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Professional paper

ADSORPTION OF CHROMIUM (VI) IONS FROM AQUEOUS SOLUTION USING ACTIVATED RAW INORGANIC SORBENTS

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Abstract

Research into toxic heavy metals released into the environment has recently received a lot of attention. One reason is that these ions pollute the air, soil, and water and affect human health. Among the heavy metals that appear as the most toxic water pollutants is chromium. For the removal of Cr(VI) ions from aqueous solution, we have activated several inorganic mineral sorbents originating from the Republic of North Macedonia. We monitored the change in chromium ion concentration before and after the adsorption process with a spectrophotometer (UV/VIS Spectrophoto-meter). It was worked with solutions of Cr(VI) ions with an initial concentration of 0.5 mg/l, pH 3. The volume of all solutions was 400 ml, while the amount of sorbents was 2.5 g/l. It was worked at room temperature in a glass reactor, which was placed on a magnetic stirrer at 400 rpm. Of the three inorganic mineral adsorbents, activated diatomite showed the best results.

Keywords: aqueous solution, Cr(VI), adsorption, inorganic sorbents

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1. Introduction

Wastewater from the paint production industry, metal processing, car parts production, petrochemical industry, etc., contains high amounts of chromium, which spreads into the environment through soil, water, and ultimately accumulates in the food chain. Cr(VI) is highly soluble in water and can be absorbed by living organisms. When it accumulates in living organisms, it can cause serious health problems. Very small amounts can cause lung, liver, and kidney tumors and various reproductive problems. The International Agency for Research on Cancer classifies it as a carcinogen [1]. Many methods have been studied to remove Cr(VI) ions from water resources, including chemical reduction, membrane separation [2], and electrochemical treatment [3]. These methods have many negative aspects, including incomplete removal, the need for large amounts of energy, the generation of toxic waste, and large capital investments [4]. Adsorption technology is finding increasing use due to its advantages, such as simple operation and low cost [5]. In recent years, adsorption has been promoted as an alternative method for the removal of hexavalent chromium from wastewater. In order to reduce capital costs, a large number of research have been carried out to find cheaper adsorbents [6, 7, 8, 9, 10]. In this direction, we have also given our contribution by using cheap adsorbents for the removal of Cr(VI) ions. A large number of factors affect the efficiency of the Cr(VI) adsorption process. The characteristics of the adsorbate, as well as the operating conditions under which the adsorption process takes place, have a major impact on the degree of metal adsorption on the adsorbent surface [11]. Also of great importance for the success of adsorption are the physical and chemical characteristics of the adsorbent. In this regard, the degree of ionization of the surface, as well as the presence of functional groups on the adsorbent by type and number, are of particular importance. In addition, the specific surface area of the adsorbent, its adsorption capacity, and its porosity also play a significant role [12].

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2. Materials and Methods

Considering the issue addressed in this paper, the spectrophotometric method was used to determine the concentration of Cr(VI) ions. For the preparation of standard solutions, the model of an aqueous solution of $K_2Cr_2O_7$ was used. Achieving the desired pH value of the solution in all investigated systems was done with the concentrated HNO_3 solution and the diluted NaOH solution. To carry out experimental research, we used the following chemicals: H_2SO_4 (95-97%, ρ=1.83 kg/l, FLUKA), HNO_3 (65%, ρ=1.4 kg/l, Alkaloid-Skopje), HCl (37%, ρ=1.19 kg/l, MERCK). As working materials, we used: aksil (Kriva Palanka), diatomite (Kozuf), pemza (Bojanciste). To improve the adsorption activity of these materials, we activated them. The activation of aksil was performed first using 0.5M H_2SO_4, and in a separate experiment, it was activated with 0.5M HCl in order to compare the results and determine which treatment yields better adsorption performance. 100g of aksil were soaked in 1000 ml 0.5M H_2SO_4 at room temperature and stirred at a magnetic stirrer 24h at 100 rpm. Activated akasil was dried at 105℃ overnight. The activation of pemza and diatomite was carried out in the same manner, using HNO_3 as the activating agent. Adsorption experiments were conducted in a 2l glass reactor in which a Cr(VI) solution with an initial concentration of 0.5mg/l was placed. The glass reactor was placed on a magnetic stirrer, and all experiments were conducted at 400 rpm at room temperature.

3. Results and Discussion

The following figures show diagrams of the change in the concentration of Cr(VI) ions depending on the adsorption time using activated sorbents. The experiments were conducted at pH 3 with an adsorbent mass of 2.5 g/l, at room temperature, at 400 rpm.

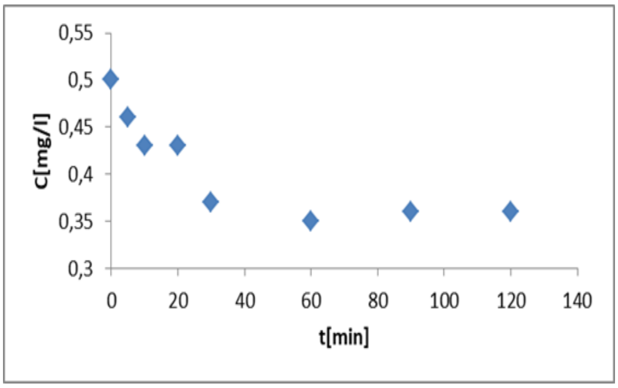

Figure 1. Dependence of initial Cr(VI) concentration from time of adsorption for the system Cr(VI) ions-activated aksil with H_2SO_4, pH=3, C_0=0.5mg/l

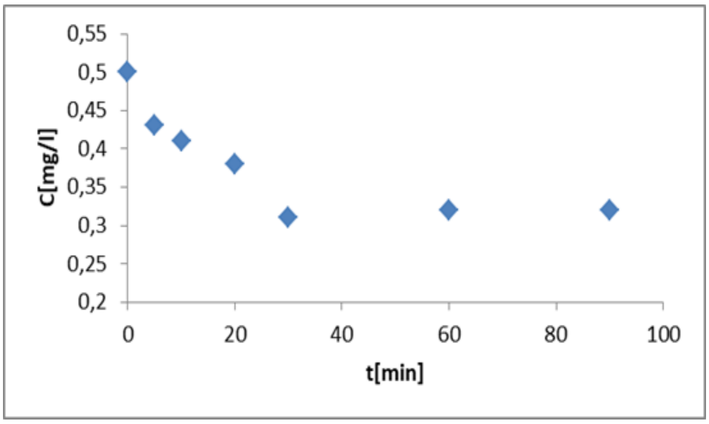

Figure 2. Dependence of initial Cr(VI) concentration from time of adsorption for the system Cr(VI) ions-activated aksil with HCl, pH=3, C_0=0.5 mg/l

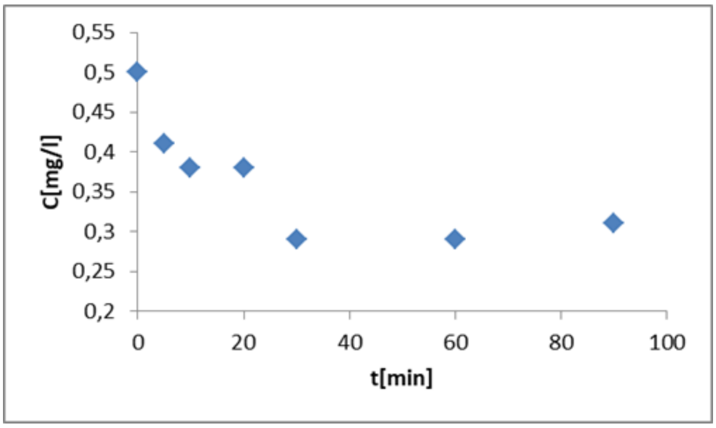

Figure 3. Dependence of initial Cr(VI) concentration from time of adsorption for the system Cr(VI) ions-activated pemza with HNO_3, pH=3, C_0= 0.5 mg/l

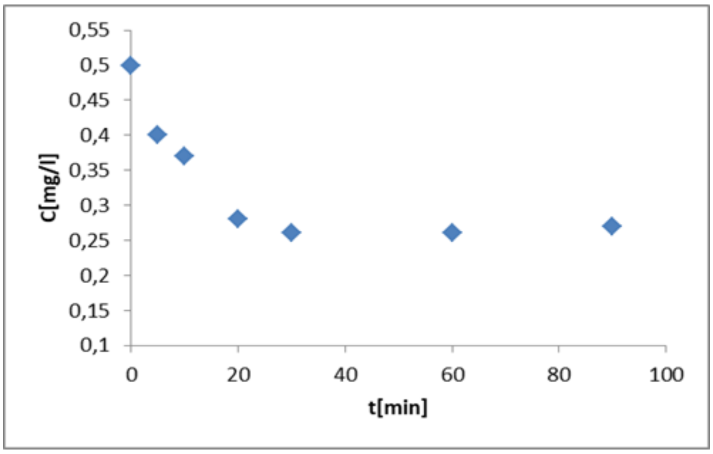

Figure 4. Dependence of initial Cr(VI) concentration from time of adsorption for the system Cr(VI) ions-activated diatomite with HNO_3, pH=3, C_0=0.5 mg/l

In all figures, it can be seen that the process of removing chromium ions as a function of time develops in two phases. The first phase is the rapid phase, in a period of 20-30 min adsorption, in which the highest efficiency in removing chromium ions is achieved. This is sufficient time to reach adsorption equilibrium on all three activated sorbents. After this comes the slow phase of the process, and until the end (120 min) we do not have significant changes in the concentration of chromium ions in the solution.

Figure 5 shows the comparison of the percentage of removal of Cr(VI) ions for activated aksil with H_2SO_4 (1) and activated aksil with HCl (2). It can be seen from the figure that the removal percentage for activated aksil with H_2SO_4 is 30% and for activated aksil with HCl is 38%.

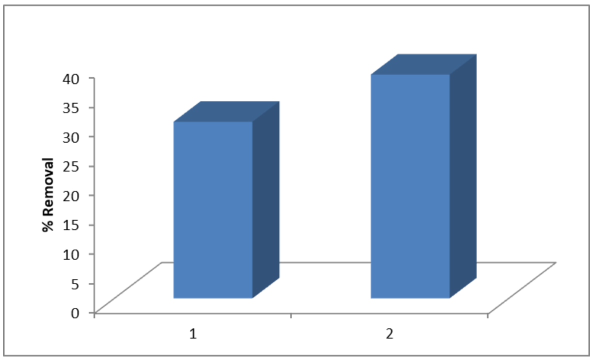

Figure 5. Comparison of Cr(VI) ion removal

From the figure given below it can be concluded that at pH 3, with an initial Cr(VI) ion concentration of 0.5 mg/l, the removal efficiency increases in the following order: activated aksil (30%) < pemza (42%) < diatomite (48%).

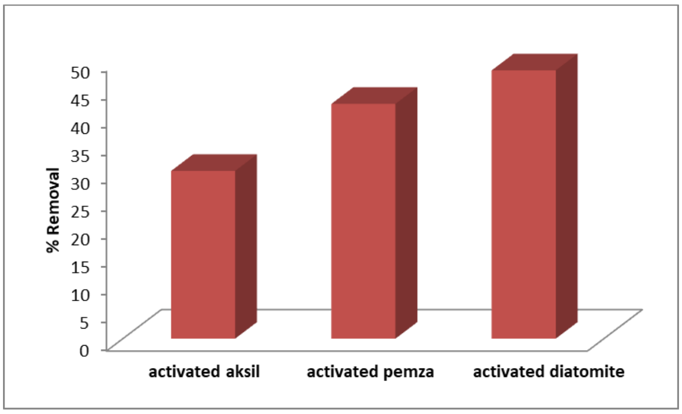

Figure 6. Comparison of the percentage of removal

4. Conclusions

In this study, the adsorption of Cr(VI) ions on avtivated adsorbents was investigated.
Investigations of activated adsorbents originating from different localities in the Republic of North Macedonia showed that the most effective adsorbent for the removal of Cr(VI) is diatomite. The adsorption characteristics have been examined at pH=3 and 0.5 mg/l initial metal ion concentrations, adsorbent dosage 2.5 g/l. The percentage of removal of Cr(VI) ions from aqueous solutions increases in the direction: activated aksil with H_2SO_4 (30%)< activated aksil with HCl (38%)< activated pemza (42%)<activated diatomite (48%).

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