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Chromium(VI) removal from aqueous medium by maize cane and agave bagasse biomasses

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ABSTRACT

Chromium(VI) is a major water pollutant from industrial effluents whose concentration is to be reduced within the permissible limits. In this paper, the use of maize cane and agave bagasse as inexpensive adsorbent for the removal of Cr(VI) from aqueous solutions is considered. In the first place, they were conditioned and characterized to determine their physicochemical properties with scanning electron microscopy; the elemental composition with energy-dispersive x-ray spectroscopy (EDS); the principal functional groups with Fourier transform infrared spectroscopy; thermal stability with thermogravimetric analysis; and surface properties by specific surface hydration kinetics, point of zero charge determination by mass titration, and active site density are described. In the second place, their adsorption properties for Cr(VI) from aqueous solution were evaluated in a batch system. The kinetics of Cr(VI) sorption with both natural adsorbents were described with a pseudo-second-order model. Equilibrium data were found to be best represented for both adsorbents by the Freundlich isotherm model. Maize cane and agave bagasse can be effectively used as an adsorbents for the removal of Cr(VI) ions from the aqueous solution.

Introduction

Chromium, which is on the top-priority list of toxic pollutants defined by the US Environmental Protection Agency, exists in aqueous solutions in nature mainly as trivalent and hexavalent chromium (Chen et al. 2010). It is a key contaminant in the wastewater of industrial dyes and pigments, film and photography, galvanometry and electric, metal cleaning, plating and electroplating, leather, and mining. Chromium [Cr(VI)] is much more toxic than Chromium [Cr(III)] (Singha and Das 2011). Cr(VI) has been reported to be toxic to animals and humans, and also it is known to be carcinogenic, mutagenic, and teratogenic (Malkoc and Nuhoglu 2007). Its concentrations in industrial wastewater vary from 0.5 mg L^{-1} to 270 mg L^{-1}. The maximum permissible limit of Cr(VI) for the discharge into inland surface water is 0.1 mg L^{-1} and in potable water is 0.05 mg L^{-1} (EPA 2009). Cr(VI) has high water solubility and mobility over almost the entire pH range.

Conventional methods for removing dissolved heavy metal ions include chemical precipitation, chemical oxidation and reduction, ion exchange, filtration, electrochemical treatment, and adsorption. However, these high-technology processes have significant disadvantages, including incomplete metal removal, high reagent or energy requirements, or generation of toxic sludge or other waste products that require disposal (Basha, Murthy, and Jha 2008). Sorption with natural biosorbents has become one of the alternatives to traditional methods of industrial wastewaters treatment, because it is a relatively inexpensive, highly efficient, non-hazardous, capable of easily

regenerating biosorbents, and may permit recovery of the metals from the sorbing biomass (Dupont and Guillon 2003).

The native exchange capacity and general sorption characteristics of these materials derive from their constituents such as cellulose, hemicellulose, pectin, lignin, and proteins, which contain a variety of functional groups that have been reported as Cr(VI) sorption sites or electron–donor groups that can adsorb certain contaminants in water (Elangovan, Philip, and Chandraraj 2008a; Ertugay and Bayhan 2008; Yang and Chen 2008; Velázquez-Jiménez, Pavlick, and Rangel Mendez 2013). Various reports have explored how each material's capacity depends on reaction time, solution pH, material dosage, and type of biomaterials (Park et al. 2008; Sud, Mahajan, Kaur 2008; Farooq et al. 2010). Among these, pH is one of the most important environmental factors, which affects not only biomass surface chemistry but also metal speciation (Blázquez et al. 2009).

Several materials (industrial, agricultural or natural waste), which are available in large quantities have been prospected as biosorbents of Cr(VI) such as *Pinus densiflora* (Park, Yun, and Lee 2011); palm flower (Elangovan, Philip, and Chandraraj 2008b); by-products of beer production (Cui et al. 2011); *Cystoseira indica*; (Basha, Murthy, and Jha 2008; Wu et al. 2010), *Sargassum* sp. (Yang and Chen 2008); pine (needle, bark, cone); oak leaf; sawdust; walnut shell; peanut shell; rice (straw and husk); banana skin; orange peel; green tea waste; fungal biomass of *Rhizopus*; and seaweed biomass of *Ecklonia, Sargasssum*, and *Enteromorpha* (Park et al. 2007); waste acorn of *Quercus ithaburensis* (Malkoc and Nuhoglu 2007); activated

carbon from olive bagasse (Demiral et al. 2008), *Casurina equisetifoli* leaves (Ranganathan 2000), coconut shell (Park and Yang 2002), peanuts shell (Al-Othman, Ali, and Naushad 2012), rice husk (Bishnoi et al. 2004); tyres and sawdust (Hamadi et al. 2001); and agricultural wastes (Singha and Das 2011).

Maize stalk is an abundant agricultural waste found in Mexico and has a high content of cellulose (Chi and Chen 2009).

Agave (*Agave salmiana*) bagasse is an abundant lignocellulosic waste material of the alcohol industry: for example, about 350,000,000 kg per year are generated in the mezcal industry of Mexico. This residue produces ecological problems due to its low natural degradation rate, and because it is commonly eliminated by burning, thereby becoming a source of atmospheric pollution (Velázquez-Jiménez, Pavlick, and Rangel Mendez 2013). Recent studies indicated that agave bagasse has higher adsorption capacity for Cr(III) than sorghum or oat straw (Krishnani and Ayyappan, 2006; García-Reyes and Rangel Mendez 2009; García-Reyes et al. 2009) and for Cd(II), Pb(II), and Zn(II) (Velázquez-Jiménez, Pavlick, and Rangel Mendez 2013), which has encouraged us to explore its potential for removal of hexavalent chromium from wastewater.

The objective of the present study was to characterize chemical and surfacely both materials. In batch studies, the effect of initial pH, adsorbent dose, isotherms, and kinetic for the removal the Cr(VI) have been evaluated and discussed.

Experimental methods

Natural materials and preparation of biosorbents

Maize (*Zea mays*) cane and inactive tissues of agave bagasse were collected from a maize cultivar zone of Lerma and a local distillery in Zumpahuacan, Mexico State, respectively. They were washed several times with running tap water and distilled water to remove surface impurities and dried at 70°C in an oven for 24 h. Both adsorbents were cut into small pieces, ground in a blender, and sieved to obtain particles smaller than 1 mm.

The physicochemical characterization was done according to Romero-Guzmán et al. (2013).

Surface characterization

Specific surface

Specific surface (m^2g^{-1}) was determined using a multipoint N_2 adsorption/desorption Brunauer–Emmett–Teller (BET) method at room temperature in a surface area analyzer (Beisorp Max, Bel Japan Inc., Osaka Japan).

Hydration kinetics

The time taken for the surface to be hydrated was determined by means of acid/base potentiometric titrations. The potentiometric titration tests were carried out with $20 \, g \, L^{-1}$ aqueous suspensions of solid in 0.5 M KNO_3 medium, keeping ionic strength constant, as it is recognized that K^+ and NO_3^- ions do not usually sorb specifically (Preocanin and Kallay 1998). Deionized water was used in order to avoid the presence of carbonates. In situ pH values were measured with a combined ORION® glass electrode. The precision of the measured pH

values was estimated to be ±0.2 units. The sample was shaken continuously to prevent settling. For the hydration step, the suspensions were shaken for 0 to 72 h of contact time at room temperature. After hydration, the pH of the initial suspension was adjusted to a value lower than the pH_{zpc} (pH close to 1) using a 0.5 M HNO_3 solution. The solution was mixed during 5 min until the pH value was constant. The solid was titrated by adding incremental volumes of a 0.1 M KOH solution.

Active site density

The surface site density was determined directly from the potentiometric titration curve of the suspension (natural adsorbents $-OH^-$ solution). When the mole number of OH^- ions added to the suspension was plotted against the mole number of these aqueous ions (related to the pH measurement), the final region of the resulting curve was linear. In this range, the reaction no longer occurs, and the total amount of hydroxide ions introduced is found entirely in the solution; the solid surface has reacted completely.

The titration curve obtained for the background salt alone (without solid) was also linear. By extrapolating this linear region to a zero OH^- concentration for both (the suspension and background salt), the uptake of OH^- by the solid phase by subtracting these two values was calculated (Bell, Posner, and Quirk 1973). Thus, by knowing the specific surface area and the quantity of powdered solid in the suspension, the surface site density was determined.

Sorption processes

Sorption experiments were carried out at room temperature. The stock solution of $1.0 \, g \, L^{-1}$ Cr(VI) was made by dissolving 2.828 g of $K_2Cr_2O_7$ in 1 L distilled water. The experimental solutions at the desired concentration were then obtained by successive dilutions. The initial pH adjustments were carried out either by HNO_3 or KOH.

Batch experiments were carried out in polypropylene tubes by adding natural adsorbent in 0.01 L of aqueous chromium solution varying initial pH, adsorbent dose, contact time, and metal concentration. The tubes were gently agitated in an electrical shaker at 40 rpm for some time. All experiments were performed in triplicates. The phases (liquid and solid) were separated by centrifugation at 3500 rpm in a BHG 1100 Segurita centrifuge, and the Cr(VI) in the liquid phases was analyzed by a UV-Vis spectrophotometer (model Perkin Elmer Lambda 10, Spain). (Hosseini-Bandegharaei et al. 2010). The purple–violet complex formed between 1,5-diphenylcarbazide-Cr(VI) in the acid condition was measured at 540 nm using the UV-Vis spectrophotometer.

The Cr(VI) adsorption by natural adsorbent considering each specific parameter is described in the following sections.

Effect of pH

The effect of pH on the sorption capacities of the natural adsorbents for chromium ions was performed at pH values from 2 to 9. Experiments were carried out with 0.01 L of $40 \, mg \, L^{-1}$ solutions of Cr(VI) and 0.1 g of natural adsorbent. The initial pH values were adjusted by adding small volumes of 1 M NaOH or 10% HNO_3 solution. The samples were

stirred during 24 h at 40 rpm, after this time the samples were centrifuged and the fractions separated to measure both the pH and the Cr(VI) content in the remaining solutions.

Sorbent dose effect

It was performed by varying the dose from 0.01 g to 0.2 g in contact with 0.01 L of 40 mg L^{-1} solution of Cr(VI) during 24 h, then the phases were separated by centrifugation to measure the Cr(VI) in the liquid phase.

Kinetic

The sorption of Cr(VI) by natural adsorbents was carried out within 5 to 4320 min at a concentration of 40 mg L^{-1}. The sorption was achieved by mixing 0.1 g of sample and 0.01 L of Cr(VI) solution.

Isotherm

The effect of Cr(VI) concentration on the uptake by the natural adsorbents was performed by varying the initial concentrations of Cr(VI): 10 mg L^{-1}, 30 mg L^{-1}, 50 mg L^{-1}, 70 mg L^{-1}, 100 mg L^{-1}, 150 mg L^{-1}, and 200 mg L^{-1}. A volume of 0.1 g of sorbent was introduced into each tube, and 0.01 L of Cr(VI) solution was added to the tubes. The samples were stirred during 24 h at 40 rpm. After this, the samples were centrifuged at 3500 rpm for 10 min, then the fractions were separated to measure the Cr(VI) content in the remaining solutions.

Results and discussion

Physicochemical characterization of natural adsorbents

Morphology and elemental composition: To characterize the textural properties of maize cane and agave bagasse, the solid material was chemically and morphologically analyzed. The natural sorbents considered in this work were brown in color. Figure 1a shows the holes or channels surface, can be observed
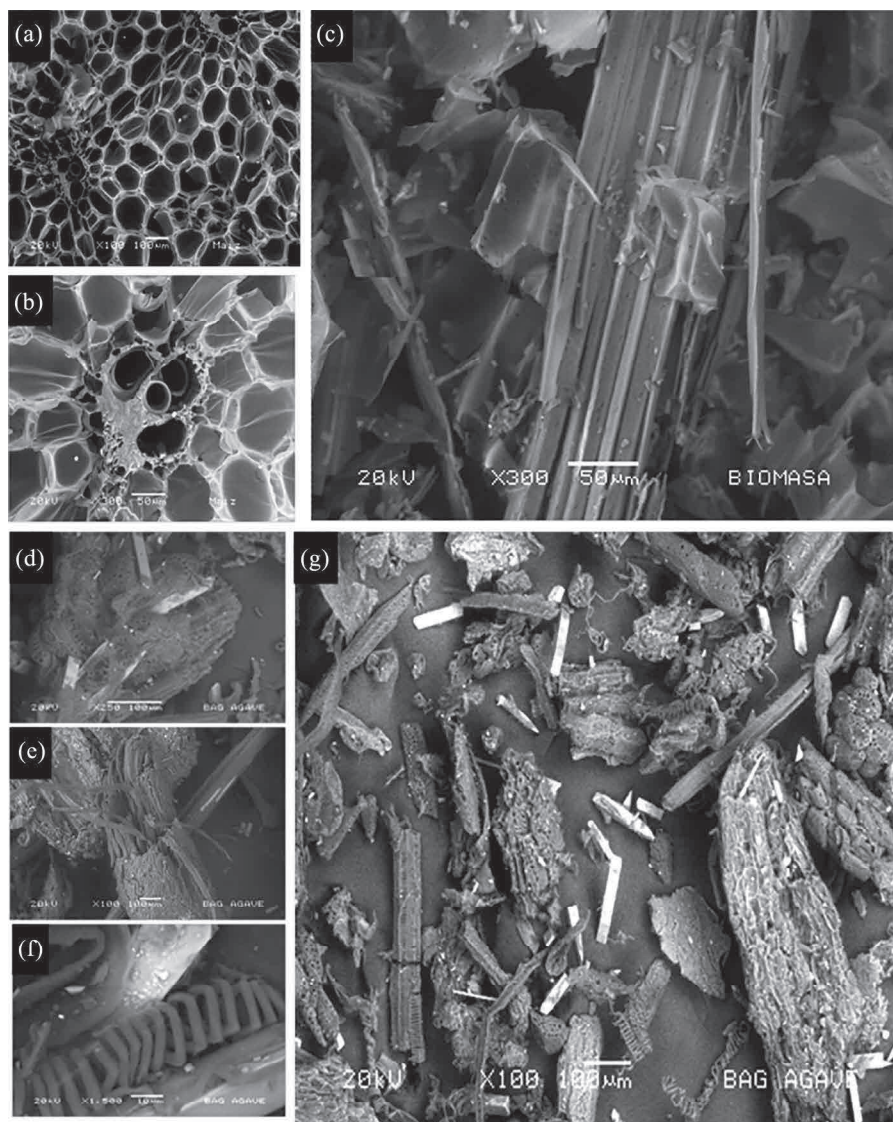

Figure 1. Scanning electron micrographs of the maize cane (a) Flats raw material, 100×; (b) tubes through the nutrients are transported, 300×; (c) maize cane grinded, 300×, and agave bagasse; (d) irregular structure with small cavities at the surface, 250×; (e) fibrillar structure, 100×; (f) spiral structure, 500×; and (g) agave bagasse grinded, 100×.

that the surface is mainly porous, with free spaces. The material displays a hexagonal structure with fine threads on the hexagonal structures with diameters between 50 μm and 160 μm. They showed transverse tubes through which nutrients are transported to the rest of the plant. The tubes had a 50-μm diameter and were distributed evenly across the stem in maize cane (Figure 1b). When the natural sorbent was ground, the hexagonal structure was destroyed, and the biomaterial resembled to the shown in Figure 1c. In the images of agave bagasse, it is apparent that the adsorbent have porous structures with different shapes and morphologies (Figure 1g): fibers (Figure 1e), spirals (Figure 1f) and others more with the irregular forms with small cavities at the surface homogeneously distributed (Figure 1d).

The energy-dispersive x-ray spectroscopy (EDS) results (weight percentages) showed that the average elemental content of maize cane was 58.98% C, 36.67% O, 2.92% K, 0.79% Cl, and 0.63% Si. For agave bagasse was found 57.05% C, 41.17% O, 1.37% Ca, 0.22% Al, and 0.19% Si. The given EDS values represent an average of ten data points obtained from random locations on the biosorbents. It is important to mention that agave bagasse presents Ca and Al and does not contain Cl in comparison with maize cane. The composition of them could be affecting the Cr(VI) adsorption behavior; however EDS, analyses yielded direct evidence of no chromium percentage in both samples, after chromium sorption process owing to the initial concentration and removal capacity.

Crystalline components: According to the JCPDS card 56-1719, the main organic compound present in both sorbents is cellulose, $(C_6H_{10}O_5)_n$ which is a mixture of crystalline and amorphous compounds (Preocanin and Kallay 1998; Luna-Zaragoza, Romero Guzmán, and Reyes-Gutiérrez 2009). The intensity of the peak between 22° and 23° for native cellulose is considered to represent the crystalline compound, and the intensity between 18° and 19° represents the background owing to amorphous components.

Functional groups: The infrared spectra (4000 cm^{-1} to 400 cm^{-1}) of natural adsorbents were done. In maize cane spectrum, the broad band observed at 3410 cm^{-1} indicated the presence of –OH and –NH groups. The absorption bands at 2920 cm^{-1} and 607 cm^{-1} could be assigned to C–H stretching. The peak at 1730 cm^{-1} corresponded to the stretching vibration of C=O that may be attributed to the lignin aromatic groups. The band appeared at 1052 cm^{-1} corresponding to the C–O stretching vibration of the cellulose (Garg et al. 2008). The Fourier transform infrared spectroscopy spectra for both natural sorbents are similar, with the difference that the agave bagasse spectrum contained vibrational frequencies around at 1551 cm^{-1} and 1246 cm^{-1} could be stretch of –NH and –SO$_3$ (Velázquez-Jiménez, Pavlick, and Rangel Mendez 2013). Therefore, maize cane and agave bagasse present diverse functional groups, which can be a potential binder for chromium ions, such as carboxyl, amide, and hydroxide groups.

Thermal stability: The thermal profiles of both bioadsorbents are similar, and they can be divided into three stages. The first stage, below 250°C, is the loss of adsorbed water and some dewatering of the cellulose structural units. The second stage, between 250 and 340°C, is expected to be the thermal decomposition of hemicellulose and cellulose b-(1 → 4)-glycosidic

Table 1. Physical properties of natural adsorbents samples.

Sample	Surface area (S_{BET}), m^2/g	Total pore volume, cm^2/g	Pore diameter, Nm
Maize cane	0.54	0.003	25.8
Agave bagasse	1.51	0.006	16.1

linkages. The third stage, above 350°C, is likely to involve the decomposition of remaining cellulose and lignin.

Surface characterization

Specific surface area (S_{BET}): The total pore volume and mean pore diameter for both was evaluated by applying the Brunauer, Emmett, and Teller (BET) equations (Table 1). According to the International Union of Pure and Applied Chemistry (IUPAC), the pore structures are classified into three groups as micropore (≤ 2 nm), mesopore (2–50 nm), and macropore (≥ 50 nm), and the sorbents have mesopores.

Hydration kinetics: The potentiometric titration curves obtained at different times demonstrated that the hydration time required for equilibrium between the dried solid and the aqueous medium was at 24 h for both, as the union of the majority of the curves is observed at this time. It can be considered that at this time, the hydration of the compound is completed (Figure 2).

Point of zero charge (pH_{zpc}): The pH_{zpc} of a sorbents is a very important characteristic that determines the pH at which the adsorbent has net electrical neutrality, and at which value de acid or basic functional groups no longer contribute the pH of the solution (Wan, Ngah, and Hanafiah 2008). Then if the pH of the system is below the pH_{zpc}, the acidic water donates more protons than hydroxide groups and the sorbent surface is positively charged (attracting anions). In consequence, above pH_{zpc}, the surface is negatively charged (attracting cations). For maize cane the $pH_{ZPC} = 5.9$, in contrast, for agave bagasse the $pH_{ZPC} = 5.1$. In accordance with these results, at pH $<pH_{zpc \, (sorbents)}$ the sorbent had a high positive surface charge and adsorption capacity (Pillay, Cukrowska, and Coville 2009). This favored the adsorption of the
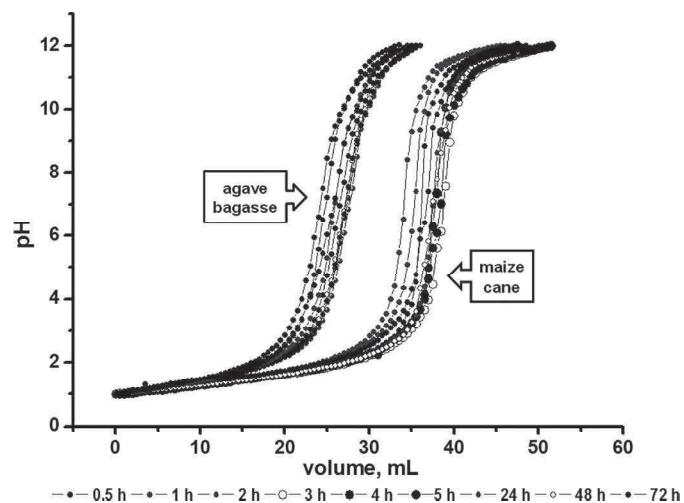

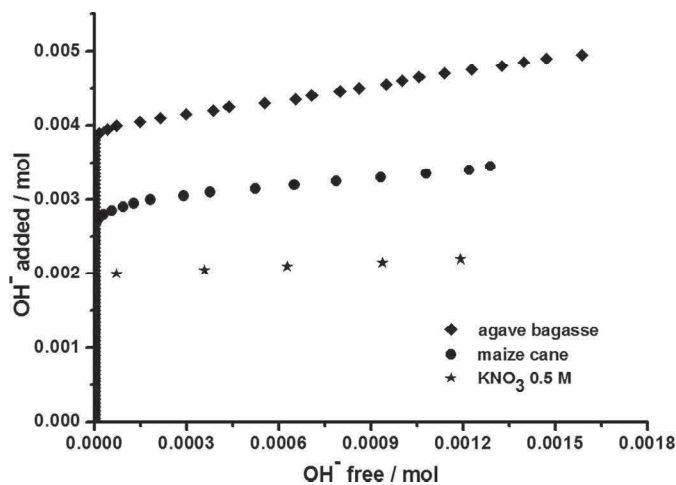**Figure 2.** Potentiometric titration of maize cane and agave bagasse suspensions (0.6 g L^{-1}) in 0.5 M KNO$_3$.

Figure 3. Surface site density of the maize cane and agave bagasse suspensions (20 g L^{-1}) in 0.5 M KNO$_3$ medium. Suspension (dots) and 0.5 M KNO$_3$.

Figure 4. Effect of pH on Cr(VI) adsorption for maize cane and agave bagasse.

negatively charged chromate ions, but the negative surface charge facilitated electrostatic repulsion of the chromate ions.

Active site density: The active surface sites for sorbents were obtained by comparing the titration curve of the suspension with the curve obtained for the background 0.5 M KNO$_3$ salt solution titrated under the same experimental conditions. Figure 3 shows the number of OH$^-$ moles added to the suspensions and to the background salt plotted against the total number of OH$^-$ moles neutralized obtained. Densities of 11.1 sites (nm^2)$^{-1}$ and 8.1 sites (nm^2)$^{-1}$ were found for maize cane and agave bagasse, respectively, considering that the surface area (SA) of maize cane was 0.54 m^{2}g^{-1} and for agave bagasse was 1.51 m^2 g^{-1}, these results are in agreement. It is important to mention that the concentration of adsorbent in solution was 20 g L^{-1}.

Sorption processes

Effect of pH

Aqueous phase pH governs the speciation of metals and also the dissociation of active functional sites on the sorbents. Hence, metal sorption is critically dependent on the pH. Not only different metals show different optimum pH for their sorption but also may vary from one kind of biomass to the other (Tiwari, Singh, and Saksena 1995).

Cr(VI) removal was studied as a function of pH over a pH range of 2–9 on adsorbents at the initial concentration of 40 mg L^{-1}, Figure 4. At pH values below the isoelectric point (<5.9 maize cane and <5.1 agave bagasse), the overall surface charge on cone biomass will be positive. Figure 4 shows that the maximum adsorption occurred at pH 2.0 for both sorbents. There was a sharp decrease in the sorption capacity when pH was raised from 2.0 to 7.0 and thereafter the effect became negligible. Cr(VI) may exist in three different ionic forms (HCrO$_4^-$, Cr$_2$O$_7^{2-}$, CrO$_4^{2-}$) in aqueous solutions, and the stability of these ions in aqueous systems is mainly pH dependent (Singh and Tiwari 1997).

The percentage of Cr(VI) removal was higher in the lower pH ranges due to high electrostatic force of attraction. As the number of H$^+$ ions increased with lowering the solution pH, which neutralized the negative charge on adsorbent surface
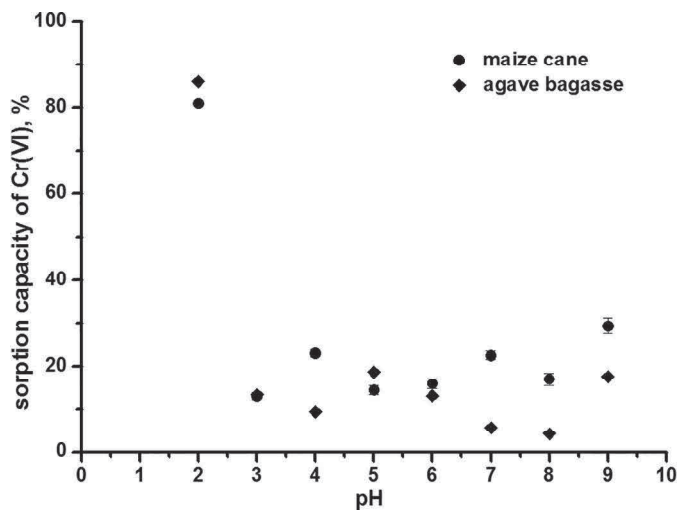
and thereby increased the diffusion of chromate ions into the bulk of the adsorbent (Rao, Parwate, and Bhole 2002). Dominant form of Cr(VI) at initial pH of 2 is HCrO$_4^-$ (Namasivayam and Yamuna 1995). So, Cr(VI) was adsorbed on the surface of bioadsorbents mostly in the form of HCrO$_4^-$ ions. The decrease in the adsorption with increase in pH may be due to the increased number of OH$^-$ ions in the bulk that retarded the diffusion of chromate ions and the competitiveness of the oxyanions of chromium.

Hence pH 2.0 was taken as the optimal values for further studies of Cr(VI) adsorption on natural adsorbents.

Effect of sorbent dose

The effect of the adsorbent dose in the Cr(VI) the maximum removal was of 90% for maize cane and 97% for agave bagasse when 0.1 g of biomasses was used with an initial concentration of 40 mg L^{-1} of Cr(VI). The equilibrium uptakes and percent removal were presented in Figure 5. When the adsorbent dosage was increased, the removal increased. It is apparent that the percent removal of heavy metals increases rapidly with
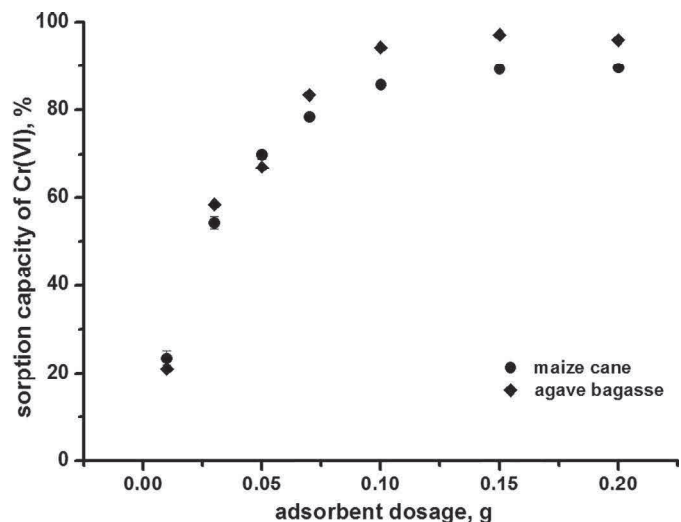

Figure 5. Effect of adsorbent dosage on Cr(VI) adsorption for maize cane and agave bagasse.

increase in the dose of the adsorbents due to the greater availability of the exchangeable sites or surface area. The decrease in adsorption uptake with increasing adsorbent dosage is mainly due to unsaturation of adsorption sites through the adsorption reaction.

Kinetic

The percentage removal was found to increase with increasing contact time and attained maximum value at 24 h for both bioadsorbents, with more than 80% and 90% from maize cane and agave bagasse, respectively, of total adsorption. There was no significant change in equilibrium concentration after 24 h. Based on these results, a contact time of 24 h was selected in subsequent studies.

Adsorption kinetics provides valuable information about the reaction pathways and mechanism of the reactions. The experimental data for the Cr(VI) sorption by sorbents were fitted to pseudo-second-order model to obtain the parameters that describe the process. The conformity between experimental data and the model predicted values was expressed by the correlation coefficients (R^2). A relatively high R^2 values indicated that the model successfully describes the kinetics of Cr(VI) adsorption.

The pseudo-second-order kinetic model (Ho and Mckay 1999) is based on experimental data for solid-phase sorption and has generally been applied to heterogeneous systems in which chemical sorption is the primary mechanism, this model assumes that chemisorption is the rate-limiting step, which involves valence forces from the sharing or exchange of electrons between the sorbent and the sorbate. The plot of t/q_t versus t gave linear plots (Figure 6). The calculated k_2, h, and the corresponding linear regression correlation coefficient (R^2) values for both natural adsorbents are summarized in Table 2.

The values of correlation coefficient for Ho equation were very high ($R^2 > 0.99$) for both adsorbents (Table 2). It can be said that the pseudo-second-order kinetic model provided a good correlation for the adsorption of Cr(VI) onto both biomasses.
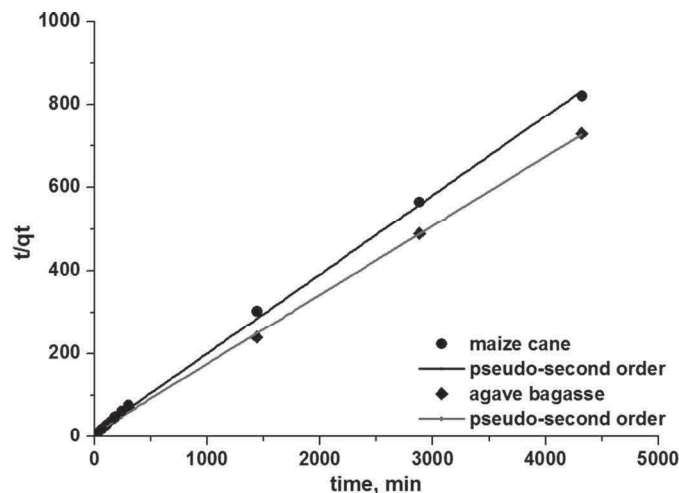
Table 2. Kinetic model parameters obtained from the adsorption of Cr(VI) onto maize cane and agave bagasse.

| Sample | Pseudo-second order | | | |
	k_2 (g/mg min)	h (mg/g min)	q_e (mg/g)	R^2
Maize cane	0.0035	0.0948	5.25	0.9986
Agave bagasse	0.0027	0.0975	6.025	0.9989

Isotherm

As can be seen from Figure 7, percent removal of Cr(VI) ion decreases with the increase in initial Cr(VI) ion concentration for adsorbents. At lower concentration, all the Cr(VI) ions in the solution would react with the binding sites and thus facilitated almost complete adsorption. At higher concentration more Cr(VI) ions left un-adsorbed in the solution due to the saturation of the binding sites. This indicates that the energetically less favorable sites become involved with increasing Cr(VI) ions concentration in aqueous solutions. The percentage removal then depended upon the initial concentration. The curves also indicated that the adsorption led to saturation, suggested the possible monolayer coverage of Cr(VI) on the surface of adsorbent.

To examine the relationship between sorbed (q_e) and aqueous concentration (C_e) at equilibrium, sorption isotherms models are widely employed for fitting the data. The Langmuir and Freundlich (Jiménez-Cedillo et al. 2013) isotherms are most commonly used to described sorption behavior. In this work, the Langmuir–Freundlich isotherm model (Nguyen et al. 2010) was also considered. The parameters obtained from the experimental data were fitted to the previously mentioned models.

Figure 8a,b shows the Langmuir, Freundlich, and Langmuir–Freundlich isotherms, and the experimental data for sorbents. The isotherms constants and R^2 values for each model are given in Table 3.

On the comparison of the R^2 values, it can be concluded that adsorption data in both adsorbents can be better described by the Freundlich isotherm model. These results also predict the heterogeneity of the sorption sites on sorbents. The Cr(VI) chemisorption was correlated with the Freundlich isotherm model.
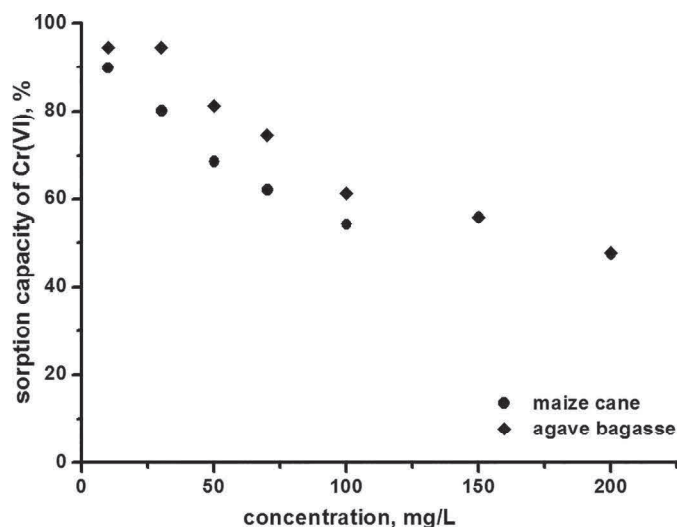

Figure 6. Kinetic model from the adsorption of Cr(VI) onto maize cane and agave bagasse.

Figure 7. Effect of Cr(VI) concentration on adsorption for maize cane and agave bagasse.
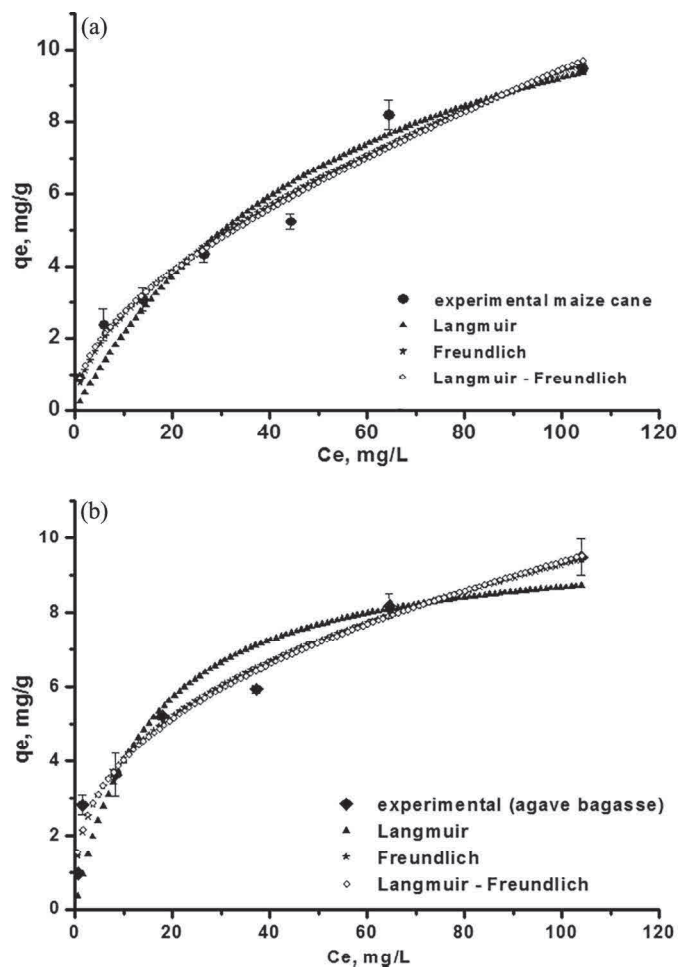
Figure 8. Isotherms for the Cr(VI) adsorption process for the (a) maize cane and (b) agave bagasse.

Table 3. Isotherm constants for the adsorption of Cr(VI) on natural adsorbents.

	Sample	
Model	Maize cane	Agave bagasse
Langmuir		
Q_0 (mg/g)	14.564	9.991
K_L (L/mg)	0.017	0.067
R_L	0.592	0.272
R^2	0.935	0.871
Freundlich		
K_F (mg/g)	0.907	1.770
n	2.015	2.776
$1/n$	0.496	0.362
R^2	0.983	0.973
Langmuir–Freundlich		
K_{LF} (L/mg)	0.874	1.761
n	2.215	3.206
R^2	0.962	0.967

Conclusions

The morphology, textural characteristics, and surface properties of the natural adsorbents, such as maize cane and agave bagasse, influence on the Cr(VI) sorption behavior.

Cr(VI) adsorption was found to be pH dependent. Effective adsorption was occurred in the pH 2 for both the adsorbents. The removal percent was decreased with increase in initial concentration. The Cr(VI) sorption kinetic processes by both natural adsorbents are well described by a pseudo-second-order model. Isotherm data of the two adsorbents were treated according to Langmuir, Freundlich, and Langmuir–Freundlich models, but the Freundlich adsorption isotherm model fitted well as compared to the other models studied for both natural adsorbents, reflecting the heterogeneity of the sorption sites on maize cane and agave bagasse biomass.

These results demonstrate the great potential of biosorbents, as low-cost heavy metal adsorbents. The Cr(VI) removal technique using such adsorbents would be an effective method for the economic treatment of wastewater.

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