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Physical and Chemical Characteristics of Organic Packing Materials of Soil, Compost, and Rubber Leaf Litter for Ammonia Biofiltration

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Abstract
Ammonia odor released from many industries to environment can be treated by biofiltration. The physical and chemical characteristics of packing materials affect to biofilter in degrading the target pollutant. The objective of the research was to characterize the physical and chemical characteristics of organic packing materials such as top soil, compost, and rubber-leaf litter on ammonia absorption and to determine the best composition of top soil, compost, and rubber-leaf litter on the characteristics of ammonia absorption. The packing materials were crushed and screened to pass a 60 mesh screener. The single and mixture of packing materials have been characterized to physical characteristics (density and porosity) and chemical characteristics (moisture content, pH, C/N ratio, water holding capacity (WHC), ammonia absorption capacity (AAC), and ammonia holding capacity (AHC)). Organic packing materials such as soil, compost, and rubber-leaf litter are nutrient-rich materials and capable in absorbing ammonia physically and chemically, so it will be very useful in the application as a packing material for biofilter. The best physical characteristics was rubber-leaf litter, and the best chemical cahracteristics was compost. The composition of soil, compost, and rubber-leaf litter by weight at 1:2:2 was the best performance.
Keywords: ammonia absorption, biofilter, compost, rubber-leaf litter, top soil

1. Introduction

Ammonia is a compound in a gas form that can pollute the air, as it is an irritant to the lungs and its main effect is on the respiratory tract. The symptoms are loss of ability to smell, cough, shortness of breath, and irritation of the mucous membranes of the eyes, vomiting, and dizziness. Industrial emissions, in particular odor, become an important issue; given the fact that public have begun to understand and complain on odor pollution. Maximum odor quality standard for ammonia is 2 ppm (The Decree of the Ministry of Environment of Indonesian No. 50/1996). Ammonia odor pollution generally occurs in the fertilizer industry, natural rubber, as well as waste treatment facilities (solid and liquid). Ammonia odor pollution from domestic wastewater treatment facilities (septic tanks) ranges from 0.2 to 5 ppm, and from industrial crumb-rubber ranges from 4 to 20 ppm (Yani & Juliana, 2012). Emission from composting facilities ranges from 0.2 to 105 ppm (compounds containing nitrogen) (Chung, 2007)

The development of gas or odor treatment technologies have been widely studied ranging from laboratory to the field using a biofilter. Various industries apply biofilter techniques as one of the methods that are reliable and simple, have low operating costs, and survive in the long term. The main factor determining the success on the use of biofilter to degrade the target pollutant is packing material (Ottengraf, 1986; Hirai et al., 2001). Good packing materials should have some specific characteristics to eliminate contaminants odors. Research on physical and chemical characteristics of packing materials include density, porosity, particle size, pressure drop, and water holding capacity (WHC), and ammonia absorption capacity (AAC) has been conducted by several researchers, among others (Hirai et al., 2001; Akdeniz et al., 2011).

Packing materials can be distinguished by their chemical nature, namely organic and inorganic packing materials. Many organic packing materials are applied as they are cheaper compared to inorganic materials. Organic packing materials coming in the form of compost, peat, soil, bark, and leaf litter have been widely used as a biofilter packing material. Inorganic packing materials of which have been used for the removal of ammonia are activated carbon fiber (Yani et al., 1998); rockwool, granular soil, cristobalt, and obsidian (Hirai et al., 2001); pine nuggets and larval rock (Akdeniz et al., 2011); and rock wool (Yasuda et al., 2009). The organic packing materials for biofilter were a mixture of compost and sludge (Yani & Juliana, 2012); peat (Yani et al., 1998; Yani et al., 2000); a mixture of compost, bark and peat (Choi et al., 2003); a mixture of compost (Poulsen & Ann, 2007); a mixture of soil, litter, and compost (Yani et al., 2006); a mixture of organic fertilizers and bagasse (Kaosol and Pongpat, 2012). Five organic materials of compost, coconut fiber, bark, pruning wastes, and peat used in a full-scale biofilter (Pagans et al., 2006).

The organic packing materials are commonly used for biofiltration rather than inorganic material. Selection of packing materials should be conducted by characterization of physical and chemical, to support growth of microorganism before applied to biofiltration. The objective of this study were (1) to assess the physical and chemical characteristics of the packing materials (soil, compost, and rubber-leaf litter) in ammonia absorption, and (2) to determine the best composition of top soil, compost, and rubber-leaf litter on the characteristics of ammonia absorption.

2. Material and Methods

2.1 Characterization of Packing Materials

At this stage, it was performed chemical analysis for each material used. Packing materials such as soil, compost, and rubber leaf litter were tested for the density, porosity, water content, pH, the content of C, N, P, and C/N ratio, Water Holding Capacity (WHC), Ammonia Absorption Capacity (AAC), and Ammonia Holding Capacity (AHC). This was performed to determine the characteristic quality of each material. Each measurement was done in three replications.

The packing materials were soil, compost, and rubber-leaf litter. The soil was in the form of top soil of forest. The compost used was commercial compost made of cow dung, straw, and husk. The litter was in the form of rubber-leaf litter having been milled to size reduction and passed to screen of 60 mesh. Combinations of packing materials sequentially were soil, compost, and litter as shown in Table 1.

2.2. Measurement of Bulk Density

Bulk density measurement was performed by putting a number of packing materials into a 25 mL measuring flask up to par, then it was weighed, and the density was calculated as $g.cm^{-3}$ in accordance with the procedures (Jury & Horton, 2004).

2.3. Porosity Measurement using Gravimetric Method

According to Akdeniz et al. (2011), porosity was measured as the ratio between air volume and the volume of bulky materials. A number of materials were put into the 25 mL measuring flask until the volume was correct, then pressed in such a way that there was no air volume between materials or no pore space for air circulation. Each measurement was done for three replications.

2.4. Water Absorption Capacity (WAC)

Single packing material and mixtures, each weighing 2 g, were mixed and poured into the filter paper. Water was added until all materials were submerged by water. Once there was no water dripping in a few minutes, the material was weighed and calculated as WAC. This procedure was similar to that performed by Akdeniz et al. (2011), as water absorption capacity (WAC) in 3 minutes.

2.5. Water Hodlding Capacity (WHC)

Once the water absorbing material was saturated, the material was left at room temperature (25-32°C), humidity 60-80%, where most of the water would evaporate from the material. Furthermore, the material was weighed every 3 hours up to 24 hours. Residual water retained by the material after 24 hours was calculated as water holding capacity (WHC).

2.6 Ammonia Absorption Capacity (AAC)

For the measurement of the absorption of ammonia (AAC) physically and chemically, a plastic jar with inner diameter of 8 inches and a volume of 4 L was used, filled with 1L solution containing of 5% ammonia. The petri dish containing the packing material was inserted into the jar, separated with a plastic screen bar so that the packing material did not make contact with ammonia solution. Single packing material and mixture, each weighing 2 g, was inserted into the petri dish, and then it was placed on top of the packing material, in a jar containing 5% ammonia solution. The jar was then closed and the packing material would absorb the ammonia gas. Ammonia absorption in every packing material was weighed every hour, until the material was saturated or constant weight was reached. The addtional weight by packing material was calculated as AAC, in which ammonia was absorbed and trapped physically and chemically in the packing material (Yani & Juliana, 2012). Each measurement was done for three replications. The AAC by packing material was operated to be saturated for 6 h and calculated as AAC.

2.7 Ammonia Holding Capacity (AHC)

Single packing material and mixtures, each weighing 2 g that had been saturated with ammonia vapor or having an AAC, was left at room temperature so that ammonia desorption from packing-material occurred, in which ammonia absorbed in the material would be physically separated or evaporate. Furthermore, the materials were weighed every 3 hours for 24 hours until they reached a constant weight. The amount of ammonia retained (trapped) was chemically suspected as AHC.

2.8 Chemical analysis

Chemical analysis parameters of packing materials were moisture content, pH, total carbon, nitrogen by AOAC method AOAC (1984), and total phosphorus by APHA method APHA (2005).

2.9 Data Processing

The design experiment used was a simple randomize. The data colected were subjective to analysis of variance using the SPSS 20 and then Duncan Multiple Range Test (DMRT). The ranking of test parameters was performed after DMRT.

3. Results and Discussion

3.1. Physical Characteristics of Packing Materials

3.1.1 Density

Density of packing material will affect the amount of materials filled for biofilter reactor. The density of packing material should be low to reduce the amount of material filled to reactor. Figure 1 shows that soil (K100) as a packing material has the highest density of 0.56 $g.cm^{-3}$ and the lowest density of rubber-leaf litter (K001) only 0.04 $g.cm^{-3}$. High-density of soil and compost are due to the fact that both of materials have high moisture content. In addition, the density will affect the porosity and absorption of ammonia. Based on statistical test, the density of each material is significantly different. The results show that each composition significantly affects to density of packing materials. This result is performed for the wet-bulk densities, so the dry-bulk density will be greater than wet bulk density. The dry bulk densities were approximately 0.8-0.9 $g.cm^{-3}$ for the yard waste compost and 0.6-0.7 $g.cm^{-3}$ for the sewage sludge compost (Poulsen & Ann, 2007). The sewage sludge compost generally yielded the highest ammonia removal rates and was the most effective material at high moisture contents. The pine nuggets and lava rock had a density of 0.19 and 0.59 $g.cm^{-3}$, respectively (Akdeniz et al., 2011).

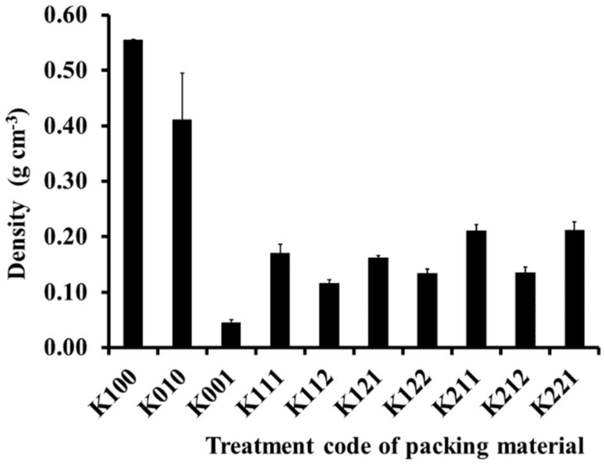

Figure 1. The density of packing material of soil, compost and rubber-leaf litter

After mixing, in accordance with the treatment, the density of a mixture seems to be influenced by the composition of the mixture (Figure 1). The analyis of variance (anova) indicated that all treatments are significantly difference. Based on DMRT, the mixture of K221 and K211 are not significantly different, K111 and K121 are not significantly different, K212 and K122 are not significantly different, and the treatment of K122 and K112 are also not significantly different. The mixture of K221 and K212 are significantly different; K211 and K112, K111 and K112 treatments are also significantly different. This shows that the composition with more soil and compost than the amount of rubber-leaf litter tends to have a greater density value. In contrast, the composition with more rubber-leaf litter than soil and compost will tend to have a lower density value. A mixture of materials that have the lowest density value is K112 with an average of 0.117 $g.cm^{-3}$, while the mixture with the highest level of density is K221 with an average of 0.213 $g.cm^{-3}$.

3.1.2 Porosity of Packing Materials

Porosity is calculated by measuring the volume of the cavity divided by the total volume. These cavities will be filled by water and air. The packing materials used have a porosity value of 25.09% for soil (K100), 34.28% for compost (K010), and 94.54% for rubber-leaf litter (K001) (Figure 2). The pine nuggets and lava rock had a porosity of 68.2 and 65.4 %, respectively (Akdeniz et al., 2011). In Figure 2, it can be seen that the addition on the amount of rubber-leaf litter on mixture K111 and K112 can increase the value of porosity. Statistical test results of each composition show the diversity on porosity value of each packing material. Duncan's Multiple Range Test (DMRT) at level of 5% shows that K121 mixture is significantly different from all the treatment mixtures. K112, K122, and K212 are not significantly different. K111, K211, and K221 are also not significantly different. This shows that a mixture with low amount of rubber-leaf litter will produce high porosity values, and the vice versa, a mixture with high amount of rubber-leaf litter will produce low porosity values. Rubber-leaf litter is in the form of dried leaves that serves to increase the porosity of the packing-material mixture. Rubber-leaf litter has finer pores than soil and compost. A big pore contains air or water easily lost through gravitational forces.

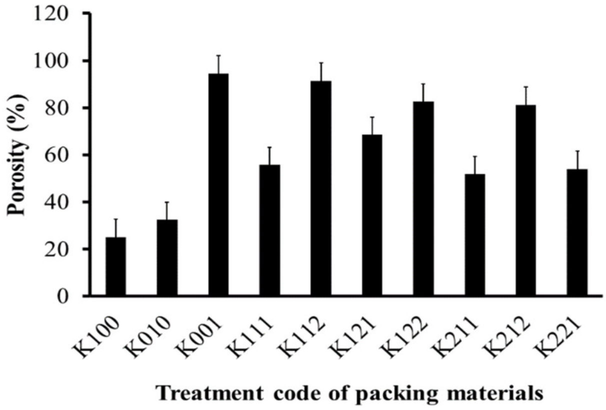

Figure 2. The porosity of packing material of soil, compost and rubber-leaf litter

Porosity is closely related to density, meaning that low porosity (K100) (Figure 2) has a high density (Figure 1). Materials having a high density have a small volume so that the packing material looks more solid; this is because the weight of the materials is bigger than the volume of the materials. The greater the volume of packing materials is, the smaller the density will be. This low density will make the packing material to have larger air cavity compared to materials having a high density.

3.2 Chemical Characteristics of Packing Materials

3.2.1 Moisture Content

Sufficient moisture content will greatly affect the performance of microorganisms and can prolong the life of packing materials. This is important because during the process, the amount of moisture content in the material will reduce. Of the three types of packing materials used, it shows that soil (K100) has moisture content of 37.7%, compost (K010) has moisture content of 56.7%, and rubber-leaf litter (K001) has moisture content of only 9.7% (Table 1). Compost has the highest moisture content compared to soil and rubber-leaf litter. Organic components present in the compost cause compost to have higher moisture content. Rubber leaf litter is a material with the lowest water content because it is already dried up. The high water content becomes one of the conditions for good packing material. Table 1 shows that the treatment of K221 has moisture content, which is quite high, compared to other treatments, which is about 40.3%. As for the composition of K112 has low moisture content, i.e. 29.3%. The more amount of soil and compost added also increases the amount of moisture content in each composition as shown in K121 and K211 treatment when compared to K111 (Table 1). Meanwhile, the addition of rubber-leaf litter will result in decreasing the amount of moisture content in the composition.

Table 1. Characterization of packing materials of soil, compost, and rubber-leaf litter

Treatment code	Composition (g) (soil : compost : litter)	Moisture content (% wb)[1]	pH	C (%)	N (%)	P (%)	C/N ratio	C:N:P ratio
K100	1 : 0 : 0	37.7fg	6.1	5.98	0.55	0.16	10.87	100 : 9.2 : 2.7
K010	0 : 1 : 0	56.7j	7.4	26.64	0.83	0.36	32.10	100 : 3.1 : 1.4
K001	0 : 0 : 1	9.67a	6.3	54.95	0.43	0.18	127.79	100 : 0.8 : 0.3
K111	1 : 1 : 1	32.7cd	6.4	29.19	0.61	0.23	47.85	100 : 2.1 : 0.8
K112	1 : 1 : 2	29.3b	6.4	35.63	0.61	0.22	58.41	100 : 1.7 : 0.6
K121	1 : 2 : 1	39.3hi	6.9	28.55	0.66	0.27	43.26	100 : 2.3 : 0.9
K122	1 : 2 : 2	34.3de	6.8	33.83	0.60	0.25	56.38	100 : 1.8 : 0.7
K211	2 : 1 : 1	35.5ef	6.3	23.38	0.62	0.22	37.71	100 : 2.7 : 0.9
K212	2 : 1 : 2	31.1bc	6.4	29.17	0.56	0.21	52.09	100 : 2.0 : 0.7
K221	2 : 2 : 1	40.3i	6.7	24.04	0.66	0.24	36.42	100 : 2.7 : 1.0

[1]Note : For the numbers followed by the same letter are not significantly different according to DMRT at 5% significance level.

Statistically, each composition has significantly different moisture content and the F-count value is higher than F-table. The results show that each composition has a significant level of moisture content. The DMRT shows that K221 and K121 are not significantly different, as well as for K211 and K122, while the treatment of K221 and K211 are significantly different, except that the comparison between K121 and K211 is also significantly different.

The optimum moisture content in the biofilter operation was between 40% and 60% (Devinny et al., 1999) or between 30-65% (Ottengraf, 1986). In the organic biofilter operation, moisture content must be maintained at 55-60% (Choi et al., 2003). Biofilter containing a mixture of litter and sludge composted had moisture content of at least 25% and maximum at 60% to achieve complete ammonia removal efficiency (100%) (Poulsen & Ann, 2007). Biofilter from the mixture of compost, activated charcoal, and sludge had moisture content ranging from 40 - 46% (Chung, 2007), top soil and sludge at 40-45%, mixture of top sol and rubber leaf litter at 40-65% (Yani et al., 2013). The compost material of biofilter had moisture content at an average of 60±3% (Chung, 2012). The optimum of moisture content will enhance ammonia absorption and support the biofilm in biofiltration. The increase in moisture content from 35 to 55% could improve NH_3 removal efficiency (Yang et al., 2014). All treatments have moisture content at range of 29.3 – 40.3% (Table 1), except compost (K010) having 56.7%. It is lower than the optimum condition for biofiltration, so later, it should be sprayed with water. This means that compost at moisture content of 56.7% is good for improving the ammonia removal in biofilter.

3.2.2 pH

The pH of the combination of the mixture must be adjusted to be suitable for the growth of microorganisms. The pH affects the growth of nitrification microbes and inhibits the degradation rate of ammonia compounds in the process of nitrification (Devinny et al., 1999). Microorganisms playing the role in oxidizing ammonia are *Nitrosomonas, Nitrosococcus, Nitrosospira, Nitrosolobus*, and *Nitrosovibrio* (Agustiyani et al., 2004; Posmanik et al., 2014). The optimum pH value for nitrification microbial growth was 6.5 to 8.5 (Yani et al., 1998; Posmanik et al., 2014; Omarani et al., 2004).

The pH is one of the environmental factors that affect the growth and activity of ammonia oxidizing bacteria. All treatments have a pH at range of 6.1 – 7.4 (Table 1). The range of pH values is very influential in the process of physical adsorption, because pH affects the solubility of a substance. The composition of the packing material (Table 1) shows rather pH neutral. This value is still within the range of the pH optimal for the growth of ammonia oxidizing microorganisms. Microorganisms degrading ammonia such as *Nitrosomonas, Nitrosococcus, Nitrosospira, Nitrosolobus,* and *Nitrosovibrio* live well in the conditions of pH at 6 - 8. In compost and litter biofilter, for the removal of ammonia gas, pH was maintained at a range of 6.6 to 7.1 (Choi *et al*., 2003); pH at 5 to 7 (Omarani *et al*., 2004); biofilter of a mixture of compost, activated charcoal, and sludge needs a pH ranging from 7.2 to 8.9 (Chung, 2007); whereas biofilter of a mixture of sludge and compost is maintained at pH range of 6 to 8 (Yani & Juliana, 2012). The compost material of biofilter had pH of 8.2±0.2 (Chung, 2007).

3.2.3 Composition of C, N, P, and C/N ratio

Microorganisms require major and minor nutrients to metabolize contaminants (Devinny et al., 1999). Major nutrients commonly required are carbon, nitrogen, phosphorus, and potassium. Minor nutrients include iron, magnesium, calcium, zinc, manganese, and sulfur. To support the sustainability of the growth of bacteria, vital nutrients required are carbon, nitrogen, and phosphorus (Table 1). Carbon and nitrogen are elements necessary for the growth of microorganisms needed in large amount. Carbon can increase energy and biosynthesis, so sufficient carbon is necessary, and nitrogen can accelerate cell growth. Phosphorus is required in sufficient amount for the proliferation and growth of microbes.

All treatments have C content at range of 5.98 – 54.95%, N content at range of 0.43 – 0.83%, P content at range of 0.16 – 0.36% and C/N ratio at 10.87 – 17.79 (Table 1). We can see that the highest carbon is in rubber-leaf litter (K001) that is 54.95%, then compost (K010) by 26.64%, and the smallest is in the soil (K100) by 5.98%. The highest nitrogen and phosphorus content is found in compost K010 at 0.83% and 0.36 %, respectively. The high content of nitrogen and phosphorus in compost becaused compost has been produced through the degradation process of organic compounds. The highest percentage of C/N is in rubber-leaf litter (K001) as much as 127.79, as the original organic matter. Such treatment has more amount of rubber-leaf litter than the amount of compost, as the case with the amount of phosphorus treatment with more amount of compost will increase the amount of phosphorus content. Treatment with increasing amount of rubber-leaf litter will increase the number of C/N ratio. It can be seen in the treatment of K112, K122, and K212 whose C/N are greater than other treatments. The biofilter use in organic and inorganic mixtures had C/N ratio from 8.7 to 28.3 as reported (Choi et al., 2003). The compost material of biofilter having a C/N ratio was 32±2 (Chung, 2007). The organic media of a mixture of compost, bark, and peat showed the highest removal capacity of ammonia (Choi et al., 2003). The C/N ratio is initially at 27.7 – 43.1 and then it decreases to 13.7-16.0 for 70 days operation.

The ratio of C : N : P is generally about 100 : 10 : 1. Table 1 shows that soil is the best medium to provide a source of nutrients for microbes, whereas a mixture of compost and litter or other materials lack of nitrogen. However, the use of biofilters for the removal of nitrogen compounds, such as ammonia, tri-methyl amine, and so on, microbes will get nitrogen sources of gas pollutants entering or removed from the biofilter.

3.2.4 Water Absorption Capacity (WAC) and Water Holding Capacity (WHC)

The WAC of single packing material and mixtures are presented in Figure 3 (a) and (b), respectively. Once the water absorbing material was saturated and there was no water dripping in a few minutes. The value of WAC is equal to the value of WHC at zero time (initially). The material was left at room temperature (25-32°C), humidity 60-80%, where most of the water would evaporate from the material. The WHC decreases and it is measured up to 24 hours.

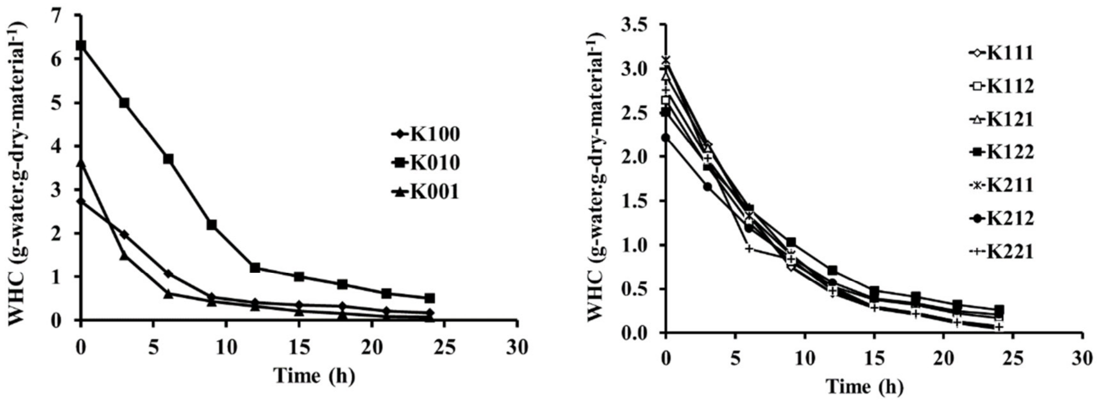

Figure 3. The ability of packing material to water holding capacity (WHC), single (a) and mixture of soil, compost, and rubber-leaf litter (b)

The WHC is the most important parameter in this test to determine physical absorption capacity of materials toward water and pollutants. The WAC and WHC of materials affects the capacity of the materials to store water, and it will be related to the solubility of gas in the absorption process in the packing material. The maximum water holding capacity was influenced by the diameter and the porosity of the pore of the material (Yani & Juliana, 2012); thereby affecting the capacity of the physical removal of pollutants. This indicates that materials with hard or big pores have small water holding capacity (WHC) compared to those with finer pores. Figure 3 shows the change of WHC from beginning and after being left for 24h, where the water will be evaporated at room temperature of 22-32 ^{o}C.

The WHC decrease for 24h in the material can be seen in Figure 3a, while the regression equations are not presented. Figure 3a shows that soil and compost have WHC value better than the rubber-leaf litter. It can be seen from the graph of WHC, the high decline in WHC of rubber-leaf litter and has a constant value on the x variable smaller than soil and compost. This condition indicates that the soil and compost can hold more water since 0 up to 6 hours. It shows that the addition of rubber-leaf litter will increase WHC value of the composition of packing materials. The addition of soil and compost will also increase the value of the WHC, but only slightly when compared to rubber-leaf litter. The amount of packing material with more addition of soil and compost will absorb water quickly and at the same time will also release water quickly. Composition of more rubber-leaf litter will be longer to absorb water, but this composition has a higher value of WHC (Figure 3b). The existence of this composition will increase WHC of the packing material. More rubber-leaf litter will improve the power of WHC in the composition.

3.2.5 Ammonia Absorption Capacity (AAC)

The mechanism in ammonia removal by biofilter occurs by adsorption, absorption, and biodegradation(Ottengraf, 1986; Hirai et al., 2001; Yani et al., 1998; Yani et al., 1998b; Pagans et al., 2006; Devinny et al., 1999). The adsorption data are successfully fitted to Langmuir and Freundlich isotherms (Pagans et al., 2006), while the absorption could be represented by a Henry's law linear equation (Ottengraf, 1986; Pagans et al., 2006).

Based on the results of the study, the adsorption and absorption of ammonia by the packing material will saturate within 6 hours. Absorption of ammonia gas pollutant to the material was observed. Figure 4a shows that compost has a very good absorption rate compared to soil and rubber-leaf litter. This is probably caused by compost containing the highest moisture content of 56.7% (Table 1) to absorb ammonia by Henry's law, that its higher than soil or rubber-leaf litter. In addition, compost contains the humic substances as well as peat that as reported by Togashi et al. (1986).

The absorption rate of each composition within 1 hour varies (Figure 4a). The rank of the absorption rate within 1 hour from the largest to the smallest is as follows: K122 = K212> K121> K112 = K221> K211> K111 (Figure 4b). During the saturated level of absorption, the amount of ammonia pollutant adsorbed from the largest to the smallest is as follows: K122> K212> K121> K112> K221> K211> K111. The treatments of K211, K122, K211, K221 are faster in saturation than the treatments of K111, K112, and K212.

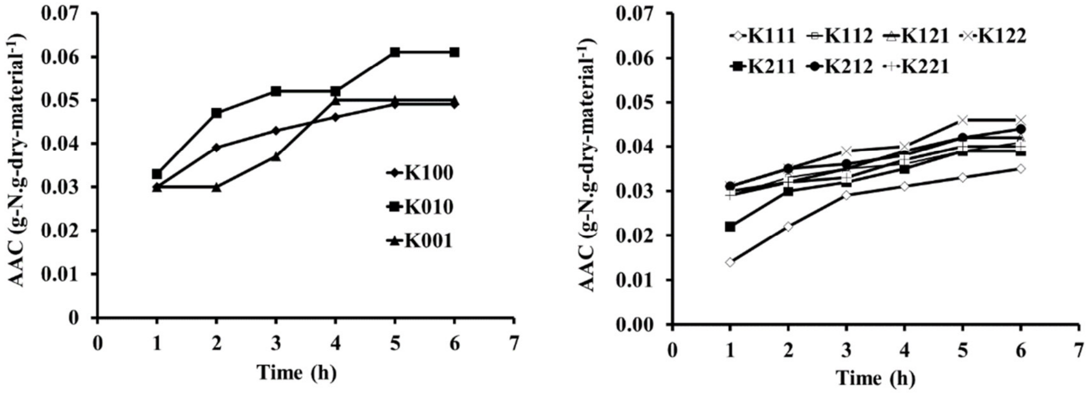

Figure 4. Changes in ammonia absorption capacity (AAC) for 6 h by packing materials, single (a) and a mixture of soil, compost, and rubber-leaf litter (b)

Based on the test on ammonia nitrogen (NH_3-N), packing material with high saturation level will have a high content of ammonia nitrogen as well. Figure 5 shows that each composition of packing material has significant differences in the content of ammonia nitrogen after the absorption of ammonia to be saturated. The highest AAC value of a packing material is the highest content of ammonia nitrogen.

The ammonia absorption rate to the type of each packing material (Figure 5) is as follows: K111 0.726 g-N·g-dry-material^{-1}, K112 1.291 g-N·g-dry-material^{-1}, K121 1.349 g-N·g-dry-material^{-1}, K122 1.430 g-N·g-dry-material^{-1}, K211 1.276 g-N·g-dry-material^{-1}, K212 1.360 g-N·g-dry-material^{-1}, and K221 0.865 g-N·g-dry-material^{-1}. The packing material with more rubber-leaf litter is likely to have high absorption of ammonia. The highest is K122 at 1.430 g-N·g-dry-material^{-1}. In general, it appears that the treatment with more compost will absorb more ammonia pollutants of K121 and K122 (Figure 5) and the fastest is K122. Treatment with more soil has a higher absorption compared to the treatment with less soil.

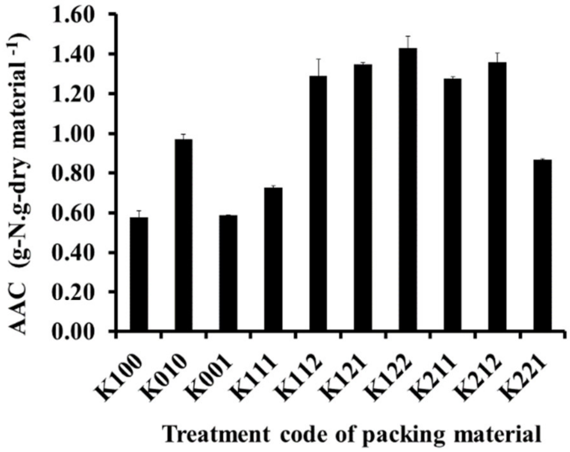

Figure 5. Total absorption of ammonia (N-NH_3) in saturated conditions of a mixture of soil, compost, and rubber-leaf litter for 24 h.

3.2.6 Ammonia Holding Capacity (AHC)

After the entire packing materials are saturated with ammonia or having AAC-saturated (Figure 6), they are allowed to stand at room temperature to release ammonia (ammonia desorption), in which ammonia absorbed in the material will be physically separated or evaporate. Furthermore, the material is weighed every hour for 24h until a constant state is achieved. Weight loss is calculated as a release of ammonia, wherein the constant release is achieved within 6-12 h after the stage. The amount of ammonia retained (trapped) is chemically suspected as AHC in this material after 24h, and the data are presented in Figure 6. The three packing materials are ammonia saturated equally release ammonia at room temperature. Compost irregularly releases ammonia producing the amount of ammonia (negative released). It is suspected that composting is still ongoing. In the process of composting and mature compost, ammonia production still occurs (Suprihatin et al., 2008). Therefore, the amount of ammonia released from compost becomes greater.

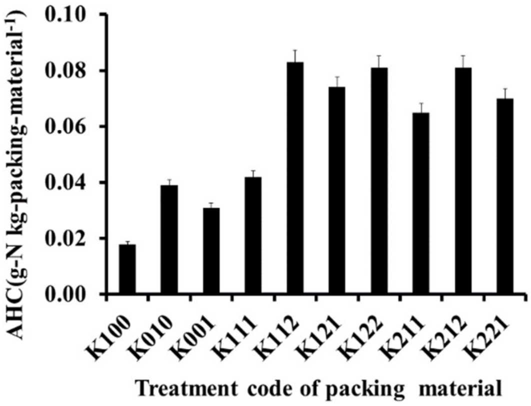

Figure 6. AHC of packing material, single and a mixture of soil, compost, and rubber-leaf litter at room temperature for 24h.

After 24 hours left at room temperature, it is assumed that ammonia released is already close to zero. The smallest amount of ammonia nitrogen (AHC) is in the composition of K111, which amounts to 0.042 g-N·g-dry-material^{-1} as this composition has a low value of AHC. More soil, compost or rubber-leaf-litter cause increase in AHC (Figure 6). The amount of ammonia chemically preserved (AHC) of treatment K112, K122, and K212 at 0.083, 0.081, and 0.081 g-N·g-dry-material^{-1}, respectively, have a higher ammonia nitrogen (NH_3-N) than the other compositions (Figure 6).

Ammonia absorption physically and chemically in these research is to assess the ammonia absorption capacity by packing materials, before operated biologically in biofilter. Ammonia removal in operated biofiltration occurred by physical, chemical and biological processes (Table 2). Ammonia removal by a peat biofilter occurred principally by physical and chemical adsorption onto functional groups of humic substances of the peat (Togashi et al., 1986). The ammonia removal non-biologically in biofilters for 7 days using packing materials of ceramic, cristobalt, obsidian, calcinated soil were 0.0009, 0.0013, 0.0037, 0.00045 g-N·g-dry-material^{-1}, respectively (Hirai et al., 2001). The study of ammonia biodegradation in biofilter media is used to evaluate adsorption, absorption, and biodegradation in five different organic materials (compost, coconut fiber, bark, pruning wastes, and peat) in full-scale biofilters (Pagans et al., 2006). The ammonia adsorption is successfully fitted to Langmuir and Freundlich isotherms and maximum adsorption capacity varied from 0.0008 to 0.0009 g-N·g-dry-material^{-1}. Compared to this research, the organic packing material of soil, compost and rubber-leaf litter are presented as ammonia absorption capacity by physically and chemically absorption (AAC, saturated), which are 0.58, 0.98 and 0.59 g-N·g-dry-material^{-1}, respectively (Figure 5). The ammonia absorption capacity (AAC) of organic packing materials is higher than ammonia removal non-biological by inorganic materials operated (Hirai et al., 2001).

Table 2. Utilization of organic and inorganic packing materials for ammonia removal in biofiltration

Organic materials	Inorganic materials	Maximum of ammonia removal capacity ((g-N. kg-dry-material^{-1}.d^{-1})	Average of removal efficiency (%)	References
Soil	-	0.36	89	Yani et al. (2012)
Soil and litter	-	0.6	85	Yani et al. (2012)
Soil and sludge	-	0.36	99	Yani et al. (2012)
Manure fertilizer and bagasse	-	-	90	Kaosol & Pongpat (2012)
Mixture of compost	-	-	>99	Poulsen et al. (2007)
Compost, coconut fiber, bark, Pruning wastes, and peat	-	0.0067 – 0.00782	-	Pagans et al. (2006)
Compost, bark, and peat	-	1.0	>95	Choi et al. (2003)
Coconut fiber	-	-	86-100	Baquerizo et al. (2005)
Soil granulated	-	0.3	95	Hirai et al. (2001)
Compost	-	-	100	Hong & Park (2007)
Organic	Inorganic	-	100	Baquerizo et al. (2005)
Peat	-	3.24	95	Yani et al. (1998)
	Lava rock and pine nugget	-	56	Shahmansouri et al. (2005)
-	Rock wool	0.82 - 1.12	90	Yasuda et al. (2009)
-	Ceramic	1.5	95	Hirai et al. (2001)
-	cristobalt	0.29	95	Hirai et al. (2001)
-	obsidian	1.5	95	Hirai et al. (2001)
-	Calcinated soil	1.5	95	Hirai et al. (2001)
-	ACF	1.5	95	Yani et al. (1998b)

Table 2 represents the utilization of organic and inorganic packing materials for ammonia removal in biofiltration by some authors. Utilization of organic materials is common for biofilter. The amount of AAC by organic packing materials will support the removal of ammonia by microbes. The maximum ammonia removal capacity (g-N·g-dry-material^{-1}) is usually calculated from deviation from inlet and outlet ammonia concentration in biofilters that ammonia removes biologically by microbe activity. Therefore, the performance of ammonia removal by biofiltration shows that organic packing materials seem to be better than inorganic materials. The organic packing materials are nutritional rich than inorganic material to support the growth of chemolitothrophic microorganisms of ammonia oxidizing bacteria. The data obtained show important differences in the behavior of the biofilter with organic versus inorganic packing material, which has important implications in the design and modelling of these systems of biofiltration.

3.3 Cost of packing materials

Economic factor becomes one of the factors that must also be considered in determining packing material selection. One of these factors is the packing material used should be inexpensive and easy to obtain. Of the three types of materials used, which were soil, compost, and rubber-leaf litter, it was only compost that must be purchased or produced. The price of compost was IDR 15,000 pack^{-1} that containing of 5 kg.

Some organic or inorganic materials used in biofiltration were very cheap. Inorganic material costs were quite high because the price was quite expensive, as well as the unavailability of nutrient naturally in the material. Organic packing materials are derived from residues of natural materials such as soil, compost, litter, bark, coconut coir, peat, bran, and so forth. The materials are easily available and inexpensive, contain high organic substances and abundant of inorganic nutrients for the life of microorganisms, and have natural microorganisms on them.

3.4 Valuation of packing materials

Ranking method was conducted by providing a serial number starting from number 1, namely the composition with the best characteristics based on measurement results, followed with other parameters as determined. Based on the physical characteristics, the rubber-leaf litter was the lowest bulk-density and the highest of porosity. However, the compost was the best on chemical characteristics (Table 3). Based on the overall ranking, compost performs better than rubber-leaf litter and soil (Table 3). The rank of compost is better than rubber-leaf litter and soil. The compost has a density of 0.41 g·cm^{-3}, porosity 34.28%, 56.67% moisture content, pH 7.4, C/N ratio 32.09, WHC 0.50 g-water·g-dry-material^{-1}, AAC 0.024 g-N·g-dry-material^{-1}, ammonia absorption capacity after being left in an open space of 0.039 g-N·g-dry-material^{-1}, and ammonia absorption capacity when saturated of 0.970 g-N·g-dry-material^{-1}.

Table 3. Valuation of packing materials of soil, compost, and rubber-leaf litter

Physical and chemical characteristics	Value (Ranking)			Criteria for ranking
	K100	K010	K001	
Density (g/cm^3)	0.56 (3)	0.41 (2)	0.04 (1)	minimum
Porosity (%)	25.09 (3)	34.28 (2)	94.54 (1)	maximum
Sub total of physical characterstics	6	4	2	
Moisture content (%)	37.7 (2)	56.7 (1)	9.7 (3)	40-60%
pH	4.1 (2)	7.4 (1)	6.3 (1)	6 – 8
C/N ratio	10.9 (1)	32.1 (2)	127.79 (3)	minimum
WHC (g-water.g-dry-material^{-1})	0.18 (2)	0.50 (1)	0.07 (3)	maximum
AAC (g-N.g-dry-material^{-1})	0.007 (2)	-0.024 (3)	0.023 (1)	maximum
AHC (g-N.g-dry-material^{-1})	0.018 (2)	0.039 (1)	0.031 (1)	maximum
Saturated AAC (g-N.g-dry-material^{-1})	0.578 (2)	0.970 (1)	0.587 (2)	maximum
Sub total of chemical characterstics	13	**10**	14	

Table 4. Valuation of mixture of soil, compost, and rubber-leaf litter

Physical and chemical characteristics	Value (Ranking)							Criteria for ranking
	K111	K112	K121	K122	K211	K212	K221	
Density (g/cm^3)	0.17 (2)	0.12 (1)	0.16 (2)	0.13 (1)	0.21 (3)	0.14 (1)	0.21 (3)	minimum
Porosity (%)	55.58 (3)	91.49 (1)	68.59 (2)	82.58 (1)	51.75 (3)	81.15 (1)	53.87 (3)	maximum
Sub total of physical characterstics ranking	(5)	(2)	(4)	**(2)**	(6)	(2)	(6)	
Moisture content (%)	32.7 (3)	29.25 (3)	39.3 (1)	34.3 (2)	35.5 (2)	31.1 (3)	40.3 (1)	40-60%
pH	6.4 (1)	6.4 (1)	6.9 (1)	6.8 (1)	6.3 (1)	6.4 (1)	6.7 (1)	6 – 8
C/N ratio	47.9 (2)	64.78 (3)	43.3 (2)	56.4 (3)	37.7 (1)	52.1 (3)	36.4 (1)	minimum
WHC (g-water.g-dry-material^{-1})	0.05 (4)	0.17 (3)	0.07 (4)	0.26 (1)	0.08 (4)	0.21 (2)	0.07 (4)	maximum
AAC (g-N.g-dry-material^{-1})	0.008 (2)	0.019 (1)	0.010 (2)	0.014 (1)	0.010 (2)	0.018 (1)	0.015 (1)	maximum
AHC (g-N.g-dry-material^{-1})	0.042 (3)	0.083 (1)	0.074 (2)	0.081 (1)	0.065 (2)	0.081 (1)	0.070 (2)	maximum
Saturated AAC (g-N.g-dry-material^{-1})	0.726 (3)	1.291 (2)	1.349 (1)	1.430 (1)	1.276 (2)	1.360 (1)	0.865 (3)	maximum
Sub total of chemical characteristics ranking	(18)	(14)	(13)	**(10)**	(14)	(12)	(13)	

Based on the ranking, the composition of K122 shows the smallest value (Table 4). This means that treatment with packing materials of soil, compost, and rubber-leaf litter with a ratio of 1: 2: 2 has the best characteristics compared to other mixtures. This treatment has good results in density of 0.13 g·cm^{-3}, porosity 82.58%, moisture content 34.27%, pH 6.8, C/N ratio 56.38, WHC 0.26 g-water·g-dry-matter^{-1}, AAC 0.014 g-N·g-dry-material^{-1}, ammonia absorption capacity after being left in an open space (AHC) of 0.081 g-N·g-dry-material^{-1}, ammonia absorption capacity when saturated of 1.430 g-N·g-dry-material^{-1}.

Organic packing materials such as soil, compost, and rubber-leaf litter are nutrient-rich materials and capable of absorbing ammonia physically and chemically, so it will be very useful in the application as a biofilter as packing material. The composition of the mixture has given different density, porosity, moisture content, pH, C/N ratio, Water Holding Capacity (WHC), Ammonia Absorption Capacity (AAC), and Saturated AAC. Valuation of ranking indicates that the composition ratio of soil, compost, and rubber-leaf litter of 1: 2: 2 (code K122) has the best characteristics compared to other compositions. This treatment has good results in density testing of 0.13 g·cm^{-3}, porosity 82.58%, water content 34.3%, pH 6.8, C/N ratio 56.4, WHC 0.26 g-water·g-dry-material^{-1}, AAC 0.014 g-N·g-dry-material^{-1}, AHC 0.081 g-N·g-dry-material^{-1}, saturated AAC 1.43 g-N·g-dry-material^{-1}, respectively (Table 4). The result of a mixture of soil with high amount of compost and rubber-leaf litter holds the potential to help the work of ammonia-oxidizing microbes to provide the removal of ammonia.

4. Conclusions

The physical and chemical characteristics on ammonia removal by soil, compost, and rubber-leaf litter are investigated. The best of physical characteristics is litter of rubber leaf, and the best chemical characteristic on ammonia removal is compost. When all materials are mixed, the addition of rubber-leaf litter would increase on physical and chemical chacteristics. The mixture of soil, compost, and rubber-leaf litter indicated differences on physical characteristics (density, porosity) and chemical characteristics (moisture content, pH, C/N ratio, water holding capacity (WHC), ammonia absorption capacity (AAC), and ammonia holding capacity (AHC)).

Organic packing materials such as soil, compost, and rubber-leaf litter are nutrient-rich materials and capable to absorb ammonia physically and chemically, therefore, it will be very useful in the application to biofiltration. The mixture of organic packing materials can be used for biofiltration of odors gases, especially ammonia odorous treatment.

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