Laboratory wastewater treatment: study case of Environmental Engineering Department ITS

Herrani Dyah Prasetyati[1], and *Ervin* Nurhayati[1*]

[1]Department of Environmental Engineering, Faculty of Civil, Planning, and Geo Engineering, Institut Teknologi Sepuluh Nopember, Surabaya, Indonesia

*Corresponding author: ervin@its.ac.id

Abstract. Laboratory wastewater contains organic and inorganic pollutants that can pollute the environment if not treated well. This study uses a coagulation-flocculation process to determine the proper operational condition for laboratory wastewater treatment in the Environmental Engineering Department of Institut Teknologi Sepuluh Nopember (ITS). The fluctuation of wastewater quality and quantity was observed consecutively for two weeks. Aluminum sulfate, poly aluminum chloride, and ferric chloride coagulant were applied with a pH variation, namely 6, 7, and 8, and a variation in coagulant dosage, namely 100, 300, and 500 mg/L. The quantity of wastewater produced is in the range of 918.33-32,045 L/day. Meanwhile, for the quality of wastewater, it has a pH in the range of 6.23-8.79, TDS 260-788 mg/L, TSS 40-380 mg/L, COD 97-611.7 mg/L, Cr 0.0174-0.2053 mg/L, Fe 0.29-7.55 mg/L, Hg 0-0.0000392 mg/L, and Pb 0-0.084 mg/L. The results of this study showed that the optimum condition for the coagulation-flocculation process is using PAC coagulant, with the original pH of the wastewater being pH 6 and the coagulant concentration being 300 mg/L. In this treatment, the removal efficiency of TDS, TSS, and COD were 7.07%, 92.59%, and 27.45%, respectively.

1 Introduction

One of the facilities that generates wastewater is the laboratory. Laboratory wastewater can originate from the disposal of expired materials, used chemical residues, used water for washing equipment, and leftover test samples [1]. Laboratory wastewater contains organic and inorganic materials, such as varying pH, COD, TSS, TDS, and various heavy metals, such as chromium (Cr), iron (Fe), mercury (Hg), and lead (Pb) [2]. Wastewater from various laboratories will certainly have different quantities and qualities. The kind of practicum or research being done, the number of people, the intensity of laboratory use, and the amount of water utilized all have an impact on this difference [3]. In terms of quantity, laboratory wastewater has a relatively small volume. Nevertheless, wastewater treatment is still required even when laboratory wastewater has a tiny volume since the organic and inorganic components it contains might harm the environment if left untreated [4].

One method for eliminating organic contaminants from wastewater is coagulation. This process has several advantages, namely it has high efficiency, ease of use, low cost, and low energy consumption [2,5]. The coagulation process involves dissolving chemicals (coagulants) in wastewater and rapidly stirring them to destabilize suspended solids and colloids to form microflocs. The interaction of microflocs that destabilizes them into macroflocs is known as flocculation [6]. Aluminum sulfate ($Al_2(SO_4)_3$) is a commonly used coagulant. Aluminum sulfate in wastewater will bind negatively charged colloidal particles and disintegrate into a positively charged colloidal dispersion, forming flocs that can settle [7]. As a coagulant, aluminum sulfate has several benefits, including high efficiency, affordability, accessibility, and ease of use [8]. Other typical coagulants for the coagulation-flocculation process include poly aluminum chloride (PAC) and ferric chloride ($FeCl_3$), in addition to aluminum sulfate. Several benefits of PAC are high efficiency and can generate flocs quickly due to their strong positive electric charge [9]. On the other hand, $FeCl_3$ coagulant has several advantages, namely high efficiency at removing dissolved organic carbon (DOC), as well as having the capacity to create larger flocs, which speeds up the sedimentation process [10].

There are five laboratories in the Environmental Engineering Department of ITS. These five laboratories' wastewater will be gathered into one collection tank. Untreated laboratory wastewater can pollute the environment. Therefore, this study aims to determine the ideal operational conditions for the chemical processes used to handle laboratory wastewater from the Environmental Engineering Department of ITS. The chemical wastewater treatment process that will be used is the coagulation-flocculation process. The ideal operational conditions of this process are conditions with optimum pH and coagulant concentration.

2 Materials and Method

This study requires glassware, jar test, pH and TDS meter, spectrophotometer, heating block for COD analysis, vacuum pump, oven, desiccator, and analytical balance. Meanwhile, the materials needed are aluminum sulfate (SAP Chemicals), poly aluminum chloride (Netafarm German PAC), ferric chloride (SAP Chemicals), NaOH 10% (SAP Chemicals) for pH adjustment, aquadest, reagent for COD analysis, and filter paper (Whatman Filter Paper number 42). The two procedures used in this study are preliminary research and coagulation-flocculation experiments. pH, TDS, TSS, COD, Chromium (Cr), Iron (Fe), Mercury (Hg), and Lead (Pb) are the wastewater quality parameters that need to be analyzed. The measurement methods used in this study can be seen in Table 1.

Table 1. Wastewater Quality Measurement Methods

Parameter	Measurement Method
pH	pH meter
TDS	TDS meter
TSS	Gravimetry (SNI 06-6989.3-2004)
COD	Closed reflux spectrophotometrically (SNI 6989.2:2009)
Iron (Fe)	Spectrophotometer
Chromium (Cr)	Atomic Absorption Spectrophotometer (AAS)
Mercury (Hg)	
Lead (Pb)	

2.1 Preliminary Research

Preliminary research is divided into several parts, namely observation of wastewater quantity fluctuations, observation of wastewater quality fluctuations, and sampling for the coagulation-flocculation process.

2.1.1 Observation of Wastewater Quantity Fluctuations

Observation of fluctuations in wastewater quantity was conducted during the active lecture period, especially when activities were carried out in the laboratory and several days after the lecture period was over, but there were still some studies carried out in the laboratory. This observation was carried out for 18 days. A pump with a 145 liters per minute capacity was used to pump water into the collection tank and the amount of time it took to pump until the tank was empty was recorded. The data obtained from this observation is the volume of wastewater.

2.1.2 Observation of Wastewater Quality Fluctuations

For two weeks, observation of wastewater quality fluctuations was done between the hours of 07.00 and 17.00. Wastewater was taken as much as 200 mL every hour. Samples collected on one day will then be combined and analyzed on the next day. The data obtained from this observation is the quality of wastewater. The wastewater quality parameters to be tested are pH, TDS, TSS, COD, and heavy metals (Cr, Fe, Hg, and Pb).

2.1.3 Sampling for the Coagulation-Flocculation Experiments

The samples used in the coagulation-flocculation experiments were taken from the collection tank. The samples taken were 30 liters. To assess the wastewater's quality, a 400 mL sample was collected before treatment. The wastewater quality parameters to be tested are pH, TDS, TSS, and COD.

2.1.4 Coagulant Preparation

The preparation for each type of coagulant with a concentration of 500 mg/L as a stock solution by dissolving 0,25 grams into 500 mL of distilled water. The coagulant preparation with 100-400 mg/L, each as much as 100 mL, was carried out by dissolving a coagulant concentration of 500 mg/L into distilled water with the appropriate volume accordingly.

2.2 Coagulation-Flocculation Experiments

The coagulation-flocculation experiment used three coagulants, namely aluminum sulfate ($Al_2(SO_4)_3$), poly aluminum chloride (PAC), and ferric chloride ($FeCl_3$). These three coagulants were chosen because they are widely used, have a high efficiency in removing pollutants, and create faster and larger flocs [8–10].

A jar test and nine 1-litre beaker glasses, each containing 800 mL of wastewater, are used in the coagulation-flocculation process. Nine 1-litre beaker glasses were used for the experiment with details of three glasses each for the experiment using three types of coagulants, namely aluminum sulfate, PAC, and ferric chloride. Each type of coagulant has a pH variation, namely 6, 7, and 8, and a variation in coagulant dosage, namely 100, 300, and 500 mg/L. This process is carried out in three stages following SNI 19-6449-2000, namely rapid mixing at a speed of 100 rpm for 1 minute, slow mixing at a speed of 40 rpm for 15 minutes, and sedimentation for 30 minutes. Wastewater quality analysis will be carried out after the coagulation-flocculation process with samples of 400 mL for each treatment. The wastewater quality parameters to be tested are pH, TDS, TSS, and COD.

3 Results and Discussion

For one month, laboratory research was carried out that covered preliminary research and coagulation-flocculation experiments. The collected data will be analyzed and examined, namely those about variations in wastewater quantity and quality and the coagulation-flocculation experiments.

3.1 Wastewater Quantity Fluctuations

For 18 days, a variety of laboratory activities that impact wastewater production were used to observe variations in the amount of wastewater generated. Ten days during active lecture weeks, one day during exam week, and seven days during lecture holidays made up the specifics of data collected across these 18 days. Because there are typically fewer laboratory activities during lecture holidays than during active lecture hours, wastewater pumping is necessary every day because the volume of wastewater released daily is comparatively lower. Figure 1 shows the amount of wastewater generated over these 18 days.

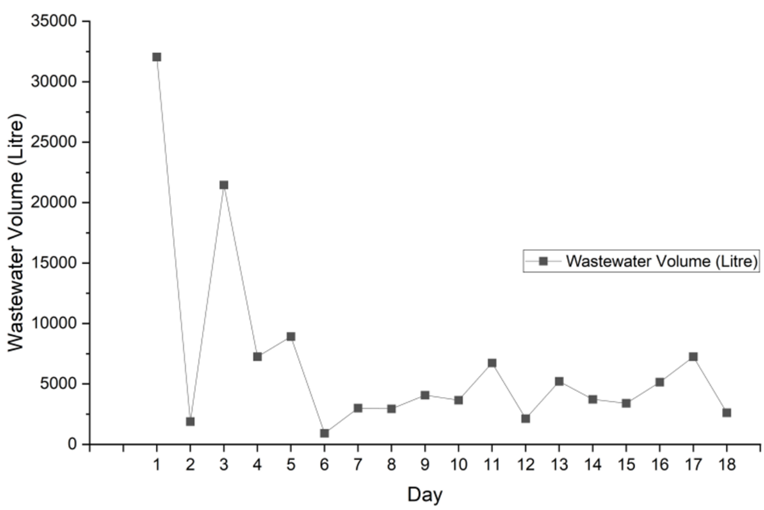

Fig 1. Wastewater Volume Fluctuations

Based on Figure 1, it can be concluded that the volume of wastewater is fluctuating, ranging from 918.33 to 32,045 liters/day. The lowest volume is on the day of active lectures but no practical activities, namely on the sixth day, while the highest volume is when there is the use of a soxhlet extractor which produces a lot of water, namely on the first day. On the fourth dan fifth days, there are practical activities, where on both days the volume of wastewater ranges from 7,250 to 8,917.5 liters/day. On the 12th to 18th day, data collection was carried out when the lectures were off, so the pumping process was carried out when the collection tank was full. The time for the collection tank to be full can range from 2 to 9 working days. These wastewater quantity fluctuation data show that laboratory wastewater has a varying volume per day. This can be influenced by several factors such as experiments being carried out in the laboratory, the amount of chemicals used, and the amount of waste from the experiment [3].

3.2 Wastewater Quality Fluctuations

For two weeks, the wastewater quality fluctuation survey was carried out. However, two to three samplings were conducted because the filter unit above the collection tank was disassembled on the 15th and 16th. The quality standards used for laboratory wastewater are based on the Regulation of the Minister of Environment (PERMENLH) of the Republic of Indonesia number 5 of 2014 concerning wastewater quality standards in attachment XLVII. In this regulation, there are no quality standards for laboratory wastewater, so the quality standards used are wastewater quality standards for businesses and/or activities that do not have established wastewater quality standards as seen in Table 2.

Table 2. Laboratory Wastewater Quality Standards

Parameter	Unit	Concentration
pH		6.0 – 9.0
TDS	mg/L	2,000
TSS	mg/L	200
COD	mg/L	100
Fe	mg/L	5
Cr	mg/L	0.5
Hg	mg/L	0.002
Pb	mg/L	0.1

Figure 2 shows the fluctuation of laboratory wastewater pH. From the graph, it can be seen that the pH of wastewater is still within the applicable standard quality range. The pH of wastewater is in the range of 6.23-8.79. Several types of laboratories, such as chemistry laboratories, biology laboratories, and others have a pH in the range of 6.60-8.10 [11]. While laboratories used for educational facilities have a range of pH between 8.30-8.58 [12,13]. Laboratories used for educational facilities are generally used for practicums and research that use various chemicals and different wastewater samples.

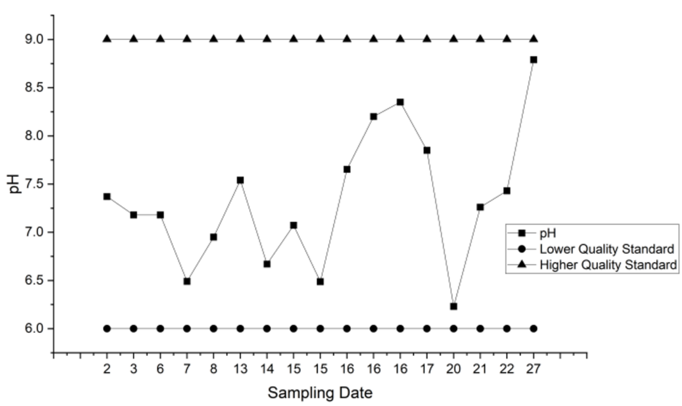

Fig. 2. Laboratory Wastewater pH

TDS concentration indicates the presence of dissolved solids in wastewater, such as mineral salts and dissolved organic matter [2]. Figure 3 shows the fluctuation of wastewater quality in TDS concentration. Based on Figure 3, the TDS concentration has met the quality standards. The TDS concentration of wastewater ranges from 260-788 mg/L. Several research state that laboratories used for educational facilities have a range of TDS concentrations between 480-549 mg/L [13,14].

TSS concentration indicates the presence of undissolved solids that are difficult to settle. High TSS concentration can cause turbidity in wastewater [15]. Figure 4 shows the fluctuation of wastewater quality in TSS concentration. Based on Figure 4, the TSS concentration has mostly met the quality standards. The TSS concentration of wastewater ranges from 40-380 mg/L. Several research state that laboratories used for educational facilities have a range of TDS concentrations between 125-1,228 mg/L [14,16].

Figure 5 shows the fluctuation of wastewater quality in COD concentration. Based on Figure 5, the COD concentrations mostly do not meet the quality standards. The COD concentration of wastewater ranges from 97-611.7 mg/L. High COD concentrations indicate the large amount of organic pollutants contained in the wastewater that can be chemically oxidized [17].

Figure 6 shows the fluctuation of wastewater quality in Iron (Fe) concentration. Based on Figure 6, the Fe concentration has mostly met the quality standards. The Fe concentration of wastewater ranges from 0.29-7.55 mg/L. Wastewater that has a high concentration of heavy metal Fe generally has a reddish-brown color [18]. This statement follows the color of the wastewater sample with code 21 which is reddish-brown as seen in Figure 7.

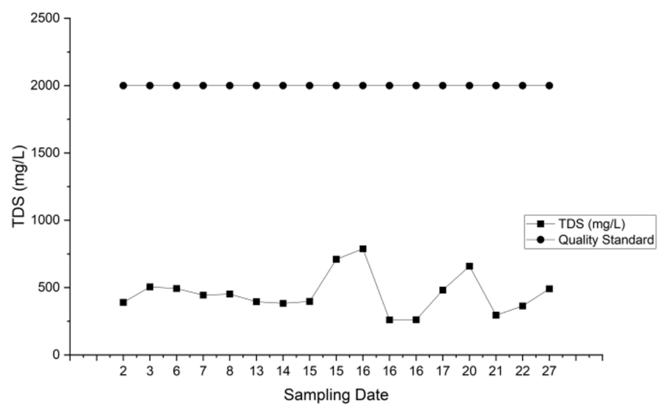

Fig. 3. Laboratory Wastewater TDS Concentrations

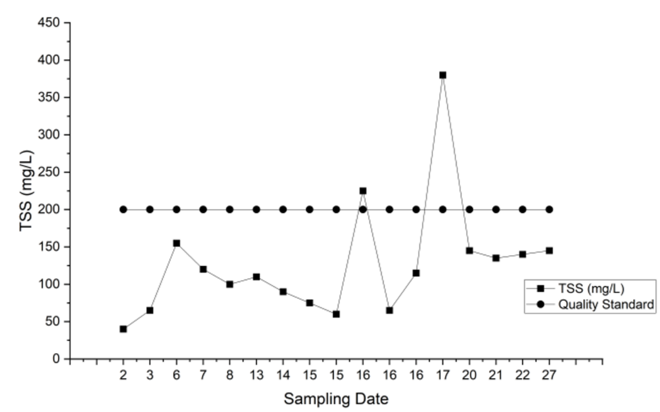

Fig. 4. Laboratory Wastewater TSS Concentrations

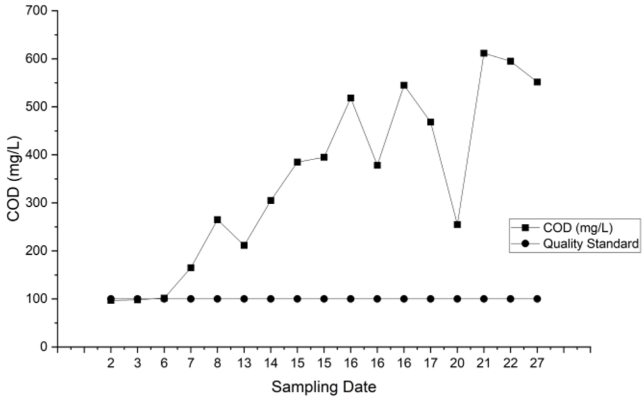

Fig. 5. Laboratory Wastewater COD Concentrations

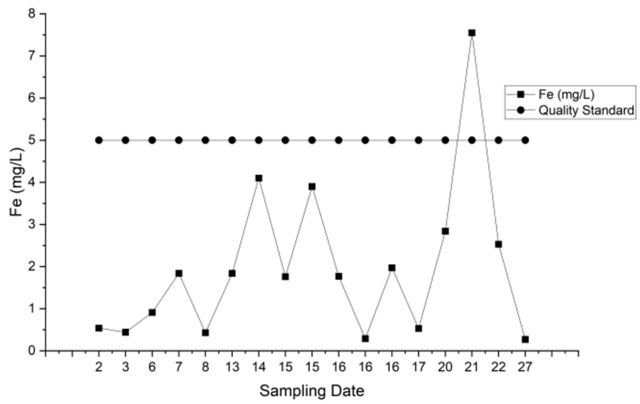

Fig. 6. Laboratory Wastewater Iron (Fe) Concentrations

Fig 7. Reddish-Brown Wastewater Sample

Figure 8 shows the fluctuation of wastewater quality in Chromium (Cr) concentration. Based on Figure 8, the Cr concentration has met the quality standards. The Cr concentration of wastewater ranges from 0.0174-0.2053 mg/L. The presence of heavy metal Cr in laboratory wastewater can come from the chemicals used, for example the use of potassium dichromate ($K_2Cr_2O_7$) for COD analysis [15].

Figure 9 shows the fluctuation of wastewater quality in Mercury (Hg) concentration. Based on Figure 9, the Hg concentration has met the quality standards. The Hg concentration of wastewater ranges from 0-0.0000392 mg/L. Mercury is one of the hazardous wastewater quality parameters, even in small concentrations. This is because mercury can turn into the neurotoxin methyl-mercury which is dangerous for the nervous system [19].

Figure 10 shows the fluctuation of wastewater quality in Lead (Pb) concentration. Based on Figure 10, the Pb concentration has met the quality standards. The Pb concentration of wastewater ranges from 0-0.084 mg/L. The presence of heavy metal Pb in wastewater can accumulate so that it is very toxic and cannot be biologically decomposed [20].

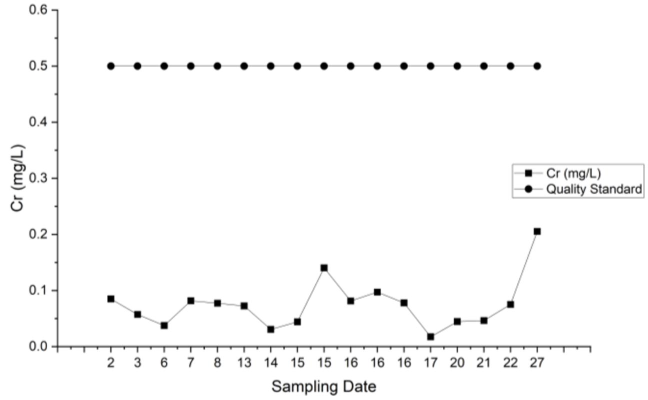

Fig. 8. Laboratory Wastewater Chromium (Cr) Concentrations

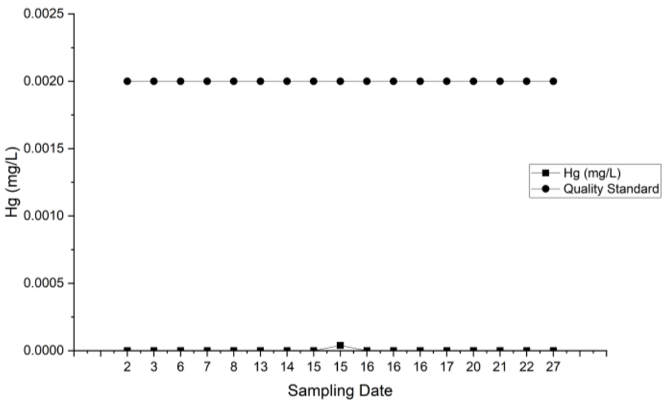

Fig. 9. Laboratory Wastewater Mercury (Hg) Concentrations

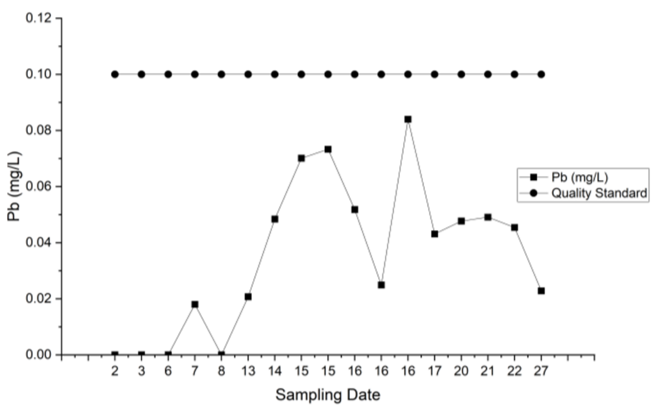

Fig. 10. Laboratory Wastewater Lead (Pb) Concentrations

3.3 The Effect of pH and Coagulant Concentrations in Coagulation-Flocculation Process

Several factors, including the type of coagulant, the dosage of the coagulant, the pH, temperature, turbidity and TSS concentration, as well as the speed and duration of stirring, can affect the coagulation-flocculation process in wastewater treatment. These factors must be managed to create ideal conditions for the wastewater treatment process to achieve the highest pollutant removal efficiency [21]. The effect of different pH and adding different coagulant doses on the quality of laboratory wastewater using aluminum sulfate, PAC, and ferric chloride can be seen in Table 3, Table 4, and Table 5, respectively.

3.3.1 Coagulation-Flocculation using Aluminum Sulfate

From Table 3, it can be seen that there was a decrease in pH. The decrease in pH along with the increasing addition of coagulant concentration is caused by the hydrolysis process that produces hydrogen ions [22]. The chemical reaction of the hydrolysis process can be seen in the following reaction.
Dissociation of aluminum sulfate:

$$Al_2(SO_4)_3 \rightarrow 2Al^{3+} + 3SO_4^{2-}$$

Hydrolysis of aluminum ions:

$$Al^{3+} + 3H_2O \rightleftharpoons Al(OH)_3 + 3H^+$$

Deflocculation, or the inability to produce flocs that can settle properly and return to colloidal particles, will occur if an excessive amount of coagulant is added [23]. This statement is proven by the increasing concentration of TDS along with the increasing concentration of coagulant used.

The addition of coagulant with a higher concentration can reduce the TSS concentration, this is because more coagulant molecules interact with suspended solids to become macroflocs which will then settle [6]. Meanwhile, the decrease in COD concentration can be caused by the ability of the coagulant to bind dissolved organic particles to become macroflocs and settle [24]. However, there are still optimum conditions where the TSS and COD removal efficiency has the highest percentage. This statement is proven by the addition of a coagulant concentration of 500 mg/L at pH 7 which causes the TSS and COD concentrations to increase again.

In the coagulation-flocculation process, lowering the coagulant dose may result in ineffective removal of some pollutants. This occurs because more organic compounds may enter the solution as a result of the destabilization process of colloidal particles, which may release organic matter that was previously bound in the particles [25]. This statement is proven by the increase in COD concentration at pH 8 with the addition of a coagulant concentration of 100 mg/L.

The use of aluminum sulfate as a coagulant will be effective if the wastewater being treated has a high alkalinity level and a pH between 5.5-8.5 [13]. This statement is proven by the fact that at pH 7, the TSS concentration can be reduced by more than 50%, while at pH 8, the COD concentration can be reduced by more than 60%.

3.3.2 Coagulation-Flocculation using Ferric Chloride

From Table 5, it can be seen that there was a decrease in pH. The decrease in pH along with the increasing addition of coagulant concentration is caused by the hydrolysis process that produces hydrogen ions [8]. The chemical reaction of the hydrolysis process can be seen in the following reaction.

$$FeCl_3 + 3H_2O \rightarrow Fe(OH)_3 + 3H^+ + 3Cl^-$$

Table 3. Coagulation-Flocculation Process using Aluminum Sulfate

Parameter	Unit	Initial Sample	$Al_2(SO_4)_3$ Coagulant									Quality Standards
			pH 6			pH 7			pH 8			
			100 mg/L	300 mg/L	500 mg/L	100 mg/L	300 mg/L	500 mg/L	100 mg/L	300 mg/L	500 mg/L	
pH		6.64	7.07	6.93	6.76	7.61	7.5	7.24	7.88	7.69	7.49	6-9
TDS	mg/L	467	433	433	436	441	442	444	443	443	445	2000
TSS	mg/L	135	55	75	65	50	45	60	95	70	75	200
COD	mg/L	85	78.33	68.33	55	65	35	71.67	165	71.67	31.67	100

Table 4. Coagulation-Flocculation Process using Poly Aluminum Chloride

Parameter	Unit	Initial Sample	PAC Coagulant									Quality Standards
			pH 6			pH 7			pH 8			
			100 mg/L	300 mg/L	500 mg/L	100 mg/L	300 mg/L	500 mg/L	100 mg/L	300 mg/L	500 mg/L	
pH		6.64	7.11	6.9	6.8	7.58	7.38	7.25	8.05	7.84	7.52	6-9
TDS	mg/L	467	432	434	438	441	443	446	441	446	449	2000
TSS	mg/L	135	30	10	10	20	30	20	15	10	15	200
COD	mg/L	85	85	61.67	58.33	55	28.33	25	41.67	21.67	8.33	100

Table 5. Coagulation-Flocculation Process using Ferric Chloride

Parameter	Unit	Initial Sample	$FeCl_3$ Coagulant									Quality Standards
			pH 6			pH 7			pH 8			
			100 mg/L	300 mg/L	500 mg/L	100 mg/L	300 mg/L	500 mg/L	100 mg/L	300 mg/L	500 mg/L	
pH		6.64	6.97	6.67	6.5	7.52	7.2	7.02	7.77	7.47	7.24	6-9
TDS	mg/L	467	431	436	441	440	445	448	443	450	425	2000
TSS	mg/L	135	30	45	50	25	40	30	35	30	75	200
COD	mg/L	85	115	115	91.67	28.33	18.33	15	55	15	18.33	100

Deflocculation, or the inability to produce flocs that can settle properly and return to colloidal particles, will occur if an excessive amount of coagulant is added [23]. This statement is proven by the increasing concentration of TDS along with the increasing concentration of coagulant used.

In the coagulation-flocculation process, lowering the coagulant dose may result in ineffective removal of some pollutants. This occurs because more organic compounds may enter the solution as a result of the destabilization process of colloidal particles, which may release organic matter that was previously bound in the particles [25]. This statement is proven by the increase in COD concentration at pH 6 with the addition of a coagulant concentration of 100, 300, and 500 mg/L. Meanwhile, the decrease in COD and TSS concentration can be caused by the formation of ferric chloride ($Fe(OH)_3$) which can form flocs together with organic matter and other substance [2].
The use of ferric chloride as a coagulant will be effective if the wastewater being treated has a pH of 8 [26]. This is proven by the fact that at pH 6 there was no decrease in TSS and COD concentrations, but there was a significant decrease at pH 8.

3.3.3 Pollutant Removal Efficiency in Coagulation-Flocculation Process

The calculation of removal efficiency is used to see how much the concentration of pollutants in laboratory wastewater decreases. The optimum coagulant is obtained from the highest removal efficiency for TSS concentration, as well as cost considerations of coagulant concentration and pH adjustment. The highest removal efficiency is only seen in the TSS concentration because the coagulation-flocculation process is more effective in removing TSS than COD. Using the coagulation-flocculation process can remove TSS and COD by 95% and 76%, respectively, according to research on wastewater treatment from paper mills [27]. The efficiency removal for the coagulation-flocculation process using aluminum sulfate, PAC, and ferric chloride can be seen in Table 6, Table 7, and Table 8, respectively.

Table 6. Removal Efficiency for Coagulation-Flocculation Process using Aluminum Sulfate

Coagulant	pH	Coagulant Concentration	Removal Efficiency (%)		
			TDS	TSS	COD
$Al_2(SO_4)_3$	6	100 mg/L	7.28	59.26	7.85
		300 mg/L	7.28	44.44	19.61
		500 mg/L	6.64	51.85	35.29
	7	100 mg/L	5.57	62.96	23.53
		300 mg/L	5.35	66.67	58.82
		500 mg/L	4.50	55.56	15.68
	8	100 mg/L	5.14	29.63	-94.12
		300 mg/L	5.14	48.15	15.68
		500 mg/L	4.71	44.44	62.74

From Table 6, it can be seen that the highest removal efficiency of the TSS parameter was found in the coagulation-flocculation process using an aluminum sulfate coagulant with a pH of 7 and a coagulant concentration of 300 mg/L. However, in this treatment, pH adjustment is needed to increase the pH from the initial pH, which is 6 to 7.

From Table 7, it can be seen that the highest removal efficiency in TSS parameters is found in three treatments, namely the coagulation-flocculation process using PAC coagulant with pH 6 and coagulant concentrations of 300 and 500 mg/L and also at pH 8 and a concentration of 300 mg/L. In the treatment using PAC coagulant, the optimum coagulant selection is at pH 6 and a coagulant concentration of 300 mg/L. The reason for this selection is because this treatment does not require a higher coagulant concentration and pH adjustment.

Table 7. Removal Efficiency for Coagulation-Flocculation Process using Poly Aluminum Chloride

Coagulant	pH	Coagulant Concentration	Removal Efficiency (%)		
			TDS	TSS	COD
PAC	6	100 mg/L	7.49	77.78	0.00
		300 mg/L	7.07	92.59	27.45
		500 mg/L	6.21	92.59	31.38
	7	100 mg/L	5.57	85.19	35.29
		300 mg/L	5.14	77.78	66.67
		500 mg/L	4.50	85.19	70.59
	8	100 mg/L	5.57	88.89	50.98
		300 mg/L	4.50	92.59	74.51
		500 mg/L	3.85	88.89	90.20

Table 8. Removal Efficiency for Coagulation-Flocculation Process using Ferric Chloride

Coagulant	pH	Coagulant Concentration	Removal Efficiency (%)		
			TDS	TSS	COD
$FeCl_3$	6	100 mg/L	7.71	77.78	-35.29
		300 mg/L	6.64	66.67	-35.29
		500 mg/L	5.57	62.96	-7.85
	7	100 mg/L	5.78	81.48	66.67
		300 mg/L	4.71	70.37	78.44
		500 mg/L	4.07	77.78	82.35
	8	100 mg/L	5.14	74.07	35.29
		300 mg/L	3.64	77.78	82.35
		500 mg/L	8.99	44.44	78.44

From Table 8, it can be seen that the highest removal efficiency of the TSS parameter was found in the coagulation-flocculation process using a ferric chloride coagulant with a pH of 7 and a coagulant concentration of 100 mg/L. However, in this treatment, pH adjustment is needed to increase the pH from the initial pH, which is 6 to 7.

The efficiency of COD removal in some treatments was negative because there was an increase in COD concentration compared to the initial concentration. This is because more organic compounds may enter the solution as a result of the destabilization process of colloidal particles, which may release organic matter that was previously bound in the particles [25]. Based on the highest efficiency for TSS parameter and cost considerations in the coagulation-flocculation process using aluminum sulfate, PAC, and ferric chloride, the optimum condition is in the process using PAC coagulant, with the original pH of the wastewater being pH 6 and the coagulant concentration being 300 mg/L. In this treatment, the removal efficiency of TDS, TSS, and COD were 7.07%, 92.59%, and 27.45%, respectively.

4 Conclusion

The wastewater volume data gathered from 18 days of observations of wastewater volume fluctuations ranged from 918.33 to 32,045 L/day. One of the many possible causes of these fluctuating results is the kind of laboratory experiment that was carried out.

Observations of wastewater quality fluctuations conducted for 14 days obtained pH ranging from 6.23-8.79, TDS 260-788 mg/L, TSS 40-380 mg/L, COD 97-611.7 mg/L, Cr 0.0174-0.2053 mg/L, Fe 0.29-7.55 mg/L, Hg 0-0.0000392 mg/L, and Pb 0-0.084 mg/L.

The optimum condition for the coagulation-flocculation process is using PAC coagulant, with the original pH of the wastewater being pH 6 and the coagulant concentration being 300 mg/L. In this treatment, the removal efficiency of TDS, TSS, and COD were 7.07%, 92.59%, and 27.45%, respectively.

References

[1] I. Nurhayati, S. Sugito, and A. Pertiwi, Pengolahan Limbah Cair Laboratorium dengan Adsorpsi dan Pretreatment Netralisasi dan Koagulasi, Jurnal Sains & Teknologi Lingkungan **10**, 125 (2018). https://doi.org/10.20885/jstl.vol10.iss2.art5

[2] P. Saengchut, N. ladtem, W. Wonglertarak, C. Kokaphan, S. Obpat, and P. Klaiklung, Properties of Laboratory Wastewater Having Influence Heavy Metals Treatment Efficiency by Chemical Precipitation, Journal of Ecological Engineering **25**, 72 (2024). https://doi.org/10.12911/22998993/188787

[3] S. Ramanathan and R. B. Lal, Physicochemical Treatment of Research Laboratory Wastewater: A Case Study, SpringerBriefs in Environmental Science, 85 (2019). https://doi.org/10.1007/978-3-319-99398-0_7

[4] R. S. Putra, A. M. Iqbal, I. Arirahman, and M. Sobari, Electroflotation-Biocoagulant Process Using Chickpea (Cicer Arietinum) for Laboratory Wastewater Treatment, in Proceedings of the 5th International Symposium on Current Progress in Mathematics and Sciences (ISCPMS2019), Depok, Indonesia, 9-10 July (2020), 2242. https://doi.org/10.1063/5.0007847

[5] M. H. M. Noor and N. Ngadi, Global Research Landscape on Coagulation-Flocculation for Wastewater Treatment: A 2000–2023 Bibliometric Analysis, Journal of Water Process Engineering **64,** 105696 (2024). https://doi.org/10.1016/j.jwpe.2024.105696

[6] B. A. Santoso, I. Apriani, and Winardi, Pengaruh Penambahan Koagulan Kapur (CaO) dan Ferri Klorida (FeCl3) terhadap Konsentrasi Logam Berat dan COD pada Air Limbah Laboratorium, Jurnal Teknologi Lingkungan Lahan Basah **12**, 385 (2024). https://doi.org/10.26418/jtllb.v12i2.76845

[7] M. S. Wijayanti, T. E. Agustina, M. H. Dahlan, and D. Teguh, Determination of Coagulant Dosage and Stirring Time in Laboratory Wastewater Pretreatment, Indonesian Journal of Environmental Management and Sustainability **6**, 137 (2022). https://doi.org/10.26554/ijems.2022.6.4.137-142

[8] S. Abusabha, G. Zaimes, and A. Marei, Applying the experiment design approach to minimize pollutants in olive mill wastewater using aluminum sulfate and ferric chloride as coagulants. West Bank—occupied Palestinian territories, Desalination Water Treat **320**, 100671 (2024). https://doi.org/10.1016/j.dwt.2024.100671

[9] N. Aziz, N. Effendy, and K. T. Basuki, Comparison of Poly Aluminium Chloride (PAC) and Aluminium Sulphate Coagulants Efficiency in Waste Water Treatment Plant, Jurnal Inovasi Teknik Kimia **2**, 24 (2017). http://dx.doi.org/10.31942/inteka.v2i1.1738

[10] M. Umar, F. Roddick, and L. Fan, Comparison of coagulation efficiency of aluminium and ferric-based coagulants as pre-treatment for UVC/H2O2 treatment of wastewater RO concentrate, Chemical Engineering Journal **284**, 841 (2016). https://doi.org/10.1016/j.cej.2015.08.109

[11] E. A. Akintunde, B. O. Atobatele, O. T. Akinola, O. Olufunmilayo, and O. Olutona, Physico-chemical, Heavy Metal and Microbial Analysis of Wastewater Discharged from Selected Laboratories in Bowen University, Nigeria, Res Sq (2023). https://doi.org/10.21203/rs.3.rs-3423976/v1

[12] Pabbenteng and E. Alwina, Desain Reaktor Pengolahan Limbah Cair Laboratorium, Jurnal Pengendalian Pencemaran Lingkungan (JPPL) **2**, 15 (2020). https://doi.org/10.35970/jppl.v2i1.142

[13] Aynuddin and Rosalina, Pengolahan Logam Berat Kromium dalam Limbah Cair Laboratorium dengan Metode Koagulasi, Adsorpsi, dan Ozonasi, Warta Akab **46**, 13 (2022). https://doi.org/10.55075/wa.v46i2.102

[14] Y. Sukmawardani and V. Amalia, Pengolahan Limbah Cair Laboratorium Kimia Menggunakan Metode Elektrokoagulasi, Jurnal Kartika Kimia **2**, 100 (2019). https://doi.org/10.26874/jkk.v2i2.29

[15] R. Sufra, J. R. H. Panjaitan, M. Alhanif, M. Mustafa, F. Yusupandi, E. Adriansyah, G. Rahmadini, M. R. Raqin, P. Herawati, and A. Suzana, Intensifikasi Pengolahan Limbah Cair Laboratorium Melalui Proses Koagulasi dan Adsorpsi Studi Pengolahan Limbah Cair Laboratorium dengan Metode Kombinasi Fisika-Kimia, Jurnal Talenta Sipil **7**, 266 (2024). https://doi.org/10.33087/talentasipil.v7i1.460

[16] P. Novitasari and F. Y. Hanifah, Penggunaan Adsorben Karbon Aktif Bambu Kuning (Bambusa Vulgaris Var. Striata) dan Bentonit dalam Proses Pengolahan Limbah Cair Laboratorium Kimia Politeknik Negeri Cilacap, Jurnal Pengendalian Pencemaran Lingkungan (JPPL) **3**, 40 (2021). https://doi.org/10.35970/jppl.v3i2.1470

[17] Y. S. Sari, Mengolah COD Pada Limbah Laboratorium, Jurnal Komunitas : Jurnal Pengabdian Kepada Masyarakat **1**, 22 (2019). https://doi.org/10.31334/jks.v2i1.289

[18] Md. M. Hossain, D. Mohotti, S. Saqib, A. Mukhtar, B. Miller, J. Zhu, and S. Wu, Investigating iron removal from wastewater and simultaneous iron oxide catalyst synthesis by dielectric barrier discharge, Journal of Water Process Engineering **65**, 105893 (2024). https://doi.org/10.1016/j.jwpe.2024.105893

[19] H. S. Kusuma, N. Illiyanasafa, D. E. C. Jaya, H. Darmokoesoemo, and N. R. Putra, Utilization of the microalga Chlorella vulgaris for mercury bioremediation from wastewater and biomass production, Sustain Chem Pharm **37**, 101346 (2024). https://doi.org/10.1016/j.scp.2023.101346

[20] L. Ton-That, T. P. T. Nguyen, B. N. Duong, D. K. Nguyen, N. A. Nguyen, T. Ho, and V. P. Dinh, Insights into Pb (II) adsorption mechanisms using jackfruit peel biochar activated by a hydrothermal method toward heavy metal removal from wastewater, Biochem Engineering Journal **212**, 109525 (2024). https://doi.org/10.1016/j.bej.2024.109525

[21] N. Al-Jadabi, M. Laaouan, M. Benbouzid, J. Mabrouki, and S. El Hajjaji, Coagulation-Flocculation Technique for Domestic Wastewater Treatment in the City of Ain Aouda, Rabat, Morocco, in International Conference on Climate Nexus Perspectives: Toward Innovative, Resilient and Sustainable Solutions for Natural Resources and Biodiversity Management (I2CNP 2021), Khenifra, Morocco, June 6 (2022), 337. https://doi.org/10.1051/e3sconf/202233702003

[22] I. Krupińska, Aluminium drinking water treatment residuals and their toxic impact on human health, Molecules **25**, 641 (2020). https://doi.org/10.3390/molecules25030641

[23] F. Ramadhan, L. T. N. Maleiva, and P. W. Nugraheni, A Study of the Effects of Alum and PAC on the Coagulation Process of Dug Well Water, Indonesian Journal of Fundamental and Applied Chemistry **9**, 55 (2024). https://doi.org/10.24845/ijfac.v9.i1.55

[24] S. Arita, T. E. Agustina, N. Ilmi, V. D. W. Pranajaya, and R. Gayatri, Treatment of Laboratory Wastewater by Using Fenton Reagent and Combination of Coagulation-Adsorption as Pretreatment, Journal of Ecological Engineering **23**, 211 (2022). https://doi.org/10.12911/22998993/151074

[25] N. M. Daud, S. R. S. Abdullah, H. A. Hasan, A. R. Othman, and N. I. Ismail, Coagulation-flocculation treatment for batik effluent as a baseline study for the upcoming application of green coagulants/flocculants towards sustainable batik industry, Heliyon **9**, (2023). https://doi.org/10.1016/j.heliyon.2023.e17284

[26] M. A. Nugti, S. M. D. Cahyani, L. Latifah, and A. Sugiharto, Uji Efektifitas Koagulan Kapur (CaO), Ferri Klorida (FeCl3), Tawas (Al2(SO4)3) Terhadap Penurunan Kadar PO4 Dan COD Pada Limbah Cair Domestik (Laundry) Dengan Metode Koagulasi, in The 11th University Research Colloquium (URECOL), Yogyakarta, Indonesia, February 2020, (2020), 345.

[27] M. Irfan, T. Butt, N. Imtiaz, N. Abbas, R. A. Khan, and A. Shafique, The removal of COD, TSS and colour of black liquor by coagulation–flocculation process at optimized pH, settling and dosing rate, Arabian Journal of Chemistry **10**, S2307 (2017). https://doi.org/10.1016/j.arabjc.2013.08.007