Start-Up of Upflow Anaerobic Sludge Blanket (UASB) Reactor Treating Slaughterhouse Wastewater

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Abstract. The main objective of this study was to observe the influence of Organic Loading Rate (OLR) on treating slaughterhouse wastewater PD RPH Medan using UASB reactor during the start-up phase. A laboratory scale UASB reactor with an effective volume of 5.8 L made of PVC pipe with gas-liquid-solid separator at the top of reactor. The reactor was inoculated with mud and fed with wastewater from anaerobic lagoon of PD RPH Medan. The UASB reactor was operated with increasing OLR gradually from 0.64-2.95 kg COD/m³d. The effluent pH is in the optimum range for aerobic decomposition at OLR 0.64-2.95 kg COD/m³d. Maximum COD and TSS removal efficiencies 58.4% and 85.5%, respectively obtained at OLR 1.01 kg COD/m³d. Maximum biogas production achieved 270 ml/d with COD removal 442 mg/l obtained at OLR 2.95 kg COD/m³d.

1. Introduction
Slaughterhouse wastewater contains high organic matter with complex fat, protein and fiber, pathogenic and non-pathogenic microorganism composition. Most of the contaminants come from the blood and intestines of the remaining cuts [1, 2]. The average content of organic matter expressed in COD in slaughterhouse wastewater reached 4221 mg/L [3]. Therefore, slaughterhouse wastewater requires significant processing in order to safely be discharged into the environment [1].

One of the most widely known methods of wastewater treatment is anaerobic processing. Upflow Anaerobic Sludge Blanket (UASB) is an anaerobic reactor with the growth of suspended microorganisms characterized by granulation. Granule sludge is formed in the start-up phase before it reaches steady state conditions. The start-up phase is a complex process with a number of factors influencing it, including the characteristics of wastewater, pH, nutrient, acclimatization of mud seed, toxic material content, loading rate, upflow velocity (Vu) and hydraulic retention time (HRT). UASB reactor start-up procedures generally require continuous feed with low organic loading rate then increase it gradually when the substrate concentration has drastically reduced [5, 6, 7].

The COD removal increases with the increase of OLR values on UASB reactors that process sugar industry waste and reach the start-up phase after 99 days [8]. While the removal efficiency of COD decreased slightly with the increase of OLR value at UASB reactor which treat dairy wastewater. The problem commonly found in dairy or cheese wastewater is when the OLR enhanced, the acidogenesis bacteria becomes activated so it inhibit the activity of methanogenic bacteria which leads to decreased reactor removal efficiency [9].

This study aims to determine the effect of Organic Loading Rate (OLR) in the treatment of slaughterhouse wastewater by using UASB reactor at the start-up phase.
2. Material and Methods
A laboratory-scale UASB reactor was made from PVC with a diameter of 7.62 cm and height of 125 cm which has a separator-gas-liquid-solid (GLS) system at the top (Fig. 1). The reactor was inoculated using mud from an anaerobic pond of PD RPH Medan. Mud was inoculated an amount of 20% of the reactor volume. The seeding process is carried out by drain off the wastewater into the inoculated reactor. Further, wastewater is recirculated into the reactor until biogas is formed. The seeding process lasts for 2 weeks.

Slaughterhouse wastewater is streamed from influent tank with flow rate of 0.63 L/hr. Organic Loading Rate (OLR) is increased gradually from 0.64 to 2.95 kg COD/m3hari. The increase of OLR value is done by increasing the feed concentration. Characteristics of wastewater for each OLR value can be seen in Table 1. UASB reactor has been operated continuously for 33 days.

Samples of wastewater were taken from the influent and effluent tank daily. The COD and TSS parameters are measured by following Standard Method [10]. While pH is measured using a digital pH meter. The volume of biogas is measured daily with the principle of the displacement of the liquid in a measuring cup.

Figure 1 Reactor Design: (1) influent tank, (2) peristaltic pump, (3) liquid outlet, (4) biogas outlet, (5) Biogas collector, (6) Effluent tank, (7) PVC pipe diameter 3” Height 125 cm, (8) GLSS system
### Table 1 Wastewater Characteristics

| OLR (Kg COD/m³d) | COD (mg/L) | TSS (mg/L) |
|-----------------|------------|------------|
| 0.64            | 240        | 179.67     |
| 1.01            | 379.85     | 249        |
| 2.95            | 1100       | 500        |

3. Result and Discussion

The pH particularly was the decisive parameter in anaerobic decomposition. The pH range must remain in the optimal value after hydrolysis and acidogenesis process in order to methanogenesis process can be held [11]. Fig. 2 shows the inlet and outlet pH of the reactor for each OLR. The inlet pH was maintained in the range 6.6-6.9 to make a suitable environment for the growth of anaerobic microorganisms [12]. While the outlet pH consistently increased with increasing OLR. The pH outlet ranged from 7-7.2 at OLR 0.64 kg COD / m³.day. While at the OLR 1.01 kg COD / m³.day ranged from 7.2-7.3 and at 2.95 kg COD / m³.day ranged from 7.3-7.5. This suggests increasing the OLR value has no significant effect on the acidogenesis process within the reactor [6]. Lower pH in the reactor due to rapid acidification which will inhibits the activity of methanogenic bacteria [9,13].

![Figure 2 Inlet and Outlet pH in Various OLR](image)

![Figure 3 COD Removal Efficiency in Various OLR](image)
The COD concentration states the total amount of waste oxygen required for the oxidation process to carbon dioxide and water [14]. Fig. 3 shows the COD removal efficiency on the various OLR. The COD removal efficiency decreased on the 12th day when OLR was increased from 0.64 to 1.01 kg COD / m³day. Stable efficiency achieved at day 20 and declined on day 23 when OLR was increased to 2.95 kg COD / m³day. This result is in accordance with the study [15] which uses the UASB reactor to treat palm oil wastewater. COD removal efficiency reaches more than 80% when OLR was increased from 2.5 to 15 g COD / L.day. However, when OLR was increased to 17.5 g COD / L per day, the removal efficiency dropped to 60%. [8] Reported a COD removal efficiency of 81-89% when OLR ranged from 8-16 g COD / L.day. Efficiency decreased to 53% at OLR more than 16 g COD / L.day. Previous study reported COD removal efficiency decreased from 94.33 to 92.98% with increasing OLR from 2.88-3.6 kg COD / m³day [9].

These results indicate the shock loading on the system caused by the accumulation of Volatile Fatty Acids (VFA) thereby inhibiting the activity of methanogen bacteria [8,9,15]. After a momentary deterioration, efficiency rises and reaches a stable, indicating methanogenic bacteria are capable to performing well at higher substrate concentrations. The maximum COD removal efficiency reached 58.4% when the OLR was 1.01 kg COD / m³hari. The efficiency of COD removal is highly dependent on Organic Loading Rate (OLR). Increasing OLR on the system gradually required to increase the growth and activity of methanogenic bacteria for the sustainability of the reactor efficiency [16].

TSS is a non-volatile residue after evaporation and drying at a temperature of 103 to 105°C [14]. Fig. 4 shows TSS removal efficiency at varying OLR. When OLR 1.01 kg COD / m³hari efficiency
tends to increase from day 14 to 17 but decreases on the 18th day and increases again on the 19th day. While the efficiency of TSS removal at OLR 2.95 kg COD / m³ hari increased from day 24 to 27 but decreased on day 28 and tended to increase from day 29 to 33. Unstable TSS removal efficiency may due to increasing substrat concentration disrupt the sludge bed and cause biosolid come along with effluent [17]. TSS removal efficiency was decreased from 77.9% to 43.6% when the OLR was increased from 1.01 to 2.95 kg COD / m³ day. This study in accordance with the results [18] which states that the TSS removal efficiency decreases from 64% to 38% with increasing OLR from 0.2 to 7.5 g COD / L day. Decreasing in efficiency occurs due to increased substrate concentration in the feed causing washout within the system. Initially, the washout of sludge due to poor settleability of seed sludge [9].

Maximum TSS removal efficiency achieved 85.5% was obtained at OLR 1.01 kg COD / m³ day. The reactor performance in removing TSS is influenced by several factors such as a relatively high upflow rate allowing the biosolid to precipitate which prevent it to not come along with effluent and appropriate HRT provide the contact time between sludge and wastewater, separating biosolid from the gas and increasing the efficiency of material organic removal [4,19].

Biogas containing methane and CO2 is one of the end products of anaerobic processing [20]. Fig. 5 shows a comparison of biogas production with the amount of COD removed at each OLR value. There is an increasing amount of COD removed and biogas production when OLR is increased from 1.01 to 2.95 kg COD / m³ day. In accordance with [21] which states the production of biogas increases with increasing amounts of COD removal, OLR, VLR and HRT. The rate of biogas production at UASB reactor which treats dairy wastewater increased from 970 ml / day to 9600 ml / day with an increase of OLR from 0.72 to 4.32 kg COD / m³ day [9]. The maximum biogas production reached 240 ml / day with the amount of COD removed 221 mg / L at OLR value 1.01 kg COD / m³ day. While at OLR 2.95 kg COD / m³ day maximum biogas production reached 270 ml / day with the amount of COD concentration degraded 442 mg / L. This shows that the OLR has a significant effect on the amount of COD removal and biogas production.

4. Conclusions
The increase in OLR value has no significant effect on the acididogenesis process in the reactor. The maximum COD and TSS removal efficiency was 58.4% and 85.5% was obtained when the OLR value was 1.01 kg COD / m³ hari. The maximum biogas production reached 270 ml / day with the amount of COD degraded 442 mg / L obtained at the value of OLR 2.95 kg COD / m³ day. Increased OLR values have significantly reduced the efficiency of COD, TSS and biogas production.

5. References
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