

## Removal of Hexavalent Chromium from Water by Adsorption Using Ginger Powder

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### Abstract

A research was conducted to determine the feasibility of using adsorption process to remove hexavalent chromium from aqueous solutions using batch technique. This work is intended to remove Cr (VI) from water with initial concentration of 2.1 ppm by adsorption using ginger powder as an effective and low-cost sorbents. The effects of pH, contact time, adsorbent dose and initial Cr (VI) concentration on hexavalent chromium removal efficiency were determined. The experimental results revealed that maximum hexavalent chromium removal was achieved at pH 3.1. The percentage of hexavalent chromium adsorbed using ginger powder reaches up to 59.5% under pH of 3.1, contact time of 60 minute and ginger powder dose of 52 gm. /l

**Key Words:** Hexavalent Chromium Removal; Ginger; Adsorption and Removal Efficiency

### أزالة الكروم السداسي من الماء بالامتزاز باستخدام مسحوق نبات الزنجبيل

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بغداد – العراق

### الخلاصة

يهدف البحث الحالي الى تحديد مدى ملائمة عملية الامتزاز بنظام الوجبات لازالة الكروم السداسي من الماء باستخدام مسحوق الزنجبيل كمادة ممتزة فعالة ورخيصة الثمن، ولغرض اجراء التجارب فقد تم تحضير مياه ملوثة صناعيا بالكروم السداسي بتركيز ابتدائي 2.1 جزء بالمليون. تم دراسة تأثير الدالة الحامضية، زمن التماس، التركيز الابتدائي للكروم السداسي في الماء وكمية المادة الممتزة على نسبة الازالة للكروم السداسي. بينت النتائج ان اعلى نسبة لازالة للكروم السداسي تم الحصول عليها هي باستخدام دالة حامضية للمياه بقدر 3.1 ، وانه تم التوصل الى نسبة ازالة للكروم السداسي هي 59.5% بزمان تماس 60 دقيقة وكمية مسحوق الزنجبيل المضافة 52 غم/ لتر

**الكلمات المفتاحية:** ازالة الكروم السداسي، الزنجبيل، الامتزاز و كفاءة الازالة

## Introduction

Contamination of waste water with heavy metals has an environmental problem due to their toxic properties, and they were accumulated in food as non-biodegradable toxic pollutant (Gupta *et al.*, 2011).

Water and waste water treatment focuses on the removal of chromium and hexavalent form which is considered to be the more hazardous form of chromium due to its carcinogenic properties.

Chromium is classified as one of the top 16<sup>th</sup> toxic pollutants, it has a carcinogenic and teratogenic properties. Environmental pollution with chromium and its compounds happen through several industrial operations like, metal finishing industry, iron and steel industries and inorganic chemicals production (Nameni, *et al.*, 2008).

The trivalent chromium is relatively non-toxic as compared with hexavalent chromium which have been considered to be very toxic and mutagenic and potential carcinogenic (Asgari *et al.*, 2008), in spite of trivalent chromium is relatively low toxic, but when it is added to soil, it will oxidize to hexavalent chromium due to the presence of manganese oxide in soil (Abdulla *et al.*, 2010).

The two oxidation states of chromium are trivalent chromium and hexavalent chromium and the latter one has a tendency to bind with oxygen, so it can exist as ( $\text{CrO}_4^{2-}$ ) and ( $\text{Cr}_2\text{O}_7^{2-}$ ) of high solubility (Kabir, and Ogbeide, 2008).

Different technological processes has been used to remove heavy metals such as adsorption (Sari *et al.*, 2007), sedimentation (Song *et al.*, 2000), electrochemical processes (Fahim *et al.*, 2006), ion exchange (Tiravanti *et al.*, 1997), biological operations (Kapoor and Viraraghavana, 1998), cementation (Filibeli *et al.*, 2000), coagulation/flocculation (Song *et al.*, 2004), filtration and membrane processes (Fabianil *et al.*, 1996), chemical precipitation and

solvent extraction (Macchi *et al.*, 1991). Adsorption is one of the important technologies that have been used to remove heavy metals from the environment (Sari *et al.*, 2007). The aim of this research is to study the ability of ginger powdered in removing hexavalent chromium from water under different operation conditions.

## Materials and Methods

### Adsorbate

The stock solution of hexavalent chromium Cr (VI) was prepared by dissolving 2.828 gram of analytical grade of potassium dichromate ( $\text{K}_2\text{Cr}_2\text{O}_7$ ) which has obtained from Fluka Company, in 1000 ml of distilled water. The stock solution is further diluted with distilled water to reach desired concentration for adsorption measurement. pH adjustment is carried out by using nitric acid solution.

### Adsorbent

Powder ginger was washed with distilled water to remove dust from it and then filtered by Whatman-31 filter paper. The wet ginger was dried by oven at 90°C.

### Analysis of hexavalent chromium concentration

The concentration of hexavalent chromium was analyzed by means of 210/211 VGP atomic absorption photometer.

### Experimental procedure

Batch adsorption was carried out to obtain equilibrium data and investigate the effect of pH, stirring time and adsorbent dose on hexavalent chromium removal at the temperature 30°C in a laboratory batch unit.

To investigate the effect of pH of hexavalent chromium solution, a set of 5 samples were prepared. The pH of these hexavalent chromium solutions were adjusted to values in the range of (2.6-5) using dilute nitric acid solution. Samples of 100 ml of these solutions were mixed with 3g of adsorbent and are shaken by

means of mechanical stirrer Fig. (1) at 130 r.p.m for 1h. After one hour of mixing the solution was separated from the solid adsorbent by filtration using Whatman-31filter paper. The filtrate was analyzed to determine the hexavalent chromium concentration in water after adsorption

Using the best pH value (that gives maximum hexavalent chromium removal) which was 3.1, the effect of adsorbent dose on hexavalent chromium removal was studied. Adsorption experiments with different amounts of adsorbent were conducted. 100 ml of hexavalent chromium stock solution with 2.1 mg/l concentration was shaken with adjusted amount of adsorbent at 130 r.p.m by means of mechanical stirrer for 1h, after that the solution was separated from solid adsorbent by filtration using Whatman31filter paper and the filtrate was analyzed by atomic absorption photometer.

To investigate the effect of stirring time, 5 samples with 100ml hexavalent chromium solution (2.1 mg/l concentration) were mixed with 3g of adsorbent at best pH (which was 3.1). The samples were shaken by using a mechanical stirrer at 130 r.p.m with stirring time (0.5, 1, 2, 2.5 and 3) hour respectively. The solution was then separated from the solid adsorbent by filtration using Whatman-31filter paper and the filtrate was analyzed to determine the percentage of hexavalent chromium in solution after adsorption.

To study the effect of initial hexavalent chromium on the removal efficiency, different concentrations of hexavalent chromium in water were studied at pH 3.1, stirring time of 1 hr and adsorbent dose of 3 gram in 100 ml of polluted water, the solution was then separated from the solid adsorbent by filtration using Whatman-31filter paper and the filtrate was analyzed to determine the percentage of hexavalent chromium in solution after adsorption



**Figure (1) Laboratory Adsorption Unit**

Equilibrium data were obtained by batch studies. Different adsorbent dose of (6, 7, 8, 9 and 10) gm respectively of ginger were added in 5 beakers containing 2.1 mg/l of hexavalent chromium solution. The beakers were then placed on a Jar test and agitated continuously for a period of 150 minute which is enough to reach the equilibrium state (because the concentration did not change with time). Afterward the solution was filtered using Whatman-31filter paper. The filtrate was analyzed by atomic absorption spectrophotometer to estimate the equilibrium concentration.

The adsorption isotherm curves were obtained by plotting the weight of solute adsorbed per unit weight of adsorbent against the equilibrium concentration of boron in the solution.

$$q_e = \frac{V_1(C_o - C_e)}{M}$$

Where:

qe = Adsorbent capacity (mg/g)

V<sub>1</sub> = Volume of sample (l)

C<sub>o</sub> = initial concentration of boron in sample (mg/l)

C<sub>e</sub> = Concentration of boron in sample after adsorption (mg/l)

<sup>86</sup> M = Mass of adsorbent (g)

The experimental data were compared using Langmuir, Freundlich Langmuir offered the following equation (Ruthven, 1984):

$$qe = \frac{abC_e}{1 + aC_e} \quad (1)$$

Where

$q_e$  is the amount of adsorbate adsorbed per unit weight of adsorbent (mg/gm)

$C_e$  is the equilibrium concentration of adsorbate in water (mg/l)

$a$  and  $b$  are constants

Taking the reciprocal of both sides of the Langmuir equation yields:

$$\frac{1}{qe} = \frac{1}{b} + \frac{1}{abce} \quad (2)$$

Freundlich offered the following equation (Ruthven, 1984)

$$qe = Kf \cdot C_e^n \quad (3)$$

Where  $K_f$  and  $n$  are Freundlich adsorption isotherm constants.

## Results and Discussion

### Effect of Water pH on Hexavalent Chromium Adsorption

Fig. (2) shows the effect of solution pH on the removal of hexavalent chromium by adsorption onto powder ginger.

As the pH was increased from 3.1 to 5 the adsorption of Cr (VI) decreased, increasing the pH from 3.1 to 3.75, percent removal of Cr (VI) decreased from 48.5 to 40.4%, whereas as the pH was increased from 3.75 to 5 the percentage removal decreased significantly from 40.4 to 19%.

It was observed that the maximum percentage of Cr (VI) removal was at pH 3.1. The high adsorption of Cr (VI) can be explained by the species of chromium and adsorbent surface. At acidic pH,  $HCrO_4^-$ ,  $Cr_2O_7^{2-}$  and  $CrO_4^{2-}$  (Nameni *et al.*, 2008; Namasivaya and Yamuna, 1995) is the prevailing ions of Cr (VI) in water.

Under acidic condition, the surface of the adsorbent becomes protonated and attracts anion species of Cr (VI). As the pH is increased above the zeta potential of the adsorbent, there is a reduction in the

electrostatic attraction between the Cr (VI) and the adsorbent surface, with a consequent decrease in the adsorption percentage.

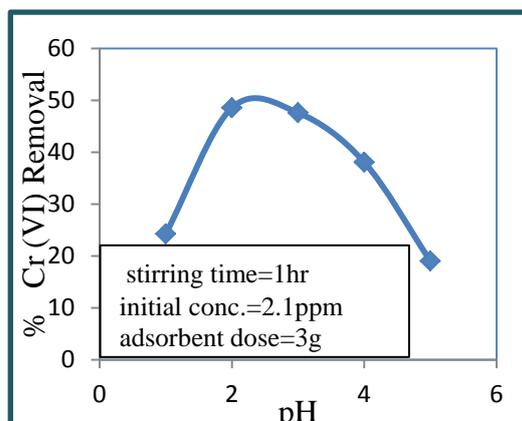


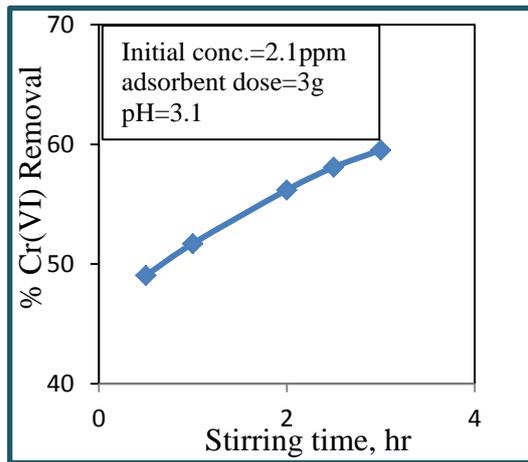
Figure (2) Effect of pH on the Removal of Hexavalent Chromium from Polluted Water. Effect of Stirring Time on Hexavalent

### Chromium Adsorption

Contact time is one of the effective factors in batch adsorption. The effect of contact time on the removal of hexavalent chromium by sorption onto powder ginger was showed in Fig. (3).

The importance of stirring lies in the fact that it maintains the adsorbent in suspension, offering the maximum surface and enough time to adsorbate adsorption.

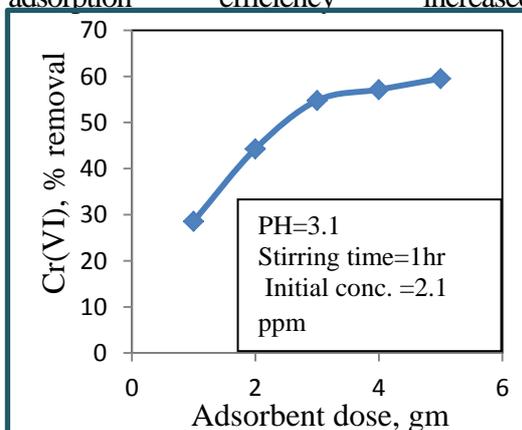
As can be observed in Fig. (3) increasing contact time from 30 minute to 120 minute, increasing the percentage of Cr (VI) removal. Maximum Cr (VI) was observed within first 120 minute, and the time required to attain equilibrium was 150 minute.



**Figure (3) Effect of Stirring Time on the Removal of Hexavalent Chromium from Polluted Water**

#### Effect of adsorbent Dose on the Removal of Hexavalent Chromium from Water

The effect of adsorbent dose on the adsorption of hexavalent chromium was presented in Fig. (4). As illustrated from the Figure, hexavalent chromium removal efficiency increased with increase in adsorbent dose due to the increase in number of adsorption sites, contact surface of adsorbent particles increased, and it would be adsorbed on adsorption sites and thus adsorption efficiency increased.

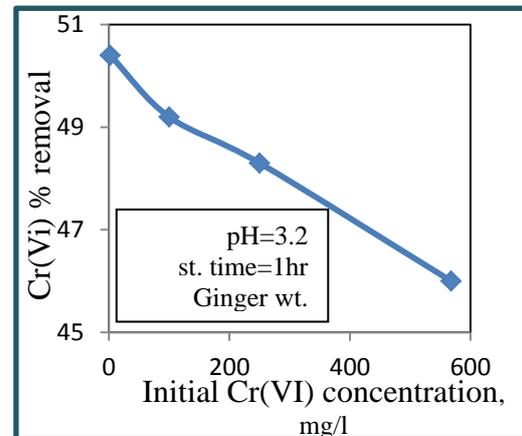


**Figure (4) Effect of Adsorbent Dose on the Removal of Hexavalent Chromium from Polluted Water**

#### Effect of Hexavalent Chromium concentration on the Percentage Removal

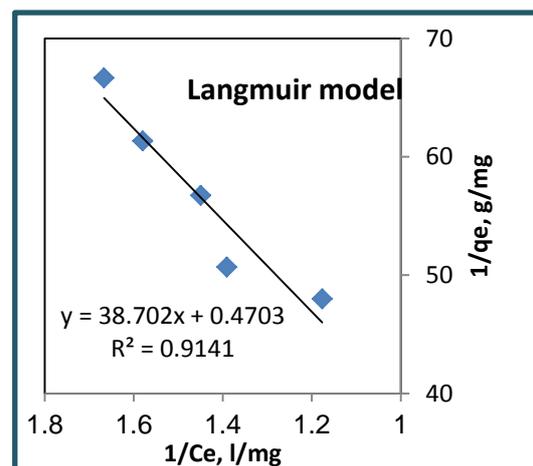
The effect of initial concentration of hexavalent chromium in water on the removal efficiency was presented in Fig. (5). As described from the figure, the hexavalent chromium removal efficiency decreased with the increase in initial chromium concentration. At higher

concentration, the available sites of adsorption become fewer and hence the percentage removal of metal ions which depend upon the initial concentration decreases.



**Figure (5) Effect of Hexavalent Chromium Concentration on the Percentage Removal Adsorption Isotherm**

Adsorption isotherm describes the relationship between adsorbate concentration and hexavalent chromium concentration remained in water, in addition to that it provides information on types of adsorption. The analysis of isotherm results is important in developing equations which represent the results.



**Figure (6) Langmuir Isotherm Model**

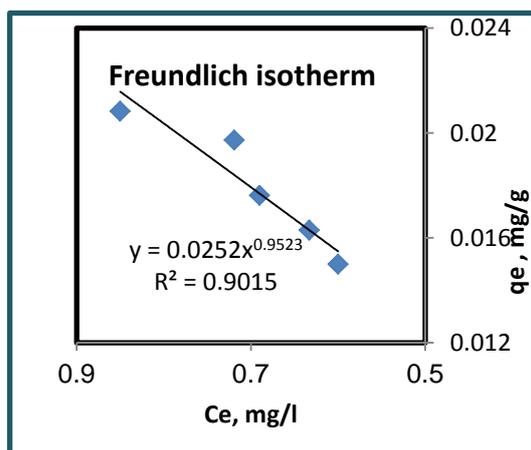


Figure (7) Freundlich Isotherm Model

Fig. (6) and (7) describe the use of the Langmuir, Freundlich models for adsorption of hexavalent chromium at initial concentration of 2.1 mg / l, pH 3.1, stirring time 150 minutes and adsorbent dose from 6 to 10 g per 100 ml.

Langmuir isotherm was achieved by plotting  $1/C_e$  versus  $1/q_e$  (equation 2) to give a straight line with a correlation coefficient ( $R^2$ ) equal to 0.9141. The constant (a) which represents adsorption capacity, (b) which is related to the energy of adsorption were estimated to be 0.01215 and 2.1263 respectively from the slope and intercept of the linear plot

Freundlich isotherm was achieved by plotting  $C_e$  versus  $q_e$  (equation 3) to give straight line with a correlation coefficient ( $R^2$ ) equal to 0.9015. The values of  $k_f$  and  $n$  which were an indicative of adsorption capacity and intensity for adsorption were calculated to be 0.0252 and 1.05 respectively from the slope and intercept of straight line

From the values of correlation coefficient of the two models, Langmuir isotherm fit very well with the experimental data.

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