Reduction of Ammonia Emissions from the Composting of Slaughterhouse Solid Waste using Zeolite

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ABSTRACT

The process of aerobic composting the slaughterhouse (SH) solid waste generate ammonia emissions. **Aim:** The objective of this research to study the ability of the adsorbent to use zeolite to reduce ammonia gas emissions during the composting process of SH solid waste. **Methodology and Results:** Reduction of ammonia emission is conducted during the aerobic composting process which is 50 days. The raw material composition of the composting process used was 100% rumen contents, 60% rumen contents: 40% straw, 50% rumen contents: 50% straw, and 40% rumen contents: 60% straw. Zeolite used in the form of granular size 100 mesh. The result of the research showed that the level of release of ammonia gas emissions during the composting process could be reduced by zeolite. **Conclusion, significance, and impact study:** The efficiency of reducing ammonia gas emissions using zeolite adsorbents in the composting process of SH solid waste ranges from 98.09 - 99.40% on average. Zeolite is an adsorbent that has high adsorption power because it has many pores and has a high ion exchange high capacity and serves as an absorbent cation that can cause environmental pollution.

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KEYWORDS

- Ammonia emissions
- Composting
- Environmental pollution
- Slaughterhouse solid waste
- Zeolite
1. INTRODUCTION

The rumen content are widely available as one of the solid wastes from slaughter activities at slaughterhouse (SH). This solid waste has organic ingredient and high nutrient (Roy et al., 2013; Ratnawati et al., 2016a). The fresh SH solid waste can’t be directly applied as fertilizer on the soil because it contains unstable organic material (Guo et al., 2012; Trihadiningrum et al., 2015a). Besides, there are also various microorganisms Ruminnococcus sp., such as Phycomycetes, fungi, protozoa, weed seeds, and bacteria which are probablu pathogenic (Ratnawati et al., 2016a; Guo et al., 2012; Durand and Ossa, 2014). In developing countries such as Indonesia, these SH solid waste are not managed well. It usually stacked in open spaces and some are immediately disposed of to the landfill. This will cause problems of odor, flies, sanitation, surface air pollution and soil (Akinyeye et al., 2012; Magaji and Chup, 2012).

The composting process is one of technology alternative which can be used for SH solid waste process (Nunes, et al., 2015; Ratnawati and Trihadiningrum, 2014). The composting process changes SH solid waste to be more stable to be applied as fertilizer and able to reduce the volume of solid waste 50-70% (Nunes et al., 2015). The composting process of SH solid waste using several systems has been investigated by Ratnawati, et al. (2016a), Ratnawati et al. (2016b), and Trihadiningrum et al., (2015b) stated that the composting process with anaerobic-anoxic-oxic (A^2O) and five stage sequencing batch reactors can produce compost but still requires a maturation stage. The process of composting with the A^2O system compared to the aerobic system, it is found that the aerobic system produced organic fertilizer with a shorter time compared to the A^2O system (Trihadingrum et al., 2015a). Ratnawati et al. (2016b) concludes that the products produced from the aerobic method achieved the fastest levels of stability compared to the anaerobic method. Ratnawati et al. (2018) conducted a composting process by varying the composition of compost raw materials. It is the contents of the rumen and straw.

The composting process using nutrient-rich raw material will generate ammonia gas emission. Ammonia gas is the main compound causing odor while composting organic matter with high nitrogen content (Suprayogi, 2013; Rini et al., 2015). Based on Mehta and Sirasi (2015), unpleasant odors caused by gases are produced by processing anaerobic and aerobic organic matter. In the study by Anderson et al., (2010), gas emissions are generated from composting windrow systems consisting of CH₄, N₂O, NH₃, and NO. The lack of use of
technology in handling and managing waste is one of the causes of the smell (Li, 2014). In the other hand, methane gas generated from anaerobic solid waste treatment was needed as biogas, and the increasing was through adding the bioactivator (Sari et al., 2015).

There are some ways which can be used in reducing NH3 emission such as using biofilter (Wu et al., 2010; Utomo et al., 2010). Biofilter has been successfully conducted by Nanda, et al (2012) implemented the biofilter in the composting process to remove ammonia and volatile organic compound (VOC). Sharadqah and Al-Dwairi (2010) study of odor reduction from broiler manure using zeolite is able to achieve ammonia uptake of 71-96%. The decrease in ammonia levels using zeolite is also carried out by Jafarpour et al., (2010); Li et al., (2010); and Zheng et al., (2010). The use of activated carbon from coconut shell can also be used in adsorbing ammonia (Xiao et al., 2008). The adsorbent in the composting process of SH solid waste needs to be further investigated in order to obtain high efficiency in its application. This research aims to examine the ability of zeolite adsorbents to reduce ammonia gas emissions during the SH solid waste composting process.

2. RESEARCH METHODOLOGY

2.1 SH Solid Waste

The raw materials used was SH solid waste included cow’s rumen Brahman Cross (BX) and rice straw. The solid waste of SH were from Gempol SH located in Gempol Subdistrict, Pasuruan District. Preparation of raw materials was drying the rumen contents, the initial moisture content met the quality standards of the composting process with a value of 50-60% (Ratnawati et al., 2016). Ratnawati et al., (2016a) stated that the contents of the rumen of cattle had a high water content of 79-81%. This value didn’t meet the optimum conditions of the composting process. Thus, it was dried for 2-3 days. The weight of the raw material of each reactor was 20 kg. The initial characteristics of raw materials are presented in Table 1. Variations in the composition of the contents of the cattle rumen and straw used were 100%: 0% (Z100), 60%: 40% (Z60), 50%: 50% (Z50), and 40%: 60% (Z40). Variations in the composition of raw materials were conducted to obtain an ideal C/N ratio for the composting process of 15-35 (Ratnawati et al., 2016a; Rini et al., 2015). The C/N ratio of cow’s rumen contents of cattle had a low value of 10,54-12,33 (Ratnawati and Trihadiningrum, 2015a). The research was conducted in duplicate, thus the reactor was needed as many as 8 pieces (Table 2).
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Table 1 Characteristics of SH solid waste

<table>
<thead>
<tr>
<th>Materials</th>
<th>Moisture content (%)&lt;sup&gt;a&lt;/sup&gt;</th>
<th>C/N ratio</th>
<th>Organic C (g kg&lt;sup&gt;-1&lt;/sup&gt;)&lt;sup&gt;b&lt;/sup&gt;</th>
<th>Organic C (g kg&lt;sup&gt;-1&lt;/sup&gt;)&lt;sup&gt;b&lt;/sup&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rumen contents</td>
<td>54</td>
<td>8</td>
<td>393</td>
<td>51</td>
</tr>
<tr>
<td>Rice straw</td>
<td>58</td>
<td>21</td>
<td>520</td>
<td>24</td>
</tr>
</tbody>
</table>

<sup>a</sup> Wet weight basis

<sup>b</sup> Dry weight basis

Table 2 Experiment condition

<table>
<thead>
<tr>
<th>Reactor code</th>
<th>Composition of rumen content:rice straw</th>
<th>Adsorbent</th>
<th>Replicate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Z100</td>
<td>100:0</td>
<td></td>
<td>2</td>
</tr>
<tr>
<td>Z60</td>
<td>60:40</td>
<td>Zeolite</td>
<td>2</td>
</tr>
<tr>
<td>Z50</td>
<td>50:50</td>
<td></td>
<td>2</td>
</tr>
<tr>
<td>Z40</td>
<td>40:60</td>
<td></td>
<td>2</td>
</tr>
<tr>
<td>Total reactor</td>
<td></td>
<td></td>
<td>8</td>
</tr>
</tbody>
</table>

2.2 Composting Process

Composting process was conducted for 50 days. The composting process with aerobic conditions using the air supply from the blower with an aeration rate was 4.74 L/kg/minute. This supply referred to the research conducted by Rini et al., (2015). The reactor used was a standing drum with a capacity of 120 L (Figure 1). The top of the reactor was filtered with zeolite adsorbent. The filtered placed in a PVC tube 4 "in diameter as high as 0.7 m. This filter was connected to the composter reactor through PVC pipe diameter 1". The output of ammonia gas emissions from the filter was connected to a 2% boric acid solution as a catcher for ammonia gas emissions (Ratnawati et al., 2016b). The side of the reactor was given a hole with a plug to facilitate sampling. Air supply by providing a blower pipe into the reactor. The bottom of the reactor was channeled to drain the leachate from the reactor which was then accommodated in a waterproof container.
2.3 Adsorption

The measurement of ammonia gas emission in reactor was conducted by injecting ammonia gas using 50 ml volume syringe into 25 mL boric acid solution (Suprayogi, 2013). The measurement of outlet ammonia gas emissions was conducted by taking as much as 25 mL of boric acid solution used to hold ammonia gas after passing the adsorbent. The solution was analyzed by the Nessler method using spectrophotometry (APHA et al., 2005).

3. RESULTS AND DISCUSSION

3.1 Ammonia Gas from Composting Process

Product of gas in composting process with one of aerobic systems is ammonia. In the process of composting ammonia gas will undergo changes that show changes in the form of nitrogen as a form of mineralization of organic matter (Wu et al., 2010). This ammonia gas arose due to the conversion of microbial peptides and amino acids (Durand and Ossa, 2014). Ammonia gas
concentrations arising during the composting process had different values (Figure 2). At the beginning of the composting process, ammonia gas had a high concentration of Z100, Z60, Z50, and Z40, respectively 0.19 mg/L; 0.46 mg/L; 0.62 mg/L; and 0.87 mg/L. On the 30th day the composting process, the ammonia concentrations were sharply decreased in Z60, Z50 and Z40. The lowest reduction in ammonia gas concentration on day 30, the concentration of ammonia gas released was 0.08 mg/L; 0.07 mg/L; and 0.12 mg/L for Z60, Z50 and Z40 respectively. At Z100 the concentration of ammonia gas increased in value on the 30th day by 0.26 mg/L, then decreased to the end of the composting process. At the end of the composting process, the concentration of ammonia gas produced at Z100, Z60, Z50 and Z40 was 0.14 mg/L; 0.06 mg/L; 0.09 mg/L; and 0.05 mg/L.

During composting process, there was transformation and nitrogen transfer such as ammonification, nitrification, and denitrification (De Guardia et al., 2010; Zhu et al., 2014). This process would take place according to the influence of the activity of microorganisms and the surrounding environment (Zhu et al., 2014). The ammonification process in which organic nitrogen levels were converted to ammonia gas (De Guardia et al., 2010; Salimin and Rachamdetin, 2011). The process by which ammonia gas converted into nitrate was called nitrification, in which this process took place aerobically (Ratnawati, et al., 2016a). Nitrification was carried out by chemoautotrophic microorganisms, namely microorganisms that obtained energy for their growth from chemical oxidation processes called ammonium. Nitrification consisted of two stages involving *Nitrosomonas* and *Nitrobacter* microorganisms. In order to achieve the goal of removing ammonium, it was necessary to proceed with denitrification (Salimin and Rachamdetin, 2011). Denitrification took place in anoxic conditions or in conditions in which the oxygen concentration had a very low value. Nitrate levels were reduced by heterotrophic bacteria to N₂. Furthermore, nitrogen was released from solid waste in the form of N₂ gas.
Figure 2 Emission of ammonia gas and pH value during composting process

The release of ammonia gas compared to pH value occurred in composting process. During the composting process, there was an increase in pH, with a value of 6.43-7.55. The release of ammonia emissions was proportional to the increase in pH value (Murti et al., 2013). This was similar with the research conducted by Sun et al., (2019) that an increase in pH value was due to gases that occurred as decomposition products of organic matter, one of which was ammonia gas. The hydrolysis process occurred at the start of composting converts organic materials such as fats, proteins, polysaccharides, and nucleic acids into simpler bonds such as fatty acids, monosaccharides, amino acids, and purines (Tchobanoglous et al., 2013). When the decomposition process occurred, microorganisms converted carbohydrates to compost to produce H₂O and CO₂. This molecule would react to form H₂CO₃, which was then ionized into HCO₃⁻ and CO₃²⁻. The water content in compost would make ammonia gas trapped and form ammonium ions and released OH⁻ ions. The process of degradation of organic matter at this stage caused the pH value of compost to increase. The presence of HCO₃⁻ in the reactor will push NH₄⁺ to release protons to HCO₃⁻ produce ammonia gas, and by taking OH⁻ ions from the environment would form H₂O and CO₂. This process would cause the pH of the compost to increase (Utami et al., 2011).
3.2 Efficiency of Ammonia Gas Reduction with Adsorbent

Mass of ammonia gas emission in reactor and solution had highly different value (Table 3). The highest point of ammonia gas emission released at Z100 was 15.26 mg/day on day 20, while on day 0 the composting process for Z60, Z50, and Z40 with each value was 18.22 mg/day; 24.80 mg/day; and 34.75 mg/day. Ammonia gas emissions passing through the zeolite absorbent were 0.19 mg/day. The release of ammonia gas emissions in this reactor as because of the decomposition of organic matter turns into a gas such as ammonia gas. The large amount of ammonia gas emissions released affected the adsorption process by the adsorbent. Controlling the conditions of the composting process and the use of biofilter can reduce ammonia produced by the adsorption process.

Table 3 Emission of ammonia gas before and after passing adsorbent

<table>
<thead>
<tr>
<th>Time (days)</th>
<th>Mass in reactor (mg)</th>
<th>Mass in solution (mg)</th>
<th>Removal (mg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>2.00</td>
<td>0.00</td>
<td>2.00</td>
</tr>
<tr>
<td>10</td>
<td>8.90</td>
<td>0.06</td>
<td>8.84</td>
</tr>
<tr>
<td>20</td>
<td>15.26</td>
<td>0.10</td>
<td>15.16</td>
</tr>
<tr>
<td>30</td>
<td>18.19</td>
<td>0.11</td>
<td>18.08</td>
</tr>
<tr>
<td>40</td>
<td>7.66</td>
<td>0.15</td>
<td>7.51</td>
</tr>
<tr>
<td>50</td>
<td>9.46</td>
<td>0.17</td>
<td>9.28</td>
</tr>
</tbody>
</table>

The enhancement of ammonia gas emission absorbed by adsorbent occurred during composting process (Figure 3). This was in line with release of ammonia gas emissions during the composting process. The average efficiency of reducing ammonia gas emissions using zeolite adsorbent had a value of 99.40% (Figure 4). Figure 3 and 4 are obtained from the composting process on Z40 with a composition of raw materials of 40% rumen contents: 60% straw. Presentation of data from Z40 showed the highest release of ammonia gas emissions from the composting process compared to other reactors.
Process of reducing ammonia gas emission using Zeolite media occurred on the surface (Utomo, Widjajanti and Budiasih, 2010). The zeolite surface significantly changed during oxidation. The adsorption capacity of ammonia gas emissions by zeolites was caused by an increase in the number of functional oxygen groups on the zeolite surface. This was the result of acids on the surface of zeolites. Nitrogen had a high electronegative, thus the hydrogen atoms
in ammonia gas could interact with oxygen atoms on the surface in the framework of hydroxyl (H-O) and carbonyl (C = O) groups due to electrostatic forces (Utomo, Widjajanti and Budiasih, 2010; Xiao, Shu and Wen, 2008).

Zeolite surface provided binded proton, thus, it had highly similarity in the surface (Suprayogi, 2013). H atoms would interact with NH₃ to form NH₄⁺. Furthermore, ion exchange reactions occurred due to differences in charge. In zeolites, this difference arose between Si⁴⁺ and Al³⁺. The Al³⁺ atom with 3 valences had to bind 4 more electronegative oxygen atoms in zeolite. This negative charge caused zeolite to be able to bind cations with weak bonds such as Na cations. This weak bond made zeolite as a cation exchanger namely Na cation with ammonium ion (Lo et al., 2012). The mechanism of the reaction of ammonium ion exchange with zeolite can be shown as follows (Lo, et al., 2012):

\[
\text{Zeolite} - \text{Na}^+ + \text{NH}_4^+ \rightarrow \text{Na}^+ + \text{Zeolite} - \text{NH}_4^+ 
\] (1)

Zeolite is an adsorbent that has high adsorption power because it has many pores and has a high ion exchange high capacity (Solikah and Utami, 2014). Zeolite serves as an absorbent cation that can cause environmental pollution such as Pb, Al, Fe, Mn, Cu, Zn. Zeolites can be used as Pb, Hg, and Cd adsorbents to absorb pollutants in water (Sumarlí, et al., 2016). The efficiency of zeolites without activation in the removal of heavy metal ions in water to above 80% for Cd, Pb, Cu and Fe, 44% for Zn and 21% for Mn. Activated natural zeolite with a contact time of 75 minutes has an absorption capacity of Cu metal ions of 0.6207 mg/g (Solikah and Utami, 2014; Sumarlí et al., 2016).

4. CONCLUSION

The result of the research showed that the level of release of ammonia gas emissions during the composting process could be reduced by zeolite. The efficiency of reducing ammonia gas emissions using zeolite adsorbents in the aerobic composting process of SH solid waste conducted 50 days ranges from 98.09-99.40% on average. Zeolite is an adsorbent that has high adsorption power because it has many pores and has a high ion exchange high capacity and serves as an absorbent cation that can cause environmental pollution.
5. ACKNOWLEDGMENT

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