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EFFECT OF FLOW RATE AND RECIRCULATION ON THE FLOTATION PROCESS IN REMOVING FAT, OIL, GREASE, AND SOLID

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Abstract

A number of wastewater treatment have been developed in order to remove suspended particles through sedimentation. A flotation unit is one of the alternative technology that can be considered due to flotation unit has several advantages over the sedimentation unit. This study aims to determine the effect of flow rate and recirculation ratio on the flotation process in removing fat, oil, grease, and total suspended solids (TSS) in raw wastewater. A pilot-scale of the wastewater treatment plant was applied under various flow rates, including 250; 275; 300 mL/minutes with wastewater recirculation is 0; 60; 80; 100%. The results show that flotation process under flow rate 275 mL/minutes with contact time 22 minutes and under 100% recirculation wastewater performed a higher percentage removal of fat, oil, and grease about 72.54%, and removal of TSS about 79.71%. Therefore, it is conjectured that flow rate and recirculation play an important role in the flotation process.

Keywords: Fat, Grease, Flotation, Flow rate, Oil, Recirculation, Suspended solid.

1. Introduction

Industrial development has resulted in decreasing environmental quality due to wastewater disposal issues. Industrial wastewater contributes to hazardous contaminants because the wastewater containing fat, oil, grease, and total suspended solids (TSS) is relatively high. It is discharged into a water body, and then it will disrupt aquatic and human life. The existence of fat, oil, grease on the water's surface will obstruct sunlight into the water deep and lead to the depletion of oxygen. Further, decomposition of fat, oil, grease to become imperfect and causing odour problem [1]. TSS has an important role in determining water quality. High TSS concentration will also increase the turbidity value of water, which results in decreased productivity in the water [2]. According to the above explanation, it is necessary to treat fat, oil, grease, and TSS through a flotation process. The flotation process is the most effective technique for removing fat, oil, grease, and TSS, induced air into wastewater from the bottom of the container [1, 3]. The air is delivered through a pipe and released at atmospheric pressure, and then the air comes out in the form of microscopic air bubbles [3]. Due to the density of air that is much smaller than water, the air bubbles will automatically rise to the surface along with particles of fat, oil, grease, and TSS. The effectiveness of the flotation process is affected by many factors, including air pressure, flow rate (discharge), detention time, recycle ratio (recirculation), coagulation-flocculation pre-treatment, and flotation tank design [4].

From several operational parameters, the most important parameters in the flotation process are flow rate, pressure, and recirculation. Flow rate is directly related to the volume of waste to be treated, and detention time is a critical factor. High detention time will cause a longer time for treating wastewater instead of a large tank capacity. However, if the flow rate increases, then detention time will be shorter, and it will allow a shorter time for the air to fully dissolve [4]. Pressure is one of the operational parameters that can affect the flotation process. Because of the change in pressure, the dissolved air is released in the form of fine air bubbles (10-100 microns) that allow for the removal of colloidal particles [5]. Previous studies have conducted varying air pressure of about 345-621 kPa. It was found that the higher pressure will provide greater air solubility and increase bubble production and obtained the best air transfer efficiency at a pressure of 621 kPa [4, 5].

Other important operational parameter in the flotation process is recirculation. The principle mechanism of a recirculation flotation system is that about 15%-120% of the effluent flotation is returned to the flotation tank inlet with a mixture of air pressure, then that solid particles will be carried by fine bubbles to the surface [3]. Previous studies have carried an experiment with various recirculation ratios. The results obtained that processing efficiency increased with a recirculation ratio of 5% to 15%. Under conditions of 0.6 mm nozzle and 4 kg / cm2 or 4 bar pressures have the highest processing efficiency, where recirculation quantity increases from 37% to 92% [6]. However, most studies have not looked into the effect of flow rate and recirculation simultaneously.

According to the information above, it is important to simultaneously observe the operational parameters of flow rate and recirculation in removing fat, oil, grease, and TSS. The objective of this research is to determine the effect of flow rate and recirculation simultaneously in removing fat, oil, grease, and TSS. Therefore it is expected that the results can be applied in the wastewater treatment appropriately.

2. Material and Method

Wastewater was taken from the inlet of the collecting chamber in wastewater treatment plant Surabaya Industrial Estate Regency (SIER), Surabaya, Indonesia. The pilot scale of the wastewater treatment plant is shown in Fig. 1. The reactor volume is 6 L with a size of 40 cm x 20 cm x 10 cm. Pump pressure is maintained at 2 bars. The water was pressurized to assess the effects of pressure, temperature, and time detention on microbubble production. The flotation tank is made of acrylic with a length of 40 cm, a width of 20 cm, and a height of 15 cm (Fig. 1). The recirculation flow design was used in the construction of this pilot-scale flotation unit.

A flow rate meter varied the incoming water at 250, 275, 300 mL/min. The pressure was maintained at 2 bar, and the water temperature was noted at 28°C and was held constant throughout the test. The recirculation ratio is varied from 60%, 80%, 100%, and 0% recirculation ratio, which is used as a control or comparison with other recirculation ratios.

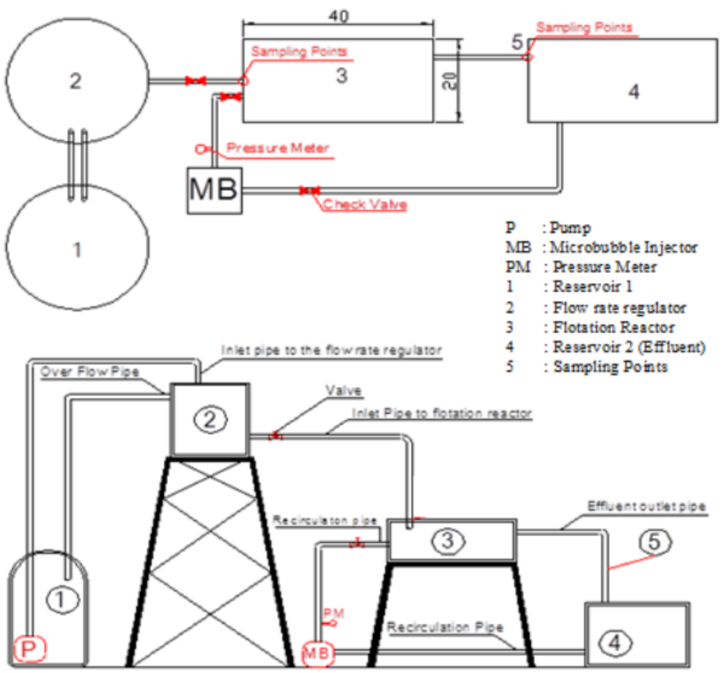

Fig. 1. Detail of flotation pilot scale.

Preliminary data collection was conducted on samples including, data on fat, oil, grease, and total suspended solids (TSS) [7]. The initial data is used to calculate the pressure requirements, recirculation flow rate, and reactor design. The design of the series of research tools is explained in the form of a plan, as well as pieces and details (Fig. 1). Then, the device is adjusted, including the regulation of the inflow rate and recirculation settings.

The recirculation process is carried out by carrying out the flotation process (control), and the effluent of clean water is accommodated in the reservoir. Then, prepare a recirculation installation connected to a reservoir containing clean water effluent from the previous flotation process (control). Next, start the flotation process by flowing wastewater into the flotation bath and followed by a recirculating pump that is turned on to recirculate wastewater. Set the flow rate by adjusting the effluent valve on the recirculation channel to a constant flow rate as planned. Pressure regulation is carried out by turning the air valve on the pump and the effluent valve on the recirculation channel.

3. Results and Discussion

Figure 2 shows the percentage removal of fat, oil, and grease in the flotation under different flow rates and the recirculation ratio. First, it can be seen that the lowest flow rate shows a lower efficiency removal of fat, oil, and grease than the highest flow rate. While a medium flow rate, 275 mL/minute, performs the highest efficiency removal of fat, oil, and grease, about 21.02% -72.54%. It has been well established that flow rate will affect detention time during the treatment process. The lower flow rate takes the longer detention time, and vice versa.

However, this study shows that a flow rate of 275 mL/minute had a detention time of 22 minutes, which was not the lowest or the highest detention time. This could be explained that a high flow rate will have shorter time detention, but the production of bubbles will increase as the discharge increases. It will make the contact process between floc and air bubbles occur in a relatively short time. Therefore there were much floc has not been separated from the fluid [4]. Meanwhile, a low flow rate will have longer time detention, but the production of bubbles will also be lower along with a lower flow rate. This makes less formed floc can contact with air bubbles due to low bubble production.

In addition, the presence of air pressure and concentration of fat, oil, and grease contribute to the effectiveness of flotation in decreasing fat, oil, and grease concentration in wastewater. Air pressure creates air bubbles which will bind oil particles, and it will be pushed onto the surface of the treatment tank [8]. Further, fat, oil, and grease will be separated from wastewater, decreasing its concentration with increasing contact time [9, 10]. Second, all flow rates indicate that the highest percentage reduction of fat, oil, and grease occurs at 100% recirculation.

These results indicate that flotation with 100% recirculation could reduce more than 70% fat, oil, and grease in wastewater. This is probably due to more recirculated water will cause more dissolved air, which can separate solids from liquids. It means that the air-solid ratio (A/S) in the recirculation system gets higher than that of non-recirculation or low percentage recirculation. Furthermore, solids can be separated. Flotation process without recirculation, a directly given high pressure with a pressurized pump to wastewater will make the solids experience a high sheer force. It tends to destroy floc that has been formed before being given pressure which causes less effectiveness of the system [11]. Conversely, in flotation with recirculation, the given high pressure to wastewater will minimize the damage to the floc formed in the process flow.

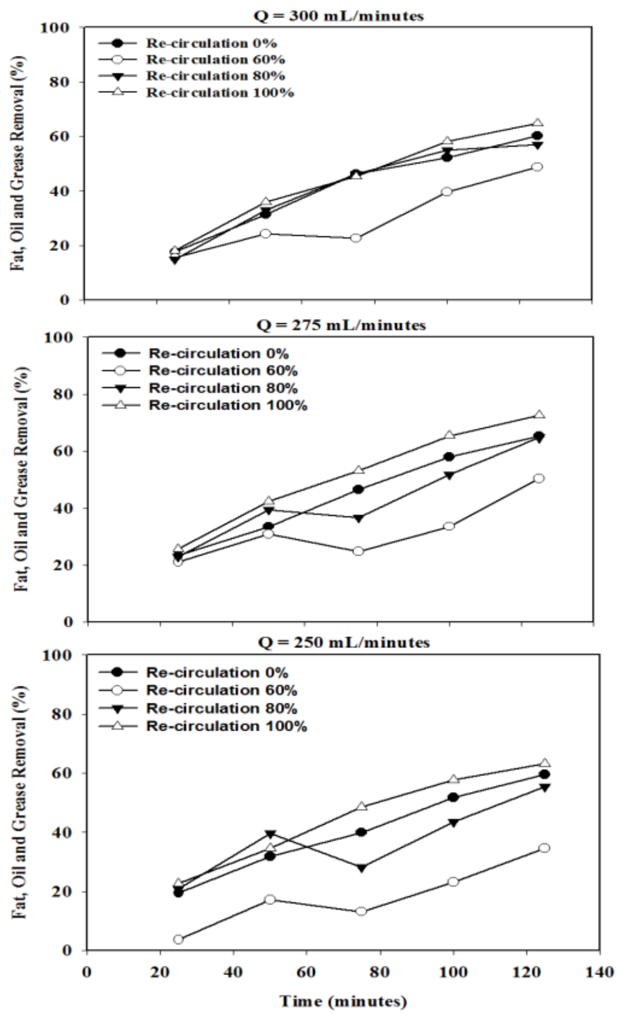

Fig. 2. Comparison of flotation operational among different flow rates under various recirculation in removing fat, oil, and grease.

Figure 3 presents the percentage removal of TSS in the flotation under different flow rates and the ratio of recirculation. It can be seen that the pattern of TSS removal is similar to fat, oil, and grease removal. The previous results have mentioned that the lowest flow rate shows a lower efficiency removal than the highest flow rate, and the highest TSS removal, 79.71%, has been achieved under a medium flow rate, 275 mL/minute.

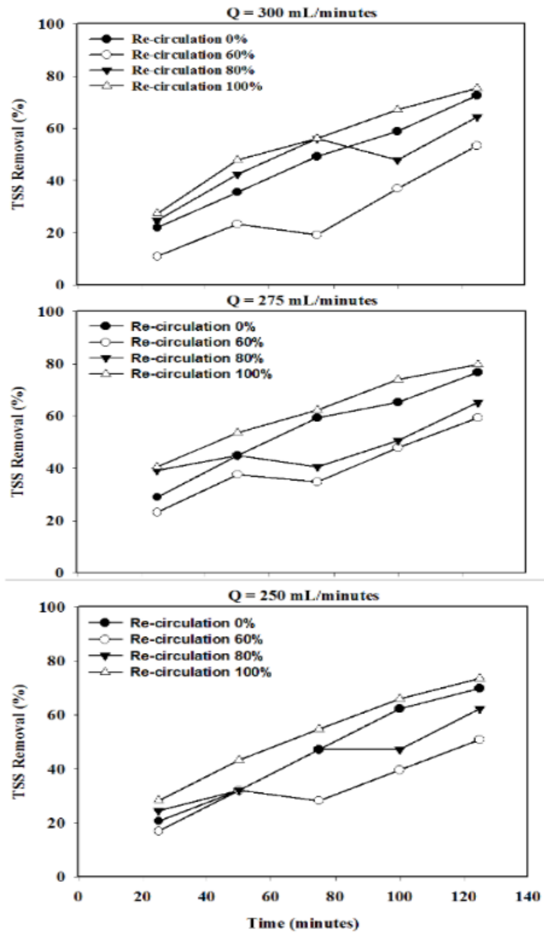

Fig. 3. Comparison of flotation operational among different flow rates under various recirculation in removing total suspended solids.

It seems that a low flow rate will result in low bubble production, therefore the amount of solidified solids will be less. Meanwhile, a high flow rate will result in shorter contact times, the interaction between solids and bubbles might not be maximum. Decreasing TSS in the flotation process is probably due to differences in particle density. If the specific gravity of the particle is smaller than the liquid, the particles will be spontaneously flexed. While the solid or liquid particles with greater specific gravity than the liquid are separated by air bubbles [4].

Second, these results indicate that the flotation ability for TSS reduction can be achieved by more than 75% at 100% recirculation. The high value of the recirculation ratio will be followed by the higher number of bubbles released into the flotation bath. Which then bubbles will cause mixing, which will increase the aggregate connection between particles and bubbles, thereby increasing processing performance [5]. This decrease in TSS value is followed by increasing recirculation, which applies to all flow rates. This shows that recirculation can affect the decrease in TSS content in the flotation process. However, it can be seen that in 100% recirculation of various flow rates, the flow rate of 275 mL/minute has the highest effectiveness while the flow rate of 300 mL/minute is still lower. Certain applications with high flow rates and high recirculation ratio values are usually avoided [6, 12]. The higher the amount of air released in the flotation bath can result in excessive turbulence in the flow. In addition, the impact due to turbulence will break the relationship of the aggregates of particles and bubbles and obstruct the processing [13, 14].

The level of effectiveness of the flotation process in terms of various variations in recirculation explains that recirculation can improve the processing process with recirculation ratio conditions balanced with the waste flow rates that enter the flotation tank. This is because, with the lower flow rate of waste entering the flotation tank, the recirculation discharge will also be smaller. It can cause the production of bubbles to be lower, and the speed of particles and bubbles to rise will be lower [1, 15]. The particle's velocity will decrease further with increasing time detention followed by low flow rates and many bubbles. This is because the available dissolved air is not enough with low recirculation flow rates, so that the air-solid ratio (A/S) is low.

It is suggested that the wastewater flow rate should be arranged with the required contact time and the amount of generated bubble production. The arrangement of wastewater flow rate, contact time, and a generated bubble will produce a more effective treatment process. Future work should consider the effect of coagulant and various types of coagulant to enhance flotation's performance in removing fat, oil, and grease, instead of TSS.

4. Conclusion

The conclusion of this study is given below.

- The operational parameters of flow rate and recirculation play an important role in the flotation process.
- Variation of wastewater flow rate is associated with the optimum detention time (125 minutes) in the flotation process for reducing the concentration of fat, oil, grease, and TSS, about more than 70%.
- The flotation process with recirculation and without recirculation shows that recirculation in the flotation process results in more optimal results.
- Comparison between flotation with recirculation and without recirculation indicates that removing fat, oil, grease, and TSS under recirculation is much higher than without recirculation, which reached more than 75%. It can be suggested that the optimum configuration of the flotation process is a flow rate of 275 mL/minute with a 100% recirculation ratio.

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