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Influence of operational condition on the performance of halotolerant enriched - activated sludge system for treating medium salinity roasted peanut wastewater

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A B S T R A C T

This research aimed to investigate the influence of operational condition on the performance of halotolerant enriched - activated sludge system for treating high organic wastewater with medium salinity from roasted peanut industry. Roasted peanut wastewater with VLR ranged from 0.268 to 4.7 kg COD/m^3.day and Chloride concentration ranged between 1582 - 4392 mg/L was treated continuously for almost 77 days. Two identical reactors with Volume 25 L, namely R1 a conventional Activated Sludge (AS) System and R2, a halotolerant enriched-AS. Both reactors were running with the operational condition: HRT (9 h to 46 h) and MLSS (1000-6000 mg/L). Compared to conventional AS system, Halotolerant enriched Activated sludge system could remove an average of 86.7% COD, compared with conventional AS which was 85.7%. Average COD effluent of Halotolerant Enriched-Activated Sludge was also considerably lower, which was 127 mg/L, than conventional AS which was 150 mg/L. Halotolerant enriched-activated sludge also produced less sludge, giving a high F/M ratio (4.9) compared with conventional AS (3.5). In order to make effluent fulfilled stream standard regulation (at central java region COD was<150 mg/L), the favorable operational condition for both reactors would be at VLR 0.268 to 2.03 kg COD, HRT was 25 hours HRT, with MLSS was 2584 – 3956 mg/L and maximum chloride concentration 1920 mg/L

1. INTRODUCTION

Food and Beverage industry falls under one of Indonesia's priority industry, and its development toward the green industry is one of the main concern of the Ministry of Industry, The Republic of Indonesia. Sustainable industrial technology in the Food and Beverage industry has been developed to support its growth. One aspect to be done toward the application of sustainable industrial technology was action related to pollution prevention within the process as well as after the process in order to minimize industrial pollution. Peanut-roasted industry specifically has difficulties to implement green industry technology especially for its wastewater treatment to fulfill stream standard regulation. Peanut-roasted industry wastewater's characterized with high organic but the moderate saline content and the problem related to it is that how to treat the wastewater using high rate technology so it can fulfil the stream standard regulation.

For that matters, high-rate technology, such as activated sludge technology, is preferable because of the

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space limitation for building wastewater treatment plant (WWTP). The more high-rate technology is, the less space needed. Peanut roasted has high organic content, up to 9000 mg/L COD, but this organic content is still not feasible to be treated using anaerobic technology. Anaerobic technology, such as UASB (Marlena et al., 2018) and immobilized UAF (Handayani et al. 2016) , need high COD inlet, long start up and retention time to achieve robust performance. Apart from that ,The combination of both anaerobic-aerobic can also be an option (Yuliasni et al., 2017) to treat more complex wastewater. However, despite its intense energy demand and massive sludge production, AS technology is still the most chosen technology for industrial WWTP, whether used as single technology or combination with other technology (Lefebvre & Moletta, 2006).

For successful full scale application, important parameters such as Mean Residence Time (SRT) , HRT , F/M ratio, MLSS/ MLVSS and DO, should be determined (Durai & Rajasimman, 2011). Hence, the objective of this research is to investigate the effect of operational condition in the performance of halotolerant enriched - activated sludge system, compare with conventional activated sludge for treating moderate salinity peanut roasted wastewater.

2. MATERIAL AND METHODS

2.1. MATERIAL

2.1.1. Activated Sludge Reactor

Two identical activated sludge (AS) reactors made of aluminum were set up, namely R1 and R2. R1 was an activated sludge system without the addition of halotolerant inoculum and R2 was an AS reactor with the addition of halotolerant inoculum. Activated sludge system consists of a feeding tank (V: 50 L), a continuous ditch oval shaped activated sludge reactor which design refers to Oxidation Ditch (V: 25 L), and a clarifier tank (V: 25 L). An aeration unit with diffusers inserted inside the AS reactor.

The activated sludge reactor set up is presented in figure 1 below.

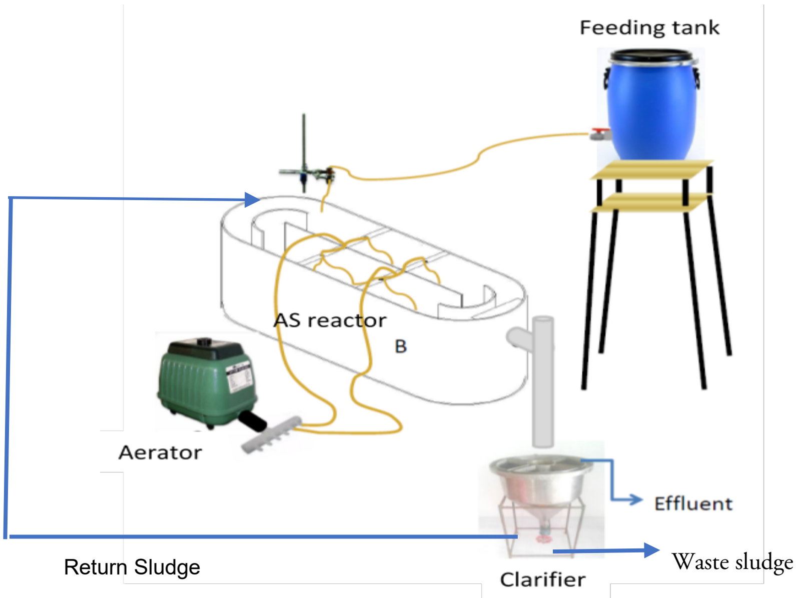

Figure 1. Activated Sludge Reactor Set Up (Two identical reactors called R1 and R2)

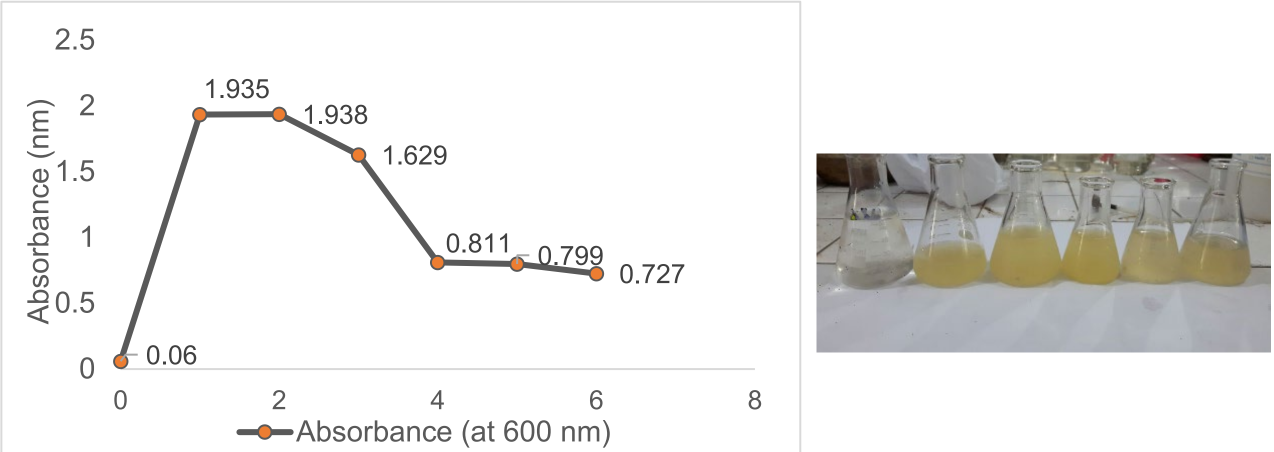

Figure 2. Optical Density (OD) measurement (left) and visual halotolerant inoculum (right)

Table 1. Wastewater typical composition

No	Parameter	Unit	Concentration
1	COD	mg/L	3,587 - 1,180
2	BOD_5	mg/L	164 - 539
3	TSS	mg/L	1,288 – 1,384
4	DHL	mS/cm	5.56 - 9,210
5	Total Nitrogen	mg/L	61.74 - 79.8
6	Total Phosphate	mg/L	0.486 – 1.476
7	H_2S	mg/L	0.152 - 0.373
8	Chloride	mg/L	1,840 – 3,375
9	Phenol	mg/L	0.004 - 0.778

2.1.2. Sludge seed and halotolerant microbial community

Sludge seed was derived from an already established activated sludge WWTP from bakery industry, with initial MLSS concentration was > 5000 mg/L.

The halotolerant inoculum was derived from a dormant seed frozen at 4^0 C, taken from the salt pond in Pati, Central Java. This seed was then inoculated in halotolerant media (refers to ATCC 1097 media) to reach a volume of 5 L, while constantly aerated prior its addition to the R2 reactor. Microbial growth was monitored qualitatively using Optical Density (OD) measurement at wavelength 600 nm, as presented in figure 1 (left). The inoculum used in this experiment was inoculum that inoculated for 24 hours, at the highest value of absorbance at 1.935. Highest absorbance value was an indication of microbial maximum growth (μ_{max})(Melanie et al., 2018).

2.1.3. High organic wastewater with medium salinity

Wastewater used for this experiment was untreated roasted peanut industry wastewater, with the composition shown in table 1.

2.2. METHODS

2.2.1. Experimental Method

8 liter seed AS sludge was added initially added to both of R1 and R2 reactors then adjust with water until volume reached 25 L, while constantly aerated. 100 mg/L sugar was initially added as a carbon source, as well as urea and buffer phosphate, with composition C: N: P = 100:5:1. Microbial growth was monitored with Sludge Volume 30% (SV_{30}) and Mixed Liquor Suspended Solid (MLSS) analysis.

The sludge was ready to be used when SV_{30} was 30% and MLSS was > 2000 mg/L. After sludge was ready, in the R2 reactor, 2.5 L AS sludge withdrawn then refilled with halotolerant inoculum. At day 33, at R2, 1 L halotolerant bacteria was added.

Wastewater was initially stored in the feeding tank, ready to be used. Feeding tank flowed to the AS reactor by gravitation. The treated water overflowed from AS reactor to the clarifier and then to the effluent. To maintain a constant flow, the feeding rate was manually adjusted every day during the experiment to achieve the desired HRT variable. Wastewater feed concentration was also adjusted to reach the desirable COD concentration in the range of 1000 – 3000 mg/L. Inlet and outlet were periodically sampled and analyzed, for parameter: Chemical Oxygen Demand (COD), pH and chloride. SV_{30} and MLSS were also periodically measured. Dissolved Oxygen (DO) was maintained at a minimum of 2.0 mg/L with adjustment of aeration flowrate. pH inlet was 5.8 – 7.5, while outlet pH was 7.1 - 8.5. The experiment was carried out in ambient temperature ± 32^0 C.

COD, DO, chloride and MLVSS was analyzed using the procedure in Standard Methods (SM) for the Examination of Water and Wastewater. Parameter collected on-site such as pH was measured using a pH meter (Krisbow KW06-744).

3. RESULT AND DISCUSSION

3.1. Overall Performance of R1 and R2 (halotolerant enriched)

Activated Sludge system was applied to treat real roasted-peanut wastewater that contains high organic with moderate salt content. The R1 reactor was a conventional activated sludge system, whereas R2 was an activated sludge enriched with halotolerant inoculum. Both R1 and R2 (halotolerant enriched) reactor was running for 77 days. To determine the overall performance of reactors and the effect of halotolerant inoculum addition in AS system, different operation condition was tested such as chloride content, Volumetric Loading Rate (VLR), and Hydraulic Retention Time (HRT). Chloride concentration ranged between 1500 – 4000 mg/L (0.1 -0.4%) , Volumetric Loading Rate ranged between 0.3 – 4.7 kg/m3.day, and HRT was initially set at 45 hours then shortened to ± 9 hours. These operational conditions were maintained at low strength during the initial stage (day 0 to 33 day), then raised gradually (from day 34 to 77). The performance of the reactor is calculated based on COD removal efficiency (%) and COD effluent concentration profile.

Figure 2 depicts the effect of chloride concentration on both R1 and R2 reactors performance. Initially, wastewater with a chloride concentration of 2300 - 2500 mg/L was fed to the reactor for 5 days, then at day 7 to 33, chloride concentrations were decreased to 1500 – 2000 mg/L. After day 33 to day 77, chloride concentrations were raised to 4000 – 4400 mg/L. Throughout the experiment period, both reactors showed a robust performance. The performance of both R1 and the R2 reactor was almost similar, with R2 has a slightly higher performance by 1%, and were uninhibited by chloride concentration < 4000 mg/L (0.4%). The average removal efficiency of R1 was 85.7% and R2 was 86.7%. Similar to (Kargi & Dinçer, 1998), (Wang et al., 2005), (Lefebvre & Moletta, 2006) and (Kargi & Uygur, 1996), that found out that NaCl concentration start to affect the Activated sludge performance when the concentration was above 1%, because of high salt concentration (>1% salt) causes plasmolysis or loss of activity of cells (Dinçer & Kargi, 2001). Furthermore, at medium chloride concentration, the addition of 1L halotolerant at day 33 did not improve the performance of the R2 reactor in terms of COD removal efficiency.

Figure 3 shows the effect of Volumetric Loading Rate (VLR) on R1 and R2 reactors performance. Volumetric loading rate was initially maintained at 0.3 – 1 kg COD/m^3.day at day 0 to 33 then later gradually increased at 2 – 4.7 kg COD /m^3.day until day 77. Figure 3 shows that COD removal efficiency of both reactors was almost similar. The maximum removal (94.2%) achieved when VLR was 2.98 kg COD/m^3.day. At VLR 4.7 kg COD/m^3.day, COD removal was still considerably high (90.6%). This result was higher, when compares with conventional AS system, that typically has maximum VLR < 2 kg COD/m^3.day. Other study proved that AS system able to treat up to 5.9 kg COD /m^3 (Petruccioli et al., 2002) with 90% COD removal. VLR can be higher for other aerobic technology such as rotating biological ontactor; > 12 kg COD /m^3.day) (Dinçer & Kargi, 2001), aerobic granule; up to 9 kg COD/m^3.day (Moy, Tay, Toh, Liu, & Tay, 2002) or membrane bioreactor (Trussell et al., 2006).

To identify the ability of both reactors fulfilled minimum COD effluent discharge standard regulation, COD effluent were compared with the effluent standard (150 mg/L, according to Central Java regulation) (Figure 4). At day 14 to day 48, when the system was stable and VLR started to increase from 0.268 to 2.03 kg COD, COD effluent concentrations were below the threshold, which means very favorable to discharge the effluent to the environment. However, when VLR raised from 2.03 to 4.7 kg COD/m^3.day, COD effluents were exceeded the threshold. Throughout the experiment, the average COD effluent of R1 was 150 mg/L, whereas R2 was 127 mg/L.

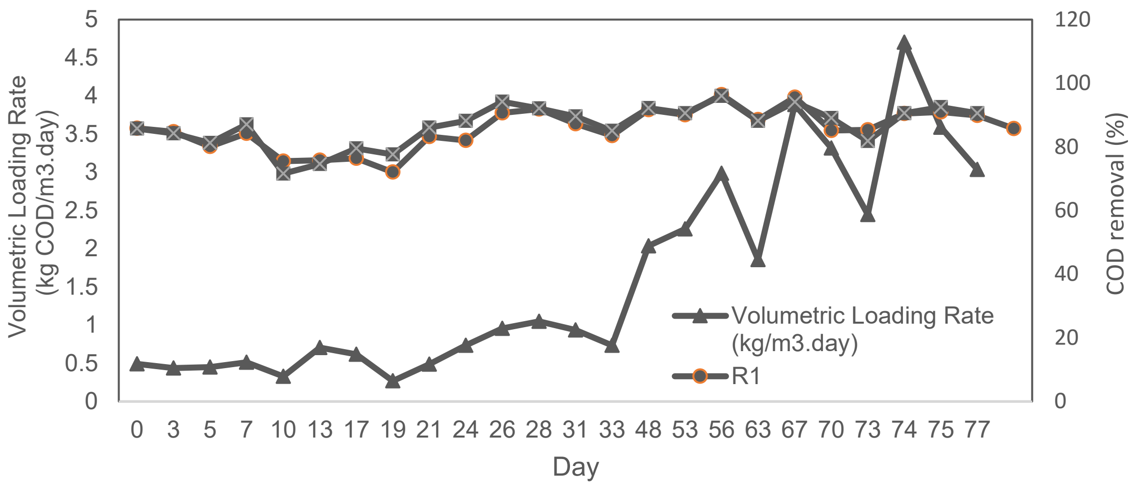

Figure 3. Effect of Volumetric Loading Rate on the COD removal of R1 and R2

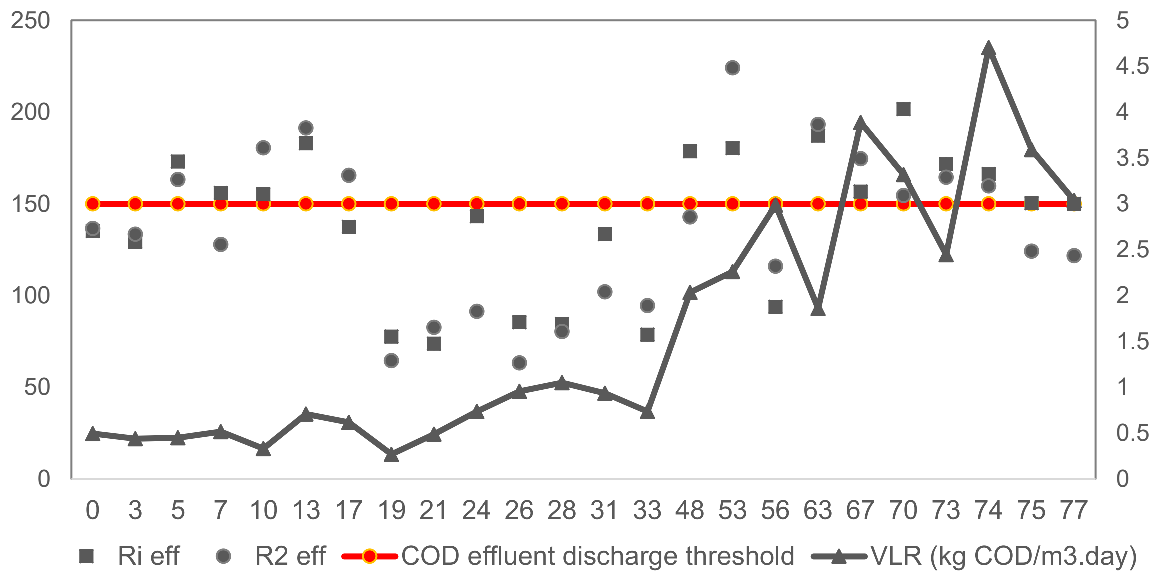

Figure 4. Effect of Volumetric Loading Rate on R1 and R2 effluent concentration

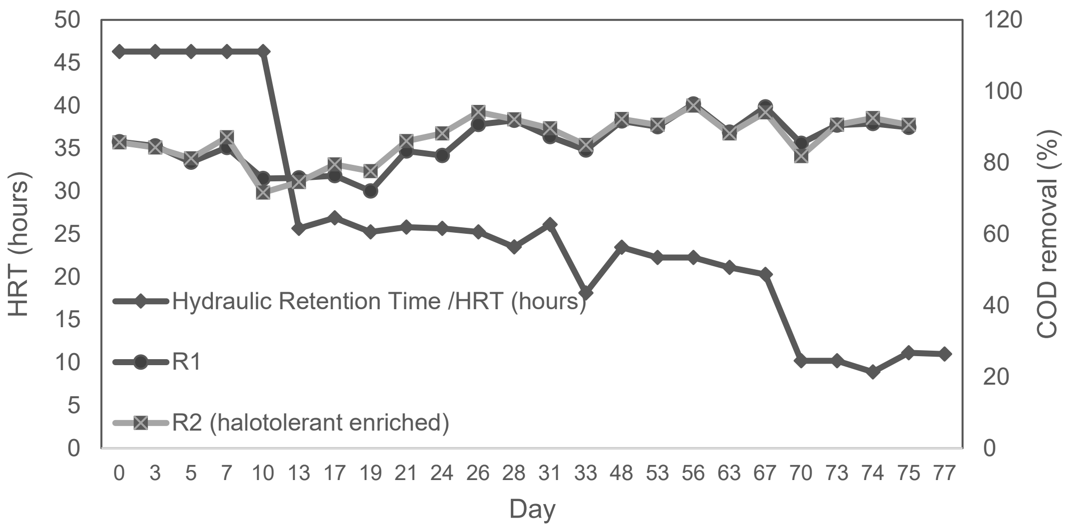

Figure 5. Effect of Hydraulic Retention Time on the COD removal of R1 and R2

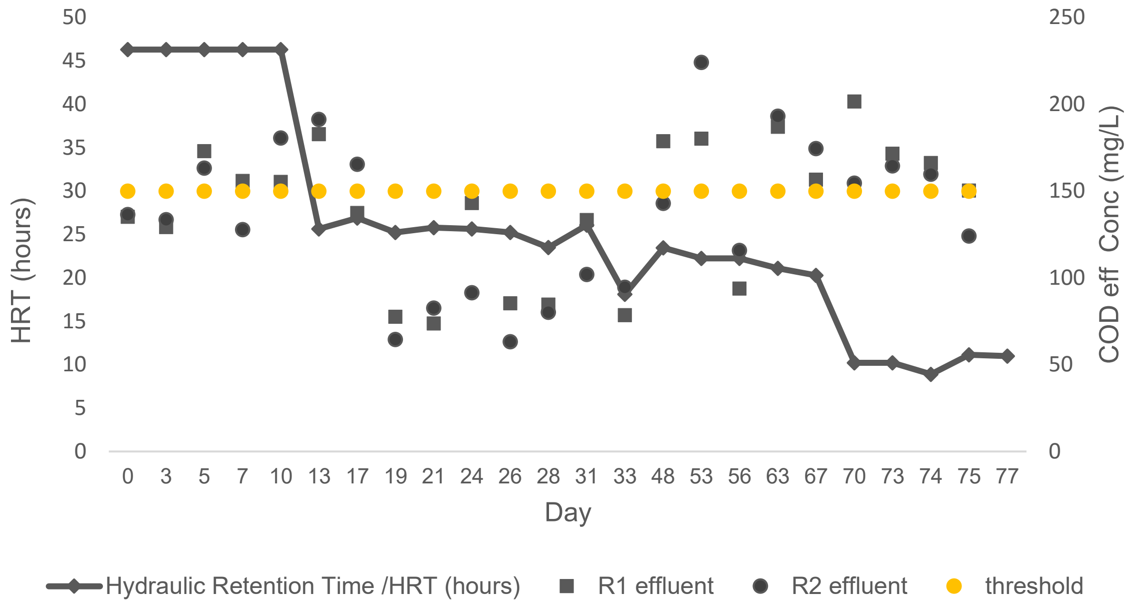

Figure 6. Effect of Hydraulic Retention Time on COD effluent concentration of R1 and R2

Figure 5 shows how hydraulic retention time (HRT) affects the performance of R1 and R2 reactor. The graph shows that in terms of COD removal efficiency, both reactors shows robust performance and did not show different results, even when HRT was shortened from 45 hours to 9 hours. This result when compared to other studies, such as Pala & Tokat (2002), González et al (2007), or Kim et al (2005) was considerably better. However, when the results were compared to the standard effluent threshold, 25 hours of HRT was favorable, with MLSS was maintained between 2584 – 3956 mg/L. At 25 hours, COD removal efficiency of both reactors were >90% and COD effluent could achieve the minimum threshold below 150 mg/L COD (Figure 6).5 shows how hydraulic retention time (HRT) affects the performance of R1 and R2 reactor. The graph shows that in terms of COD removal efficiency, both reactors shows robust performance and did not show different results, even when HRT was shortened from 45 hours to 9 hours. This result when compared to other studies, such as Pala & Tokat (2002), González et al (2007), or Kim et al (2005) was considerably better. However, when the results were compared to the standard effluent threshold, 25 hours of HRT was favorable, with MLSS was maintained between 2584 – 3956 mg/L. At 25 hours, COD removal efficiency of both reactors were >90% and COD effluent could achieve the minimum threshold below 150 mg/L COD (Figure 6).

3.2. Sludge characteristic in R1 and R2 reactors

Reactor R1 and R2 have pretty similar performance in terms of COD removal and COD effluent concentration profile. However, when it comes to microbial quantity and quality, R1 and R2 have a different characteristic in F/M ratio. F/M ratio is very important to evaluate performance in the aerobic system. Normally for best practice, F/M ratio ranges between 0.2 < F/M < 0.5 for conventional AS, for Completely mixed (CSTR) ranges between 0.2 < F/M < 1.0 and for High rate, range between 0.4 < F/M < 1.5 (Water Resources Division, 2017). The higher F/M ratio value, the better performance of AS, because to remove a certain level of COD will need less microorganisms and subsequently reduce Waste Activated Sludge (WAS) quantity and reduce the cost of solid handling as well.

In this study, F/M ratio was calculated based on amount COD inlet (kg/m^3) per MLVSS concentration in the reactor (kg/m^3) (as shown in figure 7). At day 0 to day 28, when 10% halotolerant was added to the R2 reactor, F/M of both reactors were similar. After the addition of 1 L halotolerant in R2 (14% v/v), R2 has a higher F/M ratio than R2, almost 1.5: 1. R1 has the highest F/M ratio at 3.9, and R2 at 4.7.

Feeding with similar loading rate, chloride concentration and operated with similar HRT, both reactor R1 and R2 have similar COD removal and COD effluent profile, except that R2 need fewer microorganisms than R1. This result was against Sivaprakasam et al (2008) and Kargi & Uygur (1996) that claimed that to treat saline wastewater a lower F/M should be maintained in order to achieve > 90% COD removal. Having said that the salt content in this experiment was < 0.4%, it was likely that at salt content <0.4%, F/M ratio was not affecting the reactor's COD removal but only affecting sludge density.

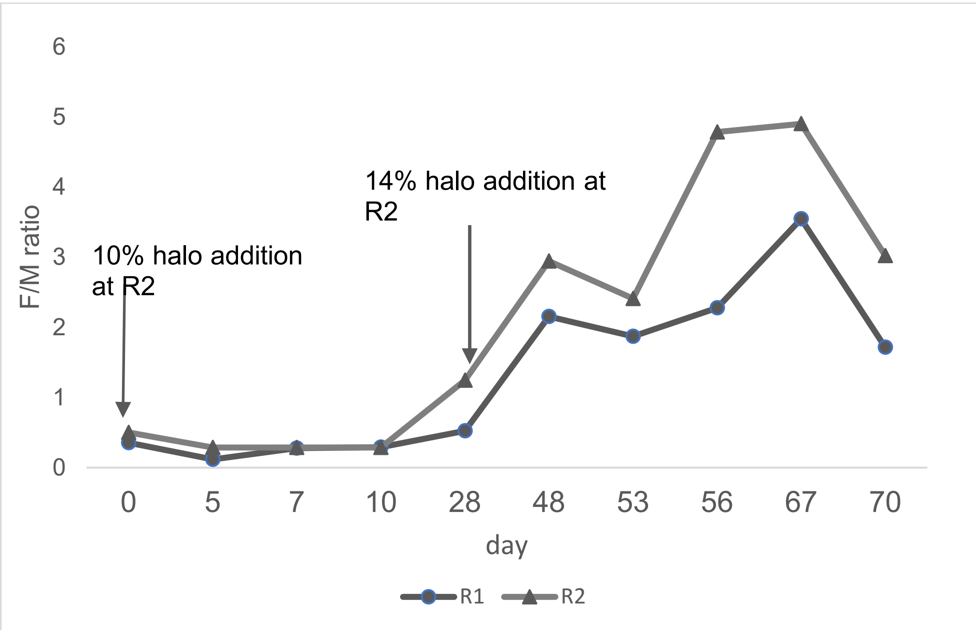

Figure 7. Comparison of the F/M ratio of R1 and R2

4. CONCLUSION

The addition of halotolerant Inoculum in conventional activated sludge system to treat high organic wastewater with medium salt content gives effect on the performance of activated sludge (AS) system. Roasted peanut wastewater with VLR ranges from 0.268 to 4.7 kg COD/m3.day and Chloride concentration ranges between 1582 - 4392 mg/L was treated efficiently until COD removal reaches a maximum of 94.6%. Compared to conventional AS system, Halotolerant enriched activated sludge system could remove an average of 86.7% COD, compared with conventional AS which was 85.7%. Average COD effluent of Halotolerant enriched-Activated sludge was also considerably lower, which was 127 mg/L, than conventional AS which was 150 mg/L. Halotolerant enriched-Activated sludge also produced less sludge, giving a high F/M ratio (4.9) compared with conventional AS (3.5).

For practical use, for both conventional and halotolerant-enriched AS system, in order to make effluent fulfilled stream standard regulation (at central java region COD was < 250 mg/L), the favorable operational condition would be VLR 0.268 to 2.03 kg COD, HRT was 25 hours HRT; with MLSS was 2584 – 3956 mg/L and maximum chloride concentration was 1920 mg/L.

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