CHAPTER 5

CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

Reactor was operated through 290 d at 5 d of HRT and the 4 phases of operating conditions; low -strength (5-7 g SS l^{-1}), high-strength (10-11 g SS l^{-1}), shock (12.5 g SS l^{-1}) and shock load recovery at SS concentration of 10 g l^{-1} were studied and evaluated. Throughout reactors operations, process performance and stability of sludge and packed zones were monitored for study of performance in organic removal efficiency under process stability variation. In addition, the role of each groups anaerobic microbes such as hydrolytic, acidogenic, acetogenic bacteria and methanogens, as well as the interaction among these groups under different reactor operations. The results can be concluded that

Under low-strength POME operation, reactor was fed by influent with SS and O&G concentrations in the range of 5-7 and 0.9-1.4 g l^{-1}, respectively. Organic removal in TCOD, SS and O&G were achieved at higher than 70% under normal condition. At initial operation time at OLR 3.0-3.8 g COD l^{-1} d^{-1}, almost of organic matters was consumed to build up cell more than that to convert in biogas which lead to low methane yield was obtained at 0.13-0.2 l CH_4-$g^{-1}COD_{removed}$. Performance and stability of sludge and packed zones were homogenous and less organic acid accumulated in the system. Normal stability in both sludge and packed zones was the cause of microbial characteristics. High performance of non-methanogenic activity was observed in the sludge zone by detecting in the range of 1.08 - 1.58 g COD g^{-1}VSS d^{-1}, while 0.43 - 0.74 g COD g^{-1}VSS d^{-1} was detected in the packed zone. Moreover, no different microbial population and dominant non-methanogen community was observed in the sludge and packed zone. Non-methanogenic population was observed at 10^7-10^8 copies rDNA g^{-1}VSS and dominant non-methanogenic community were *Pseudomonas*, *γ-Proteobacteria*, *Bacteroidetes bacterium*, *Clostriduim* and *Actinobacterium*. Under normal process stability and less organic acid accumulation, acetoclastic methanogenesis pathway was dominant in methane formation and it reflected to high methanogenic activity (0.11- 0.25 gCOD-CH_4 g^{-1}VSS d^{-1}). *Methanogesaeta* and *Methanococcoides* were dominants acetoclastic methangens.

When the reactor was fed with high-strength POME, the deteriorations of process performance and stability were observed. At reactor operating with 10 g SS l^{-1} and 1.9 g O&G l^{-1}, overall process performance in organic removal was maintained over 50%. Sludge zone was detected in high organic acid accumulation zone of AHR while the packed zone could balance of organic formation and utilization by biofilm activity and maintain normal process stability. High performance of non-methanogens still was detected in the sludge zone under slightly acidic environment.

Non-methanogenic activity of sludge and packed zones were 1.32 and 0.91 gCOD-CH_4 g^{-1}VSS d^{-1}, respectively. Non-methanogenic population increased and its community more diversifies than low -strength operation obviously. However, dominant bacteria were not changed by *Pseudomonas* and *γ-Proteobacteria*, *Bacteroidetes bacterium*, *Clostriduim* and *Actinobacterium* were detected in the systems. Therefore, it can be noted that the role of sludge zone was hydrolysis zone. Process stability of packed zone promoted methanogen activity better than that sludge zone which reflected by methanogenic activity. These values were 0.26 and 0.14 g COD-CH_4 g^{-1}VSS d^{-1}, respectively. Increasing methanogenic activity resulted in methane yield increased to 0.30 l CH_4-$g^{-1}COD_{removed}$ which was the maximum value of this study.

Influent SS concentration at 11 g l^{-1} with 2.3 g O&G l^{-1} was the critical load of reactor operation. Biogas and methane production rate decreased even both non-methanogenicic and methanogenic activities still high including overall organic removal was over 50%. Change in methanogenic community was observed that hydrogenotrophic methanogens were abundant in the system instead of acetoclastic menthanogens. Nevertheless, high acetoclastic methanogenic activity was observed. Increasing of hydrogenotrophic methanogen induced syntrophic acetate oxidation due to it need H_2/CO_2 from acetate oxidizing by syntrophic acetate oxidizing bacteria to methane production. These results impacted to decreasing of acetoclastic methanogen and methane yield in the reactor operating at 11 g SS l^{-1}. Dominant hydrogenotrophic methanogens were *Methanobacterium* and *methanomicrobiales*. AHR entranced to shock load condition when operated at 12.5 g SS l^{-1} with 2.7 g O&G l^{-1} and OLR at 6.0 g l^{-1}. It indicated by process performance in overall organic removal of the sludge zone decreased lower than 50% except SCOD. Packed zone could maintain process performance batter than that sludge which resulted in most of organic removal was over 60%. O&G was strong affected form shock load due to high acidic pH (4.42) inhibited lipase activity included lipase producer bacteria. It indicated that shock load first happened in the sludge zone because it the first part of influent upflow feeding and organic matter could attack directly with suspended microorganism. Biofilm forming in packed zone has higher resistance to acidic condition than the sludge zone. High acidic condition affected to both non-methanogens and methanogens fated out form the system. Almost of *Pseudomonas*, lipase producing bacteria were nearly fated out meanwhile syntrophic acetate oxidizing bacteria as *Clostridium* more diversified. It reflected to presenting of hydrogenotrophic methanogen in this shock load. Acetoclastic methanogen was completely inhibited under shock load. High organic acid resistant methanogens were detected as *Methanobacterium*. However, the shock load condition was recovered in short time by normal process performance and stability was resumed within 12 d.

Shock load recovery was carried out by effluent recirculating and re-feeding with lower OLR and SS concentration at 4.0 g COD l^{-1} $d^{-1}$and 10 g l^{-1}, respectively. Reactor performances and stability of sludge and packed zones increased nearby normal condition. Packed zone showed higher organic removal efficiency than sludge zone. Biogas and methane yield became to be obtained at 5470 ml d^{-1} and 0.20 l CH_4 $g^{-1}COD_{removed}$, respectively. It signifies that shock load recovery was achievement. Affectation of shock load led to the changing of non-methanogenic activity and population by detecting high non-methanogenic activity and population in packed zone instead of sludge zone. *Bacillus* was first detected in system because of high SS accumulation and it promoted cellulose decomposer as *Bacillus* presenting in the system. Acetoclastic methanogenesis became to dominant pathway of methane formation and dominant acetoclastic methanogens were *Methanosaeta* sp. and *Methanosarcina* sp.

5.2 Recommendations

5.2.1 After recovered shock load, effect of SS and O&G concentrations at 10 and 1.9 g l^{-1}, respectively was study again. Reactor was operated and obtained the best process performance and stability under this concentration under normal condition. However, the results after reactor recovery and operational back to at this condition found that process performance and stability were lower than that the best performance. Therefore, the reactor should be operated longer to ensure the reactor could become to normal condition and showed high process performance and stability. Including, microbial characteristics also have to monitoring under this condition.

5.2.2 To study of process performance of sludge and packed zone by focusing on the type and concentration of volatile organic acid (VFA). Identification of specific VFA will be useful to specify the producing and utilizing microorganism in each zone. Understanding of relation among microorganism and environmental condition may be able to control and enhance process performance and stability of the each zone and overall of AHR.

5.2.3 According to SS and O&G removal efficiencies at high organic loading load, its removal is lower than 60%. Therefore, enhancing of the removal efficiency may be able to be developed.

5.2.4 Detecting more diversify of cellulose decomposer bacteria in high SS concentration system indicated that the cellulose decomposer bacteria may be able to enrich its population and enhance its performance. Therefore, cellulose decomposer bacteria population and performance may be able to develop.