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Adsorption studies of chromium (VI) ion from aqueous solution using *Pisum sativum*

D. B. Jirekar[1], Mazahar Farooqui[2]*, Shirsh S. Pingale[3]

[1]Department of Chemistry, Anandrao Dhonde Alias Babaji College, Kada, Maharashtra, India, Affiliated to Dr B A M University Aurangabad.

[*2]Dr. Rafiq Zakaria College for Women, Aurangabad, Affiliated to Dr B A M University Aurangabad, Maharashtra, India.

[3]Department of Chemistry, Gramonnati Mandal's Arts, Com. and Sci. College, Affiliated to University of Pune, Narayangaon, Pune-410504, India

Abstract

The use of *Pisum sativum* seed husk as low-cost adsorbents was investigated for the replacement for currently costly methods of adsorption Cr(VI) ions from aqueous solutions. Batch adsorption studies showed that *Pisum sativum* seed husk was able to adsorb Cr(VI) ions from aqueous solution. The effect of contact time, effect of initial concentration, effect of adsorbent dose, etc. have been reported. Equilibrium data were analyzed using the Langmuir Freundlich isotherms whereas the adsorption kinetic data were evaluated by the pseudo-first-order and pseudo-second-order kinetic models. The results obtained indicate that the adsorption of Cr(VI) on *Pisum sativum* seed husk is maximum at 20 mg/L metal ion concentration and 1.0 gm. adsorbent dose. The results demonstrated that *Pisum sativum* seed husk have potential to be employed as the adsorbent for the adsorption of Cr (VI) metal ions from aqueous solution.

Keywords: Chromium, *Pisum sativum* seed husk, adsorption, isotherm, aqueous solution, kinetics, thermo-dynamic parameters.

Contents

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***Corresponding author**
Mazahar Farooqui
E-mail: mazahar_64@rediffmail.com
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1. Introduction

The presence of toxic heavy metals in industrial effluent has become a matter of environmental concern, chromium (VI) is known to be one of the heavy metals and widely used in many industries including leather tanning, explosives, ceramics, photography, wood preservatives [1,2] paints and pigments [3]. Disposal of untreated effluent in these industries contains a considerable amount of Cr (VI), which spreads into the environment through soil and water streams and accumulates along the food chain, resulting in a high risk to human health, as high concentration

of chromium will cause dermatitis, allergic skin reactions ulceration of intestine. It is also reported to be carcinogen to animals [4]. As Chromium does not degrade biologically, the control of chromium pollution has special importance for both organisms that live in water and those that benefit from water.The removal of heavy metals from industrial effluent has several advanced techniques to decrease their impact on the environment such as physicochemical, biological and thermal processes. A physicochemical technique includes adsorption, coagulation, chemical precipitation, ultra filtration, etc. Among of these methods adsorption is the most effective and economical because their relative low cost. In recent years different bio-adsorbents were developed from agro-wastes and used for heavy metals removal such as maize leaf[5], bajra powder[6], rice husk[7], sawdust[8], pine bark[9], sugar beet pulp[10], wood and bark[11], tea-waste[12], and papaya seeds[13].

Bio-adsorbent which produced from agro-wastes may act as a significant material for Chromium adsorption. *Pisum sativum* seed husk is an agro useless waste material. It is an abundant, readily available, low cost and, eco-friendly bio-material considering the above criteria, *Pisum sativum* seed husk was selected to prepare the Bio-adsorbent. The present study aimed to investigate the efficiency of *Pisum sativum* seed husk as adsorbents for the adsorption of Cr (VI) from aqueous solutions. Experiments were conducted to investigate the effect of contact time, effect of initial concentration, effect of adsorbent dose, etc. on adsorption efficiency of Cr (VI) by *Pisum sativum* seed husk. Adsorption equilibrium and kinetics had been studied under the optimum adsorption conditions. The Langmuir and Freundlich adsorption isotherms were applied to evaluate the adsorption properties in the batch technique.

2. Materials and methods

2.1 Materials

The stock solution of chromium was prepared by dissolving 0.2828 gm. of potassium dichromate ($K_2Cr_2O_7$) in one liter distilled water and used for all experiments with required dilution. All the chemicals used were of A. R. grade from M/S S. D. Fine Chemicals Ltd, Mumbai.

2.2 Preparation of Adsorbent

Pisum sativum seeds were collected from local market and soaked in distilled water up to 24 hrs. Remove the husk of seeds from its pulses and dried in the absence of sunlight. The dried material was grind to fine powder and passed through sieves of different sizes. Powder obtained of 60 mesh size was kept in an air tied bottle for experimental uses.

2.3 Batch adsorption experiments

Batch adsorption studies were carried out using glass stoppard conical flask, the pH of the solution was adjusted with 0.1N HCl and 0.1N NaOH solutions by using Elico-digital pH meter model No.615 with combined glass electrode. The conical flask containing sample solution and adsorbent was shaken for the required time period with a mechanical stirrer. The experiments were carried out at room temperature (301.5 K). After the appropriate time the contents of the flask were filtered and amount of chromium metal ion was determined using diphenylcarbazide by spectrophotometrically (Elico-minispec-171 model).

3. Result and Discussion

3.1 Effect of contact time

The adsorption of the Cr (VI) metal ions by *Pisum sativum* seed husk was studied at various time intervals (0 to 35 min.). 50 ml, 5 mg/L concentration of Cr (VI) metal ion solution was taken in different conical flask and each flask adds 0.5 gm. of adsorbent, and then filtered after 5, 10, 15, 20, 25, 30,35min.time intervals respectively. The filtrates were then analyzed using spectrophotometer. The amount of metal ions adsorbed was calculated for each sample, and graph is plotted percentage adsorption capacity against time. It is shown in Fig.1.

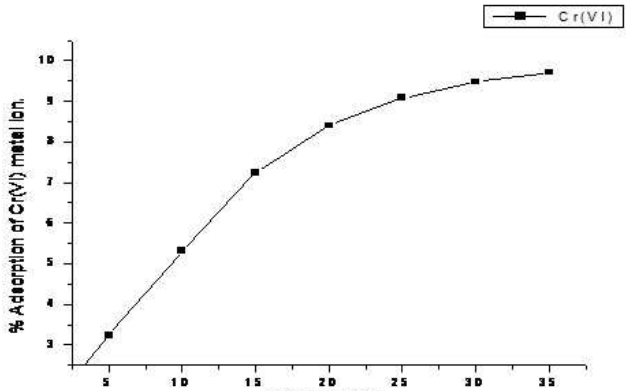

Fig.1. Effect of contact time on adsorption of Cr(VI) metal ion.
[Initial conc.= 5 mg/L., Adsorbent dose = 0.50 gm.,
Temperature = 28.5°K., pH = 5.7]

3.2 Effect of adsorbent dosage

The adsorption studies of Cr (VI) metal ions at temperature 301.5 K by varying the quantity of adsorbent from 0.25 to 1.0 gm. while keeping the concentration of the metal ion solution constant at pH = 5.7. The influence of adsorbent dosage on percent adsorption capacity of Cr(VI) metal ions is shown in <fig.2>

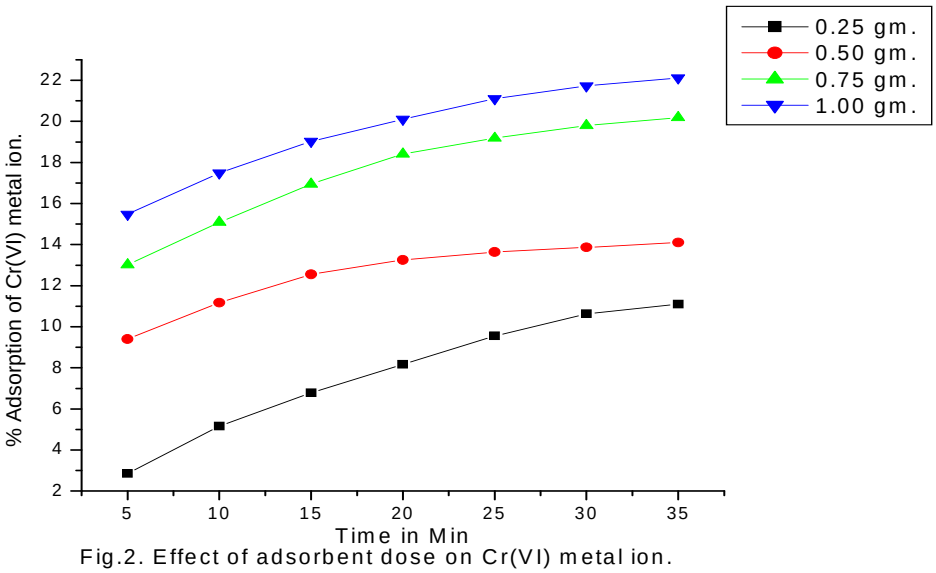

Fig.2. Effect of adsorbent dose on Cr(VI) metal ion.
[Initial conc. = 5 mg/L.,Temp.= 28.5 ^{o}K, pH = 5.7].

The result from fig.2 indicates that the adsorption increase with the increase in the dose of the adsorbent. The increase in the percentage adsorption capacity is due to the increase in active sites on the adsorbent and thus making easier penetration of the Cr (VI) metal ions to the adsorption sites.

3.3 Effect of initial concentration of metal ion

In batch technique the initial concentration of metal ion in the solution plays a vital role on driving force to overcome the mass transfer resistance between the solution and solid phase. The effect of initial ion concentration of metal ion ranging from 5 mg/L to 20 mg/L on *Pisum sativum* seed husk was studied by taking different concentrations of Cr (VI) metal ion solution at pH 5.7, while keeping the adsorbent dose 0.5 gm., 50 ml.volume of Cr (VI) metal ion solution constant and temperature at 301.5 K. Thus the result is shown in <Fig.3>

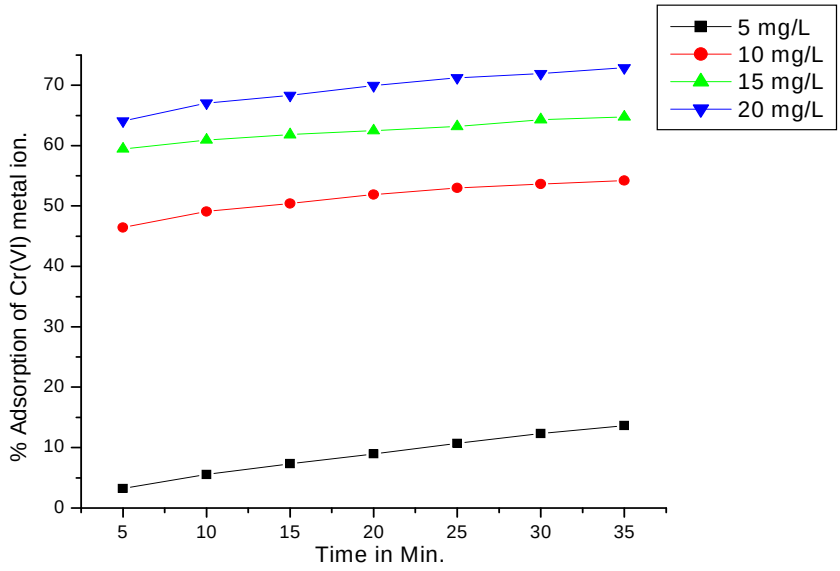

Fig.3. Effect of concentration on adsorption of Cr(VI) metal ion.
[Adsorbent dose = 0.5 gm., Temp.= 28.5^{o}K.,pH = 5.7]

Fig.3 shows that the percent adsorption capacity increases with increase of initial metal ion concentration. As the result of the above observations it is conclude that the adsorption process of Cr (VI) metal ion on *Pisum sativum* seed husk to be dependent on initial concentration of metal ion solution up to some extent.

3.4 Analysis of adsorption isotherm

3.4.1 Langmuir isotherm

The data of the equilibrium studies for adsorption of Cr (VI) ions on husk follow the following form of Langmuir model.

$$\frac{c_e}{q_e} = \left(\frac{1}{Q_0}\right) * C_e + \frac{1}{bQ_0}$$

Where, C_e is the equilibrium concentration (mg/dm^3), q_e is the amount of Cr (VI) ions adsorbed at equilibrium (mg/g). $Q_0$and b are Langmuir constants related to adsorption capacity (mg/g) and energy of adsorption (dm^3/mg).

3.4.2Freundlich isotherm

The Freundlich model can be applied for non-ideal sorption on heterogeneous surfaces and multilayer adsorption. It is expressed by the following equation,

$$\log\ q_e = log\ \ K_f + \frac{1}{n}\log\ C_e$$

The Freundlich constants *n* and $K_f$were determined from the slope and intercept of the plot respectively. The isotherm parameters are given in < table.1 >.

Table: 1. Isotherm parameters for the adsorption of Cr (VI) metal ion

Langmuir isotherm			**Freundlich isotherm**		
Q_0**(mg/g)**	***b(L/mg)***	R^2	K_f**(mg/L)**	***n***	R^2
2010.39	0.0237	0.995	6.4998	1.9653	0.987

3.5Analysis of adsorption kinetics

The linear form of the pseudo-first- order and pseudo-second-order kinetic models can be represented by equations respectively.

$$\log\ (q_e - q_t) = \log\ q_e - \frac{k_1}{2.303R}t$$

$$\frac{t}{q_t} = \frac{1}{k_{2q_e^2}} + \frac{1}{q_e}t$$

Adsorption rates were calculated from the slope and intercept the calculated values of k_1 , k_2 , $and\ q_e$values are given in <Table.2.>

Table: 2. Parameters of kinetic models for the adsorption of Cr (VI) metal ion on husk of *Pisum sativum* seeds

Initial Dye Conc.(mg/L)	q_e**. *expt.* (mg/g)**	**First order Kinetic model**			**Second order kinetic model**		
		q_e**. *cal* (mg/g)**	k_1 **(min^{-1})**	R^2	q_e**.*cal* (mg/g)**	k_2**/10^{-4} (g/mg.min)**	R^2
5	184.974	171.3957	0.1023	0.999	108.2792	3.0465	0.9596
10	651.387	181.9700	0.1603	0.9715	562.9046	6.3119	0.9996
15	1139.06	246.0367	0.0901	0.9902	919.1176	5.9187	0.9996
20	1581.28	298.5383	0.2286	0.991	1492.5373	1.7956	0.9996

4. Conclusion

This work clearly indicates the potential of using *Pisum sativum* seed husk as excellent adsorbents for the adsorption of Cr (VI) metal ions from aqueous solutions. The optimum pH was found as pH 5.7 for the adsorption of Cr (VI) metal ions by *Pisum sativum* seed husk. The Freundlich adsorption isotherm was best fitted to the experimental data, this confirms that the multilayer adsorption process. Adsorption kinetics of Cr (VI) metal ions adsorbed on *Pisum sativum* seed husk followed by the pseudo-second-order kinetic model; where the chemisorption process may be the rate limiting step in the adsorption process. This study shows that *Pisum sativum* seed husk has high potential to be employed as an effective adsorbent in adsorbing Cr (VI) metal ions and would be useful for the design of wastewater treatment plants for toxic heavy metal ions removal.

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