

Determination of Coagulant Dosage and Stirring Time in Laboratory Wastewater Pretreatment

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Abstract

The use of chemicals in practical activities or research in the laboratory will certainly produce wastewater. Wastewater generated from the laboratory is classified as hazardous and/or toxic waste. Based on the substances contained in laboratory wastewater in terms of accumulated amount and a long period of time, wastewater will pollute the environment and will have an impact on living things around it if it is directly discharged into water bodies. The composition of laboratory waste is reactive and dangerous because it contains heavy metals Pb, Fe, and Cu as well as high Chemical Oxygen Demand (COD) and Total Suspended Solid (TSS) so it is difficult to decompose in nature. This study aimed to prepare the laboratory wastewater using the coagulation process as pretreatment. Therefore, this research prioritized the reduction of heavy metal levels of Pb, Fe, and Cu and reduced the content of COD and TSS with Alum as a coagulant. The highest degradation percentage of COD and TSS content occurred at the Coagulation Dose of 80 ppm, namely 99.79% and 99.80% respectively. Meanwhile, the highest degradation percentage of heavy metal levels of Pb, Fe, and Cu as well as the optimum COD and TSS content occurred at a stirring time of 60 minutes respectively, which were 49.48%, 58.96%, 94.09%, 99.97%, and 99.40%. It was concluded that the pretreatment of laboratory wastewater using the coagulation process could reduce the levels of Pb, Fe, and Cu metals, and the content of COD and TSS.

Keywords

Laboratory Wastewater, Coagulation, Heavy Metals, COD, TSS

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1. INTRODUCTION

Even though the results of wastewater disposal from practicum activities are relatively small when compared to other industrial wastes, they can cause accumulation or buildup of residual amount from the results of practicum or research and of course this endangers living things and the surrounding environments. In certain quantities, wastewater can be detrimental to health and even cause the death of living things, so it is necessary to set limits that are permitted in the environment (Angraini et al., 2022).

In accordance with Government Regulation of the Republic of Indonesia No. 22 of 2021, the substance content contained in laboratory wastewater can be categorized into hazardous and toxic waste (B3). The content of organic and inorganic substances contained in laboratory waste must

meet the wastewater quality standards to be discharged into the environment. Organic content can include COD, BOD, DO, TSS and TDS while inorganic content can be in the form of nutrient content such as sulfates, nitrates, nitrites, ammonia and phosphates and heavy metals such as Hg, Cr, Zn, Fe, Cd, Pb, Cu, and other heavy metals (Angraini et al., 2022).

Several alternative water and wastewater treatment technologies have been developed to address wastewater problems such as coagulation and adsorption processes. Coagulation is a chemical process used to remove suspended contaminants by mixing coagulants (chemicals) or precipitators into raw water with a high rotational speed in a short time. Coagulation is the mixing of coagulant materials into water so that precipitation occurs (Raimon and Said, 2017). Alum or Aluminum Sulfate ($Al_2(SO_4)_3$) is a coagulant that

will precipitate colloidal particles in wastewater. In wastewater purification, Al^{3+} ions in alum will bind and precipitate phosphates because as a coagulant, alum sulfate (alum) is very effective for precipitating colloidal particles and suspensions in wastewater. When alum is in wastewater, alum will decompose into positively charged colloidal dispersions and will bind negatively charged colloidal particles (Butt et al., 2013).

In wastewater treatment, the use of the coagulation method can be continued with the adsorption method to remove the precipitate resulting from the previous method (Nurhayati et al., 2018). Activated carbon is an effective agent for reducing heavy metals in wastewater treatment processes. The high adsorption capacity of activated carbon is due to its small particle size, large internal surface area, and active free valence. Activated carbon has a lot of pore space with a certain size where particles with a very fine size will be caught and trapped in it (Mariana et al., 2021). Wastewater treatment using the adsorption method has several advantages compared to other methods including the process is economical and flexible, has good performance, is environmentally friendly, and can be regenerated. There are quite a lot of types of adsorbents that can be used in the adsorption method, such as coal ash, activated carbon, zeolite, and clay (Shevchenko et al., 2018).

2. EXPERIMENTAL SECTION

2.1 Chemicals and Materials

The materials used included alum ($\text{Al}_2(\text{SO}_4)_3$), activated carbon, NaOH , H_2SO_4 , H_2O_2 , $\text{FeSO}_4 \cdot 7\text{H}_2\text{O}$, $\text{Na}_2\text{S}_2\text{O}_3 \cdot 5\text{H}_2\text{O}$, Whatman filter paper, and distilled water. Laboratory wastewater come from the Integrated of Technical Implementation Unit Laboratory (UPT Laboratorium Terpadu), Universitas Sriwijaya.

2.2 Analysis/Instrumentation

Laboratory wastewater was tested for the content of heavy metals Pb, Fe, Cu, COD and TSS.

2.3 Procedure

150 mL of laboratory wastewater was put into a 1 liter beaker and added with alum coagulant with a concentration of 10 ppm. Stirring was carried out using a fast rotation of 150 rpm with a mechanical stirrer for 10 minutes then stirring slowly at 50 rpm for 10 minutes then filtered (Audina, 2017). The procedure was repeated for coagulant doses of 20, 40, 60 and 80 ppm. Furthermore, it was continued with analysis of reduction of COD and TSS. The same procedure was carried out for the coagulant dose of 80 ppm with rapid stirring for 10, 30 and 60 minutes. Then, analysis of the reduction of COD, pH, TSS, Fe, Cu, and Pb was carried out to analyze the content of heavy metals using an Atomic Absorption Spectrophotometer (AAS).

3. RESULTS AND DISCUSSION

3.1 Effect of Coagulant Concentration on Test Parameters

Table 1 showed that the most optimum use of alum coagulant was at a concentration of 80 ppm. At this concentration it was able to significantly reduce the TSS value from 2000 mg/L to 6 mg/L or 99.70%. This was because alum or Aluminum Sulfate ($\text{Al}_2(\text{SO}_4)_3$), was a coagulant which was capable of precipitating colloidal particles in wastewater. At certain concentrations, alum will decompose into positively charged colloidal dispersions and bind negatively charged colloidal particles. In wastewater purification Al^{3+} ions in alum binds and precipitates phosphate. As a coagulant, alum is very effective for precipitating colloidal particles and suspensions in wastewater (Altaber et al., 2016).

This process aimed to determine the most optimum coagulant concentration in laboratory wastewater treatment. Mixing the coagulant into the raw water caused the solid particles which had light solids and were small to become heavier and had a large size because the coagulation process aimed to reduce the TSS parameters or change the solid particles in the raw water which cannot settle to become easy to precipitate. Meanwhile, for the other test parameters there was no significant decrease.

3.1.1 Effect of Coagulant Dosage on TSS Value

Figure 1 showed that the most optimum use of alum coagulant was at a concentration of 80 ppm. At this concentration it was able to significantly reduce the TSS value from 2,000 mg/L to 6 mg/L or 99.70%. This was because alum or Aluminum Sulfate ($\text{Al}_2(\text{SO}_4)_3$) was a coagulant which was capable of precipitating colloidal particles in wastewater. At certain concentrations, alum will decompose into positively charged colloidal dispersions and will bind negatively charged colloidal particles (Arita et al., 2022).

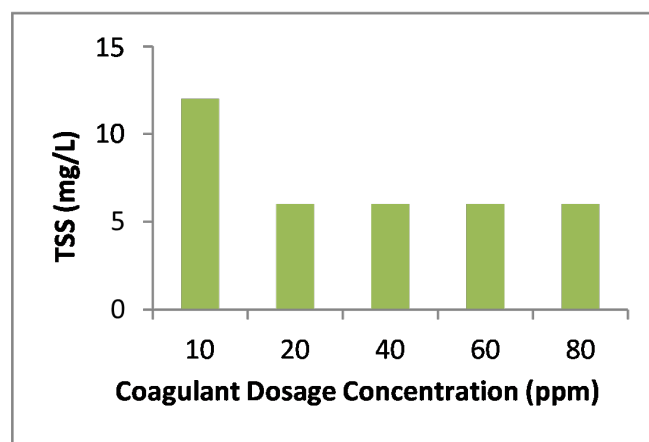


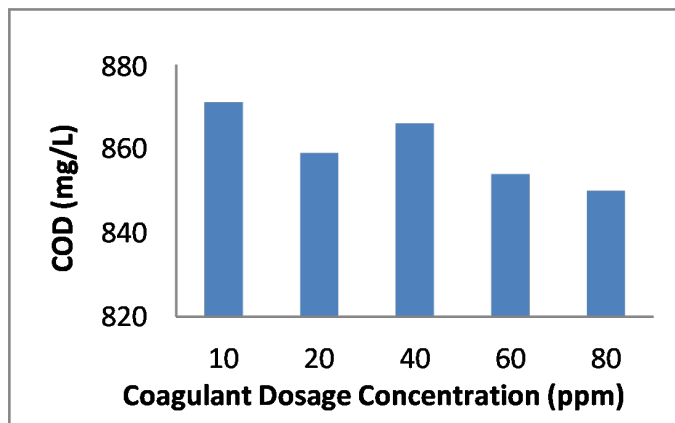
Figure 1. Effect of Coagulant Dosage on TSS Value

Table 1. Analysis Results of Determination of Coagulant Concentration (ppm)

Coagulant Concentration	COD (mg/L)	TSS (mg/L)
10	871	12
20	859	6
40	866	6
60	854	6
80	850	6
Quality Standards	100-300	6-9
Preliminary Analysis	420,000	2,000

3.1.2 Effect of Coagulant Dosage on COD Value

Alum reduced suspended substances contained in wastewater both in the form of organic and inorganic materials. This was in line with the decrease in the content of organic and inorganic materials which then reduced the COD value in wastewater. This was because the Al cations in alum underwent a hydrolysis reaction so that they formed dissolved Al species or precipitate aluminum hydroxide. Dissolved Al species that were formed were in the form of monomers and some of them were positively charged which neutralized negatively charged colloidal particles. The negative organic content tends to be adsorbed and trapped in aluminum hydroxide precipitates (Ignasius, 2014). This caused the COD value in wastewater to decrease.

**Figure 2.** Effect of Coagulant Dosage on COD Value

In Figure 2 the addition of alum with a concentration of 80 ppm in laboratory wastewater resulted in a decrease in the COD value, from the initial COD value of 42,000 mg/L to 850 mg/L. This was because the amount of alum used in this study was greater than in previous studies, so that the process of binding organic and inorganic chemicals contained in the waste became greater which resulted in a greater decrease in COD. The addition of alum to the

coagulation process caused the pH of the waste to become more acidic. This was because alum when dissolved in water will release more H^+ which causes the pH of the waste to decrease (Aziz et al., 2017). The decrease in pH that occurs can affect the performance of alum in reducing pollutant particles contained in waste. Alum can work optimally at pH 6-7.8 (Nurlina et al., 2015). The pH of acidic laboratory wastewater caused alum to not work optimally. Therefore, the COD value was still above the predetermined quality standard. The decrease in pH that occurs can affect the performance of alum in reducing pollutant particles contained in waste. Alum can work optimally at pH 6-7.8 (Naceradska et al., 2019).

3.2 Effect of Stirring Time on Test Parameters

3.2.1 Effect of Stirring Time on COD Value

In Figure 3 it could be seen that the optimum decrease in COD value in laboratory wastewater occurred at a stirring time of 60 minutes, which was 142 mg/L. This showed that the longer the stirring time, the higher the decrease in COD value. This was because at 60 minutes of stirring time, there was a greater decrease in the percentage of effectiveness compared to other stirring times. The decrease in COD was due to the floc formed by organic compound ions associated with positive coagulant ions. The molecules in the waste were formed into flocs, and the colloidal particles in the waste had the property of binding to other particles or compounds in the waste. By decreasing the number of particles, the oxygen needed to oxidize organic compounds also decreased, so that the COD value after coagulation became low.

3.2.2 Effect of Stirring Time on TSS Value

In Figure 4, it could be seen that the TSS value tends to be constant and does not change significantly if the stirring time is increased from 0 minutes to 30 minutes and then the value decreases due to the addition of stirring time up to 60 minutes. Slow stirring shortened the distance between the particles so that the attractive forces between the particles became larger and dominant than the repulsive forces, which resulted in more and more frequent contact and collisions

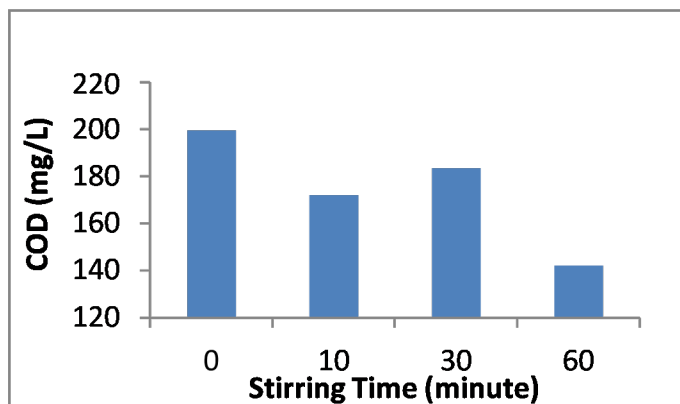


Figure 3. Effect of Stirring Time on COD Value

between the particles. It was this contact that agglomerated micro-sized coagulated dissolved solid particles into larger floc particles. Then, these flocs aggregated. When floc growth was maximal enough, these flocs settled. The addition of longer stirring time increased the optimum coagulation effectiveness where floc growth had reached its maximum point. This happened because the longer the stirring time resulted in the closest distance between particles to produce a contact. Collisions between particles occurred most frequently and produced flocs with the largest size and the largest number, so that the maximum TSS reduction was achieved.

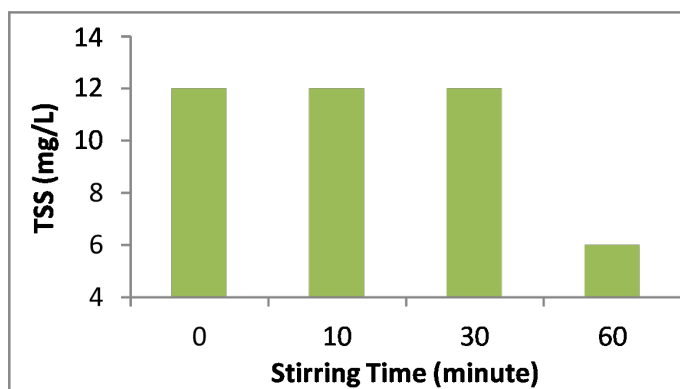


Figure 4. Effect of Stirring Time on TSS Value

3.2.3 Effect of Stirring Time on Pb Heavy Metal Content

In Figure 5, it could be seen that the percentage of effective stirring time for Pb metal tended to fluctuate and was not significant if the stirring time was increased from 0 minutes to 30 minutes and then decreased with the addition of 60 minutes of stirring time. The greatest efficiency in reducing lead (Pb) levels in laboratory wastewater occurred at a stirring time of 60 minutes. The longer the contact between the liquid waste and the chemical substance, the

more lead (Pb) ions precipitated so that the Pb level in the liquid waste decreased. This happened because more metal ions, especially Pb, were dissolved so that more metal ions were adsorbed on the surface of the coagulant with a longer stirring time.

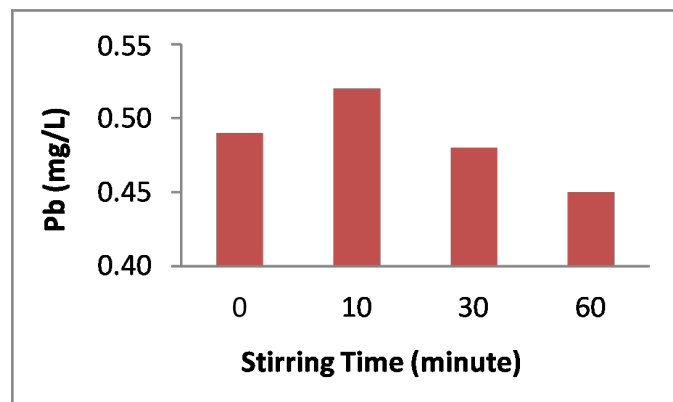


Figure 5. Effect of Stirring Time on Pb Heavy Metal Content

3.2.4 Effect of Stirring Time on Fe Heavy Metal Content

In Figure 6 it can be shown that the content of Fe metal tends to decrease from a stirring time of 0 minutes to 60 minutes in the coagulation process. The greatest efficiency in reducing the levels of ferrous metal (Fe) in laboratory wastewater occurred at a stirring time of 60 minutes. The longer the stirring time, the more Fe absorbed. This could be seen from Figure 6 which showed a decrease of Fe content with increasing stirring time. Iron was absorbed the most at 60 minutes of stirring time. The longer the stirring time, the greater the ability of the adsorbent to bind Fe was. This was because the long contact time between the adsorbent and the adsorbate allowed for more bonds to form between the adsorbent particles and Fe metal.

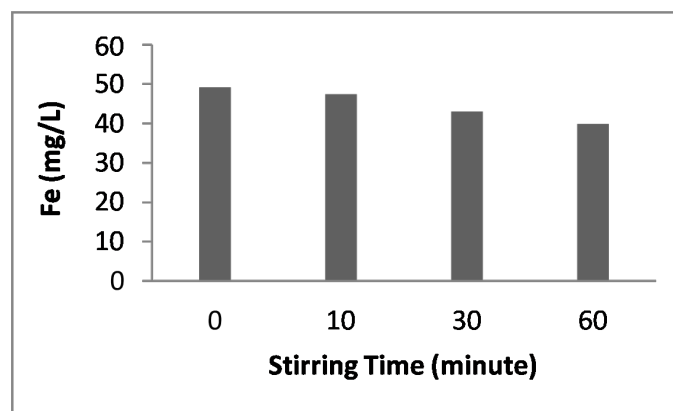


Figure 6. Effect of Stirring Time on Fe Heavy Metal Content

3.2.5 Effect of Stirring Time on Cu Heavy Metal Content

If the stirring time was increased from 0 minutes to 30 minutes and 60 minutes, there would be a decrease of metal due to the addition of the stirring time. In Figure 7 the Cu metal content tends to decrease but not significantly. This was because the longer the contact between the liquid waste and the adsorbent, the more copper (Cu^{2+}) ions precipitated so that the copper (Cu^{2+}) content in the liquid waste decreased. The longer the stirring time, the greater the adsorptive capacity of Cu^{2+} metal was. Meanwhile, the concentration of Cu^{2+} metal solution in the solution decreased until it reached an equilibrium state. Because the greater the stirring speed was, the greater the adsorption constant was obtained.

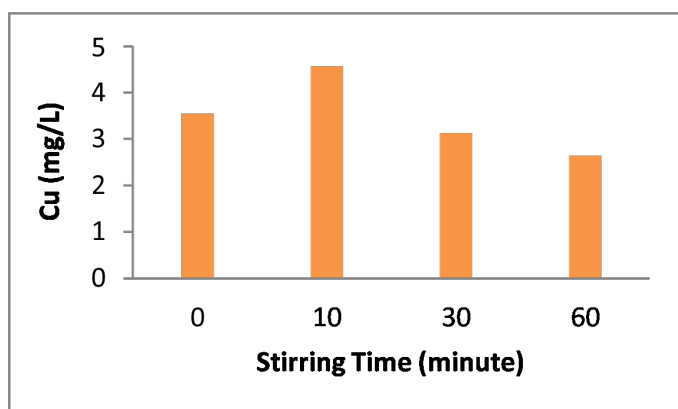


Figure 7. Effect of Stirring Time on Cu Heavy Metal Content

4. CONCLUSIONS

The optimum percentage reduction in COD and TSS content occurred at a coagulation dose of 80 ppm, which were respectively 99.79% and 99.80%. The optimum percentage of reduction in the content of Pb, Fe and Cu metals as well as COD and TSS content occurring at a stirring time of 60 minutes was 49.48%, 58.96%, 94.09% 99.97% and 99.40%. Treatment of laboratory wastewater using the coagulation process could reduce levels of Pb, Fe and Cu metals as well as reduce COD and TSS content.

5. ACKNOWLEDGMENT

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