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Cr(VI) Ions Removal from Aqueous Solutions Using Carrot Residues as an Adsorbent

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ABSTRACT

The aims of this study were to characterize carrot residues and to determine the removal of Cr(VI) in water depending on the temperature and the dosage of carrot residues. To identify the functional group present in carrot residue, Fourier-Transform Infrared (FTIR) was used to characterize it. The functional group that responsible for the metal binding is hydroxyl (-OH) group. The adsorption of Cr(VI) was conducted by using batch experiment. The effect of temperature and dosage were studied in batch experiment, in which temperatures were varied from 25ºC to 55ºC and the dosages were varied from 0.5 mg/L to 2 mg/L. Preliminary study was done to determine the time equilibrium for adsorption. The equilibrium contact time was 30 min with 12.66% removal efficiency. Meanwhile, the highest dosage for removal efficiency of metal that used was 2 mg/L with 13.09%. The optimum temperature was 25ºC with 12.66% removal efficiency. This study has indicated that the carrot residues is less likely a good adsorbent for removal of Cr(VI).

Keywords: *Heavy metals; Chromium; Carrot residue; Adsorption*

INTRODUCTION

Heavy metals are single metal and compound that can affect human health. Chromium (Cr) is one of the common heavy metals, which is naturally occurring in our environment at low levels [1]. It is a hard, steel-grey metal usually found in Earth's crust in form of chromite ore. In the Periodic Table, Cr can be found in group (VI), and it is known as a transition metal. The oxidation states of Cr range from Cr(II) to Cr (VI) [2]. Cr(VI) is known to be more toxic than Cr(III). Chromium is a vital nutrient required for sugar and fat metabolism. Normal dietary intake of Cr for human is negligible [3]. However, to some extent, little exposure related to the physiological action of trivalent Cr and the scientific literature is dominated by toxicological studies of hexavalent Cr, which is carcinogenic [4].

Biosorption can be defined as the removal of metals or metalloid species, compounds and particulates from solution by using biological materials [5]. Most adsorbent materials are coming from agricultural

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wastes [6]. In Malaysia, agricultural activities are one of the main economic activities. Therefore, more agricultural wastes will be produced.

Carrot residues are promptly accessible which make it proper to be utilized as adsorbent. In a previous study, the presence of carboxylic and phenolic functional groups is responsible of the cation particle exchange properties of carrot residues which exist in either the cellulosic matrix or in the materials related with cellulose, for example, hemicellulose and lignin [7].

As we are moving towards sustainability era, we should be concerned about the environment. This study will redound to the benefit of the environment that the use of biological wastes has greater potential in the removal of heavy metals. This technique will not require huge cost and it also readily available. In addition, the use of biological wastes can reduce the wastes from agricultural activities and domestic household wastes. Thus, the main objectives of this research were to characterize carrot residues and to determine the removal of Cr(VI) in water depending on the temperature of the solutions and dosage of carrot residues.

EXPERIMENTAL

In this study, carrot residues were used as adsorbent to remove Cr(VI) ions. Inductively Coupled Plasma – Optical Emission Spectrometry (ICP-OES) (PerkinElmer Optima 7300 DV) was used to determine the final concentrations of Cr.

Adsorbent preparation

The carrot residues were air dried in the oven at 50°C for 24 h. Then, it was ground by using a grinder. The residues were washed with 0.5 M HCl and distilled water until a constant pH is obtained; to eliminate soluble components such as tannins, resins, reducing sugars and coloring agents. The carrot residues were characterized by using FTIR (PerkinElmer FTIR Frontier, USA). This method is adapted from [7].

Single ion solution preparation

The Cr standard solutions (100 ppm, 150 ppm, 200 ppm, 250 ppm and 300 ppm) were prepared from 1000 mg/L stock solution of Cr (Fischer Chemicals, UK).

Adsorption studies

The flasks containing 100 ppm potassium dichromate ($K_2Cr_2O_7$) solution (Hmbg) and 0.5 g/L carrot residues were agitated on shaker at different time (10 min to 60 min) to determine the adsorption equilibrium, where the experiment were carried out at the desired temperature of 25˚C and pH 7. It was maintained at pH 7 to avoid Cr(VI) from transforming to Cr(III) [8]. The samples were agitated by using a shaker at 150 rpm. The amount of chromium adsorbed was determined by the difference of initial chromium ion concentration and the final one after equilibrium was achieved. This method is adapted from [7].

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Effect of temperature

The effect of temperature on adsorption at was determined at different temperatures, which were 25˚C, 35˚C, 45˚C and 55˚C. 0.5 g/L of carrot residues were added into the conical flask which containing 100 ppm of $K_2Cr_2O_7$ solution. The flask was agitated for 30 min. This method is adapted from [9, 10]. The removal percentage is given by Equation 1 as follows:

$$E = [(C_o - C_t)/C_o] \times 100\% \qquad (1)$$

where,
C_o is the concentration of Cr(VI) before adsorption and C_t is the concentration of Cr(VI) after adsorption [11].

Effect of adsorbent dosage

The effect of carrot residues dosage added to the solution was determined using sorbent dosages of 0.5 g/L, 1.0 g/L and 2 g/L. Different dosages of carrot residues were added into 100 ppm of $K_2Cr_2O_7$ solution in a conical flask. The temperature was maintained at 25˚C throughout the experiment. The flask was agitated for 30 minutes. This method is adapted from [12]. The removal percentage is given by Equation (2) as follows:

$$E = [(C_o - C_t)/C_o] \times 100\% \qquad (2)$$

where, C_o is the concentration of Cr(VI) before adsorption and C_t is the concentration of Cr(VI) after adsorption [11].

RESULTS AND DISCUSSION

In this study, the samples were analyzed using FTIR for the characterization of carrot residues and ICP-OES for the removal of Cr(VI). Carrot residues were used to remove Cr(VI) in different condition; temperature and adsorbent dosage. The samples were duplicated for each parameter. The IR spectrum in Figure 1 shows the presence of –OH stretch at 3293.25 cm^{-1}, C-H sp^3 stretch at 2925.9 cm^{-1}, C=O carboxylic stretch at 1735 cm^{-1}, C=C aromatic stretch at 1607.56 cm^{-1} and C-H aromatic bend at 1018.68 cm^{-1} in the carrot residues. Therefore, it could be concluded that the presence of carboxylic and phenolic group was responsible for metal binding. Cellulose and lignin are the main component of carrot residues [7].

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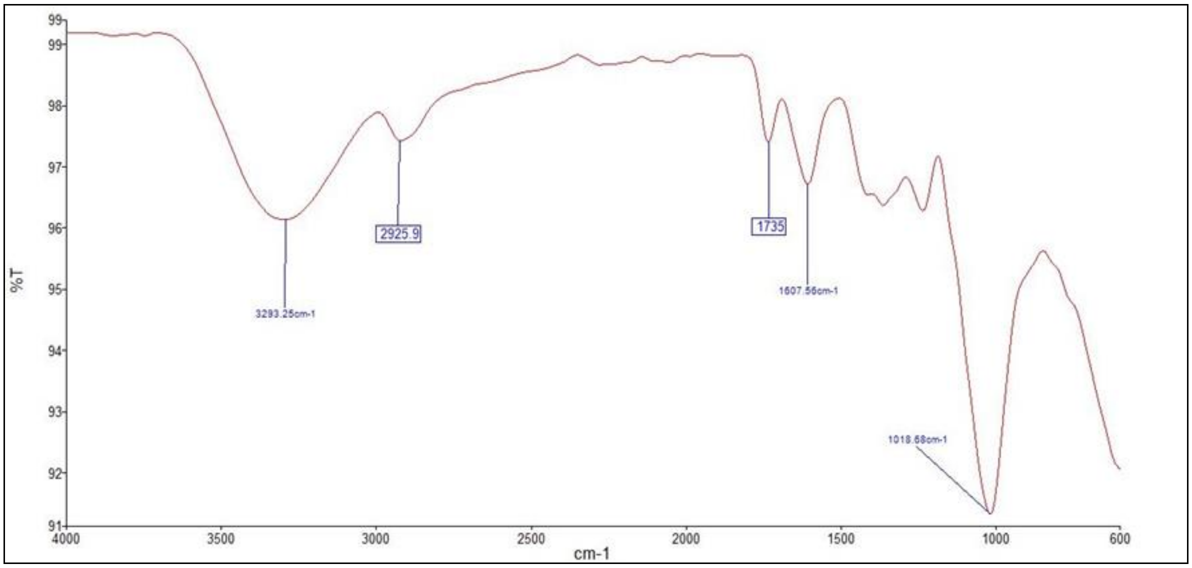

Figure 1: IR spectrum for carrot residues

Preliminary studies

Preliminary experiments were carried out to determine the time equilibrium for adsorption. Figure 2 shows the time profile of dimensionless Cr(VI) concentration. The finding from this study indicated lesser adsorbance compared with the previously reported data, where the dimensionless concentration of Cr(VI) was 0.4 [7].

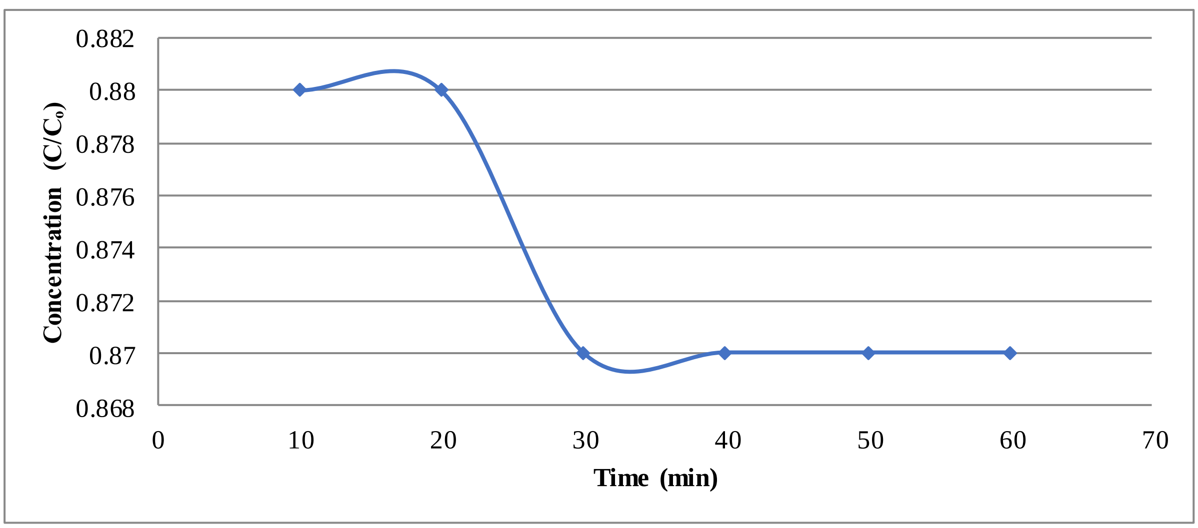

Figure 2: Biosorption rate of Cr(VI) by carrot residues at 25℃

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Effect of the temperature

The effect of initial temperature on the biosorption of Cr(VI) to the adsorbent was investigated. The effect on temperature for Cr(VI) is shown in Figure 3. The adsorption is optimum at lower temperature where 12.66% of chromium ions are removed by using carrot residues. Higher temperature does not favour the removal process of chromium ions. According to a study done by [9], the efficiency of biosorption is decreasing when the temperature is increasing. Cr(VI) adsorption was exothermic in nature [13]. The reducing adsorption efficiency at higher temperature might be caused by the supportive force between the active sites on the sorbent were weakened [14].

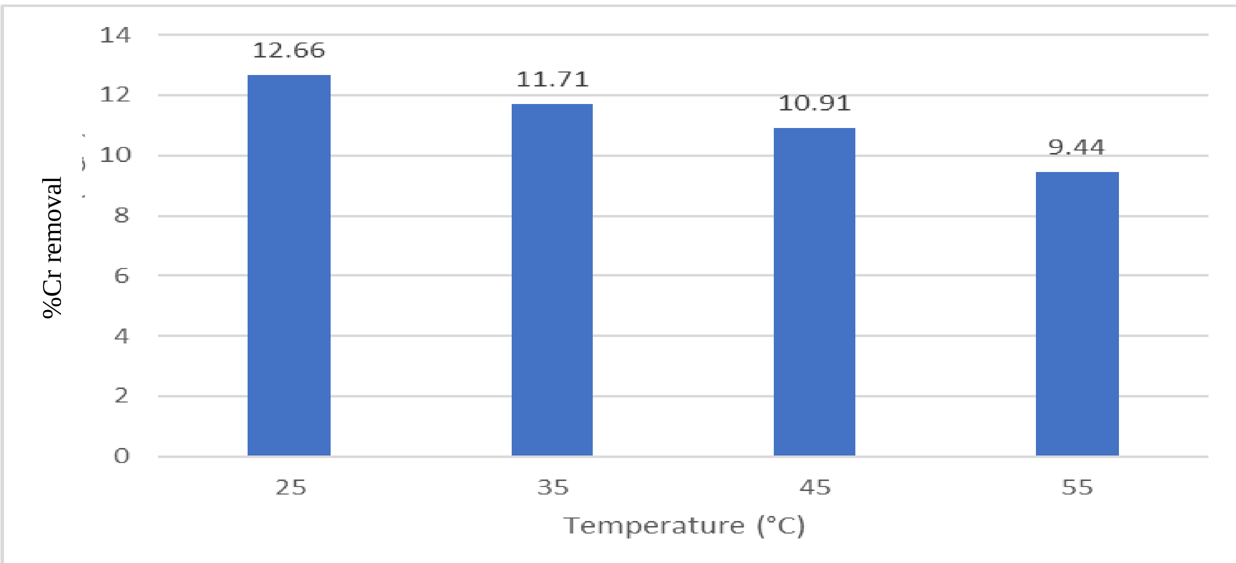

Figure 3: Effect of temperature on Cr(VI) adsorption by carrot residues

Effect of the dosage

The effect of initial adsorbent dosage on the biosorption of Cr(VI) to the adsorbent was investigated. The effect of adsorbent dosage is shown in Figure 4. The adsorption is optimum with a higher dosage of carrot residues where 12.35% of chromium ions are removed. According to a study done by [12], the efficiency of biosorption is increasing with the increase of adsorbent dosage. The increasing surface and active sites of the adsorbent would allow the metal ions to easily locate and penetrate the active sites [15]. Therefore, the results obtained from this study have the same pattern of what have been done from a previous study.

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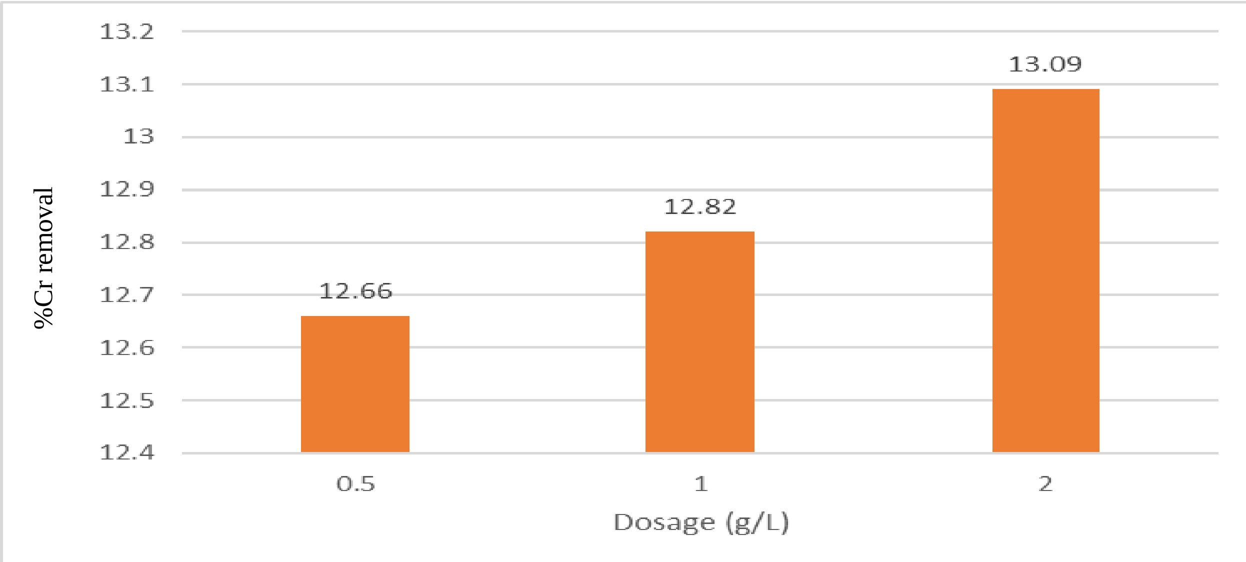

Figure 4: Effect of adsorbent dosage on Cr(VI) adsorption by carrot residues

CONCLUSIONS

In this study, carrot residues were used as adsorbent to remove Cr(VI) ions from the solution. This study was conducted to characterize carrot residues as adsorbent by using FTIR and to determine the effects of the temperature and the dosage of carrot residues on the removal of Cr(VI) in water. Preliminary experiments were carried out to determine the time equilibrium for adsorption. From this preliminary study, the equilibrium of biosorption rate was reached at 30 min. The effect of initial temperature on the biosorption of Cr(VI) to the adsorbent was also investigated. The adsorption is optimum at lower temperature where 12.66 mg/L of chromium ions were removed by using carrot residues. Higher temperature did not favour the removal process of chromium ions. The effect of initial adsorbent dosage on the biosorption of Cr(VI) to the adsorbent was investigated. The adsorption is optimum with a higher dosage of carrot residues where 12.35 mg/L of chromium ions were removed. From this study, I can conclude that carrot residues are less likely to be a good adsorbent. This is because the adsorbent dosage used is too little for it to be able adsorbed more of chromium ions. For further research, it is advised to use higher adsorbent dosage or try to remove other metal ions in order to uncover potential of carrot residues as a useful adsorbent.

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