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Comparison of Alum and Poly Aluminum Chloride Coagulant Performance on Turbidity and pH of Lematang Enim PDAM Raw Water

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ABSTRACT

Raw water is natural water found in lakes, rivers, streams, and underground sources before any treatment or purification processes. It typically contains various impurities, such as suspended solids, organic matter, pathogens, and dissolved minerals, which need to be removed to make it safe for consumption. Aluminum Sulfate and Poly Aluminum Chloride (PAC) are two commonly used chemicals in the treatment of raw water to remove impurities and make it suitable for drinking, industrial, or agricultural purposes. These chemicals play crucial roles in the purification process by aiding in the coagulation and flocculation of contaminants, which facilitates their removal through filtration. Study on raw water treatment using Aluminum Sulphate and Poly Aluminum Chloride (PAC) coagulants was carried out at Talang Jawa IPA PDAM Lematang Enim of Muara Enim District by taking raw water samples from Talang Jawa Intake and Pelita Sari Intake. This study aimed to find out the right type and dose of coagulant in the raw water treatment process. he test parameters were turbidity and pH values. The research was conducted using a jar test to determine the dose of coagulant. The results showed the use of solid PAC was more effective for both intakes. The optimum coagulant dose is 20 ppm PAC in the raw water of Talang Jawa intake and Pelita Sari intake with turbidity of 2.62 NTU and 4.15 NTU and pH of 7.8 and 7.6.

Keywords: Coagulant, Aluminum Sulfate, PAC, turbidity, pH

INTRODUCTION

UU No. 17 tahun 2017 on water resources, regulates the availability of clean water for residents. Clean water supply in villages is generally a non-pipe system due to the distance of settlements. On the other hand, the clean water supply system in urban areas already uses the services of the Regional Drinking Water Company (PDAM). However, the river water used by PDAM for clean water still does not meet quality standards, considering that river water in urban areas has been polluted by household waste.(El-Sayed Abdel-Raouf et al., 2019).The provision of clean water in the South Sumatra region must be in accordance with the quality standards set out in the Regulation of the Governor of South Sumatra Number 16 of 2005 concerning Water Designation and River Water Quality Standards. (Sisnayati, et al., 2021).

Muara Enim Regency Government in supplying clean water to the people of Muara Enim Regency, manages clean water through PDAM Lematang Enim. The raw water source used by PDAM Lematang Enim comes from Lematang River and Enim River. PDAM Lematang Enim has two raw water intake buildings, namely the Talang Jawa intake building which is sourced from the Lematang River and the Pelita Sari intake building which is sourced from the Enim River. Raw water from each intake is not the same, this is due to the geographical location of the intake itself and the large number of industries or settlements around the intakes.

Several dangerous diseases and deaths are caused by the lack of clean water supply. Cholera and other diarrheal diseases are estimated to cause around 1.8 million deaths worldwide each year. (El-Sayed Abdel-Raouf et al., 2019). Several ways have been carried out to get clean water free from contaminants because of many human activities.

In the water purification process, there are several processes: sedimentation, filtration and disinfection. Filtration process with ceramic membranes is ability to produce clean water. However, this method uses high costs for the investment (Sisnayati et al., 2018).Although this water purification system is effective, it uses expensive materials. (Zand & Hoveidi, 2015). In addition, in the sedimentation process, the addition of coagulants that do not match the specified concentration will further pollute the raw water. (Sisnayati, et al., 2021). Therefore, it is necessary to test the quality of raw water before and after the addition of coagulants to determine the most effective coagulant used to treat raw water for PDAM Lematang Enim. The coagulants used are Aluminum Sulfate (alum) and Poly Aluminum Chloride (PAC). (Widiyanti, 2019). The parameters analyzed in the study were physical parameter tests, including pH, turbidity and TDS(Gupta et al., 2017).

Several ways have been performed to get clean water free from contaminants resulted from lots of human activities. In the water purification process, there are several processes, namely filtering, sedimentation, filtration and disinfection. Although these water purification systems are effective, the materials used are expensive. (Zand & Hoveidi, 2015). In addition, in the sedimentation process, the addition of coagulants that do not match the specified concentration will further contaminate the raw water. Therefore, it is necessary to test the quality of raw water before and after the addition of coagulants to determine the most effective coagulant in treating the raw water of PDAM Lematang Enim. The coagulants used are Aluminum Sulfate (alum) and Poly Aluminum Chloride (PAC). (Widiyanti, 2019).

In the raw water purification of PDAM Gunung Poteng Singkawang with the coagulation-flocculation method using alum and PAC coagulants, the optimal dose ratio for mixing alum and PAC coagulants for initial turbidity conditions of 116 NTU was 1:2 (alum and PAC), while for the initial turbidity conditions of 9, 6 NTU was 1:3 (alum and PAC). The effectiveness of reducing turbidity levels from mixing alum and PAC coagulants for high turbidity reached 98.9% and 93.5% for low turbidity. River water generally consists of suspended particles, both free particles and colloidal particles having sizes between 0.001 µm – 1 µm (Liu et al., 2021). The particles consisted of inorganic particles and organic particles. Examples of inorganic particles are asbestos fibers, clay and silt, and examples of organic particles are viruses, bacteria and plankton (Feihrmann et al., 2017). The natural sedimentation process is very difficult for apply to water which contains a lot of suspended particles. This is due to the Van Der Waals forces, Electrostatic forces and Brownian motion which keep colloidal suspensions in a stable condition (Mustafa et al., 2013). The coagulation-focculation process is a method for separating suspended solids and colloidal particles (Afiatun et al., 2021). These suspended solids are natural minerals such as mud, clay and so on or organic matter formed from animal and vegetable decomposition processes (Liu et al., 2021). Meanwhile, colloids are suspended solids with smaller particle sizes (<1 µm) and cannot precipitate naturally, causing turbidity in raw water (Beatrice et al., 2016). Coagulation is the process of destabilizing suspended particles and colloidal particles (including bacteria and viruses) by neutralizing their electrical charges so that the repulsive forces between the particles can be reduced and the material used to neutralize these charges is called a coagulant (Bakri et al., 2019).

Meanwhile, flocculation is the process of combining the unstable particles after the coagulation process by means of slow stirring to form lumps or flocs so that they can be precipitated or filtered . Poly Aluminum Chlorida (PAC) with the chemical formula $(Al_n(OH)_mCl_{3n-m}$ is a type of aluminum polymer coagulant with Aluminum as basic element which relates to other elements and forms a repeating unit in long chain bonds that are positively charged and have a great molecular weight. Consequently, the PAC has the property of being able to neutralize electric charges and bridge colloidal particles to form flocs so that the colloidal particles approach each other and form larger flocs (Maldhure et al., 2022).The use of PAC will be effective in the pH range of 6-9. Different with alum, excessive use of PAC will not cause the water to become cloudy. One coagulant that is cheap, easy to find and often used in water treatment is alum, with the molecular formula $Al_2(SO_{4)3.}xH_2O$, where x = 14.16 (Thaldiri et al., 2017). However, the weakness in using excessive alum coagulant will result in cloudy water. The water purification process using PAC coagulants will lower the pH so that the flocs formed are difficult to precipate.

Therefore, to neutralize this decrease in pH, soda lime $(Ca(OH)_2)$ is added. If the raw water pH value is below 7.0, it is necessary to add soda lime gradually. This neutralization process will form flocs much perfectly and can soften water hardness (Orooji et al., 2020). Flocculation coagulation begin with the addition of coagulant to the raw water, the colloidal particle destabilization process, and the flocculation process. The factors affecting the coagulation-flocculation process are raw water quality, raw water characteristics and volume, pH, stirring speed and temperature. Turbidity in raw water is caused by the presence of particulate and colloidal contaminants such as clay, silt, various microorganisms, food scraps, industrial waste, and domestic waste (Syaichurrozi et al., 2022).The optimum coagulant dose in the water purification process obtained using the coagulation-flocculation technique requires the jar test method. Jar test provides data on optimum conditions for process parameters such as coagulant dosage used, pH, speed, time and intensity of fast and slow stirring (Zhou et al., 2014).

MATERIAL AND METHOD

Jar Test

The jar test method carried out in this study used 10 ml of PAC or 10 grams of alum then dissolved in 1000 ml of distilled water. After the alum/PAC solution was made, the ratio for every 1 ml was 10 ppm. The addition of alum/PAC with varying doses of 10 ppm, 20 ppm, 30 ppm, 40 ppm, 50 ppm and 60 ppm for each container. Then, quick stirring was conducted for one minute with a rotational speed of 100-150 rpm to even out the spread of alum/PAC to make the performance of the coagulant effective. After that, slow stirring was carried out at 20 rpm for 15 minutes. At this stage the flocs began to form and after 10 minutes the flocs formed completely (Sadkhan et al., 2021).

Turbidity measurement

The turbidity measurement was conducted to find out the Total Suspended Solid (TSS) from the river water. The turbidity was measured using special optical equipment. Light was directed through the water sample, and the amount of scattered light was measured. The unit of measurement is called the NepHelometric Turbidity Unit (NTU), or other turbidity units (such as FAU, FNU, etc.). The greater the scattering of light is, the higher the turbidity will be. The low turbidity value indicates high water clarity; a high value indicates low water clarity (Syaichurrozi et al, 2022)

pH Measurement

The pH meter must first be calibrated with pH 4 buffer, then adjust until it reads 4 on the calibration. Then rinse the electrode and dry it. After that, measure with a pH of 10 buffer and adjust to a reading of 10 on calibration. Furthermore, the calibrated electrode is inserted into the raw water sample container that has been carried out by the jar test.

Optimum Dosage Determination

The optimum dose is determined from the jar test water with turbidity <5 NTU and the resulting pH of 6.5-8.5 (Azhar et al., 2022).

RESULT AND DISCUSSION

Testing Jar Test on raw water for 5 days

Table 1. The results of measuring the turbidity and pH values of raw water for Talang Jawa Intake and Pelita Sari Intake using the jar test method for 5 days

Sample	Intake Talang Jawa		Intake Pelita Sari	
	Turbidity (NTU)	pH	Turbidity (NTU)	pH
1	38	8.5	47	8.0
2	39	8.5	47	8.0
3	40	8.5	48	8.0
4	41	8.5	46	8.0
5	43	8.5	46	8.0
Average	40.2	8.5	46.8	8.0

Table 1 shows that raw water turbidity at the Pelita Sari intake is high, while at the Talang Jawa intake it is similar. This shows that the raw water at the Talang Jawa Intake and Pelita Sari Intake is not suitable for consumption because it has exceeded the threshold level of turbidity, namely 5 NTU. This is caused by increasing settlements and population activities in the river basin which bring mud, sand and other materials into the river. Initial sample analysis shows that the pH of the Talang Jawa Intake and Pelita Sari Intake raw water is alkaline. This is because raw water sampling is carried out in the dry season, where during the dry season the detergent levels in the river are higher

The effect of the addition of alum and PAC on the turbidity and pH of Talang Jawa raw water

Tabel 2. The effect of the addition of alum and PAC on the turbidity of Java Talang Intake Raw Water

Coagulant Concentration (ppm)	Alum		PAC	
	Turbidity (NTU)	pH	Turbidity (NTU)	pH
10	6.81	6.9	5.63	8.0
20	5.53	6.8	2.62	7.8
30	4.54	6.7	2.27	7.5
40	3.08	6.7	1.50	7.3
50	4.42	6.4	0.93	7.2
60	5.63	6.4	0.48	7.1

Turbidity

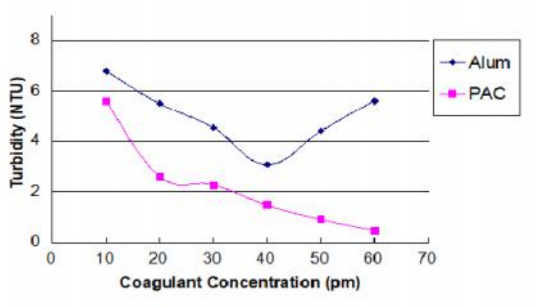

Figure 1. The effect of the addition of alum and PAC on the turbidity of Java Talang Intake Raw Water

The turbidity value in Figure 1. Show that the more alum is added up to 40 ppm, the turbidity of raw water will continue to decrease to 3.08 NTU. This is due to the content of alum $Al_2(SO_4)_3$ which is a positively charged colloidal dispersion which will bind to negatively charged fine particles and then neutralize the charge to form small flocs and precipitate. Therefore, the turbidity in raw water can be reduced. However, the addition of alum above 40 ppm will increase the turbidity in the raw water. This resulted from the excessive adsorption process of cations on the surface of colloidal particles which are negatively charged with the opposite charge Al^{3+} from Aluminum Sulfate. The use of alum concentrations at 30 ppm and 40 ppm can reduce the turbidity of raw water to below the quality standard, namely 4.54 NTU and 3.08 NTU. So the highest reduction in turbidity reached 92.34%. However, with the addition of 50 ppm alum, the turbidity started to rise again to 4.42 ppm. This is because alum has reached its saturation point to purify raw water.

Turbidity determines the brightness of water in relation to sunlight for assimilation purposes. The addition of 20 ppm PAC reduced the turbidity below the quality standard of 2.62 ppm NTU. The addition of PAC to raw water up to a dose of 60 ppm could reduce the turbidity from 40.2 NTU to 0.48 NTU (98.81% reduction). PAC in water will decompose into Aluminum Hydroxide and Hydrochloric Acid

pH

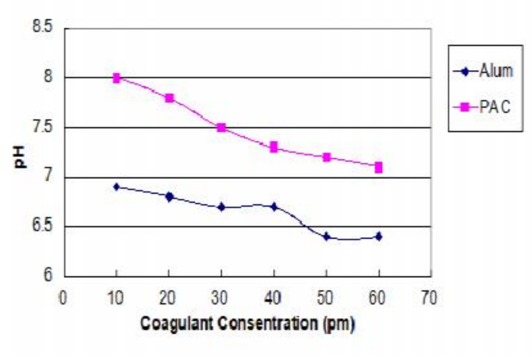

Figure 2. The effect of the addition of alum and PAC on the pH of Talang Jawa raw water

Figure 2 shows that the addition of alum up to 60 ppm causes the pH of raw water decrese from 8.5 to 6.4. This is because alum ($Al_2(SO_4)_3$) when dissolved in water will produce H_2SO_4 compounds which are acidic and will lower the pH of water with the reaction mechanism: $Al_2(SO_4)_3 + H_2O \rightarrow 2Al(OH)_3 + 3H_2SO_4$ (Tandiarrang et al., 2016). The pH value of the raw water resulting from the purification will be lower with the increase of PAC levels from the initial pH of raw water 8.5 to 7.1 with the addition of 60 ppm PAC presented in Figure 2. This is due to the greater PAC content added to the water sample , more

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H^+ ions released in water. This can be explained by the following reaction: $[Al_2(OH)_3]^{3+} + 3H_2O \rightarrow 2Al(OH)_3 + 3H^{3+}$ (Nur et al., 2020). Based on the turbidity and pH values PAC is more effective than alum. Because PAC 20 ppm has reduced the turbidity of raw water far below the permitted quality standard (5NTU) to 2.62 NTU and pH 7.8. Meanwhile, the new alum concentration of 30 ppm reduces raw water turbidity to 4.54 NTU and pH 6.7. Figure 2 shows that the addition of alum up to 60 ppm caused the raw water pH to decrease from 8.5 to 6.4. This is because alum ($Al_2(SO_4)_3$) when dissolved in water will produce H_2SO_4 which compounds are acidic and will lower the pH of water with the reaction mechanism: $Al_2(SO_4)_3 + H_2O \rightarrow 2Al(OH)_3 + 3H_2SO_4$ (Tandiarrang et al., 2016).

The pH value of the raw water resulting from clarification will be lower with increasing PAC levels from the initial pH of raw water 8.5 to 7.1 with the addition of 60 ppm PAC, which can be seen in Figure 2. This is due to the greater PAC content added to the water sample , the more H^+ ions released in water. This can be explained by the following reaction: $[Al_2(OH)_3]^{3+} + 3H_2O \rightarrow 2Al(OH)3 + 3H^{3+}$ (Nur et al., 2020). Based on the turbidity and pH values obtained, the use of PAC is more effective than alum. This is because the use of 20 ppm PAC has been able to reduce the turbidity of raw water far below the permitted quality standard (5NTU), namely to 2.62 NTU and pH 7.8. Meanwhile, new alum with a concentration of 30 ppm is able to reduce raw water turbidity to 4.54 NTU and pH 6.7

The effect of the addition of alum and PAC on turbidity and pH of Pelita Sari Intake raw water

Table 3. The effect of the addition of alum and PAC on the turbidity of Pelita Sari Intake Raw Water

Coagulant concentration (ppm)	Alum		PAC	
	Turbidity (NTU)	pH	Turbidity (NTU)	pH
10	8,23	7,4	6,45	7,8
20	7,47	7,4	4,15	7,6
30	6,21	6,8	3,47	7,4
40	5,62	6,7	2.31	7,3
50	3,85	6,7	0,97	7,2
60	2,63	6,7	0,52	7,1

- ***Turbidity***

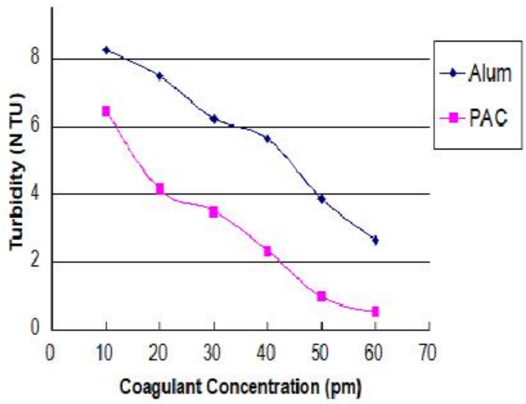

Figure 3. The effect of adding alum and PAC on the turbidity of Pelita Sari Intake Raw Water

Figure 3 shows that based on the results of the analysis of the initial measurement of turbidity of raw water of 1 Ilir Intake before the administration of alum was 46.8 NTU and after treatment with 50 ppm of alum it became 3.85 NTU (already included in the Environmental Quality Standard range for turbidity 5 NTU). This is caused by the presence of Al^{3+} ions in alum sufficient to destabilize colloids. Based on the turbidity reduction data using alum, the effectiveness of reducing raw water turbidity using alum is up to 91.77%. In line with the addition of alum, the addition of 20 ppm PAC also reduced the turbidity of raw water below the Environmental Quality Standard, namely

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4.15 NTU, with a decrease of up to 91.13%. Furthermore, with the addition of PAC, the turbidity value of raw water will decrease. This is due to the fact that the PAC coagulant has a high degree of polymerization, meaning that the compounds in the PAC have a large molecular mass which causes the PAC to easily react with the particles present in the water. Consequently, the reaction that occurs during the coagulation-flocculation process does not require a large dose. The coagulation and flocculation processes that use PAC coagulants do not require high doses.

- *pH*

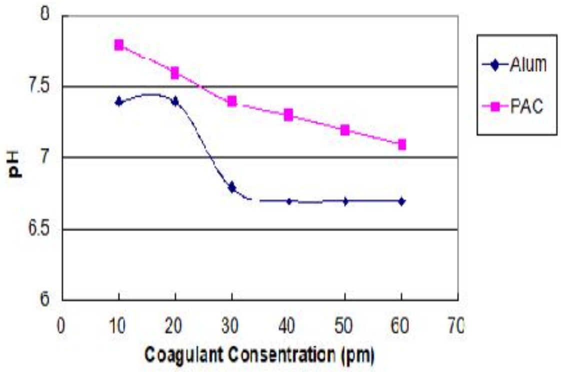

Figure 4. The effect of the addition of alum and PAC on the pH of Pelita Sari Intake raw water

The results obtained from pH measurements were changes in pH before and after the treatment using various doses of alum and PAC. Figure 4 shows that the greater the dose of alum used, the lower the pH of the raw water was. The pH of the raw water before treatment was 8. After the treatment with the addition of alum doses, the pH of the raw water decreased. This is due to the fact that the alum dissolved in water formed H_2SO_4 which was acidic that lowered the pH of the water. However, this reduction is not in accordance with environmental quality standards because the turbidity is still above the quality standards.

Figure 4 shows that increasing the dose of PAC from 10 ppm to 60 ppm can lower the pH from 8 to 7.8 – 7.1. This is because the PAC dissolved in water will release H^+ ions (has a Bronsted-Lowry acidity site) so that the more PAC is added, the greater the decrease in pH.

CONCLUSION

The addition of Alum and PAC coagulants can reduce the turbidity and pH of raw water from Java Talang and Pelita Sari. In this research, PAC reduced turbidity and pH better than Alum. The addition of the best coagulant dose, namely 20 ppm, can reduce turbidity and pH in Java Talang raw water from 40.1 NTU to 2.62 NTU by 94% and pH from 8.5 to 7.8, while for raw water in Pelita Jaya from 46.8 NTU to 4.15 NTU by 91%, pH from 8.5 to 7.6. This value meets drinking water quality standards for turbidity <5 and pH 6.5 - 8.5

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