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The Effect of Influent Concentration and Hydraulic Loading Rate (HLR) to BOD and COD Removal on UASB Reactor Treating Artificial Grey Water

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Abstract - Grey water flowing directly into drainage or ground will pollute receiving water bodies. Up-flow Anaerobic Sludge Blanket (UASB) is an alternative process to treat greywater. Its working principle is distributing the wastewater in the reactor with upward direction of low through the sludge blanket with specific hydraulic retention time (HRT). Laboratory scale research using artificial greywater was conducted in 64 days with 5 unit of transparent fiber column-shaped UASB reactor with diameter of 10.61 cm and a height of 100 cm. Reactor were operated at variations concentration 155 mg/l – 1400 mg/L: HRT 4 – 12 hours; upflow (V_{up}) 0.05-0.15m/hour and Hydraulic loading rate (HLR) 0.05 – 0.15 m3/m2 hour. At varying influent concentration, BOD_5 and COD removal efficiency is about 38%-75% and 40%-77%, respectively.. The highest removal efficiency occurs at reactor with HRT 12 hours and the lowest removal efficiency is obtained at reactor with HRT 4 hours. An optimum COD removal efficiency of 48.01 to 77.34% was obtained at HRT 8 hours with influent CD of 827-867 mg/L. Generally, the efficiency removal fluctuates but remains constant.

Key Words - UASB; influent concentration; Hydraulic Loading Rate (HLR)

INTRODUCTION

Domestic wastewater is a major source of pollution causes water bodies in urban areas. According to Henze and Ledin (2001) domestic wastewater can be divided into two categories: wastewater from latrines or toilets is termed as fecal water or black water and domestic wastewater former washing and bathing water non outhouse kitchen waste (grey water). Black water and grey water have different properties and thus require different treatment. Domestic wastewater generally contains TSS, BOD_5, COD, nitrogen, phosphorus, chloride E.coli and others.

UASB is widely used to treat industrial wastewater and domestic with the relative high ration BOD : COD (Said, 2002). In UASB, the wastewater flows upward through anaerobic sludge layer/blanket slugde where biodegradation processes of organic matter takes place (Lettinga, 1991). Usually the parameters used are BOD_5 and COD in the influent concentration variation and HLR.

MATERIALS AND METHODS

This research was conducted in a laboratory scale to determine the removal efficiency of BOD or COD. Waste is waste that used artificial domestic grey water. Characteristics of waste derived from the Housing and Urban Gabahan Bukit Semarang Baru.

The reactor (Figure 1) was build up from fiber with a diameter of 10.14 cm and 60 cm high with mud volume ± 30% of the waste volume and has working volume of 4.86 liter. Artificial grey water was pumped from a reservoir (200 liter) into an equalization basin (2 liter). The grey water was distributed into the UASB reactors. Artificial grey water was composed of distilled water and dextrose . The operation of reactors was divided by 3 stages: i. acclimatization stage with 50% of planned concentration, ii. Acclimatization stage with 100% of planned concentration, iii. Final Running Concentrations COD in influent varied as

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Table 1, where as upward velocity was controlled at rate as Table 2.

Figure 1. UASB Reactor

Table 1. Variation of Influent Concentration

Number	Influent COD Concentration (mg/L)	Concentration Range
1.	155	Low
2.	560	Low-Middle
3.	840	Middle
4.	1120	Middle-High
5.	1400	High

Table 2. Variation of HRT and HLR

	Hidraulic Loading Rate (HLR) (m³/m².hour)	Hidraulic Retention Time (HRT) (Hour)
HLR 1	0.15	4
HLR 2	0.10	6
HLR 3	0.075	8
HLR 4	0.06	10
HLR 5	0.05	12

RESULTS AND DISCUSSION

a. Effect of Hydraulic Loading Rate (HLR) Variation on COD removal

Acclimatization stage proceeded for 43 days and then was continued with final stage or running stage. Efficiency removal on the reactors flowed with different COD concentration and different HRT is shown on Figure 2.

Figure 2 (a), the efficiency removal fluctuates but remains stable. Where in each HLR has a different trend. COD removal efficiency at T4 (HRT 4 hours) or 0.15 HLR m³/m²/hour is average of 35.64 %, the smalles removal efficiency of all reactors. The reactor with HRT 12 shows the highest removal efficiency.

Figure 2 (b, c, d and e), the similar result with figure 2.a is obtained from this reactor. The efficiency removal fluctuates but remains constant. The highest removal

efficiency occurs at reactor with HRT 12 hours and the lowes removal efficiency is obtained at reactor with HRT 4 hours. During this stage stable pH and temperature ranges from 6.22 to 8.38 and a temperature between 26°-28° C. According to Tchobanoglous (2003) bacteria can live and multiply optimally at pH 6.5-7.5 and temperature of 25°C-35°C.
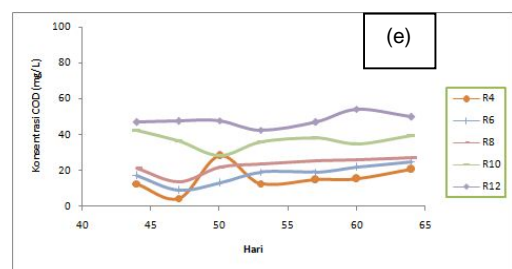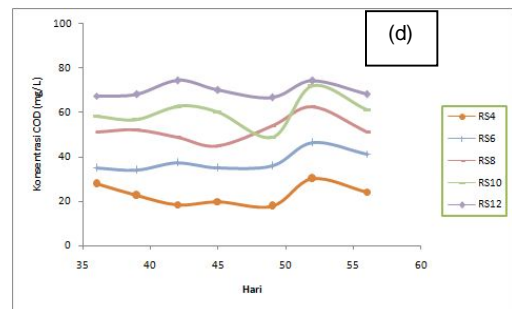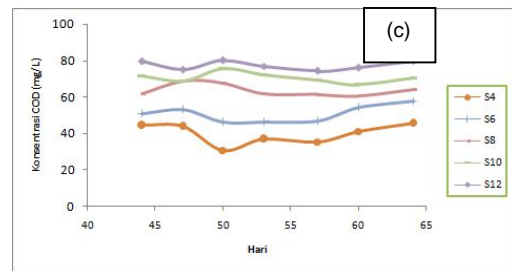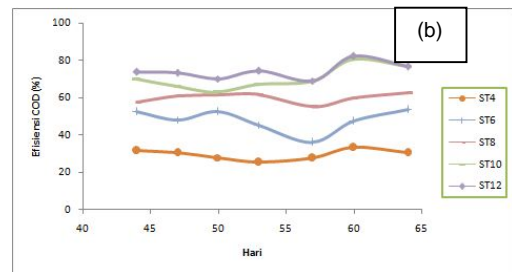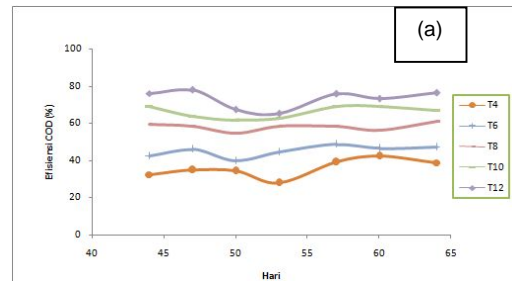

Figure 2. COD Removal Efficiency on (a) High Concentration, (b) Middle-High Concentration, (c) Middle Concentration, (d) Concentration of Low-Midle, (e) Concentration of Low

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COD removal performance at moderate concentrations shown Figure 2(c), where the efficiency of COD in the HLR 0.15 $m^3/m^2/hour$ on day 53 decreased 13 % compared to the previous day. This is due to the increase in effluent concentration and pH on the day. But the next day until the end of the running quite stable. Different result happen in the HLR 0.075 $m^3/m^2/hour$ and 0.06 $m^3/m^2/hour$ on the 47th day of effluent has the same value, so that the efficiency of both the HLR equal approximately 68.75 %. COD removal efficiency occurs at the optimum HLR 0.05 $m^3/m^2/hour$ reached 77.34%.

Performance of middle -low concentrations in Figure 2(d). Running a low concentration stage was initiated on day 36 after acclimatization. At this concentration has the greatest efficiency at the lowest HLR with an efficiency of 69.92 %. The smaller the value HLR so the value of HRT (time to live) will longer therefore will indirectly affect the flow velocity in the reactor. This is in line as described by Liu and Tay (2004), that the longer HRT (Hydraulic Retention Time), the flow rate to rise to the top will also be slower and this allows bacteria to grow and form granules.

Figure 2 (e) shows the performance efficiency of low concentration in COD aside. In general, the concentration of COD removal efficiency values were lower than the previous concentration. Where the lowest efficiency occurs at 0.15 $m^3/m^2/hour$ HLR only capable of removing COD by 16 %, while the optimum efficiency occurs at 0.05 $m^3/m^2/hour$ HLR with average of ± 48 %.

This is consistent with research conducted by R. Reindy R.R. (2012) where optimum efficiency in COD and BOD_5 aside occurs at the lowest HLR. Although different values are used HLR is 0.03 $m^3/m^2/hour$ with the longest residence times used 8 hours. Reinforced by the statement Mahmoud Moussavi (2010) HLR influence of stirring speed and residence time in the reactor so that the agitation would be fast and the residence time will be faster.

b. Effect of Concentration Influent Variation on COD Removal

Next is the removal of COD influent concentration variation based on the comparison of each HLR so as to know the optimum concentration. Hydraulic Loading Rate (HLR), the largest used in this study was 0.15 $m^3/m^2/hour$. Figure 3 (a) is the greatest performance of the HLR in this study. Allowance largest in the HLR 0.15 $m^3/m^2/hour$ occurs at high concentrations and the less COD removal at lower concentrations. Optimum efficiency in the HLR is actually happening on the concentrations being reached 39.71 % efficiency. Yet overall COD removal at high concentrations of greater than moderate concentrations. This can happen because the value of efficiency is very dependent on the influent concentration.

Based on Figure 3(b) the same as the HLR0.15 m3/m2/hour, HLR 0.10 $m^3/m^2/hour$ which has the largest allowance at high concentrations, but the HLR optimum efficiency occurs at moderate concentrations. Overall in the HLR 0.10 $m^3/m^2/hour$ have greater efficiencies than HLR

0.15 $m^3/m^2/hour$ as mixing or mixing in the reactor better. Mixing can occur due to the upflow velocity and gas bubbles rising. Upflow velocity and HLR is a factor in the performance of UASB.
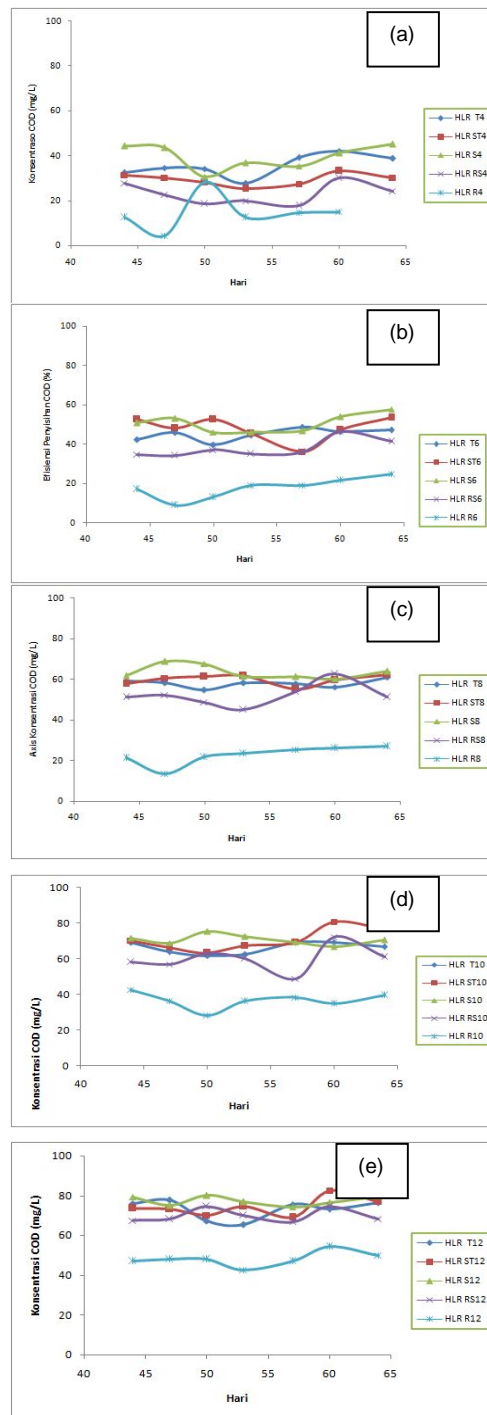

Figure 3. COD Removal Efficiency at :
(a) The HLR 0.15 $m^3/m^2/hour$; (b) HLR 0.1 $m^3/m^2/hour$; (c) HLR 0.75 $m^3/m^2/hour$; (d) HLR 0.06 $m^3/m^2/hour$; (e) HLR 0.05 $m^3/m^2/hour$

In accordance with the statement Seghezzo (2004) and Das & Chaudari (2009) which states mixing causes the breakdown of the sludge bed pressure which is a key factor in determining the formation and stability of the resulting anaerobic granular structure. Thus better mixing. Therefore, the greater removal efficiency.

Figure 3 (c) is the COD removal efficiency for the HLR 0,075 m³/m²/hour for running the greatest efficiency occurs at moderate concentrations with an average efficiency of 63.65 %. The efficiency of second largest falls on middle-high concentrations while the lowest efficiency occurs at low concentrations.

For COD removal efficiency at HLR 0.06 m³/m²/hour with 10-hour residence time can be seen in Figure 3 (d). HLR is capable of removing up to 70.6 % and COD occurred at moderate concentrations. In general, the efficiency is greater than the HLR earlier because of the value that the smaller the value of HRT will be even greater, so the efficiency will also be better. This is similar to research done by Foresti (2001) stated that HRT applied under 6 hours without any significant change in the performance of the process. So it can be seen that the HLR 0.15m³/m²/hour and 0.10 m³/m²/hour with HRT of 4 hours and 6 hours had not far adrift efficiency is 39.71 % at HLR 0.15 m³/m²/hour whereas HLR 0.10 m³/m²/hour about 10% greater.

Efficiency in HLR 0.05 m³/m²/hour can be seen in Figure 3(e), where the efficiency of COD at high concentrations increased in the early running, but then fairly stable until the end of the running. As for the other concentrations are quite stable from the beginning to the end of the running. In general, the COD removal efficiency in the HLR greater than the previous and occurred at concentrations that were on average 77.34 % of optimum efficiency. While most low efficiency occurs at low concentrations is approximately 48.01 %. In general, the efficiency of the HLR is larger than before, due to a longer residence time in the reactor. So that the HLR would go down so does Vup. HLR and Vup value is directly proportional, so the pace will be slower rise in the substrate. This can occur because of the biogas formed and attached to the granules which causes the granule rise to the top so that contact with the bacteria will be slow therefore efficiency will also increase (Narnoli and Mehotra, 1997) .

c. Effect of Hydraulic Loading Rate (HLR) Variation on BOD_5 Removal

According Sugiharto (1987) states that in addition to COD, which is an important chemical in the wastewater are BOD (Biochemical Oxygen Demand). To determine the optimum value of the HLR needs to be analyzed by each concentration.

Based on figure 4 (a) efficiency of BOD to high concentrations can be seen that, each HLR has different tendency. In the three largest HLR is 0.15 m³/m²/hour; 0.10 m³/m²/hour and 0.075 m³/m²/hour fairly stable from the beginning to the end of the running. As for HLR 0.06

m³/m²/hour and 0.05 m³/m²/hour on day-47 and day-53 has increased but fell back to a running process ends. BOD minimum efficiency at high concentrations as shown in figure 4 (a) falls to HLR 0.15 m³/m²/hour with less efficiency is only 20 % and only capable of removing BOD average of 139 mg/L.
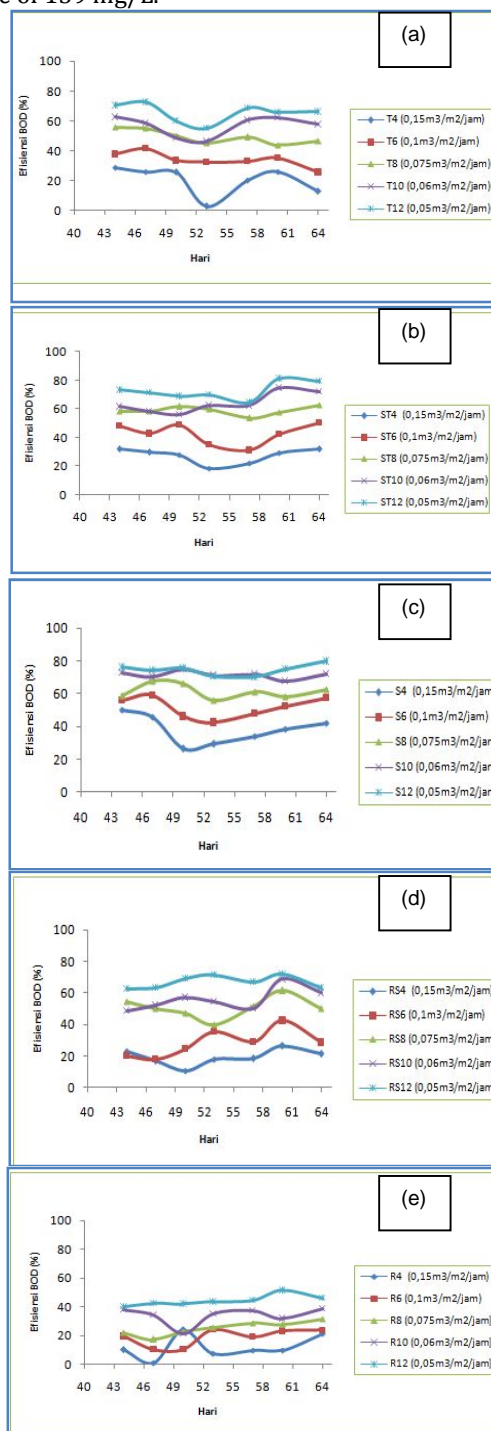

Figure 4. The Efficiency of BOD Removal in (a) High Concentration, (b) Middle-High Concentration, (c) Middle Concentration, (d) Concentration of Low-Middle, (e) Concentration of Low

Concentration was high influent concentrations between 554 mg/L to 643 mg/L. Can be seen in figure 4 (b) is a middle-efficiency at high concentrations. At HLR 0.15 m³/m²/hour stable enough to end up running, while HLR 0.10 m³/m²/hour; 0.075 m³/m²/hour and 0.05 m³/m²/hour at the beginning of the day-57 running stable then all up and down until the end of the running. Almost the same as at high concentrations where the lowest efficiency occurs at HLR 0.15 m³/m²/hour. But with greater efficiency that is adrift 7%.

Figure 4 (c) shows the efficiency at moderate concentrations. Concentrations were as stable in value so does the influent effluent, so that the concentration removal efficiency was stable from the beginning to the end of the running. Still on the HLR each variation has a different tendency. For example, the HLR 0.15 m³/m²/hour and 0.10 m³/m²/hour has almost the same trend on day-50 and then increased and stabilized down to running over. As for the HLR 0,075 m³/m²/hour have peak efficiency at the beginning of the running. As for HLR 0.06 m³/m²/hour and 0.05 m³/m²/hour have not far adrift efficiency even at day-48 to day-57 have almost the same value. But in general the optimum efficiency at a concentration falling in the HLR 0.05 m³/m²/hour which reached 75% with the ability 371 mg/L BOD removal.

Another case in low-moderate concentrations. BOD removal efficiency can be seen in figure 4 (d), where the HLR 0.15 m³/m²/hour less stable in the early to lowest efficiency occurs at the beginning of the running that day-50 is only 10.32 %. As with the HLR 0.10 m³/m²/hour on day-60 actually rose, reaching a peak efficiency of 42.31%. For HLR 0,075 m³/m²/hour; 0.06 m³/m²/hour and 0.05 m³/m²/hour quite stable until the end of the running. Optimum efficiency occurs at HLR 0.05 m³/m²/hour, reaching 67 %.

Low concentrations has an average influent concentration of 92 mg/L BOD. The efficiency of a low concentration as shown in figure 4 (e) has decreased from the previous concentration. Where optimum efficiency is still going on in the HLR 0.05 m³/m²/hour but with a much lower efficiency of only 44 % .

In figure 4 it can be seen that each HLR have diverse efficiency , the greater the value HLR removal efficiency will be smaller , nor vice versa. Both at high concentrations, concentrations of middle-high, middle concentration, low-moderate concentrations and low concentrations of BOD removal efficiency optimum falls at HLR 0.05 m³/m²/hour. Value HLR (Hydraulic Loading Rate) is influenced by the duration of stay (HRT), the longer the dwell time, the smaller the value of the HLR so that bacteria would be better to grow and thrive. As expressed by Liu and Tay (2004). When combined with HRT fast and high speed can cause granule formation by microorganisms in the effluent.

This is consistent with the results of research conducted by Ardina Sita (2012) where optimum efficiency in setting aside BOD$_5$ and COD occurs at the lowest HLR. Although it has a different value HLR because the longest dwell time that is used is 8 hours so that the value of the HLR 0,025 m³/m²/hour is used approximately.

d. Effect of Influent Concentration Variation on BOD$_5$ Removal

In figure 5 (a) HLR 0.15 m³/m²/hour has performance varies when seen from each concentration. One example for a moderate concentration decreased efficiency in the early running. But the next day quite stable. In contrast to the low concentrations of it in the early running efficiency and stable ride on the next day ended up running. For high concentrations of middle-low stable enough for running. As with the high concentration, when the initial running down but then slowly and stabilized until the end of the running. Optimum efficiency at HLR 0.15 m³/m²/hour occur in moderate concentrations despite having a smaller allowance than the concentration of middle-high or high concentrations, reaching 38 %.

In figure 5 (b) is the BOD removal efficiency at HLR 0.10 m³/m²/hour. It can be seen that the high concentration of middle-high and fairly stable during the running process. So it is with moderate concentration and low and remained stable up to running over. Unlike the case in low -moderate concentrations on day-43 and day-47 increased effluent concentrations even higher than middle, so that on the day of an HLR peak efficiency on the right, reaching 62.54 % on day-47 . Optimum efficiency at HLR 0.10 m³/m²/hour, HLR 0.15 m³/m²/hour the same as occurs in moderate concentrations.

The next BOD efficiency with a value of HLR 0.075 m³/m²/hour can be seen in figure 5 (c). Under the allowance for BOD, is the largest in the HLR occurs at middle-high concentrations followed later high concentration, then the concentration of middle, middle and low concentrations of low concentration. However, the amount of the removal for BOD not necessarily have a greater efficiency. It is very dependent on the influent concentration. Where optimum efficiency in BOD aside occurs at moderate concentrations, reaching 62 % or ten percent greater than HLR 0,010 m³/m²/hour .

Tentative conclusion can be drawn that the greater the concentration of the allowance value would be greater.

Figure 5 (d) is HLR 0.06 m³/m²/hour efficiency. At high concentrations of efficiency resembles a horse saddle, when the initial running stable then down and up again on day-57 and day-60, and at the end running down the back. As for the high concentration of middle - and low-concentration was increased in the early running but, then fairly stable until the end of the running . As with the concentration being stability would occur at the end of running. As for the low concentrations remained stable from the beginning to the end of the running. The minimum efficiency at HLR 0.06 m³/m²/hour occurs at low concentrations although at day-64 was greatest efficiency at this concentration but the concentration was not able to beat the BOD set aside .
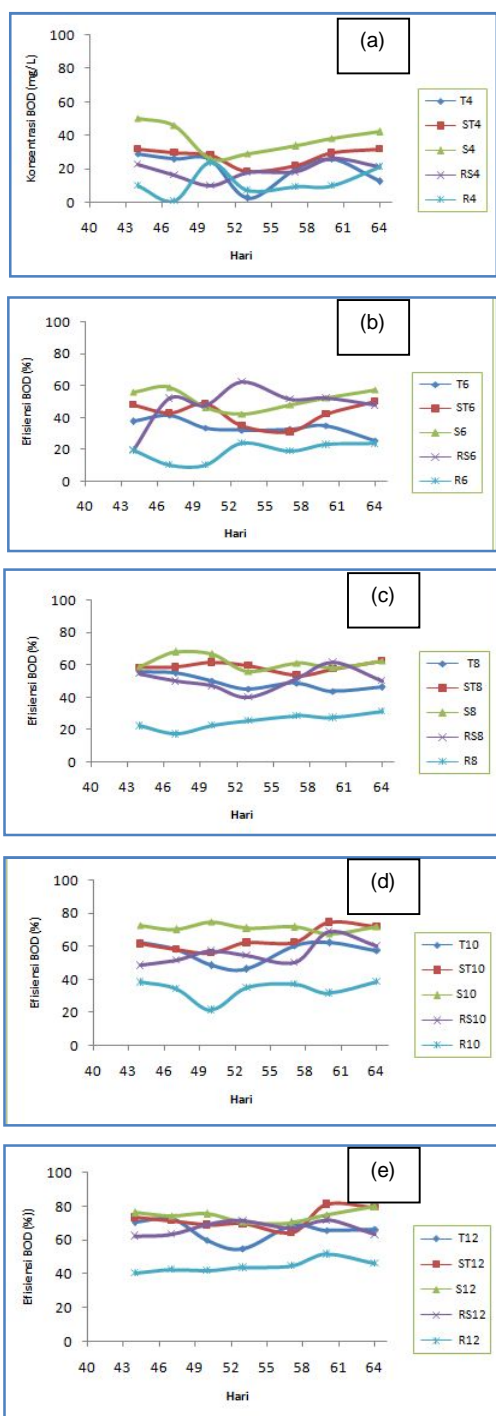
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Figure 5. The Results of the BOD Allowance (a) HLR 0.15 m³/m²/hour; (b) HLR 0.1 m³/m²/hour; (c) HLR 0.75 m³/m²/hour; (d) HLR 0.06 m³/m²/hour; (e) HLR 0.05 m³/m²/hour

The efficiency of BOD at HLR 0.05 m³/m²/hour can be seen in figure 5 (e). As well as the HLR 0.06 m³/m²/hour the efficiency of BOD, high concentrations resembles a horse saddle. Concentration was high in the early running quite stable even in the 50th and 53rd day is the peak efficiency at this concentration. As for the three other

concentrations are quite stable during the running process. Optimum efficiency HLR 0.05 m³/m²/hour occurs at moderate concentrations with peak efficiency occurs on the last day of running, reaching 79.84 %.

In general, it can be seen from figure 5 that each HLR has a diverse removal efficiency. Based on the above results when compared with different concentrations of the greatest efficiency occurs at moderate concentrations to achieve 74.58 % efficiency. The efficiency of BOD is less than the efficiency due to the value of the influent COD and pretty much adrift effluent so removal also getting smaller. Additionally it is supported by Tchobanoglous et.al (2003) the relationship between BOD and COD is a part of the COD BOD.

Ultimate BOD value is always smaller than the value of COD. This happens for several reasons, one of which many organic substances that are difficult to be oxidized biologically as lignin because only can be used chemically oxidized.

e. Conditions Hydraulic Loading Rate (HLR) and The Optimum Concentration In The UASB Reactor to COD Removal and BOD

In the COD removal and BOD based on variations of Hydraulic Loading Rate (HLR) and the variation of the influent concentration has almost the same tendency. Here are the results of this study.

Table 3. The Relationship Matrix HLR and Influent Concentration

Variation	Removal Efficiency (%)		
	COD	BOD	Ket.
Variation of HLR (*Hydraulic Loading Rate*)			
1. High Concentration	73.08	65.51	HLR 0,05 m3/m2/hour
2. Middle-High Concentration	74.26	72.6	HLR 0,05 m3/m2/hour
3. Middle Concentration	77.34	74.58	HLR 0,05 m3/m2/hour
4. Low-Middle Concentration	69.92	66.95	HLR 0,05 m3/m2/hour
5. Low Concentration	48.01	44.47	HLR 0,05 m3/m2/hour
Variation of Concentration			
1. HLR 0,15 m3/m2/hour	39.71	38.02	Middle Concentration
2. HLR 0,1 m3/m2/hour	50.68	51.63	Middle Concentration
3. HLR 0,075 m3/m2/hour	63.65	61.66	Middle Concentration
4. HLR 0,06 m3/m2/hour	70.6	71.47	Middle Concentration
5. HLR 0,05 m3/m2/hour	77.34	74.58	Middle Concentration

CONCLUSION

1. COD removal efficiency based on the variation of Hydraulic Loading Rate (HLR) reached 48.01%-77.34% and is 39.71%-77.34% variation in concentration; allowance BOD$_5$ based on variations of Hydraulic Loading Rate (HLR) which is 44.74%-

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74.58% and by varying the concentration between 38.02 %-75.58%.

2. Effect of influent concentration variation and the variation of the concentration of COD and BOD$_5$ are:
   a. The larger the greater the concentration of influent COD and BOD$_5$ incurred but not necessarily high efficiency because it is influenced by the influent concentration;
   b. Value Hydraulic Loading Rate (HLR) is getting smaller, then the removal of COD and BOD$_5$ greater , therefore the removal efficiency is also getting better .

3. Conditions of the influent concentration and Hydraulic Loading Rate (HLR) in the UASB reactor for the optimum parameter set aside are:
   a. The optimum COD removal occurs at moderate concentrations and Hydraulic Loading Rate (HLR) 0.05 m^3/m^2/hour with 77.34% removal efficiency capabilities;
   b. Allowance BOD$_5$ optimum occurs at moderate concentrations and Hydraulic Loading Rate (HLR) 0.05 m^3/m^2/hour with 74.58% efficiency capabilities.

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