RETROFITTING OF DISSOLVED AIR FLOTATION TANK VIA AUTO SCRAPPER SYSTEM WITH LEVEL SENSOR

Roziah Zailan, Amanda Saarani, Norhidayah Abdull

Abstract

A dissolved air flotation tank requires retrofitting to address technical problems such as inefficient manual scrapper option. This study presents an analysis of retrofitting the auto scrapper system for the dissolved air flotation tank via ultrasonic level sensor installation. It promotes operation time and operation cost saving, prevents human mistakes, and simultaneously moves towards full automation technology. Wastewater quality is improved by producing an optimal solid-liquid separation at the dissolved air floatation tank. The research methodology covers the comparative analysis of the findings before and after the dissolved air floatation retrofitting along with the observation on site. Cost analysis has been developed to identify the level of sensor installation potential and the impact of the sensor on the dissolved air floatation auto scrapper system. The amount of chemical oxygen demand and total suspended solids are significantly lower after the retrofitting. Cost-saving from this project is induced by labour cost to maintain the monthly dissolved air floatation system and water cost-saving using clean final discharge water. Total annualised cost-saving is at RM 22,380/year. Meanwhile, the investment return was calculated for 2.4 months, indicating a shorter period to recover investment and attain a profit.

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Introduction

Typical problems in the wastewater treatment plant nowadays are circulating between technology limitation, workforce and financial issues. Dissolved Air Flotations (DAF) tank is widely assembled in industrial wastewater treatment to separate solid-liquid solution through flotation. The DAF functions when a high-pressure supersaturated solution of the gas-liquid mixture stimulates wastewater flow and produces bubbly gases that move total suspended solids to the water surface (Back, 2021). An advance DAF is automated via supervisory control and equipped with a data acquisition system (SCADA) (Fonseca et al., 2017). A conventional flotation unit was modernised and upgraded into an automated pressure flotation unit and sensor installation (Yantsen et al., 2020). Yet, not every industry is technically and financially ready to install an automation DAF system. According to Bäck (2021), the DAF system requires high energy demand of producing a pressure of 3-6 atm and incurs a greater utility cost as compared to conventional sedimentation.

This study focuses on the retrofitting of the DAF system in an Industrial effluent treatment system (IETS) plant in a natural rubber gloves production manufacturing plant (Top Gloves, 2015). The DAF is installed after the primary treatment, which is a physical-chemical process that involves coagulation and flocculation process, and reduced chemical oxygen demand (COD), total suspended solids (TSS) and heavy metal, particularly zinc before DAF. At DAF, when sludge is thick and accumulated on top of the DAF tank due to the flocculation process, workers will manually switch on the motor to run the scrapper while the sludges skimmed off into the holding tank. Scrapper will run manually based on the worker's estimation and observation of the sludge thickness. However, sometimes, when the workers did not follow the scrapper's schedule, it causes the carry-over of sludge from DAF into a sequential batch reactor (SBR) tank. Figure 1(a) shows such problem at the DAF tank. This condition has led to high TSS at the final discharge point. Figure 1(b) represents poor settling of sludge at the SBR tank before the discharge point.

(a)

(b)

Figure 1: Problems faced (a) Suspended solids carry-over due to thick sludge accumulation at the dissolved air Flotation tank. (b) Poor settling of sludge at sequential batch reactor tank prior to discharge.

More specifically, the objective of this study is to upgrade the wastewater treatment plant by installing an automated DAF system. The comparative analysis of the findings before and after the DAF retrofitting was conducted along with the observation on-site. An autonomous system improves the current system by reducing workforce dependency and saving time to operate the DAF system. It prevents human mistakes by moving towards automation. Financially, it saves water supply costs by improving effluent quality to be recycled for leaching tanks, toilet flushing and housekeeping usage. In addition, concise cost analysis has been developed to identify the level of sensor installation potential and the impact of the sensor on the DAF auto scrapper system.

Methodology

A dissolved air flotation system before retrofitting design is provided in Figure 2. A wastewater pump is required to pump wastewater from the coagulation and flocculation into the DAF.

Meanwhile, a circulation pump is used to pump air from the dissolved air tank to the DAF and surge the generation of bubbles.

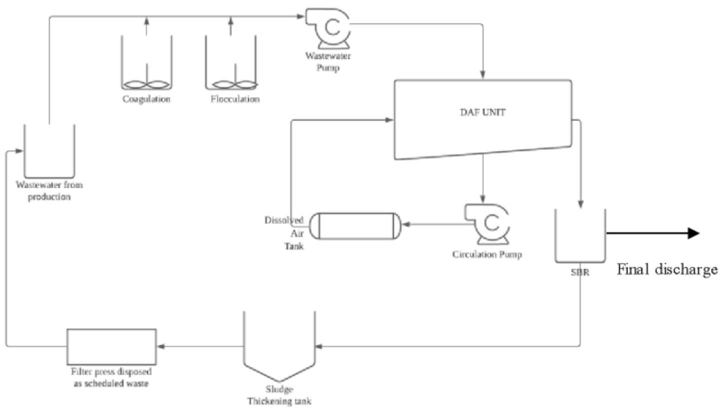

Figure 2: Schematic diagram of the dissolved air flotation system.

The ultrasonic level sensor was installed on top of the DAF tank in Figure 3. Any changes in sludge level in the DAF chamber will be detected and controlled by the installed sensor (Galdino et al., 2015). With a constant feed rate of polymer dosing at 2 L/min, a cluster of floc forms at a level of 0.5 cm. The sensor will detect the level of sludge, which is the optimum solid-liquid separation performance. The working mechanism of the sensor functions when it evaluated the reflected sound of the object. This kind of sensor can trace the appearance of any object and is suitable for level monitoring in this project. The sensor can detect objects regardless of their substances, gaseous, liquid or solid form, colour or transparency (Wenglor, 2021).

Figure 3: Ultrasonic level sensor installed on top of the dissolved air floatation tank.

The automation system is controlled by an ultrasonic level sensor controller shown in Figure 4. The system panel will automatically switch on the motor to run the scrapper. One DAF cycle took about 1 minute and 45 seconds to complete, hence it will automatically switch off when it completes one cycle. Before the ultrasonic sensor installation, the unnoticed on site manpower increased the wastewater quality level parameter. However, after the retrofitting, the sensor will respond towards the sludge level and indirectly reduce the parameters' level.

Figure 4: Ultrasonic level sensor controller.

Result and Discussion

As a result, the DAF system retrofitting with a sensor installation has effectively solved the problems. Several improvements had been visualised through the observation on site. The DAF chamber has resulted in no suspended solids carry-over (Figure 5(a)). The sensor was able to maintain the sludge level and direct a scrapper that runs automatically. According to Figure 5 (b), clear water at the SBR indicates good sludge settling at the SBR tank before being discharged.

(a) (b)

Figure 5: Improvement of retrofitting (a) No suspended carry- over at the Dissolved Air Flotation Chamber. (b) Clear water and good sludge settling at the sequential batch reactor.

Other than an observation on-site, the quantitative results were provided to support the finding. Monitoring for two parameters, relatively COD and TSS, is carried out during one day of operation time about four times (hourly) before and after the retrofitting. Apparently, the amount of chemical oxygen demand and total suspended solids are significantly lower after the retrofitting. The amount of COD at the DAF chamber is presented in Figure 6. The amount of COD at the DAF chamber was reduced and proven by the percentage of removal around 46.6 % to 55.4%. The COD analysis demonstrated the maximum removal percentage from the third hour of the sampling through reduction from 720 mg/L to 321 mg/L. Meanwhile, the lowest COD reduction was during the fourth hour of 552 mg/L to 295 mg/L.

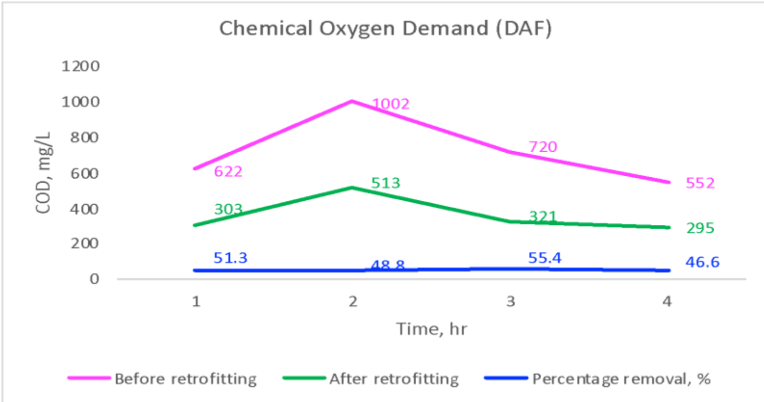

Figure 6: Comparison of COD at DAF chamber before and after DAF retrofitting

Big gaps figured out between the upgrading times for COD are observed in Figure 7. The removal efficiency of TSS at the DAF chamber increased after retrofitting exhibits less suspended solids carry-over at the DAF chamber. Large percentage removal was logged between 86.3 % to 95.1 %. The highest TSS reduction was recorded during the third hour of the sampling fall from 651 mg/L to 32 mg/L. In contrast, the lowest reduction was from 432 mg/L to 59 mg/L, during the fourth hour of the sampling.

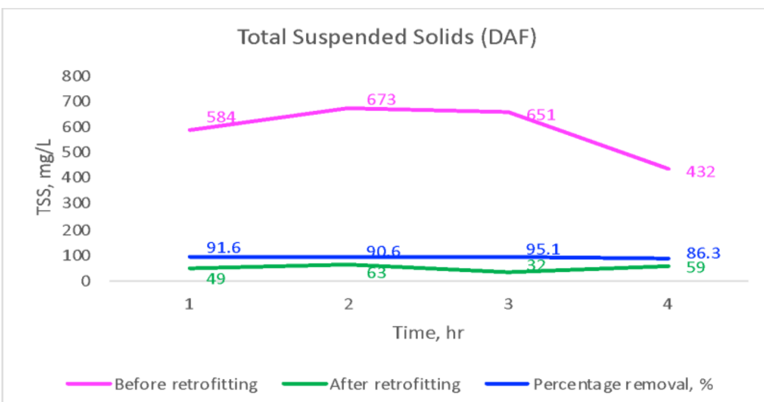

Figure 7: Comparison of TDS at DAF chamber before and after DAF retrofitting

Wastewater quality assessment is also taken at the point before the effluent enters the drainage system. The finding supports the sludge settling at the SBR tank and complied with the final discharge DOE Standard B: <200mg/L. Figure 8 demonstrates a similar trend with the DAF chamber as a lower COD amount has resulted at the SBR tank after the retrofitting. Though the recorded amount fluctuates during those four hours, the percentage removal value is approximately 41 % to 82 %. The highest reduction, during the third hour of sampling, is down from 131 mg/L to 37.4 mg/L. The lowest was in the fourth hour of wastewater sampling downward from 131 mg/L to 82 mg/L.

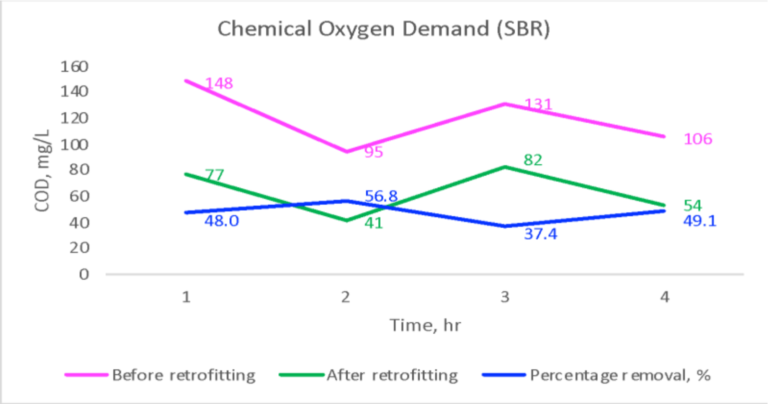

Figure 8: Comparison of COD at SBR tank (final discharge DOE Standard B: <200mg/L) before and after DAF retrofitting

Finally, Figure 9 clearly shows that the TSS values at the SBR tank are lower than the DAF tank, as it demonstrates the effectiveness of the DAF system. After all, the removal efficiency of TSS at the SBR tank is also improved after DAF retrofitting. It shows lesser suspended solids carry-over at the SBR relatively, referring to the final discharge of the effluent. The percentage of the removal varies between 36 % to 84.3 %. TSS values for the first hour of sampling moved down from 89 mg/L to 14 mg/L, while for the final hour reduced slightly from 75 mg/L to 48 mg/L.

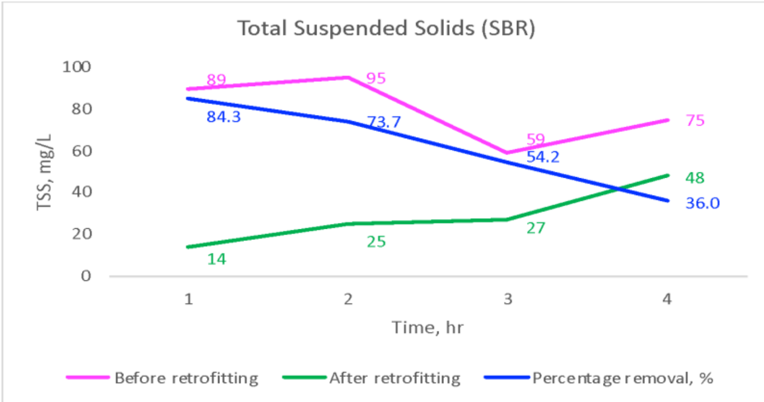

Figure 9: Comparison of TSS at SBR tank (final discharge DOE Standard B: <200mg/L) before and after DAF retrofitting

Cost Analysis

Cost analysis is used to measure the benefits of the decision to retrofit the DAF chamber. According to the cost analysis prepared in Table 1, investment costs considering the level sensor and control panel system are estimated at RM 4,500. Meanwhile, cost-saving from this project is induced by labour cost to maintain the monthly DAF system and water cost-saving using clean final discharge water. Both resources achieved total cost savings of about RM 1,865 per month. High saving was figured out from the annualised cost-saving at RM 22,380/year that appeals industrial plant owners to implement those systems.

Next, return on investment (ROI) was calculated to analyse the benefits harvested from retrofitting (Zailan et al., 2017). As a result, the ROI was calculated for 2.4 months. This figure indicates a shorter period to recover investment and attain profit from the automation of the DAF technology in the wastewater treatment plant.

Table 1: Cost Analysis.

Investment Cost	
Level Sensor	RM 2,000
Control panel system	RM 2,500
Total	***RM 4,500***
Cost Saving	
The time taken for the worker to operate the DAF system is approximately 6 minutes and 6 times per day	
Labour cost per month	18 hours per month x RM 7 per hour RM 126 per month
Water cost saving per month using clean final discharged water	36 m^3/day x RM 1.61 x 30 days RM 1,739 per month
Total cost saving	***RM 1,865 per month***
Annualised Cost Saving	***RM 22,380/year***
Return of Investment	
Investment cost/cost saving	RM 4,500/ RM 1,864.80 ***2.4 months***

Conclusion

The proposed retrofitting of manual DAF system into auto scrapper for DAF promotes operation time and cost saving. As a consequence, it reduces dependence on the workforce by installing a level sensor. The level sensor automatically detects sludge levels, prevents human mistakes and simultaneously moves towards full automation technology. This project improves water quality by producing an optimal solid-liquid separation at the DAF tank. Overall, the retrofitting project drives the sustainability of the wastewater plant operation.

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