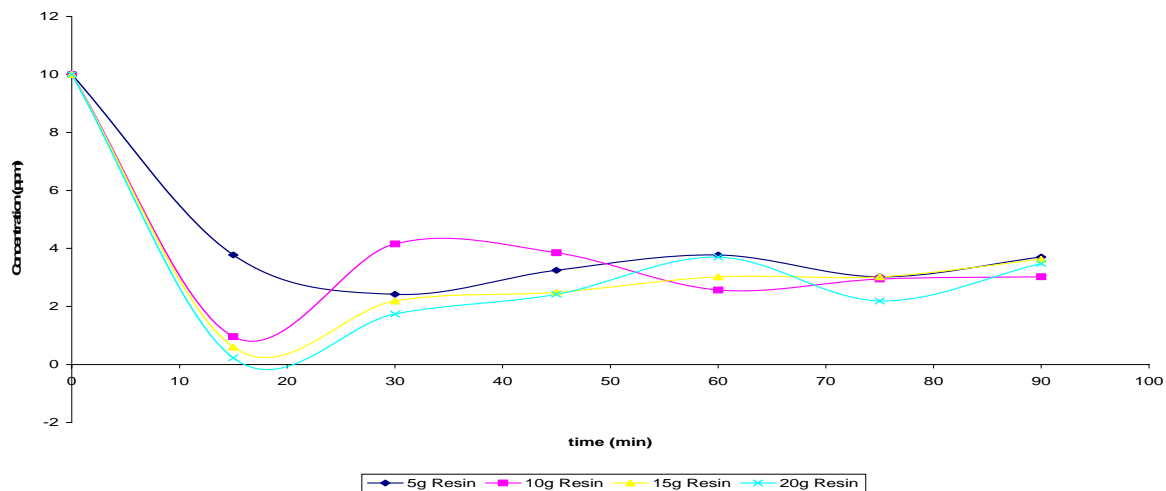
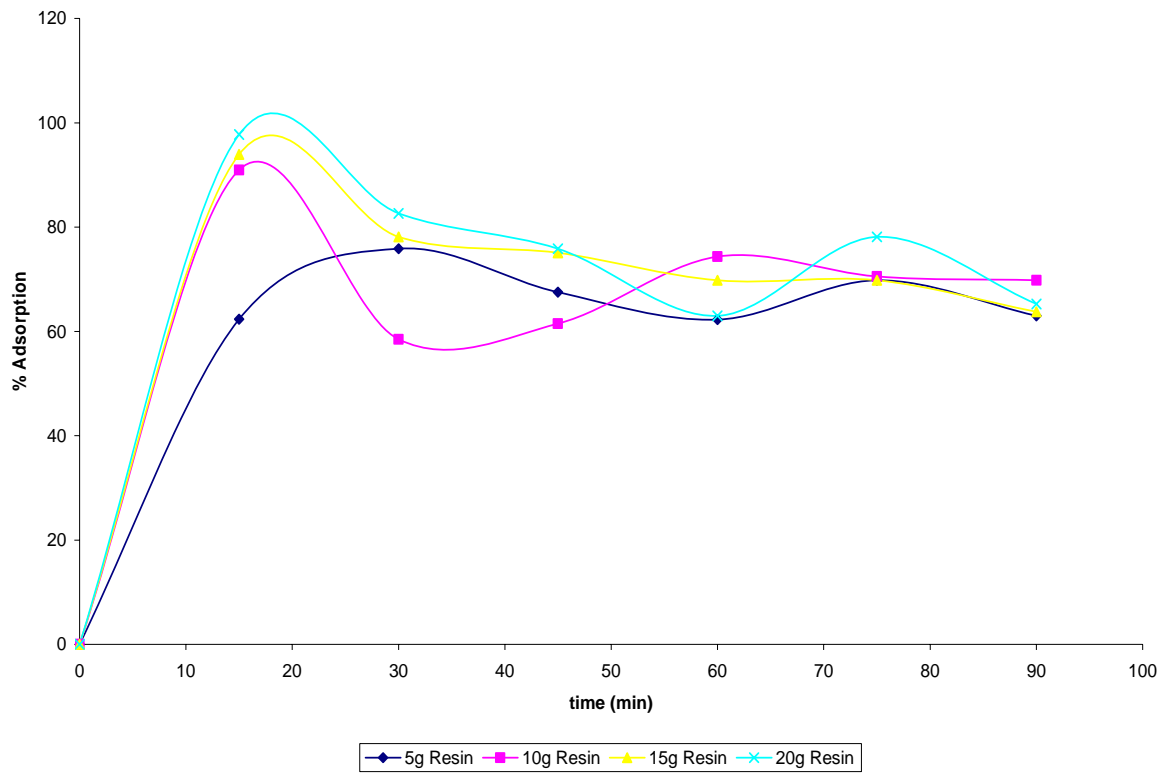
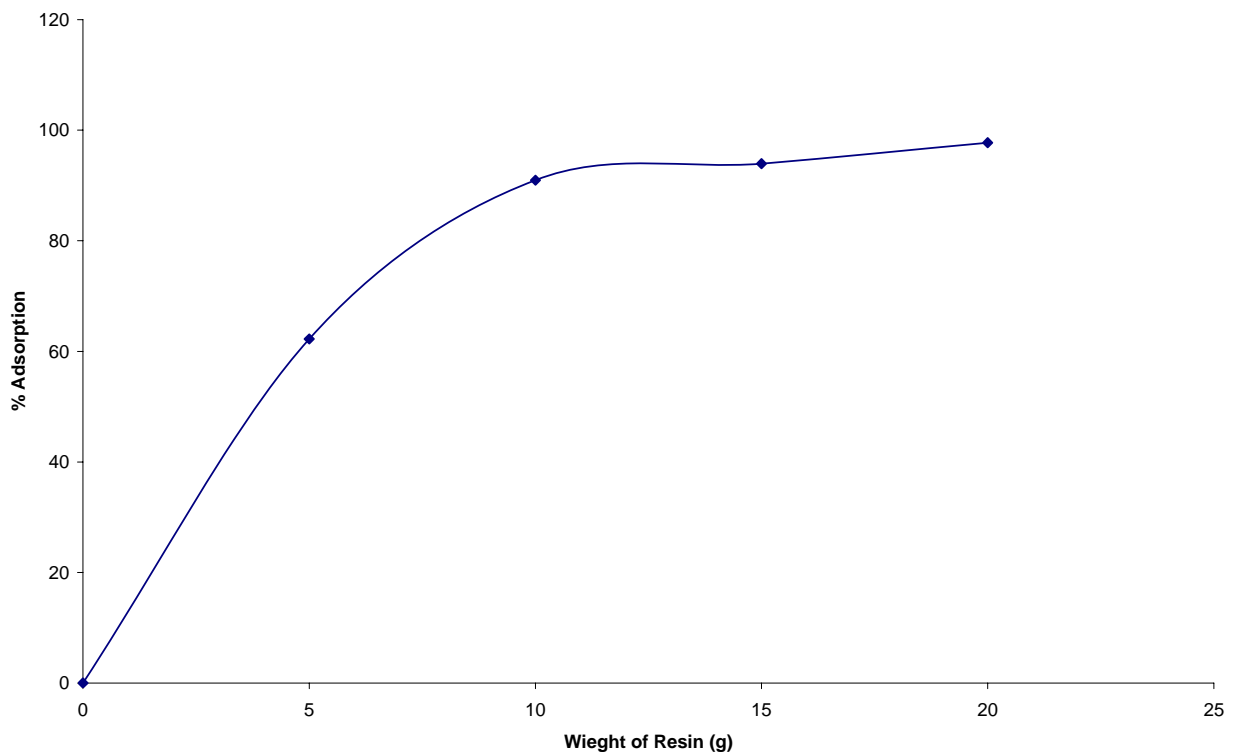


Fig. 1: Variation of concentration with time for the Various weight of Resin



**Fig. 2: % Adsorption with time for the Various weights of the Resin**



**Fig. 3: Variation of % Adsorption with increasing weight of the Resin**

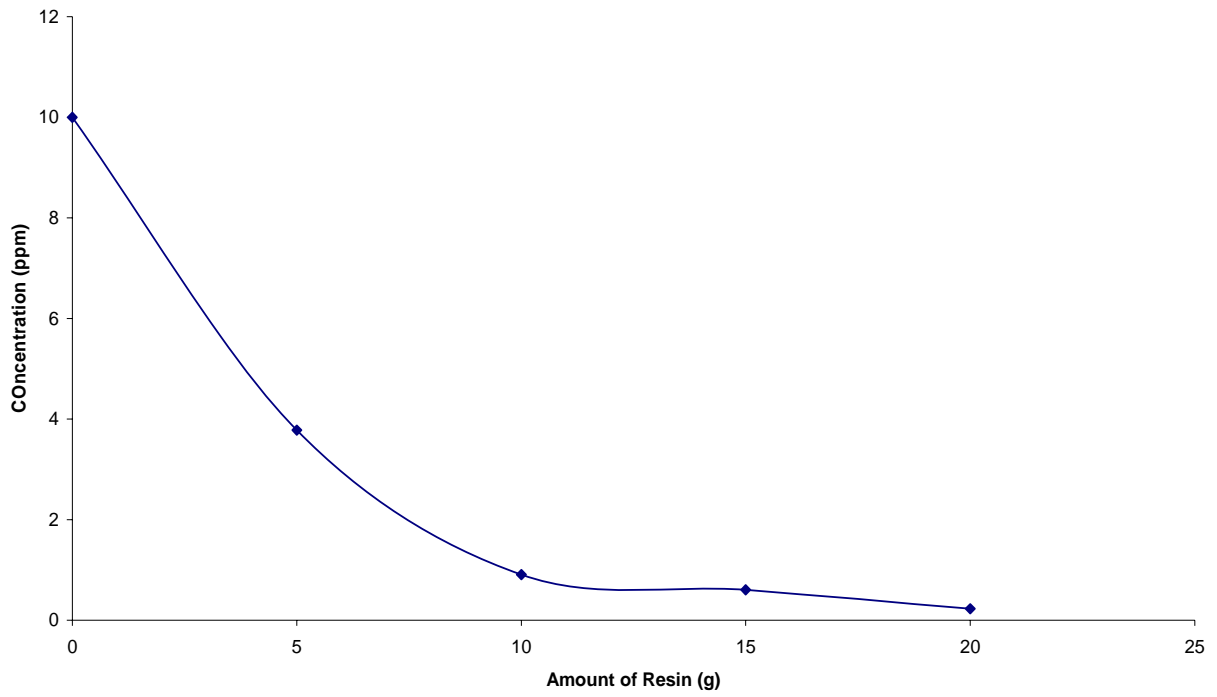


Fig.4: Variation of Concentration with Amount of Resin

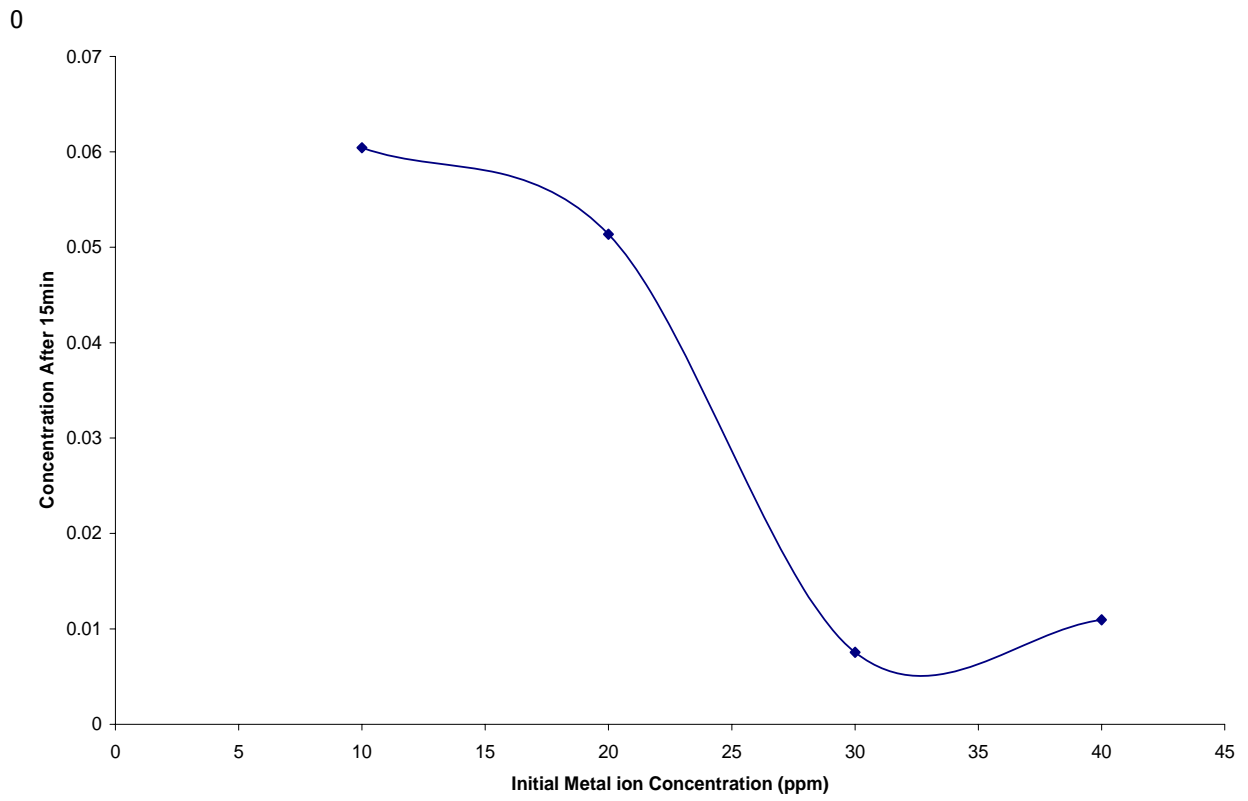


Fig.4: variation of Concentration After 15min for 20g Resin with Initial  $\text{Cr}_2\text{O}_7^{2-}$  Concentration

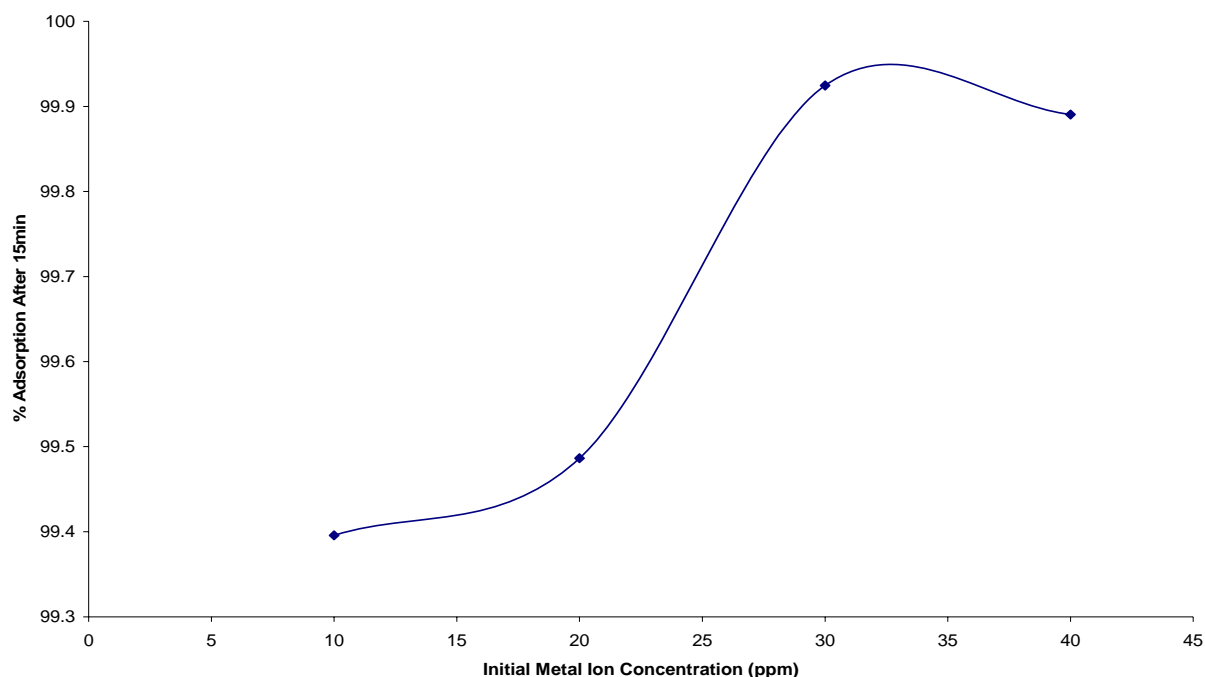


Fig. 5: Variation of % Adsorption After 15min for 20g Resin with Initial  $\text{Cr}_2\text{O}_7^{2-}$  Concentration

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