

# Utilization of Sugarcane Bagasse Activated Carbon As An Adsorbent for The Reduction of COD and Total Chromium in Tannery Wastewater Treatment

Priska Valeria Putrisuri<sup>1\*</sup>, Candra Dwiratna W<sup>2</sup>, Sudiro<sup>3</sup>

<sup>1,2,3</sup> Faculty of Civil Engineering and Planning, Malang National Institute of Technology, Malang, East Java.

\* Corresponding Author:

Email: [riskasuri14@gmail.com](mailto:riskasuri14@gmail.com)

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## Abstract.

*The leather tanning industry is a sector that processes raw hides into tanned leather using specific tanning agents and has the potential to degrade water quality due to the high concentration of organic substances, indicating that organic compounds in tannery wastewater are difficult to degrade and that heavy metal contamination is present in the effluent, particularly chromium (Cr). This study aims to determine the capability of sugarcane bagasse activated carbon in reducing COD and total chromium concentrations and to evaluate the effectiveness of adsorbent mass and contact time in reducing COD and total chromium in tannery wastewater using pre-sedimentation and adsorption methods. The study employed adsorbent mass variations of 10 g and 15 g and contact times of 90 and 150 minutes. The results showed that the sedimentation and adsorption processes reduced COD concentration by 579 mg/L (82.13%) and total chromium by 20.02% (81.74%); however, these reductions did not meet the established wastewater quality standards.*

**Keywords:** Adsorption; Tannery Wastewater; Activated Carbon and Sugarcane Bagasse.

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## I. INTRODUCTION

According to the Regulation of the Minister of Environment of the Republic of Indonesia Number 5 of 2014 concerning Wastewater Quality Standards, wastewater is defined as liquid waste resulting from an activity or business process. Wastewater, or effluent, is discharged from various sources such as households, industries, and public facilities, and generally contains substances or materials that have the potential to harm human health and cause environmental disturbances [1]. According to [2], the leather tanning industry is a sector that processes raw hides into tanned leather using specific tanning agents. Finished leather is obtained from animal hides that have undergone tanning after the removal of hair, connective tissue, and residual flesh. The tanning process requires the use of chemicals and large volumes of water, thereby generating liquid waste containing organic compounds from the hides as well as residues of chemicals used during the process [3]. This problem arises from the utilization of animal hides and the dependence on various chemicals in the production process, such as dyes, salts, tannins, oils, lime, biocides, enzymes, chromium sulfate, acids, and solvents for finishing. Only about 20% of these chemicals are absorbed by the hides during tanning, while the remainder is discharged with the wastewater [4]. The leather tanning industry has the potential to reduce water quality due to the high concentration of organic compounds, which are difficult to degrade [5], as well as heavy metal pollution in its effluent. One of the major heavy metals present in this wastewater is chromium (Cr).

Heavy metal pollution is a global environmental issue because these metals can accumulate in the food chain, causing disruptions to ecosystems and human health [6]. One of the effective wastewater treatment techniques for reducing heavy metal and organic content is adsorption. Adsorption uses a material (adsorbent) to capture and bind heavy metals present in wastewater [7]. This method can help mitigate increasing heavy metal pollution due to several advantages, including relatively low cost, simplicity, high effectiveness and efficiency, and no production of toxic by-products [8]. In water treatment, activated carbon functions to remove odors, color, and pollutants, thereby improving water quality and making it suitable for clean water sources [9]. To enhance its ability to remove heavy metal ions, an activation process is commonly applied to increase the number of oxygen-containing functional groups. Chemicals frequently used as activators include KOH [10]. Different activators produce variations in the material's surface area, as each has a unique activation mechanism. In a study comparing NaOH, KOH, and H<sub>3</sub>PO<sub>4</sub>, chemical activation

increased the carbon surface area from 4.0841 to 218.8230 m<sup>2</sup>/g. Activation using KOH produced optimal conditions, with micropores comprising 83% of the total surface area [11]. Bagasse contains approximately 90% organic material, making it a potential raw material for activated carbon production. It contains compounds such as cellulose, hemicellulose, lignin, and pectin, making bagasse suitable as a raw material for activated carbon production [12].

Additionally, bagasse has a relatively low moisture content, supporting efficient drying before the activation stage [13]. Bagasse is considered an alternative because it is abundantly available, is a low-cost industrial waste, and has high development potential [14]. The use of bagasse as an adsorbent activated with KOH has been applied to reduce iron and manganese concentrations in acid mine drainage. According to [15], this method achieved a reduction of Chemical Oxygen Demand (COD) by 95.37%. Nailongan, 2023 reported that experimental adsorption using bagasse as an adsorbent efficiently removed chromium, with an average reduction of 82%, from an initial concentration of 1 mg/L to 0.18 mg/L. Therefore, bagasse can be used as an adsorbent to reduce both organic compounds and heavy metals. Based on the data above, this research is important to conduct. COD and total chromium (Cr) are common parameters found in wastewater from the leather tanning industry. Analysis of wastewater quality from leather tanning shows COD values of 2977 mg/L and total chromium of 5028 mg/L [17], exceeding the quality standards set by the Regulation of the Minister of Environment of the Republic of Indonesia Number 5 of 2014, which stipulates COD at 110 mg/L and total chromium at 0.60 mg/L. Therefore, it is expected that using activated carbon from bagasse as an adsorbent in wastewater treatment can reduce the potential for environmental pollution.

## II. METHODS

This experimental laboratory-scale study aimed to evaluate the effectiveness of bagasse-derived activated carbon in reducing Chemical Oxygen Demand (COD) and total chromium (Cr) in leather tanning wastewater. The study was conducted at the Mechanical Engineering and Environmental Engineering laboratories of ITN Malang, using wastewater samples collected from a leather tanning industry, PT. X, in Malang Regency, Indonesia. The main equipment included furnaces, ovens, hotplate stirrers/shakers, 100-mesh sieves, atomic absorption spectrometers (AAS), and standard laboratory glassware. Activated carbon was prepared from sugarcane bagasse by cutting, washing, and sun-drying for five days to reduce moisture content, followed by carbonization at 450°C for 2 hours. The carbonized material was sieved through a 100-mesh screen and chemically activated with 1 M KOH at a 1:7.5 ratio, stirred at 150 rpm and 80°C for 4 hours, left to stand for 24 hours, washed with 0.1 M HCl and distilled water until neutral pH, and dried at 115°C for 4 hours.

Characterization was performed using Fourier Transform Infrared Spectroscopy (FTIR) to qualitatively identify functional groups and chemical bonds (ASTM-E1252). Wastewater samples were collected following SNI 6989.59:2008 using grab sampling between 08:00 and 15:00 WIB, with a volume of 10 L, and pre-sedimented for 100 minutes to reduce turbidity, TDS, and TSS. Adsorption experiments were carried out using 250 mL of wastewater with varying activated carbon doses (10 g and 15 g) and contact times (90 and 150 minutes). Synthetic chromium solutions (370 mg/L) were also used to evaluate Cr removal. Samples were stirred at 100 rpm until homogeneous, filtered, and analyzed. COD was measured using closed reflux titrimetry (SNI 6989.15:2019), and total chromium was determined by Atomic Absorption Spectrophotometry (SNI 6989.17:2009). Data were analyzed using descriptive statistics to summarize results and two-way ANOVA to evaluate the effects of activated carbon mass and contact time on COD and Cr total removal. The research process followed a structured workflow to ensure methodological consistency and reproducibility.

## III. RESULT AND DISCUSSION

### Initial Characteristics of Tanning Wastewater

The leather tanning wastewater used in this study, generated from chromium-based tanning and dyeing of raw hides, was black, turbid, and odorous. Grab sampling was conducted between 09:00 and 11:00 WIB at the outlet of the equalization tank, following SNI 6989.59:2008. Samples were stored in plastic

jerrycans and initially analyzed. Pre-sedimentation for 100 minutes reduced COD by 21.71%, as longer settling promoted flocculation and organic matter removal, while total chromium (Cr) showed no significant change. The initial wastewater characteristics are summarized in the table below:

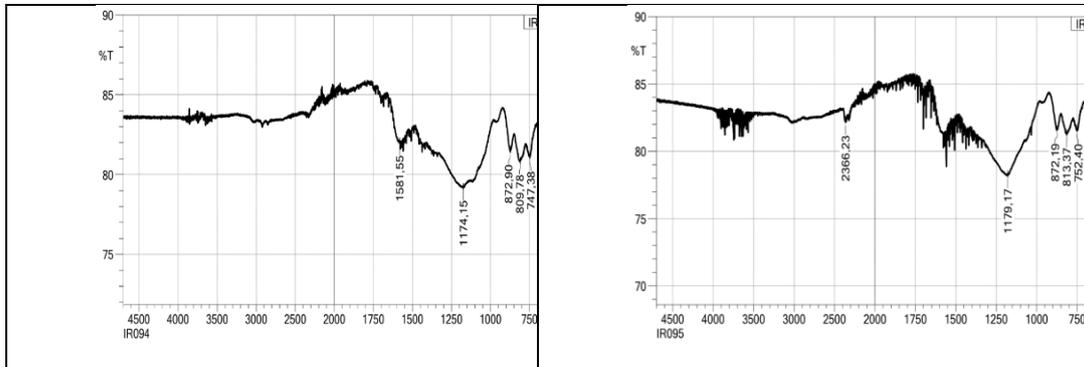
**Table 1.** Characteristics of Liquid Waste from the Leather Tanning Industry

No.	Parameter	Initial Concentration*	Wastewater Quality Standards **
1.	COD	3241 mg/L	110 mg/L
2.	Cr Total	109,67 mg/L	0,60 mg/L

Based on laboratory analysis conducted by the Environmental Engineering Laboratory of ITN Malang (2026), the wastewater from the leather tanning industry exceeded the regulatory limits for COD and total chromium (Cr), failing to meet the quality standards set by the Indonesian Minister of Environment Regulation No. 5 of 2014, Annex II, which stipulates a maximum COD of 110 mg/L and Cr total of 0.60 mg/L.

**FTIR Functional Groups**

Functional group identification was conducted on bagasse-based activated carbon by comparing Fourier Transform Infrared Spectroscopy (FTIR) results before and after activation with 1 M KOH to determine its chemical composition. The analysis produced infrared spectra illustrating the functional groups present in the bagasse adsorbent, as shown in the figure below:



**Fig 1.** Results of FTIR test of Bagasse Activated Carbon before activation (left) and FTIR test of Bagasse Activated Carbon after activation (right)

Based on the FTIR analysis shown in Figure 4.1, the relationship between the wavenumber (X-axis) and transmittance (Y-axis) can be observed. The activation process aims to enlarge the pores formed during carbonization and create new pores within the carbon structure. Figure 4.1 compares the FTIR spectra of sugarcane bagasse activated carbon before (left) and after activation (right), with detailed results presented in Tables 2 and 3

**Table 2.** FTIR Test Results on Sugarcane Bagasse Activated Carbon Before Activation

No.	Wavenumber (Cm-1)	Functional Group	Intensity
1.	1581,55	C = C Aromatik	82,04
2.	1174,15	C - O	79,22
3.	872,90	C – H Alkena	81,48
4.	809,78	C- H Alkena	80,87
5.	747,38	C-H Aromatik	81,09

Source: Research Results, 2026

Table 2 presents all absorption peaks and their intensities from the infrared spectrum, which is divided into four main regions: single bond stretches (4000–2500 cm<sup>-1</sup>), triple bonds (2500–2000 cm<sup>-1</sup>), double bonds (2000–1500 cm<sup>-1</sup>), and the fingerprint region (skeletal vibrations, 2000–1500 cm<sup>-1</sup>). Each compound exhibits characteristic absorptions in these regions. The spectrum revealed peaks at 1581.55 cm<sup>-1</sup> corresponding to aromatic C=C, 1174.15 cm<sup>-1</sup> to C–O–C, 872.90–809.78 cm<sup>-1</sup> to alkenic C–H, and 747.38 cm<sup>-1</sup> to aromatic C–H, indicating the presence of aromatic structures typical of lignin [18].

**Table 3.** FTIR Test Results on Sugarcane Bagasse Activated Carbon After Activation

No.	Wavenumber (Cm-1)	Functional Group	Intensity
1.	2366,23	C - H Bending	82,19

No.	Wavenumber (Cm-1)	Functional Group	Intensity
2.	1179,17	C - O	78,24
3.	872,19	C -H Alkena	81,61
4.	813,37	C-H Alkena	81,28
5.	752,40	C-H Aromatik	81,56

Source: Research Results, 2026

Based on the FTIR analysis (Figure 1, right; Table 3), the KOH-activated carbon exhibited functional groups indicative of chemical surface modifications. The spectrum showed C-H bending from hydrocarbon fragments at 2366.23 cm<sup>-1</sup>, C-O functional groups at 1179.17 cm<sup>-1</sup>, C-H alkene groups between 872.19–813.37 cm<sup>-1</sup>, and aromatic C-H groups at 752.4 cm<sup>-1</sup>. These functional groups act as active sites that contribute to the adsorption process [19].

**Descriptive Analysis.**

**COD Descriptive Analysis**

**Table 4.** COD Measurement Test Results

No.	Initial Concentration (mg/L)	Adsorbent Mass (gr)	Contact Time(minutes)	COD			Average
				Testing			
				1	2	3	
1.	3241 mg/L	10 gr	90 minutes	1034	1056	1012	1034
2.	3241 mg/L		150 minutes	748	726	704	726
3.	3241 mg/L	15 gr	90 minutes	792	748	770	770
4.	3241 mg/L	15 gr	150 minutes	572	550	616	579

Source: Research Results, 2026

The mean value was calculated from three replicates for each test. To ensure the replicates were suitable for averaging, the standard deviation (SD) was determined using the sample standard deviation formula. SD was considered acceptable if it was smaller than the mean, and unacceptable if it exceeded the mean, indicating high variability in the measurements.

$$SD = \sqrt{\frac{\sum(xi - \bar{x})^2}{n - 1}}$$

The standard deviation (SD) was calculated to assess the variability of the test results. Using the formula  $SD = \sqrt{[\sum(x_i - \bar{x})^2 / (n - 1)]}$ , where  $x_i$  represents each test value,  $\bar{x}$  is the mean, and  $n$  is the number of repetitions (3 in this study), an example calculation was performed as  $SD = \sqrt{(968 / (3 - 1))} = \sqrt{484}$ , resulting in a standard deviation of 22. Subsequent calculations followed the same procedure to determine the variability of other measurements.

**Table 5.** Standard Deviation Test Results

No.	Adsorbent Mass (gr)	Contact Time (minutes)	COD			Average	SD	Average SD
			Testing					
			1	2	3			
1.	10 gr	90	1034	1056	1012	1034	22	1034 ± 22
		150	748	704	726	726	22	726 ± 22
2.	15 gr	90	792	748	770	770	22	770 ± 22
		150	572	550	616	579	33,60	579 ± 33,60

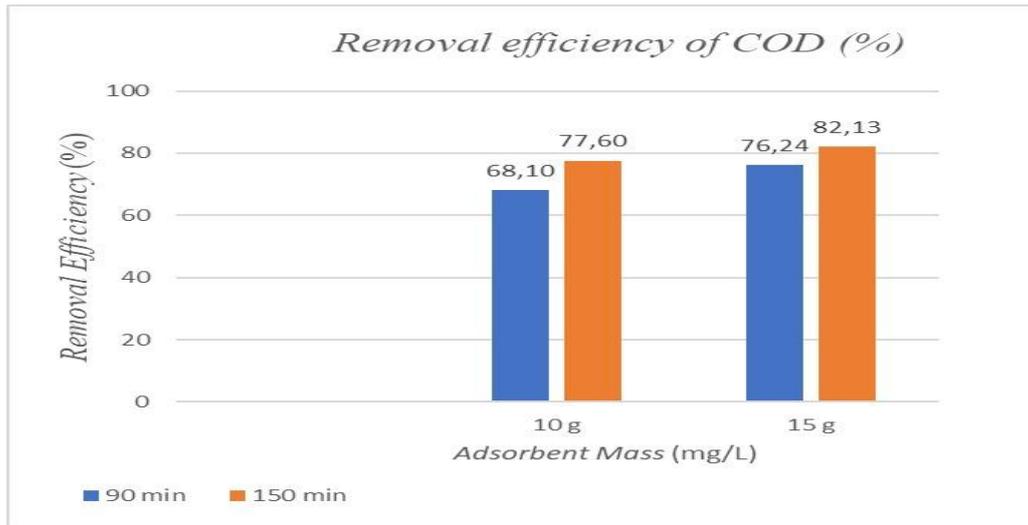
Source: Research Results, 2026

Based on the data in Table 5, the standard deviation was 22 mg/L, while the mean was 1034 mg/L, indicating that the variability is small compared to the average, and the measurements are consistent and suitable for averaging. After treatment, the COD concentration was analyzed, showing a removal efficiency of 68.10% for the example calculation. Further results are presented in the corresponding table

**Table 6.** COD Elimination Percentage

No.	Adsorbent Mass (gr)	Contact Time (minutes)	Initial Concentration (mg/L)	Final Concentration (mg/L)	Presentation (%)
1.	10 gr	90	3241	1034	68,10
		150		726	77,60
2.	15 gr	90	3241	770	76,24
		150		579	82,13

Source: Research Results, 2026



**Fig 2. COD Allowance Percentage**

Based on Table 6 and Figure 2, the lowest COD removal of 68.10% (1034 mg/L) occurred with 10 g of adsorbent at 90 minutes (blue bar), while the highest removal of 83.71% (579 mg/L) was achieved with 15 g of adsorbent at 150 minutes (orange bar).

**Descriptive Analysis of Total Cr**

Based on the research results, the concentration of Total Cr was shown. The results of the Total Cr test can be seen in the following table.

**Table 7. Results of Total Cr Measurement Test**

No.	Initial Concentration (mg/L)	Adsorbent Mass	Contact Time (minutes)	Cr Total			Average
				Repetition			
				1	2	3	
1.	109,67 mg/L	10 gr	90	27,62	27,34	27,46	27,47
			150	22,38	22,38	22,30	22,42
15 gr		90	24,48	24,36	24,60	24,48	
		150	20,00	21,15	19,92	20,02	

Source: Research Results, 2026

The average values were obtained from three repeated measurements, and data reliability was assessed using sample standard deviation. A standard deviation smaller than the mean indicates good precision, while a larger value suggests low precision. In this study, the calculated standard deviation showed that the data were precise and reliable

**Table 8. Results of the Total Cr Standard Deviation Test**

No.	Adsorbent Mass (gr)	Contact Time (minutes)	Cr Total			Average	SD	Average SD
			Testing					
			1	2	3			
1.	10 gr	90	27,62	27,34	27,46	27,47	0,139	27,47±0,139
		150	22,38	22,38	22,30	22,42	0,119	22,42±0,143
2.	15 gr	90	24,48	24,36	24,60	24,48	0,143	24,48±0,119
		150	20,00	21,15	19,92	20,02	1,121	20,02±0,121

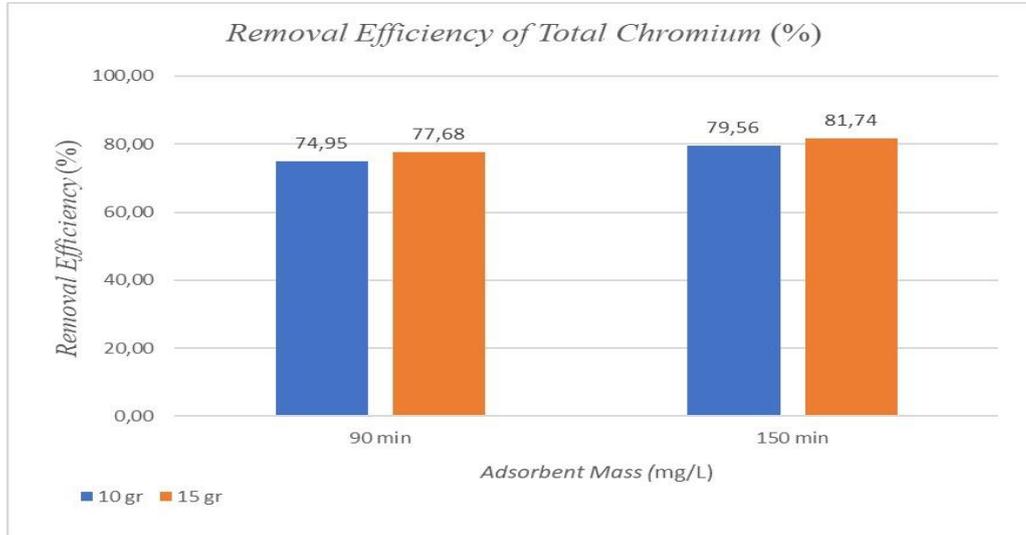
Source: Research Results, 2026

The standard deviation of the data was 0.139, while the mean value was 27.47 mg/L, indicating that the data were consistent and suitable for averaging, as was the case for other variables. After treatment, total chromium (Cr) concentrations were analyzed to determine the removal efficiency, with the results showing a Cr removal of 74.95%, demonstrating the effectiveness of the treatment process

**Table 9.** Percentage of Total Cr Removal

No.	Adsorbent Mass (gr)	Contact Time (minutes)	Initial Concentration (mg/L)	Final Concentration (mg/L)	Presentation (%)
1.	10 gr	90	109,67	27,40	74,95
		150		19,74	79,56
2.	15 gr	90	109,67	25,08	77,68
		150		20,02	81,74

Source: Research Results, 2026



**Fig 3. Percentage of Total Cr Allowance**

Based on Table 9 and Figure 3, the lowest total chromium (Cr) removal of 74.95% (27.47 mg/L) occurred with 10 g of adsorbent at 90 minutes, while the highest removal of 81.74% (20.02 mg/L) was achieved with 15 g of adsorbent at 150 minutes.

**Mass Balance of Processing Process**

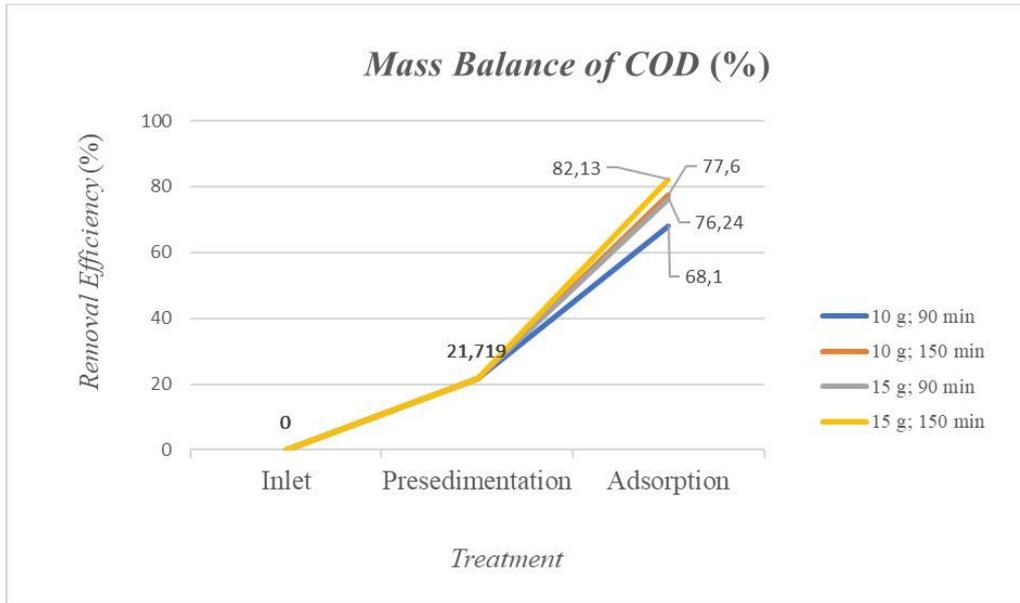
A mass balance is a comprehensive calculation/total amount of raw materials in a production process. (Falah et al., 2025). The pre-sedimentation and adsorption processing processes can be seen in the following mass balance.

**Table 10.** Mass Balance of Processing Process

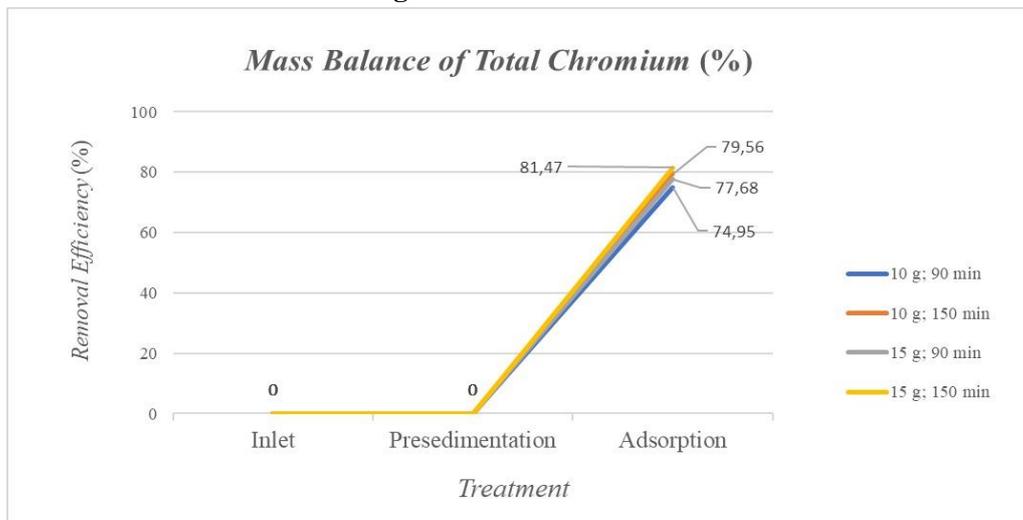
Wastewater Parameters (mg/L)	Research variable		Mass Balance of Planned Waste Processing Unit						Fulfil	
			Pre- sedimentation			Adsorption				Quality standards (mg/L)
	Mass (gr)	Time (minutes)	Inlet (mg/L)	Outlet (mg/L)	%	Inlet (mg/L)	Outlet (mg/L)	%		
COD	10	90	3241	2537	21,719	2573	1034	68,10	110	No
	10	150					726	77,60		No
	15	90					770	76,24		No
	15	150					579	82,13		No
Cr total	10	90	109,67	109,67	-	109,67	27,47	74,95	0,60	No
	10	150					22,42	79,56		No
	15	90					24,48	77,68		No
	15	150					20,02	81,47		No

Source: Calculation Results, 2026

Based on the mass balance results in Table 10 for the pre-sedimentation unit, COD showed a reduction between the inlet and outlet, indicating that pre-sedimentation can remove some easily settleable organic compounds and suspended solids. In contrast, total chromium (Cr) concentrations did not decrease, suggesting that most chromium remained dissolved and was unaffected by physical settling. Subsequent adsorption significantly improved removal efficiency, particularly with higher adsorbent mass and longer contact time, increasing overall treatment efficiency; however, neither process alone met the required quality standards. Mass balance graphs were used to clearly illustrate the changes at each process unit.



**Fig 4.** COD Mass Balance



**Fig 5.** COD Mass Balance

Based on Chart 4 and 5, COD and total chromium (Cr) removal were 0% at the inlet. After pre-sedimentation, COD decreased by 21.72%, while Cr showed no change, indicating that pre-sedimentation is more effective at removing organic compounds than chromium. During the adsorption stage, removal efficiencies increased, with COD ranging from 68.1% to 82.13% and Cr total from 74.95% to 81.74%. The highest removal was achieved with 15 g of adsorbent at 150 minutes, while the lowest occurred with smaller adsorbent mass and shorter contact time.

**Statistical Analysis**

**Two-Way ANOVA Analysis of COD**

Normality and homogeneity tests were conducted as preliminary steps to ensure that the data met the assumptions required for further statistical analysis. The normality test for COD, shown in Figure 2, indicated a significance value (Sig.) of 0.251, which is greater than 0.05, confirming that the data were

normally distributed. The homogeneity test, presented in Figure 3, yielded a Sig. value of 0.768, also greater than 0.05, indicating that the data were homogeneous. These results validated the assumptions needed to perform a two-way ANOVA to assess the effects of adsorbent mass and contact time on COD reduction. The two-way ANOVA results (Figure 4) showed that both contact time (Sig. = 0.001) and adsorbent mass (Sig. = 0.001) had a significant effect on COD removal, and their interaction was also significant (Sig. = 0.004). Post-hoc analysis using the Tukey HSD test (Figure 5) indicated that the combination of 15 g of adsorbent with 150 minutes contact time resulted in the highest COD reduction. Treatments of 150 minutes; 10 g and 90 minutes; 15 g were grouped in the same subset, showing no significant difference, whereas 90 minutes; 10 g produced the highest COD value and was significantly different from the other treatments

#### **Two-Way ANOVA Analysis of Total Cr**

Normality and homogeneity tests were conducted to ensure the validity of the data prior to statistical analysis. The normality test showed a significance value of 0.078, greater than 0.05, indicating that all research data were normally distributed and suitable for further analysis. The homogeneity test yielded a significance value of 0.958, also greater than 0.05, confirming that the data were homogeneous and met the assumptions required for Two-Way ANOVA. Two-Way ANOVA results indicated that both contact time and adsorbent mass significantly affected total chromium (Cr) removal, with significance values of 0.001 for each factor, and 0.004 for their interaction (all < 0.05), demonstrating that these variables independently and jointly influence Cr reduction during adsorption. Subsequent Tukey HSD tests showed that all combinations of contact time and adsorbent mass belonged to different subsets, confirming that each treatment had a significantly different effect on Cr concentration. The lowest Cr total was observed with 15 g of adsorbent and 150 minutes of contact time, indicating the most optimal adsorption condition.

#### **Discussion**

##### **The Effect of Mass and Contact Time on COD**

The results of this study indicate that the adsorption process using bagasse-derived activated carbon effectively reduced COD concentrations in leather tanning wastewater. COD removal increased with higher adsorbent mass and longer contact time, with the highest efficiency achieved at 15 g of activated carbon and 150 minutes, reducing COD from 3241 mg/L to 579 mg/L (82.13%) [20], [21]. Pre-sedimentation was effective in partially reducing COD by 21.72% through the gravitational settling of suspended solids, thereby lowering the organic load [22]. Smaller particle sizes and chemical activation using KOH further enhanced adsorption efficiency by increasing surface area, micropore formation, and the presence of active functional groups (Mulyati et al., 2017; Urhasanah et al., 2024; E. E. Putri et al., 2025; Hariyanti & Razif, 2019). FTIR analysis confirmed the presence of functional groups such as C=C, C-O, and C-H, which contributed to strong interactions between the adsorbent and organic compounds, improving COD removal [23]. Factors such as stirring speed also influenced adsorption performance, with 150 rpm providing optimal COD reduction due to enhanced interaction between adsorbent and adsorbate [24]. Despite the significant reduction, COD concentrations did not meet the maximum limit of 110 mg/L set by the Indonesian Ministry of Environment Regulation No. 5 of 2014. The efficiency of COD removal is affected by adsorbent mass and saturation conditions; excessive adsorbent can reduce the effective surface area, limiting adsorption capacity and performance [25]. Overall, bagasse-derived activated carbon demonstrated high potential as an adsorbent for removing organic contaminants from leather tanning wastewater.

##### **Effect of Mass and Contact Time on Total Cr**

The results of this study indicate that the adsorption process using bagasse-based activated carbon effectively reduced total chromium (Cr) concentrations in leather tanning wastewater. Increasing the adsorbent mass from 10 g to 15 g and extending contact time from 90 to 150 minutes improved Cr removal, with the highest reduction of 81.74% achieved at 15 g and 150 minutes, decreasing Cr from 109.67 mg/L to 20.02 mg/L [26]. Pre-sedimentation did not significantly reduce Cr due to limited contact time and laminar flow conditions [21]. Bagasse-based activated carbon showed higher Cr removal efficiency compared to other adsorbents, such as palm shell (43.93%) and tobacco stem (75.83%) [17]. The use of 1 M KOH for activation provided higher selectivity toward metal ions compared to 3 M or 5 M, as higher KOH concentrations can capture non-metal molecules and reduce adsorption efficiency [16]. FTIR

characterization revealed that functional groups such as C-H and C-O were involved in Cr adsorption through chemical and physical interactions, forming complexes on the adsorbent surface [7]. Adsorbent mass and particle size were key factors, as higher mass and smaller particle size (100 mesh) increased surface area and active sites for Cr binding, enhancing removal efficiency up to 82.56% [2]. Stirring at 150 rpm improved adsorption by homogenizing the wastewater, facilitating contact between metal ions and adsorbent, although Cr concentrations did not reach the regulatory limit of 0.60 mg/L due to adsorbent saturation [4].

#### IV. CONCLUSION

The use of bagasse-based activated carbon as an adsorbent for leather tanning wastewater was effective in reducing COD and total chromium (Cr) concentrations, with the highest removal achieved at 15 g of adsorbent and 150 minutes of contact time (82.13% COD, 579 mg/L; 81.74% Cr, 20.02 mg/L). However, the treated wastewater did not meet the quality standards set by the Indonesian Ministry of Environment Regulation No. 5 of 2014, indicating that the process, while efficient, is not yet fully effective. Future research is recommended to explore a wider range of adsorbent masses and contact times, combine adsorption with other treatment methods, conduct adsorption isotherm analysis to determine maximum capacity at equilibrium, and investigate adsorption kinetics using pseudo-first and pseudo-second order models to better understand the adsorption rate and mechanism.

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