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Potential of single and double-combined adsorbents in removing chromium from an industrial wastewater

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Abstract. Nowadays, there is much attention in using low-cost methods for removing heavy metals' pollution from wastewaters. In this research, the ability of different adsorbents including zeolite, peat, activated carbon, cationic resin and anionic resin (in single and double-combined forms) in decreasing Cr(III) and Cr(VI) concentration to below the legal limits from an industrial wastewater was investigated. The results showed that for single-adsorbent treatments, all adsorbents were more effective in reducing Cr(VI) concentration than Cr(III). The highest removal efficiency (Er=100%) was obtained by anionic resin. Presence of anionic resin in each double-adsorbent caused an improvement of chromium removal. Among the double-adsorbents treatments, combination of peat and activated carbon was the most proper treatment in removing chromium.

Keywords: Heavy metals; Chromium; Adsorbent

Introduction

Heavy metals (HMs) are among the most important environmental pollutants which are becoming a severe public health problem. One of the toxic HMs in the wastewaters is chromium. Chromium compounds occur mainly in the environment as trivalent, Cr(III), and hexavalent, Cr(VI) ions. Cr(VI) is a highly toxic metal. Cr(III) is an essential element and is much less toxic than Cr(VI). Adsorption is one of the effective techniques for HMs removal from wastewaters. Application of different adsorbents such as zeolite, peat, activated carbon, anionic resin and cationic resin to remove HMs from the aqueous phase has been widely studied (Wu et al., 2008; Zeng et al., 2010; Ulmanu and Anger, 2008; Choi et al., 2009 Pehlivan and Cetin, 2009; Alguacil et al., 2004).

It is often necessary to remove chromium from wastewaters so that the effluent could be reused as irrigation water. The permissible limits of Cr(III) and Cr(VI) concentration for surface irrigation reuse of water is 2 mg L^{-1} and 1 mg L^{-1}, respectively (Environmental Protection Organization of Iran, 2000). The adsorption capacity of various adsorbents in removing HMs is different. Finding low-cost adsorbents with high adsorption capacity is the best method for alleviating the HMs pollution. For this reason, the objective of the present research was to study the ability of different adsorbents in single and double forms, to remove Cr(III) and Cr(VI) from an industrial wastewater.

Materials and Methods

Zeolite, peat, activated carbon, anionic resin and cationic resin were used as an adsorbent in the single and doubled combined. Table 1 shows the main treatments of this study. The amount of total adsorbent in each treatment was the same. Characteristics of each adsorbent are described as follows.

In this research, the industrial wastewater from one of the steel factories in the region was used as the aqueous solution for testing the efficiency of the above-mentioned adsorbents for removing chromium. Initial concentrations of total chromium and Cr(VI) were 60.2 mg L^{-1} and 45.15 mg L^{-1}, respectively. pH of the wastewater was 5.45. In this experiment, for each treatment, 1.0 gram of single or combined adsorbent was added to 50 ml of the solution and the flasks were shaken thoroughly (at a speed of 180 rpm) in the laboratory temperature for 4 hr. For combination

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Table 1- Single adsorbents and their combinations used in the experiment

Specified letter	S1	S2	S3	S4	S5	D1	D2	D3
Adsorbent	Z*	P	AC	AR	CR	Z, P	Z, AC	Z, AR
Specified letter	D4	D5	D6	D7	D8	D9	D10	
Adsorbent	Z, CR	P, AC	P, AR	P, CR	AC, AR	AC, CR	AR, CR	

*Z= Zeolite, P= Peat, AC= Activated carbon, AR= Anionic resin, and CR= Cationic resin

treatments, one-half of each adsorbent was used. At the end of the reaction period, each mixture was filtered to separate the substrate.

Initial and final pH was measured by a pH meter (MetrOhm). An atomic absorption apparatus (PerkinElmer AAnalyst 200) was used for quantitative determination of the total chromium concentration. The Cr(VI) concentration was analyzed by a UV spectrophotometer at a wavelength of 540 nm. The Cr(III) concentration was obtained from the difference between these two measurements.

Results and Discussion

The efficiency of Cr(III) and Cr(VI) removal from the wastewater by different adsorbents is shown in Figure 1 to Figure 2.

Zeolite could remove 42% of Cr(VI) and 19% of Cr(III) from the wastewater, respectively.

Peat removed Cr(VI) and Cr(III) from the wastewater solution 100% and 65%, respectively. A positively charged surface is a likely material for Cr(VI) sorption.

Activated carbon could reduce both Cr(III) and Cr(VI) concentrations in the wastewater. The presence of acid and basic functional groups on the surface of carbons assures that these materials are able to capture metallic cations by surface complexation and cation exchange mechanisms. The adsorption of anions is more complicated, but it can be related to surface complexation reactions with protonated-activated sites or eventually to the presence of basic or electrophilic surfaces.

Anionic resin removed 100% of Cr(III) and Cr(VI) from the wastewater. Anionic resin exchanges the anion in solution and therefore increases the pH of solution by removing OH-. Increasing pH caused precipitation of $Cr(OH)_3$ on the adsorbent surface and removal of Cr(III) from the aqueous solution.

Cationic resin reduced Cr(VI) concentration by 47% and Cr(III) by 31%. The interactions of metals with cationic resin are complex, probably simultaneously dominated by ion exchange and adsorption.

Generally, all adsorbents used in this experiment were more effective in reducing Cr(VI) concentration than Cr(III). This is probably due to small size of Cr(VI).

For double-adsorbent treatments, removal efficiency of Cr(III) was between 41% and 100% and removal efficiency of Cr(VI) was between 36.4% and 100%. Among the double-adsorbent treatments, treatment D5 (peat + activated carbon) was the most appropriate in removing chromium from the wastewater. The removal of Cr(III) and Cr(VI) ions by this combination was about 96% and 100%, respectively.

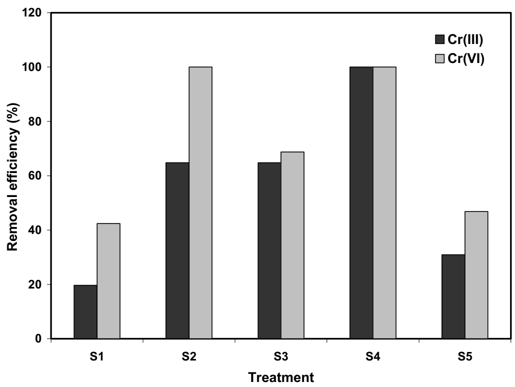

Fig. 1. Removal efficiency for single treatment

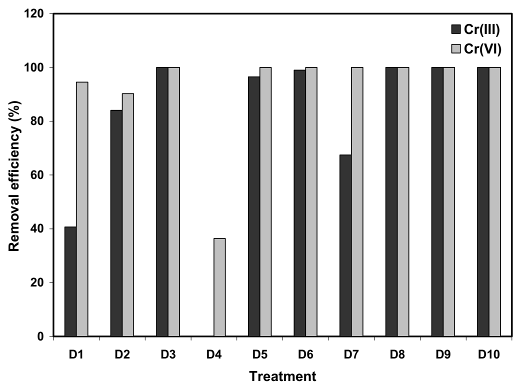

Fig. 2. Removal efficiency for double-combined treatment

Conclusions

Anionic resin in single form had the highest chromium removal efficiency (Er =100%). Both anionic resin and peat in single form could remove Cr(VI) completely. In single form, the highest and the lowest removal efficiency of Cr(III) was by anionic resin (Er = 100%) and zeolite (Er =19.6%), respectively.

Most double combinations were more effective than some of the single adsorbents.

Among the double-adsorbent treatments, treatment D5 was the most appropriate in removing chromium from the wastewater.

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