Optimization of Coagulation-Flocculation Process for Tello River Water Treatment Using Poly Aluminum Chloride and Aluminum Sulfate

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Abstract. Tello River Water was utilized by PT. PLN SULSERABAR as Boiler feed water. Total Suspended Solid (TSS) in river water can be removed by the coagulation-flocculation process. Improved performance of coagulation process can be done by optimizing coagulant concentration and pH on coagulation. This research focused on optimization of pH and percent (%) removal of TSS using Poly Aluminum Chloride (PAC) and Aluminum Sulfate (Alum). The concentration of coagulant was 25% of the initial TSS of the sample for PAC and 35% of the initial TSS of the sample for Alum. The sample used in this research is Tello River Water which has initial TSS concentration of 195 mg/L with rapid mixing (350 rpm) for 1 minute, slow mixing (50 rpm) for 20 minutes and 30 minutes of sedimentation. The coagulation-flocculation process was carried out in the pH range of 4-10 and the TSS concentration was analyzed using the Gravimetric method. The optimum pH on coagulation and percent (%) TSS removal obtained from this study were 7, 99.23% for PAC and 6, 89.48% for Alum. These results indicated that PAC was the perfect coagulant for the removal of TSS because it was able to eliminate TSS nearly 100%.

1. Introduction

Tello River Water was utilized by PT. PLN SULSERABAR as boiler feed water. Total Suspended Solids (TSS) from river become deposits inside the boiler. This deposit cause by decreased of heat transfer and reduced of the efficiency of the boiler [1]. TSS can be removed by a coagulation-flocculation process [2, 3]. Types of coagulants, coagulant concentrations, initial pH [4], speed of rapid mixing [5-7], speed of slow mixing [8] settling time [9] and additional aid coagulants [10] are several factors that influence the efficiency of the coagulation-flocculation process. Coagulant concentration and pH are the most important factors for efficiency of the coagulation-flocculation process [11]. The addition of coagulant is not always directly proportional to the percent of TSS removal. Particle restabilization can occur due to the addition of excess coagulants [12]. Stabilization of suspended particles and coagulant surface charge are affected by the pH of the process. A suitable pH can help neutralizing the negative charge on the particles and help floc formation [13].

Commonly used chemical coagulants such as calcium, aluminum, and iron. Based on the results of the experiment, Aluminum Sulfate and Poly Aluminum Chloride coagulants were selected coagulants [11]. Those coagulant with Aluminum basis, metal ion hydrolized to Aluminum hydroxide and Hydrogen ion. Hydrogen ion will be reacting within water alkalinity and it process, decrease of water pH can be shown from equation below:
For Alum [13]

\[
\text{Al}_2(SO_4)\text{.16H}_2\text{O} \rightarrow 2\text{Al}^{3+} + 3\text{SO}_4^{2-} + 16\text{H}_2\text{O} \rightarrow 2\text{Al(OH)}_3 + 6\text{H}^+ + 3\text{SO}_4^{2-} + 10\text{H}_2
\]  

(1)

For PAC [14]

\[
\text{Al}_2(\text{OH})_3\text{Cl}_3 \rightarrow \text{Al}_2(\text{OH})_3^{3+} + 3\text{Cl}^- + 3\text{H}_2\text{O} \rightarrow 2\text{Al(OH)}_3 + 3\text{H}^+ + 3\text{Cl}^-
\]  

(2)

Based on the theory of coagulation-flocculation, the surface of precipitate from PAC with positive charges can neutralize the charges on the surfaces of primary particles suspended in the water [15]. After neutralization of the particle charge, microflocs is formed which has not been seen by eyes about 1 - 100 µm. Due to Brown's forces, microflocs collide and bind to each other to form larger aggregates (perikinetic flocculation). Slow mixing is done to give microflocs a chance to bind to each other so that a larger floc is formed until it is steady and settles [12].

Research on optimization of coagulant concentration and pH of coagulation-flocculation process has been carried out. Coagulant concentration, pH of process, and percent removal of TSS were 300 mg/L, 6, 97% for Poly Aluminum Chloride (PAC) and 500 mg/L, 6, 92% for Aluminum Sulfate (Alum) respectively [16]. Optimization of coagulant concentrations with Tello River Water samples was carried out, the result was 25% of initial TSS for PAC and 35% of initial TSS for Alum with percent removal of TSS were 89.6% and 86.67% [17]. Percent removal from the study has not been maximized so that in this study aims to improve the efficiency of the performance of the coagulation-flocculation process by optimizing the pH of the process using PAC and Alum coagulants through same operating conditions.

2. Methods

The water sample used in the research from Tello River Water Makassar on April 2018. Initial TSS concentrations and pH of Tello river water were 195 mg/L and 5. The conditions of the coagulation-flocculation process in various research can be seen in Table 1.

| Parameter                        | Range     | Reference |
|----------------------------------|-----------|-----------|
| Speed of rapid mixing (rpm)      | 80 - 350  | [3,17 – 21]|
| Duration of rapid mixing (min)   | 1 - 4     | [3,17 – 21]|
| Speed of low mixing (rpm)        | 30 - 50   | [3,17 – 21]|
| Duration of low mixing (min)     | 15 - 20   | [3,17 – 21]|
| Settling time (min)              | 15 - 45   | [3,17 – 21]|

PAC with a concentration of 25% of the initial TSS was added to the sample. Based on Table 1 can be seen a summary of the conditions of the coagulation-flocculation process from various research. In this research used rapid mixing at 350 rpm for 1 minute, slow mixing at 50 rpm for 20 minutes, after 5 minutes from the beginning of the flocculation process measurements and adjustments pH were made (pH adjusted by adding NaOH or H_2SO_4) and sedimentation for 30 minutes. The supernatant was taken 2 cm below the upper limit of the sample solution, then TSS was analysed using the Gravimetric method. Variations in process pH 4-10 and coagulant Aluminum Sulfate were carried out with a concentration of 35% from the initial TSS.

3. Results and Discussion

Coagulant concentration and pH of process are the most important factors of the efficiency of the coagulation-flocculation process. When the coagulation-flocculation process works in optimal conditions, the use of coagulants can be minimized as needed. The required coagulant concentration increases in proportion to the amount of suspended particle concentration to complete destabilize
through charge neutralizing and bridging. However, the addition of excess coagulant makes particle restabilization and the suspended particle concentration increases again. pH can affect the stabilization of suspended particles and coagulant surface charge. Suitable pH can help neutralize the negative charge on the particles and help the formation of the floc.

TSS removal resulting from the coagulation-flocculation process will not optimal when optimizing the coagulant concentration without observing to the pH process. Research on optimization of coagulant concentration without observing to pH gets the optimum results of PAC and Alum coagulant concentrations at 25% and 35% from initial TSS concentrations with TSS removal percent were 89.6% for PAC and 86.67% for Alum [17]. This study optimizes the coagulation-flocculation process by optimizing the pH of the process using coagulant concentrations obtained from Widiyanti research [17]. There was an increase in percent TSS removal resulting from the coagulation-flocculation process in this research. TSS removal percent using PAC and Alum coagulants increased from 89.6% to 99.23% for PAC and 86.67% to 89.48% for Alum. Figure 1 shown the relationship between pH and percent TSS removal using PAC and Alum coagulant results from this research.

The highest TSS removal percentage was obtained at pH 7 for PAC and pH 6 for Alum based on Figure 1. Percent removal of TSS results from the coagulation-flocculation process in this research is greater using PAC than Alum. This is cause by the PAC coagulant is a coagulant resulting from polymerization of metal coagulants which is used to improve the performance of conventional coagulants such as Alum [22].

The conditions of the coagulation-flocculation process chosen are crucial in the success of removing TSS in water. Comparison of coagulation-flocculation process conditions between percent TSS removal during pH optimization using the PAC coagulant from this research and Nasir and Daud research [16] can be seen in Table 2 and Figure 2.

Figure 2 shown that the percent TSS removal results from this research are greater than the previous research which obtained the highest percent removal of 77%. This is because when determining the optimal pH of the process, the concentration of PAC coagulant used is not optimal. Since of coagulant concentration and pH of the process in optimal conditions, there was an increase in percent removal from 77% to 97% [16]. Due to the coagulant concentration and pH of the process was the most important factor in the success of the coagulation-flocculation process [11].
Table 2. Comparison of operating conditions of the coagulation-flocculation process of this research and Nasir and Daud research [16]

| Parameter                        | Reference | This research | [16] |
|----------------------------------|-----------|---------------|------|
| Initial of TSS sample (mg/L)     |           | 195           | 348  |
| Speed of rapid mixing (rpm)      |           | 350           | 150  |
| Duration of rapid mixing (min)   |           | 1             | 4    |
| Speed of low mixing (rpm)        |           | 50            | 20   |
| Duration of low mixing (min)     |           | 15            | 20   |
| Settling time (min)              |           | 30            | 30   |
| Concentration of coagulant (mg/L)|           | 48.75         | 100  |
| pH                               |           | 4-10          | 2-12 |

Figure 2. The relationship between pH and percent TSS removal results from the coagulation-flocculation process of this research and Nasir and Daud research [16] using PAC coagulant

Table 3. Comparison of operating conditions of the coagulation-flocculation process of this research, Nasir and Daud research [16] and Asadollahfardi et al. research [20]

| Parameter                        | Reference | This research | [16] | [20] |
|----------------------------------|-----------|---------------|------|------|
| Initial of TSS sample (mg/L)     |           | 195           | 348  | 287  |
| Speed of rapid mixing (rpm)      |           | 350           | 150  | 100  |
| Duration of rapid mixing (min)   |           | 1             | 4    | 3    |
| Speed of low mixing (rpm)        |           | 50            | 20   | 30   |
| Duration of low mixing (min)     |           | 15            | 20   | 15   |
| Settling time (min)              |           | 30            | 30   | 30   |
| Concentration of coagulant (mg/L)|           | 68.25         | 100  | 1000 |
| pH                               |           | 4-10          | 2-12 | 2-10 |
Comparison of coagulation-flocculation process conditions and percent TSS removal during pH optimization using Alum coagulant from this research, Nasir and Daud research [16] and Asadollahfardi et al. research [20] can be seen in Table 3 and Figure 3.

Figure 3. Chart of the relationship between pH and percent TSS removal results from the coagulation-flocculation process of this research and Nasir and Daud research [16] and Asadollahfardi et al. research [20] using Alum coagulant

Figure 3 shown that the pH optimum of the three research is 6. The percentage of TSS removal from this research is greater compared to the research of Nasir and Daud [16] and Asadollahfardi et al. [20]. This is caused when determining the optimal pH of the process, the concentration of Alum coagulant used is not optimal. At the time of coagulant concentration and pH of the process at optimal conditions, there was increasing removal percent from 53% to 92% [16] and 83.9% to 91.6% [20].

Based on the results of the coagulation-flocculation process from several research it can be seen as the most important factor to improve the performance of the coagulation-flocculation process are the optimal coagulant concentration and pH of coagulation. The highest percentage of coagulant PAC when compared with from Nasir and Daud research [16]. Whereas the percent uses the lowest Alum coagulant when compared with results from Nasir and Daud research [16] and Asadollahfardi et al. research [20], but the differences is not too large, which is around 3%. The advantage of optimizing the coagulation process of this research is that it can overcome the problem of TSS whereas water is always fluctuating depending on the season.

4. Conclusion
The optimum pH on coagulation and percent (%) TSS removal obtained from this study were 7, 99.23% for PAC and 6, 89.48% for Alum.

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