



Removal of hexavalent chromium concentration from the aqueous solution using chemically treated sugarcane bagasse powder

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The elimination of hexavalent chromium (Cr^{6+}) concentration from aqueous solution by adsorption technique using sugarcane bagasse powder was examined. The main objective of this study is to find out the removal efficiency of Cr^{6+} with low cost, eco-friendly and highly effective. The impact of agitation intensity, hydrogen power (pH), temperature, dosage level, adsorbate concentration and time of contact on the selectivity and responsiveness of the removal progression has been studied. Physical and chemical properties of sugarcane bagasse powder have been analyzed using various classification methods such as FTIR, SEM, XRD, BET, area of the surface and porosity. The intense removal of Cr^{6+} in the batch adsorption process was observed to be 150 mg/g at pH 2, with the primary concentration of 500 mg/L, rate of flow 40 ml/min and a bed height of 2 cm. The outcome of various adsorption parameters, such as flow rate, adsorbate concentration and dosage intensity, for the removal of Cr^{6+} was considered.

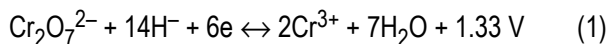
Keywords: Hexavalent chromium, sugarcane bagasse powder, batch adsorption study, thermodynamic analysis.

Introduction

Environmental pollution is snowballing due to population growth and our expedition to lead a calm lifespan leading to a short-tempered growth in industrial and agricultural activities. The three types of pollutions are gas, liquid and solid and may contain of soluble ions of metals or toxic chemicals and greenhouse gases, precursors of acids, ozone depletion substances etc. To order to preserve the ecological equilibrium, scientists are improving every effort either to reduce pollutant emissions at source, or to take action to remove pollutants after discharge. So it's the huge job and scientists join your hands to stop our world from being full collapse and maintain quality of life. The volume of poisonous metal pollution in the environment is growing due to the rise in population associated with mining, removal and use of various metals as different industrial and domestic materials. In general, the unwanted things from the metallurgical/mining sectors create disruption in the ecosystem, as maximum heavy metal ions are poisonous to living beings. Yet some of these

heavy metals show a major role in the human metabolism, in fragments. Compared with all heavy metals, chromium demand has globally developed due to its widespread use in various metallurgical, pharmaceutical and leather tanning industries owing to its distinct physical and chemical properties. Cr^{3+} plays a substantial role in our physique aside from industrial uses. In addition to industrial uses, Cr^{3+} has a significant role to play in our physique¹. Without Cr^{3+} in our food, the body misplaces the capacity to efficiently use sugar, carbohydrate, and fat, which can impact weight loss or decreased growth, inadequate nervous system activity, and swallow diabetic situations. Because of its strategic importance in different metallurgical processing, chromite is either traded as a high-grade or intermediate ore, like ferrochrome/charge chrome, on the world market. Modern technology finished products use ferrochrome of varying degrees worldwide. Intake of chromite in India is snowballing at the same time as its global demand. By transferring high-grade chromite and ferrochrome, India is getting important foreign conver-

sation. The consumption of India in 2001 was 0.5 MT (metric ton), 86% of which accounted for mining use, 8% for refractories and the remaining (6%) for the synthesis of chemicals. The overall production of chromite in that year was 1.05 MT (metric ton) and thus >50% of it was transferred². For rather around some period, the chromite matrix has been known to be the most robust and hexavalent chromium contamination due to chromite extraction or interference. Advanced studies have shown that Cr^{3+} wedged in chromite is oxidized by many physico-chemical processes³ and biological processes for the production of Cr^{6+} . From the chromite mining, chromium has been obtained in two different oxidation states. i.e. for aqueous solution, Cr^{6+} and Cr^{3+} . Of such, Cr^{6+} is of a particularly toxic nature⁴. The first statement on the harmful effects of Cr^{6+} seemed in the 1930s due to the occurrence of cases of lung cancer in the chromium handling industry⁵ also investigated data to support the adverse effects of chromate has been catalogued after extensive epidemiological research. Brief lists of significant uses of chromium for diverse purposes are given in Table 1². The interaction between the trivalent and the hexavalent form of chromium is defined by:



The key chromite concentrations have been located in South Africa, Tanzania and the former Soviet Union. Chromite is

Table 1. Application of chromium and chromium chemicals in different sectors

Sl. no.	Use	% of total consumption
1.	Metal finishing and corrosion control	35
2.	Pigments and allied products	27
3.	Leather tanning and textiles	22
4.	Wood preservatives	6
5.	Drilling mud	5
6.	Catalyst/batteries/magnetic tapes etc.	5

popular in India as well. A summary of their occurrence² is given in Table 2, maximum of these deposits come under the strati form type, except those found in the Himalayan regions, such as Ladakh and Nagaland, which are related with the ophiolite belt. Nevertheless, Orissa plays a leading position in India's chromite reserves and accounts for > 98% of the country's chromite sales. Information of the numerous

Table 2. Chromite reserves in India (2000)

Grade/State	Proved	Probable	Possible	Total
All India	27,404	31,210	29,737	88,351
Metallurgical	10,927	12,292	7,315	30,534
Refractory	1,607	409	2,204	4,220
Charge chrome	8,635	6,936	10,062	25,633
Low grade	—	21	31	52
Beneficial	5,747	9,939	8,944	24,630
Others	—	15	—	15
Unclassified	471	1,598	1,042	3,111
Not known	17	—	139	156

grade chromite deposits in India are shown in Table 3. Orissa accounts for ~98% of the chromite deposit in the Sukinda Valley of the Jajpur district and the Baula-Nuasahi belt of the Bhadrak district. Chromite veins occur at a depth of 50–250 meters. It was obvious from the cited literature that a low-cost solution was required to eliminate toxic heavy metal pollutants from water. The protocol should have the simplic-

Table 3. Production of chromite in India

State	Production (ton)	Value (Rs.)
All India	9,26,148	12,24,248
Andhra Pradesh	460	211
Karnataka	48,145	22,173
Maharashtra	86	21
Manipur	92	48
Orissa	1,54,472	1,28,676
Bhadrak	1,54,472	1,28,676
Dhenkanal	26,241	24,152

ity of a method so that country people can use it with the least realistic knowledge. Adsorption is generally accepted as a conventional approach for the treatment of industrial/mine wastewater for the elimination of soluble radioactive materials. The treatment process is also quick and effective. Considering the value of treating Cr^{6+} runoff from industrial and mining operations, the current research focuses on the possibility of Cr^{6+} adsorption by utilizing different low-cost, environmentally friendly adsorbents.

Materials and methods

Preparation of adsorbent: The adsorbent was selected to remove chromium from the sugarcane bagasse powder. This is a waste product of sugar mill composed primarily of

glucose, cellulose, pentose and lignin. Sugarcane bagasse includes a number of organic groups that are effective cleaning agents and also strong binders for various metal ions. It has also the ability to handle pollutants with heavy metal ions. The curiosity in the usage of sugarcane bagasse as an adsorbent was intensified by the promising findings obtained by other researchers⁶. The sugarcane bagasse collected was dehydrated in an oven until nearly all of the moisture had vanished. It was crushed to fine powder and sifted to +125 μ to -250 μ in size. Sugarcane bagasse contained water such as tannin, which give brown color to the effluent at the time of treatment. Treatment of effluent with sugarcane bagasse is also likely to produce a great BOD in that. Therefore the sugarcane bagasse is needed the chemical treatment prior to its use in the removal of heavy metal polluted wastewater. Chemical treatment of formaldehyde helps in the polymerization of the materials accountable for coloring. Sugarcane bagasse (50 g) was often washed with purified water and then dried for 24 h at 60°C to eliminate tannins and other solvent organic complexes. To boost stability, either 1% formaldehyde was treated at a ratio of 1:4 (sugarcane bagasse: formaldehyde, w/v) or 0.2 N H₂SO₄. The water has been heated up to 6 h at 100°C. Table 4 displays the physical belongings of sugarcane bagasse powder before and after treatment. The collected sugarcane bagasse powder was cooled and purified by several times by adding distilled water and dried in an oven at 60°C.

Batch adsorption study: Sorption studies were performed under various pH, contact duration, temperature, and con-

centration of sorbate conditions. Batch adsorption tests were conducted by touching a sufficient volume of sugarcane bagasse powder with 100 mL of aqueous hexavalent chromium solution at specific initial amounts at various pH solutions. Experiments were normally conducted for 120 min at 28°C in 250 mL conical flasks, which were mounted in the HY-2 orbital shaker at a steady agitation speed of 125 rpm. The mixture was agitated constantly to compensate for good mass transfer with a high adsorption surface area.

SEM analysis: The adsorption of Cr⁶⁺ on the surface of the processed sugarcane bagasse powder was measured by SEM. The SEM images of sugarcane bagasse powder for before and after the adsorption of chromium ions are shown in Figs. 1 and 2 respectively. Fig. 1 shows that the adsorbent surface is smooth. However, in the case of sugarcane bagasse powder after adsorption, many of the adsorbent sur-

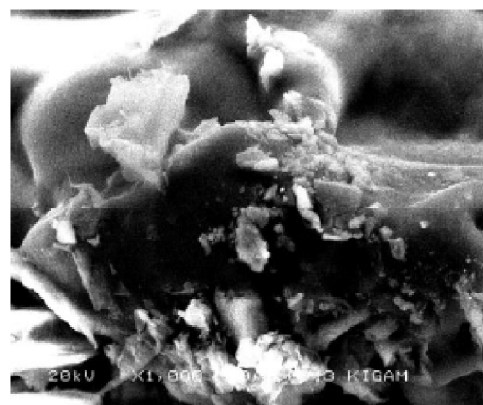


Fig. 1. SEM image of treated sugarcane bagasse powder.

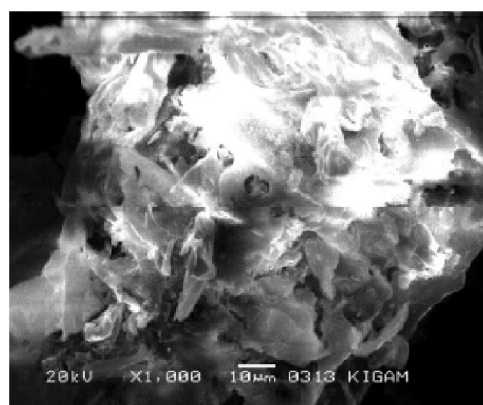


Fig. 2. SEM image of treated sugarcane bagasse powder after adsorption.

Table 4. Physical properties of raw and treated sugarcane bagasse powder

Physical parameters	Sugarcane bagasse powder	Treated sugarcane bagasse powder
Specific gravity	0.6	0.55
Bulk density (g/cc)	0.54	0.51
Porosity (%)	61	69
Surface area (m ² /g)	16	18
Avg. particle size (Micron)	0.7	0.65
Moisture content (%)	55.7	51.4
Loss in ignition	91.6 (w/w%)	91.22 (w/w%)
Al ₂ O ₃	2.3 (w/w%)	2.3 (w/w%)
SiO ₂	1.1 (w/w%)	1.1 (w/w%)
FeO ₂	0.23 (w/w%)	0.23 (w/w%)

faces of sugarcane bagasse powder is found to be filled with a tinny layer which endorses the adsorption of Cr^{6+} on the surface of the bagasse. Due to the pore size and surface area, the chromium ions are positioned on the surface of the adsorbent. At the time of adsorption process, the permeable surface on the adsorbent (sugarcane bagasse) gets occupied by the metal ions. The presences of functional groups in the bagasse surface inner walls, the metal ions were adsorbed⁷. From the above surface morphology study, the sugarcane bagasse powder loaded with the chromium ions can be absorbed in the internal walls of the adsorbent surface. More adsorption of Cr^{6+} on the surface of the sugarcane bagasse was calculated by the critical application of the EDAX process.

EDAX analysis: The EDAX process is mainly used to identify the elemental composition of the materials. The EDAX pictures for processed sugarcane bagasse powder before and after adsorption are seen separately in Figs. 3 and 4. The EDAX report found that the weight percentage of chromium is higher in the case of processed sugarcane bagasse after adsorption, which supports the adsorption of Cr^{6+} . Physical properties of specific gravity, bulk density, permeability, specific surface area, particle size, etc., along with the chemical properties of the sugar cane bagasse powder as such and the refined sugar cane bagasse powder are shown in Table 4.

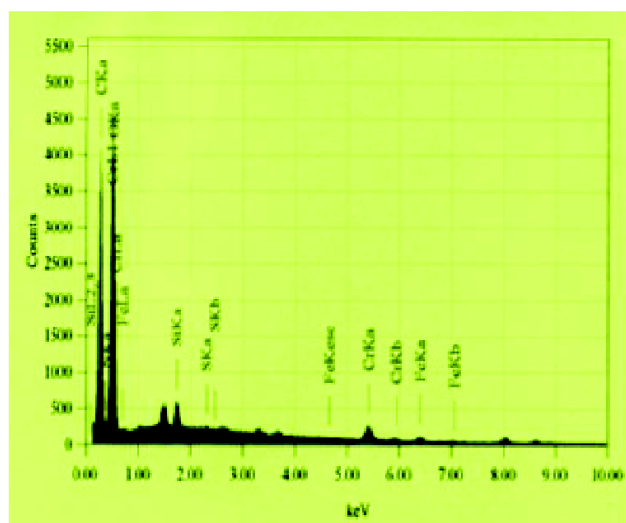


Fig. 3. EDAX image of treated sugarcane bagasse powder.

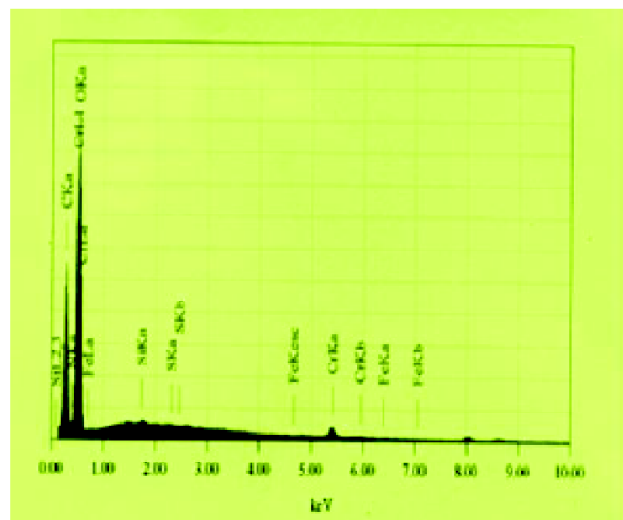


Fig. 4. EDAX image of treated sugarcane bagasse powder after adsorption.

FT-IR analysis: The FTIR spectra of the sugarcane bagasse powder before and after treatment are represented in Fig. 5 and the absorption bands are also indicated which are given in Table 5. The sawdust spectra showed peaks at 3230 cm^{-1} , 3010 cm^{-1} , 1640 cm^{-1} , 1530 cm^{-1} , 1450 cm^{-1} , 1420 cm^{-1} , 1240 cm^{-1} and 1160 cm^{-1} which can be attributed to the group of hydroxyl ($-\text{OH}$), aliphatic C-H group, unsaturated groups such as alkenes, amide, deformation group ($-\text{CH}$), OH deformation, aromaticity and OH deformation, cor-

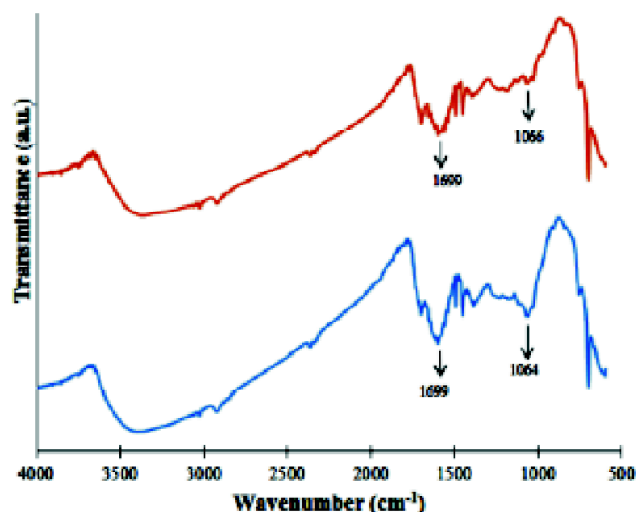


Fig. 5. FT-IR spectra for sugarcane bagasse powder before and after treatment.

Table 5. FT-IR peaks and assignment of groups

Peak wavelength (cm ⁻¹)	Assigned to
3240	OH group
3015	Aliphatic C-H group
1650	Alkenes group
1540	Amide group
1450	CH deformation
1420	OH deformation
1250	Aromatic stretch
1160	OH stretch

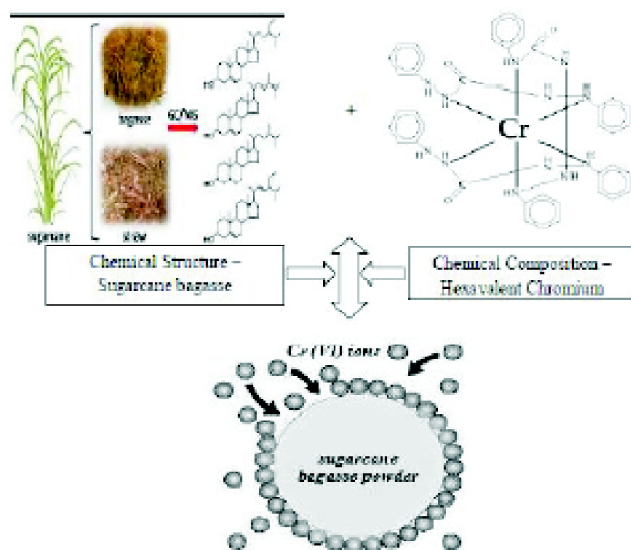
respondingly. In the case of treated and adsorbed sugar cane bagasse material, the peak amplitude was either decreased or slightly increased. These results are the same as those reported earlier (Cui-Xia Chen, 2012).

The quantity of hexavalent chromium adsorbed/gram of the adsorbent was assessed using the formula:

$$X_e = (S_0 - S_e) V/W \quad (2)$$

$$\% \text{ Removal} = \{C_0 - C_e/C_0\} \times 100 \quad (3)$$

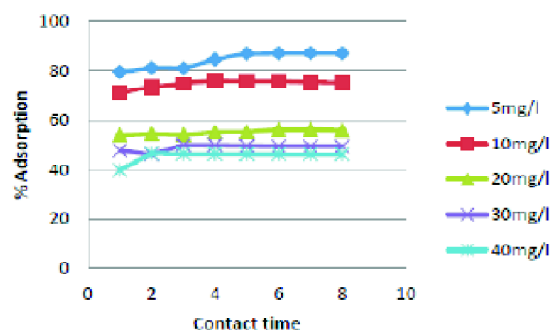
where S_0 and S_e are the original and stabilized liquid phase concentrations of Cr^{6+} ions in mg/L, V is the volume of solution in litres and W is the quantity of adsorbent utilized in gram. The extraction performance of the two adsorbents was examined and measured on the basis of the following findings. The adsorption efficiency of X_e is determined from the

**Fig. 6.** Process of removal of Cr^{6+} using sugarcane bagasse powder.

expression in eq. (2), and the percentage Cr^{6+} removal is obtained using eq. (3). Here C_0 and C_e are initial and final adsorbate concentrations in mg/L respectively. The adsorbent was selected to remove chromium from the sugarcane bagasse powder. This is a waste product of sugar mill composed primarily of glucose, cellulose, pentose and lignin. Sugarcane bagasse is the primary waste resource in sugar production units. Waste materials are either deposited near manufacturing or used to create combustible aggregates by combining with dust of coals and other flammable commodities. The availability of sugar cane bagasse is quite high and has almost very little profitable value. The sugarcane bagasse contains a variety of organic functional groups, which are good chelating agents and therefore good binders for different metal ions. The interest in the use of sugarcane bagasse as an adsorbent was enthused by the decent results found by other researchers⁶.

Results and discussion

Impact of contact time: The percentage plot of adsorption vs adsorption time is shown in Fig. 7. It is evident from the figure that the concentration of the adsorbate depends on the time of balance. The contact time was adjusted from 2–5 h with decreasing the adsorbate concentrations from 40 mg/L to 5 mg/L respectively. From this adjustment it was observed that, all the curves obtained were representative monolayer formation on the sorbent surface. In the initial stage, the slope of the plot was 1 and it decreased over time. The rate of uptake was rapid in the early stages, but gradually decreased and became constant when the balance was reached.

**Fig. 7.** Impact of contact time on adsorption at different adsorbate concentrations.

Impact of pH: The study shows that the percentage of metal ion diminishes with rise in the pH solution up to 6.0 and the effect reduces subsequently. The surface of the adsorbent was enclosed by hydronium ions in the lower pH level are shown in Fig. 8. The figure shows the interaction between the metal ions and the adsorbent was reduced due to the presence of high positively charged adsorbent surface. When the pH is low, the surface of the adsorbent becomes low positively charged stimulating the faster removal of heavy metal ions⁸. The adsorption test was performed in a concentration of 2.72 mg/L to 10 mg/L of Cr(VI) as a func-

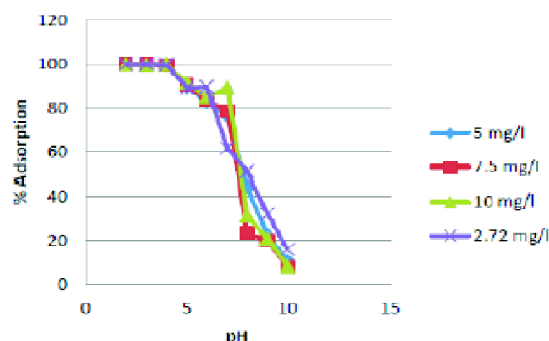


Fig. 8. Impact of pH on adsorption at different adsorbate concentrations.

tion of pH equilibrium, as seen in Fig. 8. This calculation indicates that the level of adsorption is greater at lower pH, achieving an average of 4.5 to 6.0 in the pH range. When the pH rose, there was a small rise in the volume of adsorption and a significant increase in pH of 5.5. A strident decrease in the amount of adsorption was found as the pH was further increased. Due to the weakness of electrostatic force, the attraction between the adsorbent and the negatively charged adsorbate could lead to a decrease in the sorption capacity. A slow decrease in amount adsorption was observed when the pH was increased beyond 6.0 due to the OH⁻ and chromate-ion resistance (CrO₄²⁻). However, it reduced with an increase in pH and is stable at pH > 9.0. Decrease in adsorption at higher pH is attributed to the formation of soluble hydroxyl complexes⁹.

Impact of starting adsorbate concentration: The study of percentage adsorption and loading capacity versus initial concentration (Fig. 9) tested at different contact times indi-

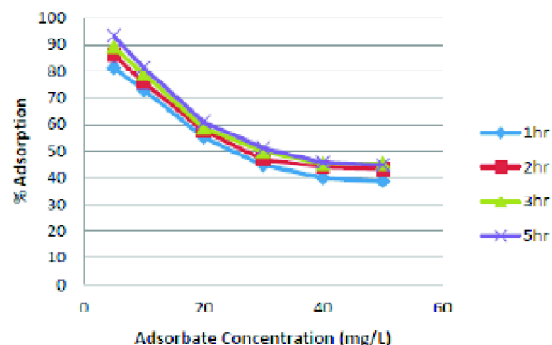


Fig. 9. Impact of adsorbate concentration on adsorption at different time.

cated an increase in the initial adsorbate concentration. The intensity of elimination declines with rise in the concentration of metal ions due to the weakening of active sites of the adsorbents¹⁰. The quantity of metal ions decreased at low concentrations and the adsorption is improved when a similar dosage of adsorbent is present in solution. The transformation in the initial concentration of metal ion is proportional to the number of accessible places on the adsorbent. As the initial concentration of the adsorbate increased, the absorption potential also increased (Fig. 10). The amount of adsorption increased from 45 to 92% when the adsorbate concentration decreased. The rise from 50 to 5 mg/L and the absorption decreased from 9.5 to 1.4 mg/g. It may be due to increased recognition of the existence of more Cr⁶⁺ ions in sorption solution. In addition, the stronger driving power, provided the higher initial adsorbate concentration, is used to resolve all the mass transition resistances of the metal ions from the aqueous to the solid phase resulting in a higher

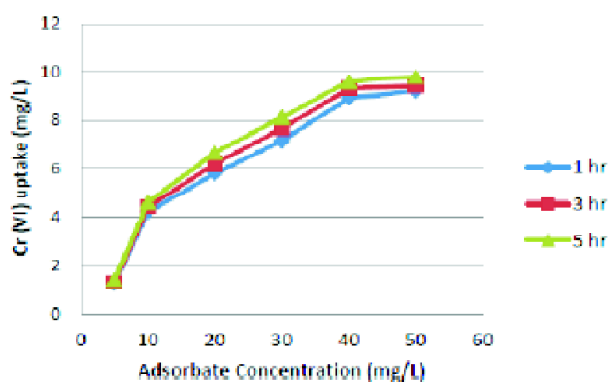


Fig. 10 Impact of chromium uptake on adsorption at different time.

likelihood of impact between the Cr^{6+} ions and the active sites. It also culminated in higher absorption of Cr^{6+} with the volume of bagasse powder being processed. This is due to the assumption that the usable surface region of the adsorbents becomes reduced when the Cr^{6+} molecules are adsorbed to the adsorbent surface (Banat *et al.*, 2000). As the Cr^{6+} concentration becomes too high, the adsorbent surface becomes filled and the efficiency starts to decrease and the molecules desorbed from the adsorbent surface.

Impact of adsorbent dosage: As the adsorbent dose level raised, the percentage of adsorption also raised and was plotted (Fig. 11). The adsorbent dose increased from 0.25 g/L to 2 g/L and the percentage of adsorption also increased from 20–98%. Nevertheless, it was found that the Cr^{6+} absorption potential (Fig. 12) of bagasse powder decreased from 2.8 mg/g at a low adsorbent dose (0.25 g/L) to 1.2 mg/g at a high adsorbent dose (2 g/L). Other Cr^{6+} sorption in-

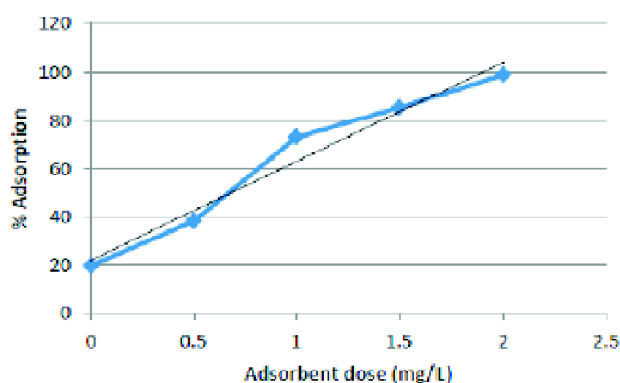


Fig. 11. Impact of adsorbent dosage on adsorption.

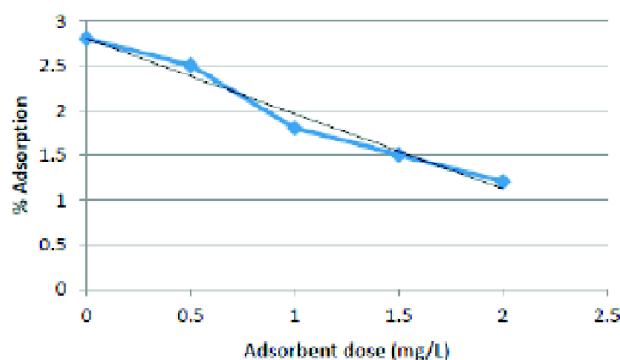


Fig. 12. Impact of chromium uptake on adsorption.

vestigators¹¹ have identified similar patterns. The reduction in Cr^{6+} absorption at a higher adsorbent dose could be due to rivalry of Cr^{6+} ions for accessible sites. The increase in the volume of adsorbent increases the number of active sites required for the absorption of metal ions. The adsorption of Cr^{6+} will not improve by growing the adsorbent mass higher, because the usable metal ions are still adsorbed by the adsorbent.

Impact of temperature: Temperature is a major factor in the adsorption process. The percentage of Cr^{6+} adsorption was considered to be a role of temperature in the range from 305 K to 320 K. The findings attained are shown in Fig. 13. As the temperature increased from 305 K to 320 K, the rate of adsorption decreased from 87 to 46% and the uptake decreased from 1.12 to 0.63 mg/g. The decreased level of adsorption with a rise in temperature could be attributed to a change in temperature may be owing to desorption induced by rise in the thermal energy available. Higher temperature triggered higher sensitivity of the adsorption causing desorption.

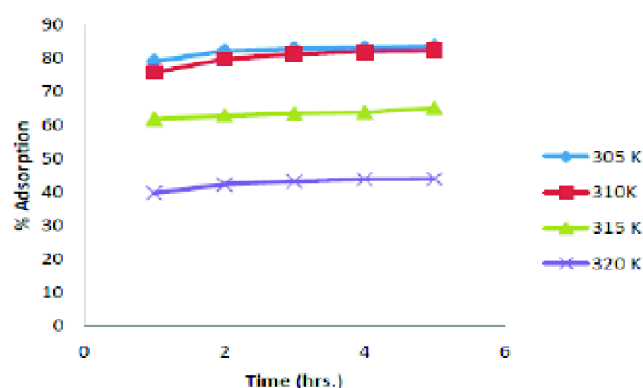


Fig. 13. Effect of temperature on adsorption at different time.

First order reversible kinetics: Cr^{6+} sorption on treated bagasse powder can be known as a reversible first order reaction¹². The first order reversible kinetic plot (eq. (4)) was drawn for bagasse powder at different temperatures (Fig. 13).

$$q = \frac{BQC_f}{(C_s - C_f) [1 + (B - 1) C_f/C_s]} \quad (4)$$

Correlation coefficients R^2 rate constants K_c , k_1 and k_2 have been determined for various plots (eqs. (5) and (6)) and are shown in Table 6.

$$C_e/q_e = 1/Q_0b + C_e/Q_0 \quad (5)$$

On the basis of the two equations alluded to above, it was observed that the values of k_1 and k_2 reduced from 5.06 to 0.54 and 0.47 to 0.20, respectively, as the temperature raised from 305 K to 320 K. K_c values decreased from 0.96 to 0.37 as the temperature reduced from 305 K to 320 K. The correlation coefficient (R^2) ranged from 0.896 to 1 for the first order reversible plot at different temperatures.

Table 6. First order reversible kinetic rate constants with regression

Temperature (K)	Coefficients for different temperatures			R^2
	k_1 (min^{-1})	k_2 (min^{-1})	K_c	
305	5.06	0.47	0.96	0.8963
310	2.83	0.43	0.15	0.952
315	1.06	0.42	0.22	0.988
320	0.54	0.20	0.37	1

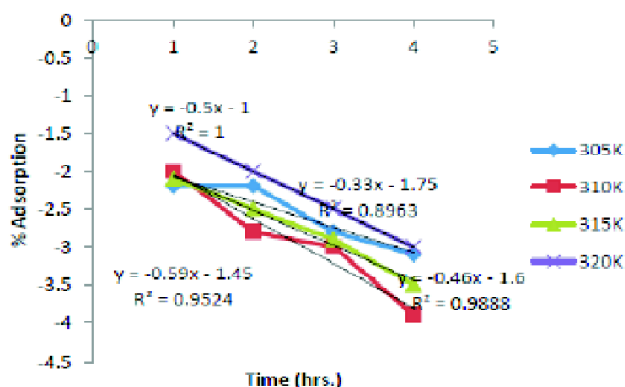


Fig. 14. First order reversible kinetics for different temperatures.

Pseudo-primary kinetics: Based on the pseudo-primary reaction model, the adsorption kinetics may also be defined¹³. The plot of $(q_e - q) \text{ vs } t$ (eq. (6)) was shown at various temperatures (Fig. 15). Correlation coefficient and rate factors have been recognized and are listed out in Table 7. The table indicates that the k values fell from 0.60 to 0.45 as the temperature goes up from 305 K to 320 K. Based on the R^2 values the correlation coefficients are in strong contract ($R^2 > 0.95$) with pseudo-primary kinetics.

$$\log (q_e - q) = \log q_e - (k/2.303)t \quad (6)$$

Pseudo-second order kinetics: Pseudo-second order ki-

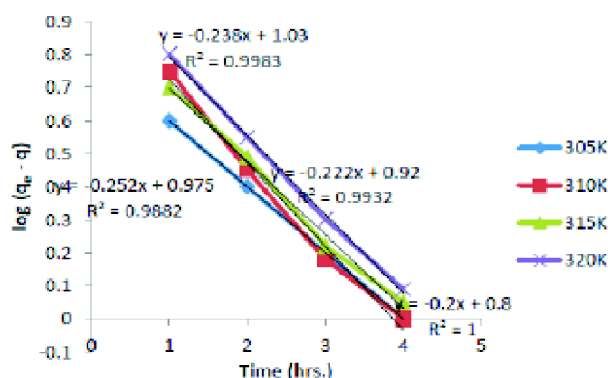


Fig. 15. Pseudo-primary reversible kinetics for different temperatures.

Table 7. Pseudo-primary kinetic rate constants with regression coefficients for different temperatures

Temperature (K)	k_1 (min^{-1})	R^2
305	0.60	0.9982
310	0.57	0.9932
315	0.54	1
320	0.45	0.9983

netic model¹³ can also be appropriate to sorption kinetics. The plot of $t/q \text{ vs } t$ (eq. (7)) were produced at various temperatures (Fig. 16) and the values of the correlation coefficients (h and k) were obtained from the plot as seen in Table 8. From the plot, it was observed that, the h values were decreased from 251 to 70 with increase in temperature from 305 K to 320 K. But the k values dropped from 0.18 to 0.09 with increase in temperature from 305 K to 320 K. From the

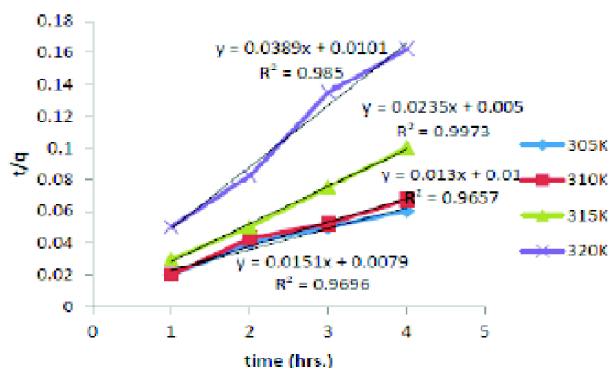


Fig. 16. Pseudo-secondary kinetics for different temperatures.

Table 8. Pseudo-secondary kinetic rate constants with regression coefficients for different temperatures

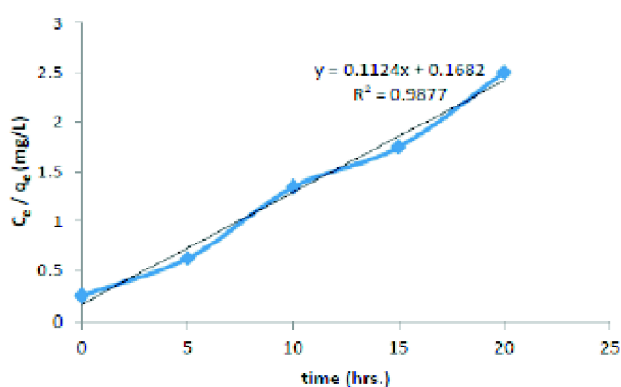
Temperature (K)	K (g/mg min)	h (g/mg min)	R ²
305	0.188	251.6	0.9696
310	0.133	251.5	0.9657
315	0.191	224.42	0.9973
320	0.092	69.25	0.985

above observations, it can be established that the system of Cr⁶⁺ adsorption in processed sugarcane bagasse powder is best to fit ($R^2 > 0.95$) with pseudo-second order kinetic model.

$$t/q = \{1/kq_e^2\} + t/q_e = 1/h + t/q_e \quad (7)$$

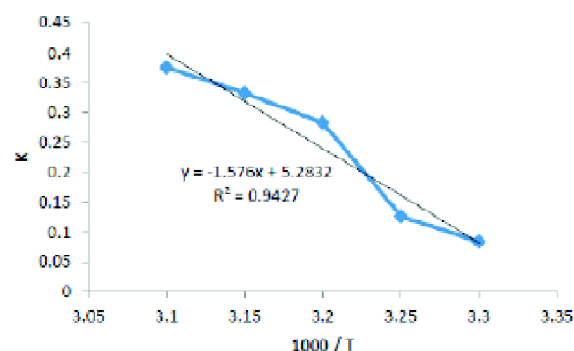
Adsorption isotherm and thermodynamic parameters:

Langmuir adsorption isotherm: Adsorption studies were performed with a range of primary adsorbent doses (0.1 g) and variable adsorbate concentrations. The information was verified to assess the applicability of the Langmuir adsorption isotherm. The data collected corresponded well to the linearized Langmuir adsorption isotherm using eq. (5). The quantities of Q_0 and b were calculated from slope and plot interruption (Fig. 17) and were estimated to be 3.2 mg/g and 1.85 mg/g respectively.

**Fig. 17.** Langmuir adsorption isotherm.

Thermodynamic parameters: Using the Arrhenius equation (eq. (8)), the activation energy were calculated.

From the Fig. 18 the $\ln k$ values were represented against $1000/T$ and the initial energy was calculated as 18357 kJ/

**Fig. 18.** Arrhenius plot for evaluation of activation energy.

mol. The energy value is very low and it was diffused by the film diffusion method. Using the eq. (9), the Gibbs free energy was calculated ($\Delta G^0 = -746$ J/mol) in negative value which indicates that the precipitation and adsorption process efficiency. The iso-steric adsorption heat ($r\Delta H$) has also been calculated using eq. (10). The $r\Delta H$ value estimated in the 305 K to 320 K temperature range was found to be -2068 kJ/mole which indicate that exothermic type.

$$\ln k = \ln A - E_a/RT \quad (8)$$

$$\ln (1/b) = (\Delta G^0/RT) \quad (9)$$

$$\Delta H_r = R \ln (C_1/C_2)/[1/T_2 - 1/T_1] \quad (10)$$

Mass transfer model: The adsorbent used in this case is sugarcane bagasse powder, a soluble material. Hence, the mechanism of adsorption follows that the surface or intra-particle diffusion or a combination of both.

The contact time method may be used to check the phase determination intensity in the adsorption cycle. Although the adsorption tests were performed under agitated conditions, the mass diffusion coefficient, i.e. the transformation from the adsorbate ion to the adsorbent surface, could be negligible if not negative. The phase detection intensity would then be either film or intra-particle dispersion, since all processes work in sequences. The rate constant for intra-particle dispersion can be calculated using eq. (11).

$$Q = k_{id} t^{0.5} \quad (11)$$

Fig. 19 shows the linear plot of q_t vs $t^{0.5}$ and the k_{id} value was obtained from the slope as 0.03 mg/g min $^{0.5}$.

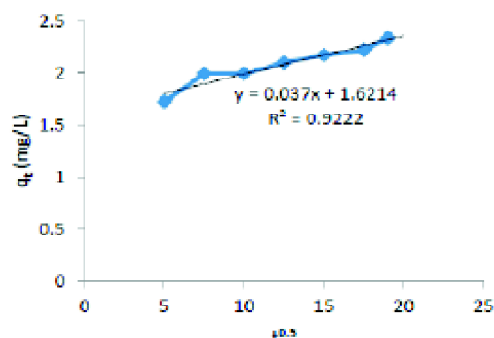


Fig. 19 Mass transfer model.

Conclusion

Sugarcane bagasse powder was prepared and its physico-chemical properties were characterized. From the FT-IR analysis and surface morphology, it has a very high surface area, porous level also its functional groups. The efficiency of the adsorption was tested with varying metal ion concentrations of aqueous solutions. The chromium ions was found to be strongly reliant on the pH of the solution, dosage level of the adsorbent, concentration of the metal ions, contact time and the temperature. The adsorption of metal ions onto the adsorbent was increased with an increase in contact time and adsorbent dosage level. On the other hand, the process of metal ion adsorption was decreased with increase in solution's pH, concentration of the adsorbate and changes in temperature. The Langmuir isotherm fitted with the equilibrium data and pseudo-second order kinetic model data has been followed in this adsorption process. From the above discussions, this work concluded that the sugarcane bagasse powder is the most efficient adsorbent to remove the heavy metal contaminations from the aqueous solutions.

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