



Adsorbents for Cr(VI) Uptake from Contaminated Water: Part I Activated Carbon

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Abstract

Chromium in its hexavalent form (Cr(VI)) poses a significant threat to the environment and human health due to its toxicity, mobility, and bioaccumulation capacity. This paper presents a study on the removal of Cr(VI) from aqueous solutions using three types of activated carbon: BIOMUS PYL 22 (PAC), NORIT 1240 (GAC), and SORBOTECH LGCO (GAC). The effects of key process parameters, such as contact time, stirring speed, pH, temperature, initial Cr(VI) concentration, and sorbent dosage, on adsorption efficiency were analyzed. The results indicate that powdered activated carbon (PAC) exhibits the highest Cr(VI) removal efficiency, reaching 80–90% under optimal conditions. Cr(VI) adsorption is most effective at acidic pH (~2) and elevated temperatures (40–60°C), although high removal efficiencies were also achieved at room temperature. The Langmuir and Freundlich isotherm models confirm the favorable nature of the adsorption process. These results provide a basis for designing efficient and economically viable processes for the removal of Cr(VI) from industrial wastewater.

Keywords: activated carbon, Langmuir and Freundlich isotherm models

1. INTRODUCTION

Chromium (Cr) is a transition metal extensively utilized in various industrial applications owing to its high durability, corrosion resistance, and hardness. It plays a significant role in sectors such as leather tanning, electroplating, pigment manufacturing, textile dyeing, and wood preservation. Chromium commonly occurs in two oxidation states: trivalent chromium (Cr(III)), which is an essential micronutrient in trace amounts, and hexavalent chromium (Cr(VI)), which is highly toxic and carcinogenic (Elahi et al., 2020; Igiri et al., 2018; USEPA, 2021).

The widespread use of chromium in industrial processes has resulted in severe environmental contamination, particularly in regions with inadequate regulation and waste management. Industries such as tanning and metal finishing often discharge effluents with significant concentrations of Cr(VI), which is highly soluble, mobile, and bioavailable. Once in the environment, Cr(VI) can easily penetrate biological membranes, causing cellular damage and leading to genotoxic, mutagenic, and carcinogenic outcomes (Saranraj and Sujitha, 2013; Majumder et al., 2017; WHO, 2020; EPA, 2022).

Conventional treatment methods for chromium-contaminated wastewater include chemical precipitation (Qasem et al., 2021), flotation (Saleh et al., 2022; Matis et al., 1991), ion exchange (Bashir et al., 2019; Tiravanti et al., 1997; Rengaraj et al., 2001; Petruzzelli et al., 1995; Gode et al 2007) reverse osmosis (Ozaki et al., 2002; Kapelula and Luis, 2024; Abdullah et al., 2019), membrane filtration (Atès and Uzal, 2018; Kozłowski and Walkowiak, 2002; Shaalan et al., 2001), membrane technologies (Mohammadi et al., 2005) and electrochemical reduction (Roundhill and Koch, 2002). Chemical precipitation is one of the most commonly used methods, where chromium is converted into an insoluble form such as chromium hydroxide and removed by sedimentation. However,

this method is generally inefficient at low concentrations and generates large volumes of toxic sludge. Ion exchange techniques involve the replacement of chromium ions with less harmful ions using ion-exchange resins, but these are sensitive to competing ions and require frequent regeneration. Reverse osmosis and membrane filtration provide high removal efficiency but involve high operational and maintenance costs and membrane fouling. Electrochemical reduction involves reducing Cr(VI) to Cr(III) using electrical current, which can be effective but energy-intensive. These methods, while effective in controlled settings, often struggle with variability in industrial effluent composition and require careful optimization to ensure consistent performance. Although these methods can be effective, they often entail high operational costs, complex maintenance, and generation of hazardous sludge, limiting their sustainability (Singh and Goyal, 2010; Sepehr et al., 2013; Kumar and Riyazuddin, 2013; Xiang et al., 2022; Qasem et al., 2021).

Activated carbon has long been regarded as one of the most effective and widely utilized adsorbents for the treatment of water and wastewater contaminated with heavy metals, including hexavalent chromium (Cr(VI)). Its effectiveness is primarily attributed to its exceptionally high surface area, porous structure, and rapid adsorption kinetics, which collectively facilitate the efficient removal of a broad range of contaminants (Allen, Whitten, and McKay, 1998; Mohan and Singh, 2005). In particular, activated carbon demonstrates a high sorption capacity, enabling effective treatment even in wastewater streams with elevated initial chromium concentrations, commonly exceeding 100 mg/L (Crini, 2005). Moreover, its ability to yield a high-quality effluent renders it particularly valuable in applications where stringent discharge standards must be met (Pollard et al., 1992). Historical evidence suggests that the use of carbonaceous materials for purification dates back thousands of

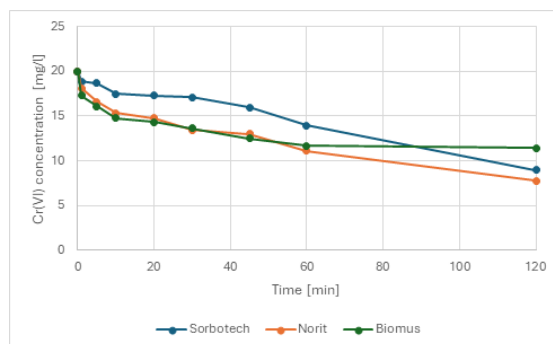


Fig. 1. Effect of contact time on the concentration decay curves for Cr(VI) adsorption on activated carbons ($C_0 = 20 \text{ mg/L}$, $T = 25^\circ\text{C}$, activated carbons quantity = 1 g, shaking speed = 150 rpm).

Rys. 1. Wpływ czasu kontaktu na krzywe spadku stężenia dla adsorpcji Cr(VI) na węglach aktywnych ($C_0 = 20 \text{ mg/l}$, $T = 25^\circ\text{C}$, ilość węgla aktywnych = 1 g, prędkość wytrząsania = 150 obr./min).

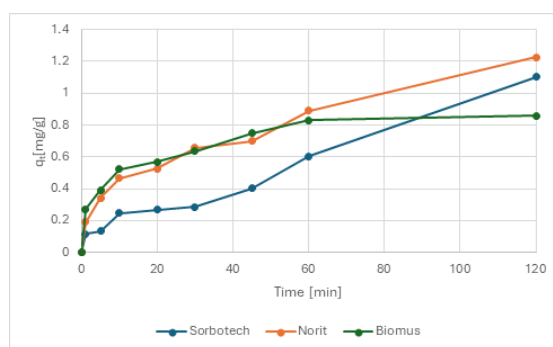


Fig. 2. Effect of contact time value on adsorption capacity of chromium ions for Cr(VI) adsorption on activated carbons ($C_0 = 20 \text{ mg/L}$, $T = 25^\circ\text{C}$, activated carbons quantity = 1 g, shaking speed = 150 rpm).

Rys. 2. Wpływ czasu kontaktu na pojemność adsorpcyjną jonów chromu w przypadku adsorpcji Cr(VI) na węglach aktywnych ($C_0 = 20 \text{ mg/l}$, $T = 25^\circ\text{C}$, ilość węgla aktywnych = 1 g, prędkość wytrząsania = 150 obr./min).

years, highlighting its longstanding significance in water treatment (Cheremisinoff and Angelo, 1980).

Despite these advantages, the application of activated carbon is not without limitations. Its production and regeneration can be costly, and performance is highly dependent on the type and source of the carbon material used (Allen et al., 1998; Gupta, Srivastava and Mohan, 1997). Additionally, activated carbon is generally non-selective and may exhibit reduced efficiency in the presence of hydrophilic substances or certain types of dyes (Crini, 2005). The need for chemical modification to enhance specificity or reusability further complicates its implementation in large-scale operations (Gupta, Park, Sharma, & Mohan, 1999). Consequently, while activated carbon remains a cornerstone in adsorption technologies, ongoing research continues to explore lower-cost and more selective alternatives derived from agricultural or industrial waste products (Babel and Kurniawan, 2003; Pollard et al., 1992; Mui, Ko and McKay, 2004).

The present study describes the influence of several important operational parameters such as shaking speed, activated carbon dosage, initial pH and temperature, and contact time on the adsorption of Cr(VI) from aqueous solutions. In addition, the isotherm of Cr(VI) adsorption on 3 different types of activated carbons was investigated.

2. MATERIALS AND METHODS

2.1. Adsorbents

Three types of activated carbon were used in the study. BIOMUS PYL 22

- Type: Pure, without additives, from deciduous trees.
- Form: Powdered carbon, very finely ground, with a grain size similar to flour.

NORIT 1240

- Type: Lignite-based activated carbon.
- Form: Granular activated carbon (GAC). Compared to coal- and coconut-based carbons, it is lighter in weight (lbs per ft³), has a lower iodine number, and a higher molasses number.

SORBOTECH LGCO

- Type: Coconut-based activated carbon.
- Form: Granular activated carbon (GAC). This type has small and uniform pores, making it useful for the reduction of smaller molecular contaminants.

2.2. Determination of Cr concentration in aqueous solution

Analytical grade potassium dichromate ($\text{K}_2\text{Cr}_2\text{O}_7$) was used as the source of Cr(VI). All aqueous solutions were prepared with deionized water produced by a WG-HLP demineralizer. HLP systems produce water that meets the requirements of the following standards: PN-EN ISO 3696:1999, ASTM, CLSI, and FP VIII. Cr(VI) in aqueous solutions was determined by UV-vis spectrophotometry using a Dr. Lange Cadas 200 spectrophotometer at an absorption wavelength of 540 nm. 1,5-diphenylcarbazide was used as the indicator.

2.3. Adsorption experiments

Each sample was prepared in triplicate to minimize measurement error. After the adsorption process the chromi-

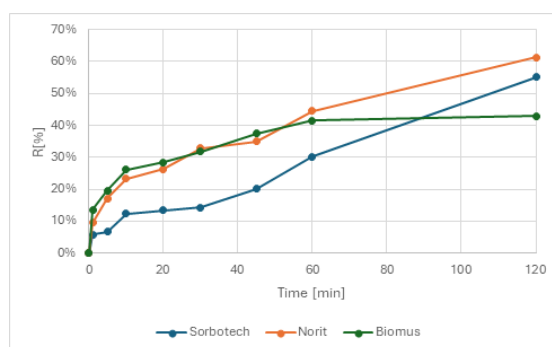


Fig. 3. Effect of contact time value on the percentage removal of chromium ions during Cr(VI) adsorption on activated carbons. ($C_0 = 20 \text{ mg/L}$, $T = 25^\circ\text{C}$, activated carbons quantity = 1 g, shaking speed = 150 rpm).

Rys. 3. Wpływ czasu kontaktu na procent usunięcia jonów chromu podczas adsorpcji Cr(VI) na węglach aktywnych. ($C_0 = 20 \text{ mg/l}$, $T = 25^\circ\text{C}$, ilość węgla aktywnych = 1 g, prędkość wytrząsania = 150 obr./min).

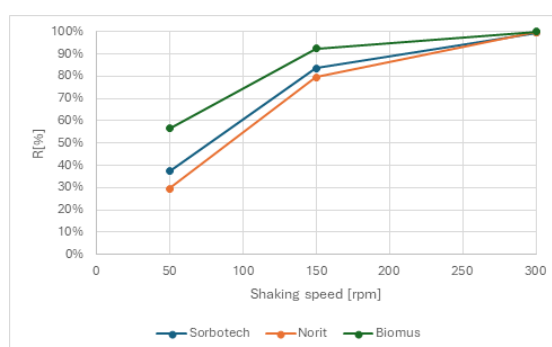


Fig. 4. Effect of shaking speed on the percentage removal of chromium ions during Cr(VI) adsorption on activated carbons ($C_0 = 20 \text{ mg/L}$, $\text{pH}=2,5$, activated carbons quantity = 1 g, $T=25^\circ\text{C}$; $t=1\text{h}$).

Rys. 4. Wpływ szybkości potrząsania na procent usunięcia jonów chromu podczas adsorpcji Cr(VI) na węglach aktywnych ($C_0 = 20 \text{ mg/l}$, $\text{pH}=2,5$, ilość węgla aktywnych = 1 g, $T=25^\circ\text{C}$; $t=1\text{h}$).

um(VI) content in the solutions was measured using a UV-VIS spectrophotometer. The Cr (VI) adsorption capacity (q_t) and percentage removal (R) were calculated by Eq. (1) and Eq. (2) (Wang et al., 2020):

$$q_t = \frac{(C_0 - C_t)V}{m} \left[\frac{\text{mg}}{\text{g}} \right] \quad (1)$$

$$R = \frac{C_0 - C_t}{C_0} \cdot 100[\%] \quad (2)$$

where V is the volume of the solution (dm^3), C_0 and C_t (mg/dm^3) are the concentrations of Cr(VI) at initial and equilibrium in the solution, respectively, and m is the weight of activated carbon used (g).

2.3.1 Effect of contact time

100 mL aqueous solution with a 20 mg/l Cr (VI) concentration was contacted with 1 g of adsorbent in 250 mL Erlenmeyer flasks, which were shaken in an orbital shaker at a constant speed of 150 rpm, temperature 25°C and at a certain time (1, 5, 10, 20, 30, 45, 60 and 120 min).

2.3.2 Effect of shaking speed

To evaluate the effect of shaking speed on adsorption process 1 g of adsorbent was added to a 250 ml Erlenmeyer flask containing 100 mL of aqueous solution with a 20 mg/l Cr (VI) concentration. The flasks were placed for 1 hour in an incubator with a shaker at different shaking speed (50, 150, 300 rpm) at 25°C .

2.3.3 Effect of pH

To evaluate the effect of different pH on adsorption process 1 g of adsorbent was added to a 250 ml Erlenmeyer flask containing 100 mL of aqueous solution with a 20 mg/l Cr (VI) concentration. The assumed pH level (2,5-12) was obtained with 0.1M/1M NaOH solution or 0.1M HCl solution. The flasks were placed in an incubator with a shaker at 25°C and 150 rpm for 1 hour.

In this study pH 2,5 was chosen, considering the higher removal efficiency compared with that at other pH values.

2.3.4 Effect of temperature

100 mL aqueous solution with a 20 mg/l Cr (VI) concentration was contacted with 1 g of adsorbent in 250 mL Erlenmeyer flasks, which were shaken in an orbital shaker at a constant speed of 150 rpm, at a certain time 60 min and different temperatures (25, 40 and 60°C)

2.3.5 Effect of Cr(VI) concentration

100 mL aqueous solution with a different Cr(VI) concentration (20 mg/L, 50 mg/L, 100 mg/L, 200 mg/L and 500 mg/L) was contacted with 1 g of adsorbent in 250 mL Erlenmeyer flasks, which were shaken in an orbital shaker at a constant speed of 150 rpm, temperature 25°C and at a certain time 60 min.

2.3.6 Effect of adsorbent dosage

The test was conducted for activated carbon samples weighing 1, 2, 3, 5, and 10 g. The samples were tested in solu-

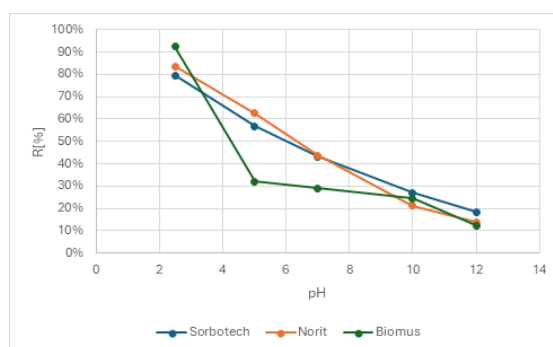


Fig. 5. Effect of pH on percentage removal of chromium ions during Cr(VI) adsorption on activated carbons ($C_0 = 20$ mg/L, $T=25^\circ\text{C}$, activated carbons quantity = 1 g, shaking speed = 150 rpm).

Rys. 5. Wpływ pH na procent usunięcia jonów chromu podczas adsorpcji Cr(VI) na węglach aktywnych ($C_0 = 20$ mg/l, $T=25^\circ\text{C}$, ilość węgla aktywnych = 1 g, prędkość wytrząsania = 150 obr./min).

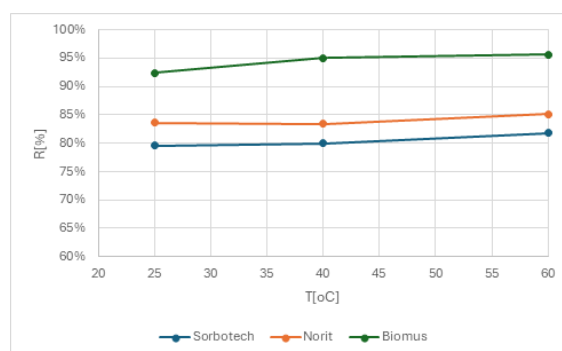


Fig. 6. Effect of temperature on the percentage removal of chromium ions during Cr(VI) adsorption on activated carbons ($C_0 = 20$ mg/L, $\text{pH}=2.5$, activated carbons quantity = 1 g, shaking speed = 150 rpm; $t=1\text{h}$).

Rys. 6. Wpływ temperatury na procent usunięcia jonów chromu podczas adsorpcji Cr(VI) na węglach aktywnych ($C_0 = 20$ mg/l, $\text{pH}=2.5$, ilość węgla aktywnych = 1 g, prędkość wytrząsania = 150 obr./min; $t=1\text{h}$).

tions with a Cr(VI) concentration of 20 mg/L. The appropriate amount of activated carbon was weighed into 250ml Erlenmeyer flasks and then 100 ml of Cr(VI) solution was added. The prepared samples were placed on a shaker for 15 minutes. The time was shortened to obtain comparable and representative results that did not fall below the determination range.

3. RESULTS AND DISCUSSION

3.1 Effect of contact time

Figure 1-3 shows the change in Cr (VI) concentration and adsorption capacity in aqueous solution as a function of adsorption time at 25°C .

It can be seen that all activated carbons, both GAC and PAC, adsorb significant amounts of Cr(VI) ions, and the amount adsorbed at a given concentration varies between carbons. After 120 minutes of shaking, Sorbotech reduces the Cr(VI) concentration to 8.96 mg/L, Norit to 7.75 mg/L and Biomus to 11.40 mg/L. Although Norit ultimately shows the best adsorption capacity after the longest shaking time, Biomus shows significantly better results over a shorter period, which may be beneficial in processes requiring rapid adsorption.

3.2 Effect of shaking speed

Figure 4 shows the change in Cr (VI) concentration in aqueous solution as a function of shaking speed at 25°C .

A higher shaking speed improves the diffusion of Cr(VI) ions into the adsorption sites, which increases the efficiency of the adsorption process. Biomus continued to show the highest adsorption efficiency, but the difference between it and the

other sorbents was no longer as pronounced as at the lower shaking speed. The slight increase in process efficiency for a value of 300rpm led to the shaking speed being set at 150rpm in further experiments. Yang et al. (2020) also observed the effect of shaking speed on the adsorption rate. They found that the adsorption rate increases with increasing shaking speed between 70 and 170 rpm and remains constant when it exceeds 170 rpm. This indicates that external diffusion of the adsorbate into the adsorbent can be ignored.

3.3 Effect of pH

Fig. 5 shows the effect of pH on the adsorption process of Cr(VI) ions by activated carbons.

As can be seen from Fig. 5, the removal of Cr(VI) from aqueous solution is highly dependent on the pH value, with maximum adsorption occurring when the pH value is 2.5. This impact is due to the fact that Cr(VI) occurs in various forms in aqueous solutions, and the stability of these species, such as CrO_4^{2-} , HCrO_4^- , or $\text{Cr}_2\text{O}_7^{2-}$, depends on the solution pH. In the pH range of 2.0–6.0, HCrO_4^- and $\text{Cr}_2\text{O}_7^{2-}$ are the dominant species in equilibrium, gradually shifting towards the chromate ion (CrO_4^{2-}) as pH increases. The chromate ion (CrO_4^{2-}) requires two active adsorption sites due to its double negative charge, whereas HCrO_4^- and $\text{Cr}_2\text{O}_7^{2-}$ typically occupy only one active site. Therefore, the adsorption capacity of Cr(VI) increases as the pH decreases, primarily because of the higher proportion of HCrO_4^- formed at the expense of CrO_4^{2-} . Additionally, at higher pH values, the reduction in adsorption capacity may result from competition between chromate and

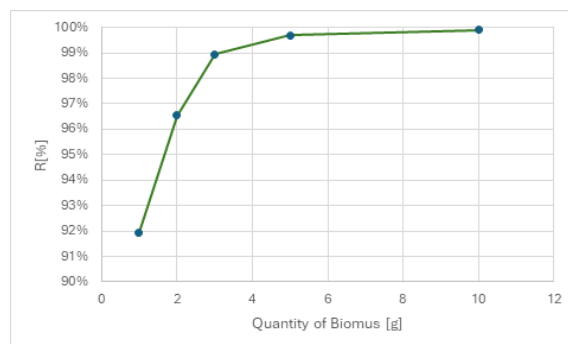


Fig. 7. Effect of quantity of Biomus on the percentage removal of chromium ions during Cr(VI) adsorption on activated carbons ($C_0 = 20 \text{ mg/L}$, $\text{pH}=2,5$, shaking speed = 150 rpm; $T=25^\circ\text{C}$; $t=1\text{h}$).

Rys. 7. Wpływ ilości Biomusu na procent usunięcia jonów chromu podczas adsorpcji Cr(VI) na węglach aktywnych ($C_0 = 20 \text{ mg/l}$, $\text{pH}=2,5$, prędkość wytrząsania = 150 obr./min; $T=25^\circ\text{C}$; $t=1\text{h}$).

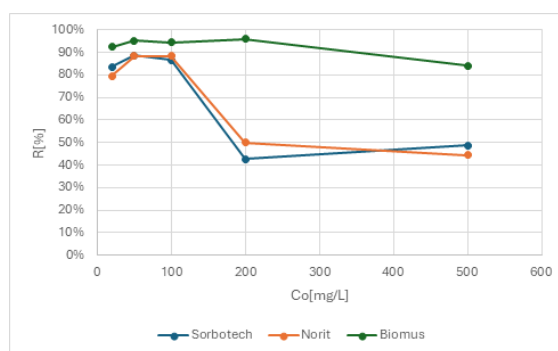


Fig. 8. Effect of concentration on the percentage removal of chromium ions during Cr(VI) adsorption on activated carbons ($\text{pH}=2,5$, activated carbons quantity = 1 g, shaking speed = 150 rpm; $t=1\text{h}$; $T=25^\circ\text{C}$).

Rys. 8. Wpływ stężenia na procent usunięcia jonów chromu podczas adsorpcji Cr(VI) na węglach aktywnych ($\text{pH}=2,5$, ilość węgla aktywnych = 1 g, prędkość wytrząsania = 150 obr./min; $t=1\text{h}$; $T=25^\circ\text{C}$).

Tab. 1. Langmuir and Freundlich isotherm models parameters

Tab. 1. Parametry modeli izoterm Langmuira i Freundlicha

Adsorbent	Langmuir		Freundlich	
	Q_m	K_a	K_F	n
Sorbotech	23,95	0,0169	1,55	1,58
Norit	24,18	0,0185	1,52	1,61
Biomus	58,88	0,0326	2,26	1,57

hydroxyl ions for active sites (Yang et al. 2020). Based on these observations, an initial pH of 2,5 was chosen as the optimum condition for Cr(VI) adsorption in all subsequent experiments. Previous studies also have shown a strong dependence of Cr(VI) adsorption on activated carbons on the initial pH of the aqueous solution (Wang et al., 2020; Yang et al. 2020; El-Sikaily et al., 2007).

3.4 Effect of temperature

Based on the fact that temperature affects all adsorption processes (Wang et al., 2020), its effect on Cr(VI) adsorption at temperatures of 25, 40 and 60°C and pH 3.5 was evaluated. Figure 6 shows final concentration of Cr(VI) after 1h of adsorption process for three different temperatures.

Analysis of the obtained data indicates that the efficiency of Cr(VI) adsorption by Sorbotech, Norit and Biomus sorbent is temperature-dependent. An increase in temperature increases the mobility of molecules and the kinetics of sorption reactions, leading to faster diffusion of Cr(VI) ions to the sorbent surface. Biomus sorbent showed the highest efficiency over the entire temperature range, suggesting its high efficiency in Cr(VI) removal regardless of temperature conditions. Sorbotech and Norit also showed improved performance with

increasing temperature, but were less effective than the Biomus sorbent. Given the small differences in values, it was decided to conduct further processes at 25°C .

3.5 Effect of adsorbent dosage

Figure 7 shows the change in Cr (VI) concentration in aqueous solution as a effect of activated carbon dosage at 25°C .

Analysis of the data indicates that the efficiency of Cr(VI) adsorption by the Biomus sorbent is strongly dependent on the dosage of sorbent used. An increase in the amount of sorbent increases the availability of adsorption sites, leading to a larger contact area and more efficient adsorption of Cr(VI) ions. In the case of Biomus, even with a relatively low sorbent mass, it achieves a high removal efficiency of Cr(VI) ions from solution, which demonstrates its high adsorption capacity.

3.6 Effect of Cr(VI) concentration

Figure 8 shows the change in Cr (VI) concentration in aqueous solution as a effect of initial Cr(VI) concentration at 25°C .

The study showed that an increase in the initial sorbate concentration results in a more pronounced difference in ef-

iciency between the sorbents, which may be due to the different adsorption capacity and specific surface properties of each sorbent.

3.7 Adsorption isotherm

Adsorption isotherms are important for the description of how adsorbate will interact with an adsorbent and are critical in optimizing the use of adsorbent. Equilibrium studies in adsorption give the capacity of the adsorbent. It is described by adsorption isotherm characterized by certain constants whose values express the surface properties and affinity of the adsorbent. Equilibrium relationships between adsorbent and adsorbate are described by adsorption isotherms, usually the ratio between the quantity adsorbed and that remaining in the solution at a fixed temperature at equilibrium. In order to investigate the adsorption isotherm, two equilibrium models were analyzed.

3.7.1. Langmuir isotherm model

The Langmuir equation may be written as (El-Sikaily et al., 2007):

$$q_e = \frac{Q_m K_a C_e}{1 + K_a C_e} \quad (3)$$

The above equation can be rearranged to the following four linear forms:

$$\frac{C_e}{q_e} = \frac{1}{K_a Q_m} + \frac{1}{Q_m} C_e \quad (4)$$

$$\frac{1}{q_e} = \frac{1}{K_a Q_m} \frac{1}{C_e} + \frac{1}{Q_m} \quad (5)$$

$$q_e = Q_m - \left(\frac{1}{K_a}\right) \frac{q_e}{C_e} \quad (6)$$

$$\frac{q_e}{C_e} = K_a Q_m - K_a q_e \quad (7)$$

where C_e is the equilibrium concentration (mg/L); q_e the amount of metal ion sorbed (mg/g); Q_m the q_e for a complete monolayer (mg/g); K_a is the sorption equilibrium constant (L/mg).

3.7.2. Freundlich isotherm model

The Freundlich equation may be written as (El-Sikaily et al., 2007):

$$q_e = K_F C_e^{1/n} \quad (8)$$

The equation is conveniently used in the linear form by taking the logarithm of both sides as:

$$\log q_e = \log K_F + \frac{1}{n} \log C_e \quad (9)$$

The constants K_F and $1/n$ of the Freundlich model are the constants indicative of the relative adsorption capacity of the adsorbent (mg g⁻¹) and the constant indicative of the intensity of the adsorption, respectively.

The Langmuir model describes Norit and Biomus better (higher R^2), indicating a monolayer adsorption process and a finite number of adsorption sites.

The Freundlich model is slightly better for the Sorbotech, which may suggest a more heterogeneous surface or complex interactions in this concentration range.

The n values in all cases are >1 , confirming the favourable adsorption in the Freundlich model.

4. CONCLUSIONS

Activated carbons are materials with a very broad spectrum of applications. When analyzing the results obtained, it is evident that powdered activated carbon (PAC) is significantly more effective at purifying aqueous solutions containing chromium(VI) than granular activated carbon (GAC). Interestingly, the higher effectiveness of Biomus activated carbon is observed primarily under optimal or near-optimal conditions for each of the analyzed materials, particularly when assessing the effect of individual parameters. Under conditions deviating from the optimum, Biomus activated carbon does not consistently demonstrate the highest chromium(VI) adsorption efficiency—for instance, at neutral or alkaline pH, where it achieved even lower efficiencies than other sorbents. Analyses conducted under different conditions, such as reduced temperatures below room temperature, may yield similar findings.

In each of the analyzed cases, it was possible to determine optimal conditions for conducting the purification processes or, at the very least, to outline a direction toward achieving higher efficiencies in the removal of chromium(VI) ions from aqueous solutions. Based on the results, the optimal pH for the purification process among the tested variants was found to be pH = 2. The analysis of the obtained results indicates that lowering the pH creates favorable conditions for adsorption. The optimal temperature appears to be in the range of 40–60 °C or higher; however, no significant improvement in chromium(VI) ion removal efficiency was observed with increasing temperature. This suggests that room temperature or slightly elevated temperatures may be sufficient for practical applications while still maintaining high purification efficiency.

A significant influence of the sorbent batch size on the efficiency of chromium(VI) removal from solution was observed. These findings provide a foundation for developing optimal technological conditions that also account for economic factors such as cost-effectiveness and the minimum required amount of activated carbon for industrial wastewater treatment.

Additionally, the shaking speed—and thus the dynamics of the process—was shown to have a strong effect. The higher the shaking speed, the more effective the purification. In practice, when other parameters are properly optimized, shaking speed may not be a dominant factor, but the results clearly demonstrate a strong correlation between shaking speed and purification efficiency.

The activated carbons analyzed also performed well under increasing initial chromium concentrations. Granular activated carbons achieved up to 50% removal efficiency at higher concentrations, whereas powdered activated carbon maintained removal efficiencies of 80–90%. It is worth noting that a 1 g sample was used in these experiments. The results suggest that increasing the sorbent dosage would likely result in significantly improved performance, approximately in a linear relationship. These observations justify further investigation to optimize the sorption process.

Under appropriate conditions, a contact time of 15–30 minutes is sufficient to achieve satisfactory chromium(VI) removal.

By selecting suitable values for pH, sorbent dose, and shaking speed, it is possible to reduce chromium concentrations to levels that comply with regulatory standards for drinking water, surface waters (Classes I–III), and wastewater discharged into water bodies, soil, and sewage systems. The results strongly indicate that powdered activated carbon is the most effective

sorbent for chromium(VI) ions. However, it has notable disadvantages—PAC is difficult to completely remove from treated water, particularly in the case of fine particles. Moreover, it is cumbersome to use due to its tendency to cause pressure drops (a result of high flow resistance), and it cannot be regenerated, primarily due to the small particle size.

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Adsorbenty do wychwytywania Cr(VI) z zanieczyszczonej wody: Część I Węgiel aktywowany

Chrom w formie sześciowartościowej (Cr(VI)) stanowi poważne zagrożenie dla środowiska i zdrowia ludzkiego ze względu na swoją toksyczność, ruchliwość i zdolność do bioakumulacji. W niniejszym artykule przedstawiono badanie usuwania Cr(VI) z roztworów wodnych przy użyciu trzech rodzajów węgla aktywnego: BIOMUS PYL 22 (PAC), NORIT 1240 (GAC) i SORBOTECH LGCO (GAC). Przeanalizowano wpływ kluczowych parametrów procesu, takich jak czas kontaktu, szybkość mieszania, pH, temperatura, początkowe stężenie Cr(VI) i dawka sorbentu, na wydajność adsorpcji. Wyniki wskazują, że sproszkowany węgiel aktywny (PAC) wykazuje najwyższą wydajność usuwania Cr(VI), sięgającą 80–90% w optymalnych warunkach. Adsorpcja Cr(VI) jest najskuteczniejsza w kwaśnym pH (~2) i podwyższonej temperaturze (40–60°C), chociaż wysoką wydajność usuwania osiągnięto również w temperaturze pokojowej. Modele izoterm Langmuira i Freundlicha potwierdzają korzystny charakter procesu adsorpcji. Wyniki te stanowią podstawę do projektowania wydajnych i ekonomicznie opłacalnych procesów usuwania Cr(VI) ze ścieków przemysłowych.

Słowa kluczowe: węgiel aktywny, modele izoterm Langmuira i Freundlicha