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Adsorption of Chromium (VI) from aqueous solution using a solid waste (Bagasse)

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ABSTRACT

The adsorption process is being widely used by various researchers for the removal ofheavy metals from waste streams. Despite its extensive use in the water and wastewater treatment industries, activated carbon remains an expensive material. In recent years, the need for safe and economical methods for the elimination of heavy metals has increased. The objective of this study is to contribute in the search for less expensive adsorbents and their utilization possibilities for various waste byproducts such as various saw dust's, sugarcane bagasse, rice husk, oil palm shell, coconut shell, coconut husk etc. for the elimination of heavy metals from wastewater.

Chromium is a highly toxic metal ion and is considered as a priority pollutant released from various chemical industries like electroplating mixing activities, smelting, battery manufacture, tanneries etc. Effluents have been excessively released into the environment due to rapid industrialization and have created a global concern. Therefore, they must be removed before discharge. In the present paper, the experimental results carried out in batch adsorption process using solid waste (Bagasse as adsorbent) with synthetic samples prepared in laboratory are presented. The various parameters such as solution P^H, initial chromium concentration, effect of temperature and adsorbent dosage on the adsorption of Cr (VI) are studied and presented. It is found that the adsorption data is fitted well by Langmuir isotherm. The Langmuir adsorption capacity is estimated as 21.8 mg/g for Bagasse. The maximum removal of Cr (VI) above 89% is observed at P^H of 6 for bagasse 100 mg/L Cr (VI) solution.

Key words: Chromium (VI), Bagasse, low cost adsorbent, adsorption, UV-spectrophotometer.

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1. INTRODUCTION

The waste water treatment and prevention of contamination of drinking water from toxic metals are of great concern because of health risks on humans and animals. Among the toxic metal ions, chromium is one of the common contaminants which gains importance due to its high toxic nature even at very low concentration [1]. Water pollution by chromium is of considerable concern, as this metal has found widespread use in electroplating, leather tanning, metal finishing, textile industries and chromium preparation. Chromium exists in two oxidation states as Cr (III) and Cr (VI). The hexavalent form is 500 times more toxic than the trivalent [2].Chromium (VI) is a carcinogic agent and can pose health risks for humans. Human toxicity includes kidney, liver, dermatitis and gastrointestinal ulcers [3]. Chromium and its compounds are widely used in industries such as metal finishing, dyes, pigments, inks, glass ceramics, chromium tanning, textile, and dying.

The conventional methods used to remove Cr (VI) from aqueous effluents include chemical precipitation, ion exchange, electro flotation, membrane separation, reverse osmosis, electro dialysis, solvent extraction, etc. However, these approaches have proved to be costlier and difficult to implement. Adsorption is one of the physico-chemical treatment process found to be effective in removing heavy metals from aqueous solutions. Adsorbents can be considered as cheap or low cost if it is abundant in nature, requires little processing and is by product of waste material from industrial or agricultural operations may have potential has inexpensive adsorbents. Plant wastes are in expensive as they have no or low economic value.

The aim of the present investigation is to detect the performance of bagasse on chromium (VI) removal from aqueous solutions by varying chromium (VI) concentration, P^H and adsorbent dosage. Langmuir and Freundlich isotherms were applied to fit the experimental data.

2. MATERIALS AND METHODS

All the chemicals used in this study were of analytical grade and were procured from Sd. Fine Chem. Ltd such as $K_2Cr_2O_7$, 1, 5- diphenyl carbazide, H_2SO_4 etc. The adsorbent selected for removal of chromium (VI) is Bagasse. Bagasse was grounded and washed with deionized water. The adsorbents were dried at room temperature (32 $\pm 1^0$C) till a constant weight of the adsorbents was achieved (after 20 hrs). Adsorption is an effective and versatile method for removing chromium.

2.1 Preparation of adsorbent

Firstly, the adsorbent is washed and dried at room temperature to avoid the release of color by adsorbent into the aqueous solution. The activation of adsorbents is carried out by treating it with concentrated sulphuric acid (0.1N) and is kept in an oven maintained at a temperature range of 150^0C for 24hr. Again it is washed with distilled water to remove the free acid [5].

2.2 Batch experiments

A stock solution of Cr (VI) is prepared by dissolving 2.8287 grams of 99.99% potassium dichromate ($K_2Cr_2O_7$) in distilled water and the solution is made up to 1000ml. This solution is diluted as required to obtain the standard solutions containing 5 mg/L – 500 mg/L of Cr (VI)[4]. The P^H is adjusted in the range of 2-10 by adding 0.1N H_2SO_4 and 0.1N NaOH solutions and is measured by a P^H meter (ELICO, LI 613).

The batch experiments are carried out in 250ml borosil conical flasks by shaking a pre-weighed amount of the Bagasse with 100ml of the aqueous chromium (VI) solutions of known concentration and P^H value. The metal solutions were agitated in a rotary shaker at 120 rpm for a desired time. The samples were withdrawn from the shaker at the predetermined time intervals and adsorbent was separated by filtration. Chromium (VI) concentration in the filtrate was estimated using Atomic Adsorption Spectrophotometer(AAS) The experiments were carried out by varying the chromium (VI) concentration in the solution (50mg/L-500mg/L), P^H (2-10). The adsorbent dosage 2-10 gr/lit for contact time is 5hrs. We can get high removal of Cr(VI) which is above 99%with initial metal concentration of 100mg/L at room temperature 32ºC and solution P^H 6. The samples were collected at different time intervals 15 min to 5 hrs and the adsorbent was separated by filtration using filter paper.

2.3. Determination of chromium content

The chromium concentration of Cr (VI) ions in the effluent is determined by AAS. For this purpose, $K_2Cr_2O_7$ solutions of different Concentrations were prepared and their absorbance recorded by AAS. The calibration plots for Cr (VI) were drawn between "%" absorbance and standard Cr (VI) solutions of various strengths [3, 5].Runs were made in triplicate. The percentage removal of chromium was calculated as follows:

% removal of chromium = $(C_{int} - C_{fin}) \times 100 / C_{int}$

Where, C_{int} and C_{fin} are the initial and final chromium concentrations, respectively.

3. RESULTS AND DISCUSSION

3.1 Effect of pH

The effect of pH on the batch adsorption studies on 100 mg/l Cr (VI) at 30^0C and adsorbent dosage 0.2 gr/100 ml. It is obvious that the increased pH from 2 to 6 and then the percentage removal is decreased pH 6 to 10. It was observed that the maximum percentage of Removal of Cr (VI) at p^H 6 (Fig1.)

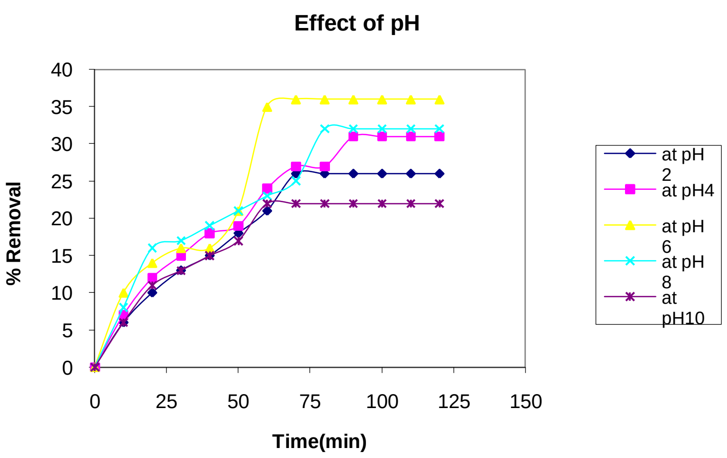

Fig.1: Effect of pH on the removal of Cr (VI) by adsorbent Bagasse at 30 ^{0}C

3.2 Effect of contact time

The time is one of the most important factors for the adsorption of Cr (VI) on adsorbent. Fig. 2 shows the percentage removal of Cr (VI) for different initial concentration ranging from 50 to 500 mg/l at pH 6. Hence the Equilibrium time obtained is 210 min (3.5 hrs) for the Cr (VI) adsorption on Teak saw dust. It is obvious that increase in contact time from 30 min to 160 min enhanced significantly the percent removal of Cr(VI). The initial rapid adsorption gives away a very slow approach to equilibrium. The nature of adsorbent and its available sorption sites affected the time needed to reach the equilibrium.

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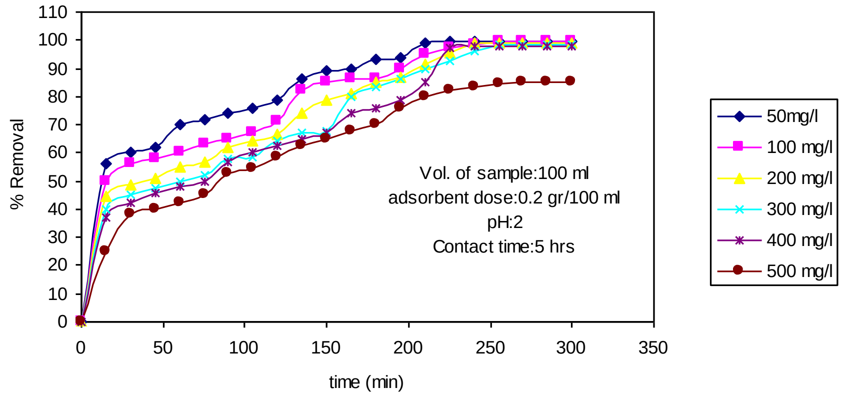

Fig.2: Effect of contact time on the adsorption of Cr (VI) using Bagasse at 30^{0}C at different initial Cr (VI) concentrations.

3.3 Effect of Adsorbent dose

Removal of Cr(VI) increases with increase of adsorbent dosage. The percentage removal increases from 88.3% to 99.8% by increasing the adsorbent dosage from 2 – 10 gm/l. (Fig.3), for a constant initial Cr(VI) concentration of 200 mg/L in the solution. The increase in Cr(VI) removal percentage with increasing adsorbent amount is due to the increasing surface area and adsorption sites available for adsorption.(Fig.3) However, the adsorption capacity decreases from 9.65 to 1.995mg/gr by increasing the adsorbent amount from 2 to 10 grams /lit.

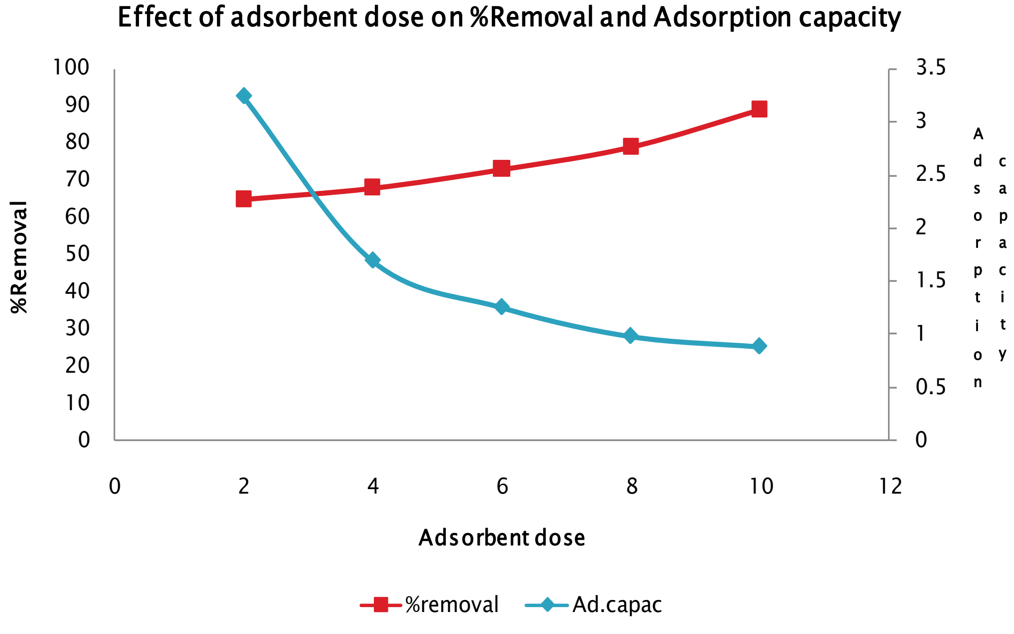

Fig: 3 Effect of adsorbent dosage on % removal and adsorption capacity (mg/g) of Cr (VI)

3.4 Effect of initial concentration on % Removal and Adsorption Capacity

In the present study , the removal of Cr (VI) by using Bagasse at different initial concentrations of Chromium (50 -500 mg/l) at fixed dosage 2 gm/lit and contact time 5 hrs, the results show that with increase in Cr (VI) concentration from 50-500 mg/l(Fig.4), the Percent removal decreases from 83 to 28% and adsorption capacity increases from 2.45 to 18.475 mg/g.(Fig.4)

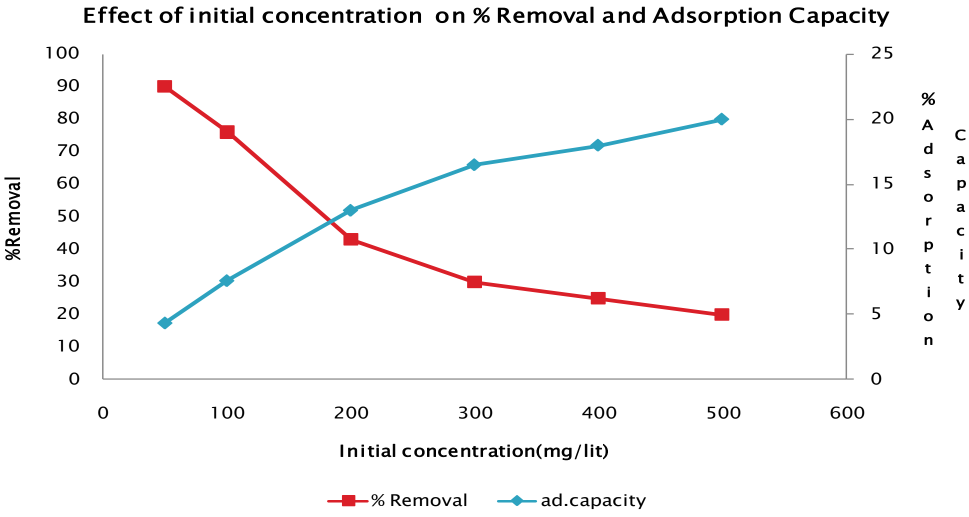

Fig.4. Effect of initial concentration on %Removal and adsorption capacity (mg/g) of Cr (VI)

3.5 Effect of Temperature

Temperature also plays a vital role in the adsorption process. The removal of Cr(VI) by Teak sawdust was studied at different temperature range from,30 ºC ,40 ºC 50 ºC, and 60 ºC for a constant initial Cr(VI) concentration 100mg/l,contact time 3 hrs at pH 4,adsorbent dose 4gr/Lit.It has been observed that percent removal was minimum(72%) at 30 ºC and increases as the temperature was increased. At Temperature 50 ºC, removal was maximum (81%) then again, started decreasing and was 75% at 50 ºC as shown in Fig.5.

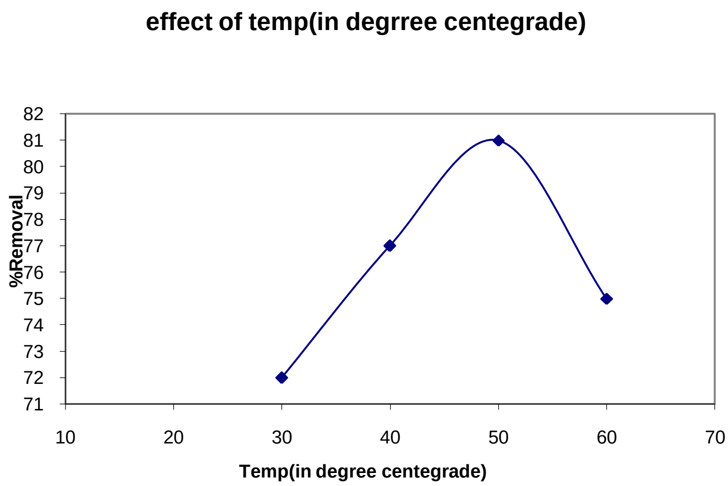

Fig: 5. Effect of temperature on % Removal of Cr (VI) at initial concentration 100 mg/lit.

3.6 Adsorption Isotherms

Langmuir and Freundlich isotherms

The Langmuir adsorption isotherm plot between Ce/q_e verses Ce, From Fig.6 shows the Langmuir constant $q_{m,}$ which is a measure of the monolayer adsorption capacity of Teak wood saw dust is obtained 21.58mg/gr. The Langmuir constant b, is found to be 0.024. A high value of regression correlation coefficient (R^2=0.994) is obtained. The dimensionless parameter R_L, which is a measure of adsorption favorability is found to be 0.034 ($0< R_L<1$) which confirms the favorable adsorption process for removal of Cr (VI) by Teak saw dust. R_L, also known as the separation factor [7], given by

$$R_L = 1/(1+bC_0)$$

Langmuir and Freundlich equations are given in equations [5].are

$$Ce/q_e = 1/(bq_m) + (1/q_m)\, Ce$$

$$\ln q_e = \ln K_f + (1/n) \ln Ce$$

Freundlich isotherm is analyzed based on adsorption Cr (VI) by using the same equilibrium data of Teak saw dust. Freundlich constants, K_f and n are obtained by plotting the graph between log q_e versus log Ce (Fig.7). The values of K_f and n are 2.56 and 2.18 respectively. It is found that the regression correlation coefficient obtained from Freundlich isotherm model for this adsorbent is 0.9946 which is lower than the Langmuir isotherm model as given in Table.1.

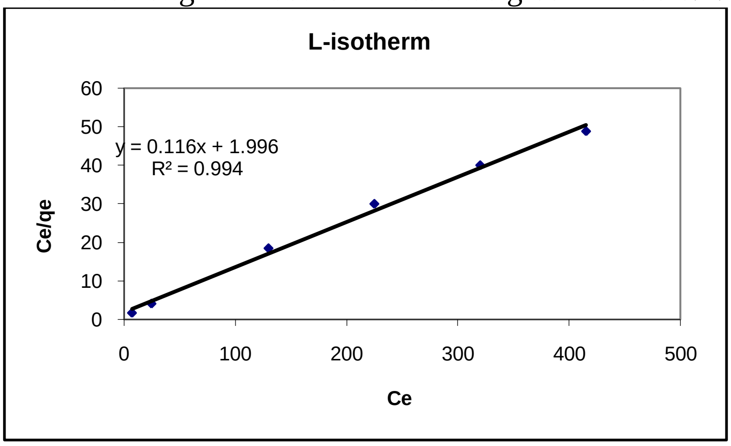

Fig 6. Langmuir isotherm for adsorption of chromium (VI)

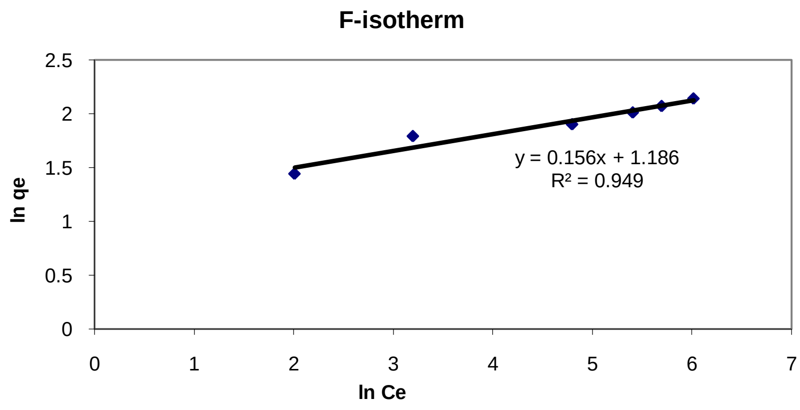

Fig.7. Freundlich isotherm for adsorption of Chromium (VI)

Table 1: Isotherm constants and regression data for various adsorption isotherms for adsorption Of Cr (VI) on Bagasse

Langmuir isotherm			**Freundlich isotherm**		
Constants		**Correlation coefficients(R^2)**	**Constants**		**Correlation coefficients(R^2)**
q_m	**b**		k_f	**n**	
21.8	0.024	0.994	2.18	2.56	0.9826

CONCLUSIONS

Following conclusions are drawn from the above discussed results

- Adsorbent (Bagasse) could be used for the removal of Cr (VI) from aqueous solutions.
- The maximum adsorption of Cr (VI) (89%) is observed at pH6 and Experiments showed that the equilibrium was reached after a contact time of 4 hrs.
- The adsorption isotherm data of Cr (VI) on mixing of Bagasse was best modeled by both Langmuir and Freundlich isotherm.
- Adsorption of Cr (VI) on Bagasse yielded maximum adsorption capacity - 21.8 mg/gm.
- Removal of Cr (VI) increases with increase of adsorbent dosage at pH 6.
- Removal of Cr (VI) decreases with increase of the initial concentration and also with pH, However Adsorption capacity increases with increasing the initial concentration of Cr (VI).
- Adsorption capacity decreases with increase of the adsorbent amount.
- Removal of Cr (VI) increases with increase of temperature from (30 ºC-50 ºC) & again starts decreasing with increase of temperature(50 ºC).

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