Effect of Cover Soil to Concentration of Ammonia, Nitrate and Nitrite in Leachate with Bioreactor Landfill Simulation

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Abstract: Leachate is one of the wastes from the waste processing site that must be handled appropriately so as not to pollute the environment. One method of handling leachate is leachate recirculation. Ammonia contained in leachate can pollute the environment. This study simulated landfills in two bioreactors with recirculation leachate and the addition of water and distinguished them using (1) and without using cover soil (2). The study was conducted for 30 days. The parameters analysed were ammonia, nitrate, and leachate nitrite. The observations of the two bioreactors showed that the concentration of ammonia and nitrate in bioreactor 2 tended to be higher than in bioreactor 1. Nitrite concentrations did not show significant differences in the two bioreactors. Ammonia, nitrate, and nitrite compounds in both bioreactors have been formed since the beginning of the study even though they initially had relatively low values. The decrease in the height of the organic waste is faster in bioreactor 1 with a percentage of final waste reduction of 79.03%. The highest waste temperature occurs in bioreactor 2, which reaches 43^0C. The pH of waste in both bioreactors tends to be neutral, while the pH of leachate in both bioreactors tends to be acidic.

1 INTRODUCTION

Indonesia is a developing country with a population that continues to increase every year. The impact of population growth increases the amount of waste generated. The problem that occurs in Indonesia is the increasing number of waste generated every day, while the land that can be used as disposal and processing of waste is increasingly limited. Waste generation has a direct impact on environmental conditions, such as siltation of rivers, air pollution, causing various diseases, and damaging aesthetic values.

Jambi City is one city that is inseparable from the problem of garbage. In 2015 the population of Jambi City was 569.296 people with an annual waste generation of 571.444 m^3 (Central Statistics Agency, 2015). The landfill used is the Talang Gulo landfill which has a controlled landfill system. Many problems occur in implementing this system, such as limited land, methane gas production, and the high volume of leachate produced. Leachate produced contains various pollutants, including ammonia, nitrate, and nitrite. Therefore, there must be a way to accelerate the stabilization of waste to overcome the problem of limited land and reduce the organic content of leachate in a faster time. According to Chan (2002) by conducting leachate recirculation can improve leachate quality, accelerate the decomposition of waste, and reduce leachate processing costs.

Based on the above problems, the authors conducted a study on the condition of leachate in landfill modelling to be made with the type of organic waste in two different reactors, namely using cover soil and without cover soil. This study was conducted to analyse the effect of cover soil on decreasing the height of the waste, the temperature of the garbage, the pH of the waste and the pH of leachate water in each reactor. Determine the concentration of ammonia, nitrate, and nitrite in leachate produced from each reactor. The landfill is a physical facility that is used as a place for final waste processing. The landfill is a method of handling waste by storing garbage into the soil. The most widely known final disposal method is open dumping, controlled landfills, and sanitary landfills (Tchobanoglous et al., 1993).

Leachate is liquid waste arising from the entry of external water into landfills, dissolving, and rinsing dissolved materials, including organic matter resulting from biological decomposition processes

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(Damanhuri, 2008). One of the characteristics in leachate is ammonia, which, if excessive, is harmful to the environment. Ammonia in leachate must be removed because it is toxic, inhibits anaerobic degradation and can affect human health (Dini, 2014).

Increasing the concentration of ammonia-nitrogen will increase the level of toxicity in leachate (Dini, 2014). High concentrations will potentially inhibit the degradation process and require treatment of leachate before being discharged into the water body. In leachate, most ammonia-nitrogen is in the form of ammonium (NH4 +) because the pH level is less than 8 (Reinhart et al., 2002 in Dini, 2014).

Parameter of ammonia (NH_3), nitrite (NO_2^-) and nitrate (NO_3^-) produced in the bioreactors are formed due to decomposition reactions of organic matter containing nitrogen, such as proteins and amino acids. Protein must undergo the process of hydrolysis into amino acids so that it can be used as an energy source by a microorganism. The process of protein hydrolysis and fermentation by microorganisms causes ammonia (NH_3) to form in leachate.

The process of changing from amino acids to ammonia is called ammonification, which helped by microorganisms such as bacteria and fungi. In the case of sufficient oxygen, ammonia will be converted biologically through the nitrification process. Nitrification is a two-stage process that also involves two types of bacteria, Nitrosomonas and Nitrosococcus, which can decompose ammonia into nitrite, and Nitrobacter, which is able to decompose nitrite compounds into nitrates.

2 MATERIALS AND METHODS

In this study, there were two different bioreactors those are bioreactor 1, which used cover soil and bioreactor 2 without cover soil. The cover soil used is sandy clay soil. The bioreactor is made using 85 cm tall drums with a diameter of 48 cm. Organic waste filled into the bioreactors with weight 57 kgs. Organic waste was taken from Talang Banjar Traditional Market, Jambi City and was chopped in Makmur Waste Bank, Eka Jaya.

The temperature of waste is carried out using a thermometer. Waste temperature is measured at each port that is in each reactor. The measurement pH of leachate was carried out every day for 30 days of study. Leachate water is taken from the reservoir of leachate water from each reactor, which will then be measured for its pH value using a pH meter. The layout of bioreactors used is as follows:

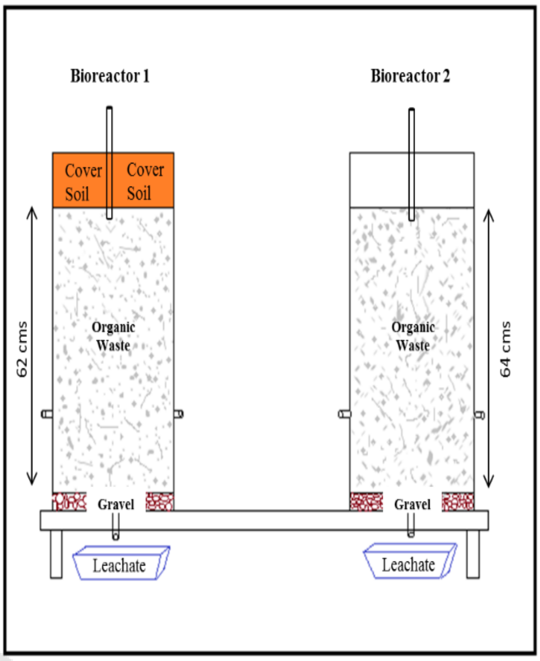

Figure 1: Layout of Bioreactor.

This study was conducted for 30 days. The parameters observed in this study were the decreased of the height of waste, temperature, and pH of waste, pH of leachate, the concentration of ammonia (NH_3), nitrite (NO_2^-) and nitrate (NO_3^-). Both bioreactors will be treated with leachate recirculation and addition of rainwater. Recirculation of leachate carried out will redistribute nutrients needed by microorganisms in landfills (Adam, 2015). The amount of water added was 477 ml, with the calculation of rainfall in Jambi City. Addition of water is carried out every day during the study.

Recirculation of leachate is carried out in the first week for seven days, then in week-2 to week-4 only once a week. For the addition of water is done every day. The method used to measure the concentration of each parameter, like Ammonia is SNI 06-6989.30-2005, Nitrite (NO_2) is SNI 06-6989.9-2004, and Nitrate (NO_3) is SNI 6989-79-2011.

3 RESULTS AND DISCUSSION

3.1 Effect of Cover Soil to Reduction of Organic Waste

Decreasing the height of the waste is classified into 3 stages, namely the initial reduction of waste, the decrease in primary waste, and the subsequent decrease in waste (El-Fadel, 2014). The reduction in waste caused by the addition of external loads to the waste is referred to as the initial reduction in waste. The external load added above the layer of waste can reduce the amount of space formed between the surfaces of the waste (Adam, 2014). The initial reduction of waste on the day-1 of the bioreactor 1 decreased to 33.87%, while in bioreactor 2 decreased to 25%.

Furthermore, the reduction of waste height continues and is observed at each stage. Stage 1 is a decrease in waste height in the first week of the study. At this stage, the decrease in the height of the waste occurs as a result of the weight of the waste itself or can be said as a primary decline (Elagroudy et al., 2008). At this stage, the height of waste in bioreactor 1 decreased by 43.55%, while in bioreactor 2 decreased by 51.56%.

At the end of stage 2 on the day-14 of the study, the height of bioreactor 1 decreased by 62.90%, while in bioreactor 2 decreased by 62.50%. At the beginning of stage 3 on the day-15, the height of waste in bioreactor 1 decreased by 62.90%, while in bioreactor 2 decreased by 65.63%. At the end of stage 3 on the day-30, the height of waste in bioreactor 1 was 13 cm, while in bioreactor 2 was 14 cm. Based on the results, it was obtained that the percentage of reduction of waste in bioreactor 1 was 79.03%, while bioreactor 2 was 78.13%.

The reduction in waste that occurs from stage 2 to stage 3 can be categorized as a secondary decrease in waste. It occurs as a result of the physical and biochemical decomposition processes that have occurred (Elagroudy et al., 2008). Reduction in waste will continue until it reaches a stable condition. As shown in Figure 2, the accumulated percentage of waste reduction. In this case, the initial decline in waste and the decrease in primary waste is shown in stage 1. While the secondary decrease in waste is shown in stages 2 and 3.

3.2 Effect of Cover Soil to pH and Temperature of Organic Waste

In general, the temperature of waste in bioreactor tends to fluctuate because it is influenced by ambient temperature or the temperature outside the bioreactor. Besides that, the temperature is one indicator that shows that the decomposition process of organic compounds runs smoothly is the change in the temperature of the waste. The heat generated from organic waste is caused by the decomposition of organic fractions from the waste mass. The heat generated is influenced by the operating system applied to landfills and climatic conditions (Yesiller et al., 2011).

The temperature of waste becomes an important parameter because it affects the solubility of organic compounds and heavy metal compounds contained in waste (Sethi et al., 2013). The measurement of waste temperature is carried out every day for 30 days. The results of the temperature of the waste in bioreactor 1 are in the range of 30-36^{0}C, this is suitable for the process of decomposition of waste. Meanwhile, the temperature of waste in bioreactor 2 is in the range of 30-43^{0}C. The condition of microorganisms or mesophilic bacteria can grow optimally in the range of 30-38^{0}C.

The temperature of waste in each bioreactor has increased during the first stage. The temperature range of waste in bioreactor 1, which uses cover soil during stage 1 is between 33-35^{0}C, while the range of temperature values of waste in bioreactor 2 during stage 1 is 33-43^{0}C. This is related to the phase of aerobic waste degradation that is taking place at both bioreactors. In this phase of aerobic waste degradation, oxygen trapped in waste is consumed very quickly by aerobic bacteria to degrade the organic material contained in waste into carbon dioxide, water, organic residues which are partially degraded and also produce heat (Anindita, 2013).

The heat generated from the aerobic degradation process is what causes the initial temperature of the waste to be high — exothermic processes in waste degradation caused by respiration and metabolism microorganism. The metabolism of microorganisms is closely related to the organic fraction so that if the temperature of the waste gets higher, it is also the metabolic process of microorganisms is high (Rahmawati, 2017).

The value of the waste temperature for bioreactor 2 increased dramatically on the day-3, which was 43^{0}C. This is due to an exothermic reaction in the bioreactor. An exothermic reaction is a reaction that experiences heat transfer from the system to the environment or in that reaction can emit heat. In exothermic reactions generally, the system temperature will increase. With a waste volume of 0.115 m^3, it can produce a maximum waste temperature value of 43^{0}C.

At stage 2, the value of the waste temperature tends to fluctuate. The temperature range of waste obtained during stage 2 in each bioreactor is between 31-36^{0}C for bioreactor 1 and 33-36^{0}C for bioreactor 2. The waste temperature during stage 3 is the same as stage 2 because the temperature of the waste is fluctuating, but the temperature the waste of the two bioreactors decreased on the day-30 or at the end of

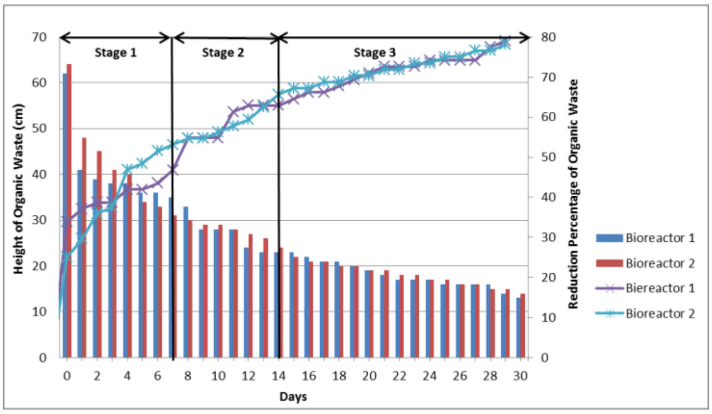

Figure 2: Reduction of Organic Waste.

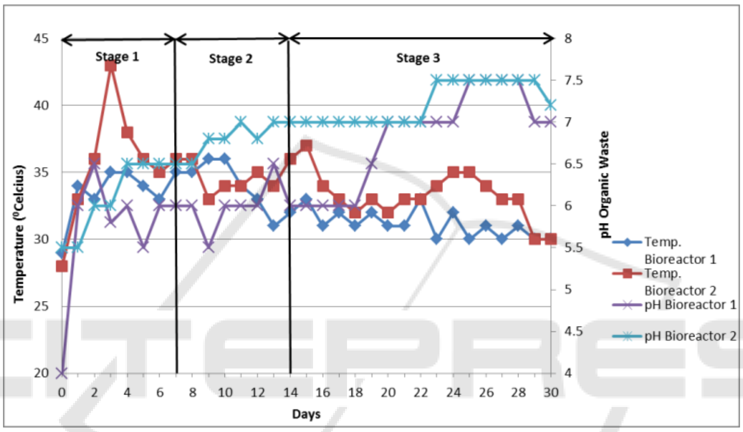

Figure 3: Temperature and pH of Organic Waste.

stage 3, the study was 30^{0}C. According to Sahidu in Anindita (2013), the optimum temperature for the growth of anaerobic bacteria ranges from 30-35^{0}C. This indicates that the process of degradation of waste in both bioreactors after entering the anaerobic degradation phase does not take place optimally.

The results of pH waste in this study tend to be neutral in each reactor. The process of recirculation leachate does not change the pH value to acid. This is because the process of adding water is done every day. The process of adding water every day affects bioreactor 2, in the absence of a layer of soil covering the water that enters the organic waste, it will seep faster to the bottom of the organic waste where the bottom has a port or hole to check the pH of the waste. The pH of waste in bioreactor 2 is more neutral. Conversely, the pH of waste in bioreactor 1 is longer to reach a neutral pH. This is because the addition of water is done through the cover soil first, then it seeps into the garbage. Graph of temperature and pH of waste can be seen in Figure 3.

3.3 Effect of Cover Soil to pH of Leachate

The pH of leachate is one of the most significant parameters in influencing leachate concentration in landfills. In Figure 4, we can see the change in pH of leachate for 30 days. The pH of leachate is closely related to the concentration of the material dissolved in it. The pH of leachate can also provide an illustration of the ongoing phases in the landfill reactor. On day-1 until day-30, it was seen that the pH of leachate tended to be acidic in both bioreactors.

The range of pH of leachate in bioreactor 1 was ranged from 3.2 until 5.3, while in reactor 2 it was ranged from 3 until 5.2. This is due to the formation of organic acids and increased carbon dioxide in the waste. The formation and accumulation of organic acids also result in a small amount of methane produced because acidogenic bacteria, not methanogenetic bacteria dominated the bioreactor.

The pH of leachate at both bioreactors tends to be low, indicating that the degradation process that takes place in the waste has entered the acid phase or commonly called the acidogenesis phase. In the acidogenesis phase, there is a decreasing of pH leachate as a result of the formation of acetic acid and hydrogen. The pH of leachate in the acidogenesis phase ranges from 5-6.5 (McBean et al., 1995). If the leachate has an acidic pH and it recirculates to the waste without a pH adjustment and buffering, it will increase the solubility of organic acid in the leachate, so that the pH of the next produced leachate tends to decrease due to the accumulation of organic acids which dissolved in leachate. In this study the pH value did not reach neutral pH, this was related to Dini (2014) where the pH value began to enter the normal stage on the day-35 of the study with a pH of 7.2.

3.4 Effect of Cover Soil to Concentration of Ammonia, Nitrate and Nitrite in Leachate

The results obtained from this study were that on the day-1 of the study, the concentration of ammonia in leachate was 20.6 mg/L for bioreactor 1 and 11.9 mg/L for bioreactor 2. On day-6, the concentration of ammonia was increased to 26.4 mg/L for bioreactor 1 and 116.4 mg/L for bioreactor 2.

This increase in concentration occurs because the process of decomposition of organic material that contains protein has begun. Proteins are converted into amino acids in the process of hydrolysis, and amino acids are converted back to ammonia (Ayuningtias, 2013). On the day-12, the concentration of ammonia increased to 468.7 mg/L for bioreactor 1 and 449.6 mg/L for bioreactor 2.

The concentration of ammonia increased on day-12 due to leachate recirculation process carried out for seven days, respectively in the first week of the study. This result is in accordance with what was stated by Vazquez (2008) that leachate recirculation could increase ammonia concentration because the process can make ammonia in the dissolved bioreactor in leachate. On the day-18, the concentration of ammonia in bioreactor 1 decreased to 175.2 mg/L, but for bioreactor 2 was increased to 462.3 mg/L. On the day-24, the concentration of ammonia decreased to 19.7 mg/L for bioreactor 1 and 41.3 mg/L for bioreactor 2. Furthermore, on the day-30 of the study, the concentration of ammonia continued to decrease to12.35 mg/L for bioreactor 1 and 37.12 mg/L for bioreactor 2.

This decreasing concentration of ammonia is thought to be due to the recirculation process of leachate, which is no longer carried out every day but once a week. In this study, the measured ammonia concentration tended not to be too high because of the constant addition of water. Purcell et al. (1999) said that one method of ammonia removal is by washing by water. Graph of ammonia concentration can be seen in Figure 5.

In this study, it can be seen that ammonia concentration in bioreactor 1 was lower than bioreactor 2. This is related to the system used at the landfill.

A landfill that applies a controlled landfill system which was modeled with bioreactor 1 and open dumping system was modeled with bioreactor 2. Comparison of ammonia concentrations from the two landfill sites with different systems shows that low ammonia concentrations are found in landfills that implement a controlled landfill system.

Furthermore, for concentrations of nitrite, there was not too much difference in both bioreactors. Concentrations of nitrite showed the nitrification process in the bioreactor. The nitrification reaction is triggered by the entry of oxygen due to leachate recirculation and the addition of water. Besides, it is estimated that the conditions in the bioreactor are influenced by oxygen entering through several parts of the bioreactor that are not tightly closed, such as holes for testing pH and temperature of the waste. In this study, the concentration of nitrite continued to increase until day-12. After increasing, there was a decrease in the concentration of nitrite in both bioreactors until the last day of the study. However, different things happened in bioreactor 1 because of the concentration of nitrite, which had increased on the last day of the study. Increase the concentration of nitrite on day-30 in line with the decrease in ammonia concentration because it has turned into nitrite through the nitrification process.

In bioreactor 2, the concentration of nitrite tends to be higher compared to bioreactor 1. This is because the waste in bioreactor 2 is more quickly exposed to the outside air or the waste inside the bioreactor is readily reacted with oxygen; the nitrification process will rapidly occur. Conversely, in bioreactor 1, air from the outside is difficult to enter into the waste in the bioreactor.

In addition to ammonia and nitrite concentrations, nitrate concentrations were also examined to see the association as one of the essential components in the nitrification reaction. On the day-1 until day-18, the concentration of nitrate was increased. Furthermore, until the day-30, the concentration of nitrate was

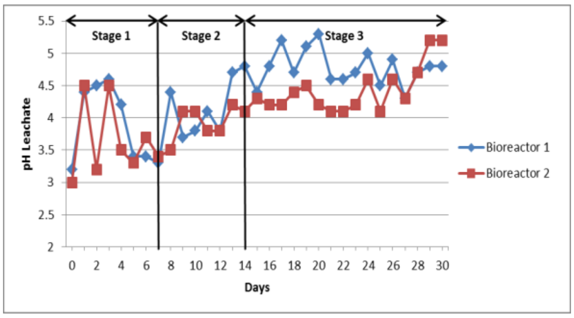

Figure 4: pH Leachate.

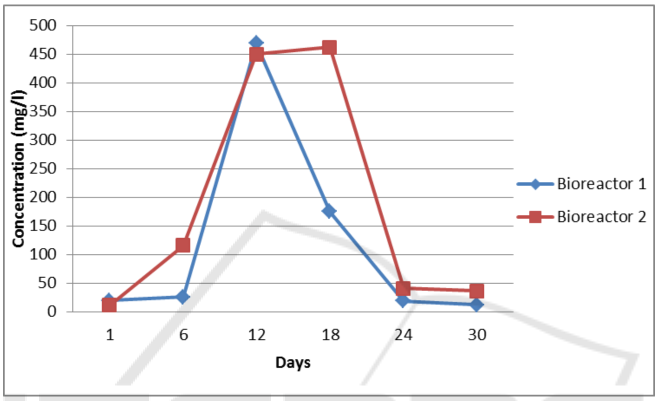

Figure 5: Concentration of Ammonia.

decreased. Nitrates can cause water to become cloudy, reduce dissolved oxygen, and cause foul odors. This was proven by organoleptic testing, wherein this study the leachate produced tended to be colored and foul-smelling. Graph concentration of nitrate and nitrite can be seen in Figure 6.

3.5 Analysis of Recirculation Leachate

Recirculation of leachate is one of the factors to accelerate the process of degradation of waste that occurs in the reactor. Recirculation of leachate water will trigger the stabilization process of reducing waste in the reactor because it contains various substances in leachate such as ammonia, nitrate, nitrite, methane, carbon dioxide, sulfate, sulfite, water and microorganisms (Damanhuri, 1993).

In this study, the recirculation of leachate was carried out at both reactors with the frequency of leachate administration in the first week of each day and the following week only once a week. With the provision of different recirculation in the first week and the following week, the differences in the results obtained in this study differ. Decreasing the height of the waste in both bioreactors tended to occur faster in the first week of the study, the height of the garbage was reduced by around 1-21 cm in the first week. For the pH value of the waste, the effect of recirculation of leachate is not very visible because of the addition of rainwater that is done every day so that in the two reactors the organic waste pH tends to be neutral.

According to Priyambada in Anindita (2013), the reactor which received leachate water recirculation treatment experienced an increase in waste temperature faster, because the content contained in leachate can increase the rate of stability of waste degradation. This is indicated by the temperature of the waste at the two reactors is higher in the first week compared to the following week. The pH value of leachate in both reactors tended to be acidic, although the recirculation of leachate water in the 2nd to the fourth week was only done once a week.

Ammonia, nitrate, and nitrate concentrations on the day-12 or at 2 weeks increased. This is due to the provision of leachate recirculation carried out in the first week every day. According to Vazquez (2008) that leachate recirculation can increase ammonia concentration because the process can make ammonia in the dissolved reactor in leachate. Then the concentration of ammonia, nitrate, and nitrite tends to decrease in the following week.

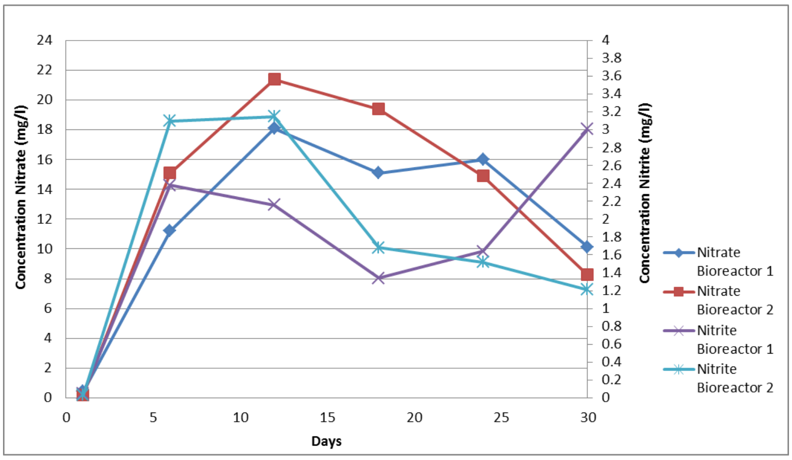

Figure 6: Concentration of Nitrate and Nitrite.

Organoleptic Testing to Leachate Characteristics	Day-1		Day-6		Day-12		Day-30	
	Bioreactor 1	Bioreactor 2	Bioreactor 1	Bioreactor 2	Bioreactor 1	Bioreactor 2	Bioreactor 1	Bioreactor 2
								
Color	Brownish	Brownish Yellow	Brownish Yellow	Yellow	Green	Blackish	Green	Green
Smell	Foul Odor	Smell Sour	Smell Sour	Stings Foul	Stinging Smell	Stinging Smell	Stinging Smell	Stinging Smell

Table 1: Characteristics of Leachate.

Then the concentration of ammonia, nitrate, and nitrite tends to decrease in the following week.

3.6 Organoleptic Testing to Leachate Characteristics

Organoleptic test or also called physical test using testing using sensory devices. In this study, the color and smell of leachate in each bioreactor will be tested using the sense of sight and sense of smell. On day-1 the bioreactor 1 produces brownish leachate with a foul odor. Whereas in bioreactor 2 it produces brownish yellow leachate and smells sour.

On the day-6 of the study, from bioreactor 1, leachate was still brownish yellow and sour. Whereas in bioreactor 2 the leachate is solid yellow and there is much foam in the water, the smell of leachate at that time stings foul. On the day-12 until day-30, on bioreactor 1 the leachate was thick green with a stinging smell.

While in bioreactor 2 the blackish leachate on the day-12 of the study with the smell of very thin leachate was also accompanied by the number of maggot caterpillars that were accommodated in the reservoir. For the day-18 until the day-30, the leachate was thick green with a stinging smell. According to Yatim and Mukhlis (2013), the odor in leachate is produced from the process of overhauling or decomposing organic matter, especially anaerobic reformation of components will produce rancid and foul-smelling compounds in the form of ammonia, H_2S and methane compounds.

In bioreactor 1, leachate produced better smell and color of leachate than bioreactor 2. In bioreactor 1, the odor produced did not smell rancid, but in bioreactor 2, the odor produced was more stinging and rancid. The color produced in each reactor is also different. In the bioreactor 2 colors produced tend to be darker.

4 CONCLUSIONS

Reduction of waste was faster in bioreactor 1, with the percentage of final waste reduction was 79.03%. The percentage of the reduction of waste in bioreactor

2 was 78.13%. The pH of waste in both bioreactors at the beginning was acidic. However, the next day until the end of the study, the pH of the waste tended to be neutral at both. The recirculation process of leachate water in both reactors does not change the pH value to acidic. This is because the process of adding water is done every day.

The condition of microorganisms or mesophilic bacteria that can grow optimally is in the range of 30-38^{0}C. The waste temperature in bioreactor 1 was in the range of 30-36^{0}C; this is suitable for the process of decomposition of waste. Meanwhile, the temperature of waste in bioreactor 2 was in the range of 30-43^{0}C. The pH value of leachate in both bioreactors tended to be acidic for 30 days. In this study, the pH value did not reach neutral. Ammonia, nitrate, and nitrite in both bioreactors have been formed since the beginning of the study, even though they initially had relatively low values. Over time, the concentration of the three experienced an increase in the day-12 of the study, and then finally decreased on the day-30.

REFERENCES

Adam, G. A., 2015. Influence of Physical-Chemical Waste Properties on Waste Volume Reduction and Leachate Characteristics of an Aerobic and Anaerobic Bioreactor. *Unpublished Master Thesis. Environmental Engineering Study Program, Department of Civil Engineering, Faculty of Engineering, Universitas Indonesia* (in Bahasa).

Anindita, Fathia. 2013. Effect of Recirculation Leachate to Total Suspended Solid (TSS) and Total Dissolved Solids (TDS) in Lysimeter. *Unpublished Bachelor Thesis. Environmental Engineering Study Program, Department of Civil Engineering, Faculty of Engineering, Universitas Indonesia* (in Bahasa).

Ayuningtias, L., 2013. Analysis of Leachate Recirculation Effect in Lysimeter on Ammonia, Nitrite, and Nitrate Concentration in Leachate. *Unpublished Bachelor Thesis. Environmental Engineering Study Program, Department of Civil Engineering, Faculty of Engineering, Universitas Indonesia* (in Bahasa).

Central Statistics Agency, 2015. Jambi City in Numbers. *Jambi: BPS Jambi City* (in Bahasa).

Damanhuri, E., 2008. Leachate Management. *Dictate of Waste Landfilling-Version 2008, Bandung: FTSL ITB* (in Bahasa).

Dini, A., 2014. Leachate Recirculation Effect Analysis on Bioreactor Landfill Towards Refuse Decomposition and Concentration of Ammonia, Nitrate, Nitrite With Continued Waste Filling Method. *Unpublished Bachelor Thesis. Environmental Engineering Study Program, Department of Civil Engineering, Faculty of Engineering, Universitas Indonesia* (in Bahasa).

Elagroudy, S. A., Abdel-Razik, M. H., Warith, M. A. & Ghobrial, F. H., 2008. Waste Settlement in Bioreactor Landfill Models. *Waste Management and Research*, 0(0) 1-11.

El-Fadel, M., Fayyard, W., & Jihan, H., 2012. Enhanced Solid Waste Stabilization In Aerobic Landfills Using Low Aeration Rates and High Density Compaction. *Waste Management and Research*, 0(0) 1-11.

McBean E. A., Rovers F. A., & Farquhar G. J., 1995. Solid Waste Landfill Engineering and Design. *Prentice-Hall, Inc. A. Simon Schuster Company, Englewood Cliffs, New Jersey 07632*

Purcell, B. E., Butler, A. P., Sollars, C. J., & Buss, S. E., 1999. Leachate Ammonia Flushing from Landfill Simulators, J.CIWFM, 13

Rahmawati, H.N., 2017. Effect of Aeration on Leachate's Characteristic Results for Organic Vegetable Waste with Biodrying Method (Case Study: Cabbage). Environmental Engineering Journal, Vol. 6, No. 1 (2017) Universitas Diponegoro (in Bahasa).

Sethi, S. & Kothiyal, N.C. 2013. Stabilization of Municipal Solid Waste in Bioreactor Landfills – An Overview. International Journal Environment and Pollution, Vol. 51.

Tchobanoglous, G., Theisen & Vigil, S. A., 1993. Integrated Solid Waste Management: Engineering Principles and Management Issues. *McGraw- Hill, Inc. Singapore.*

Vazquez, R.V., 2008. Enhanced Stabilisation of Municipal Solid Waste in Bioreactor Landfills. *Netherlands: CRC Press/Balkema*.

Yatim, E. M. dan Mukhlis. 2013. "Effect of Leachate to Well Water Around Air Dingin Landfill." Journal Public Health 7:2(2013):54-59 (in Bahasa).

Yesiller, N., Hanson, J. L., Yoshida, H. 2011. Landfill Temperature Under Variable Decomposition Conditions. Conference Paper in Geotechnical Special Publication, Geo-Frontiers 2011:1055-1065