Removal of hexavalent chromium from aqueous solutions by granular activated carbon

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Abstract

Batch adsorption trials were used to assess the effectiveness of using activated carbon as a sorbent for the removal of hexavalent chromium from solution. The results show that, although the pH for maximum efficiency varied slightly with the concentration of Cr(VI) being applied, the most effective pH was in the range 2.5 to 3.0. Based on linear regression analysts, the data obtained from the batch studies showed a good compliance with both the Langmuir and the Freundlich equations. The values obtained for the isotherm constants showed that the maximum adsorption capacity, X_m, was 145 mg/g. An examination of the adsorption kinetics was also made and an analysis of the data shows that pore diffusion is not the only factor governing the sorption rate.

Nomenclature

c_e	:	equilibrium concentration (mg//)
C_o	:	initial concentration *(mg/l)*
K_1	:	forward kinetic constant (mol/s)
K_F	:	Freundlich constant (mg/g)
n	:	Freundlich constant
K_r	:	rate factor
[M]	:	concentration of free metals in solution (mol/l
[P]	:	concentration of binding sites (mol/l
[PM]	:	concentration of metals bound to carbon (mol/l)
%	:	adsorption density (mg chromium/g activated carbon)
W_s	:	carbon dose *(g/l)*
X_m	:	Langmuir constant (mg/g)
k	:	Langmuir constant *(l/mg)*

Subscripts

init	:	initial value
fin	:	final value
lim	:	equilibrium value

Introduction

Waste waters containing chromium are generated by a number of industries, for example, metal plating and tanning. Chromium may also be found in cooling tower blow-downs. Although chromium can exist in a number of oxidation states, industrial effluents are most likely to contain the trivalent, Cr(III), or the hexavalent, Cr(VI), forms. Of the two, the hexavalent form is generally thought of as being the more toxic (Coleman and Paran, 1991). Environmental legislation within the member states of the European Community has, over the last decade, imposed increasingly rigorous standards on discharges to the environment and for the concentrations of the more significant pollutants in both natural and treated waters. For example, the maximum concentration permitted in drinking water by the United Kingdom Water Supply (Water Quality) Regulations 1989 is 0.05 *mg/l.* Similarly, the concentrations of total chromium in surface waters which are to be abstracted for potable supply are restricted to a maximum value of 0.075 mg/l by an EC Directive (Mance et al., 1984). It is, therefore, essential that chromium-rich waste waters are treated adequately and discharges of chromium to the aquatic environment are minimised.

Reduction/precipitation is probably the most commonly used technique for the treatment of industrial effluents containing chromium (Wild, 1987). However, it is a process which can give an incomplete removal, has a high chemical requirement and produces a voluminous, toxic sludge which may pose disposal problems. Because of this, a variety of otherltreatment technologies have been evaluated. These have included ton exchange (Neville, 1994) and adsorption with naturally occurring products (Tan et al., 1993; Sharma and Forster, 1993) or activated carbon (Lee and Low, 1989; Huang and Wu, 1975). The use of activated carbon certainly does not require the regular use of chemicals, but obviously the question of disposal must be considered, as must the costs of any regeneration stage. Nevertheless, activated carbon must be thought of as the material which sets the standard for adsorption and as such its role in removing chromium from waste-water streams, either as a complete treatment or as alfinal "polishing", has been examined previously (for example, Kim and Zollek, 1977; Bowers and Huang, 1981). The results which have been reported are very variable, particularly in terms of the optimum pH for chromium removal. Faust and Aly (1987) have reported that the greatest removal was achieved at pH values of 5 to 6 whereas other workers have noted that the best results were achieved at lower pH values *(<2.5)* (Huang and Wu, 1975; Huang and Bowers, 1979).

In developing countries, pollution control measures frequently need to be based on lower-cost technologies. In this context, one area which is being explored is the use of naturally occurring materials which have the potential for adsorbing pollutants. These have included low-cost biosorbents, such as pine bark (Vascoucelos and Beca, 1994) and coconut husk fibre (Tan et al., 1993), and activated carbons produced from low-cost or waste materials have

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