TINJAUAN

MUNICIPAL ORGANIC WASTE AS SUBSTRATE OF BIOENERGY AND FERTILIZER PRODUCTION

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ABSTRACT

Municipal solid waste is still a big problem in the cities of Indonesia especially in the Capital and capital of province. Open dumping in TPA is operated through all of Indonesian cities, this bring to consequences a bad influence to the environment. Conversion of Organic solid waste either to energy or biofertilizer is one of the best choices on the solid waste management. These methods will create a good manageable of cities environment, producing fertilizer for the farmer, energy for the communal and jobs for the people. Municipal organic wastes were grinded and fermented in anaerobic or aerobic conditions. Anaerobic conditions produce hydrogen or methane as bioenergy meanwhile aerobic fermentation was used to get either compost or liquid biofertilizer. The result of Bioenergy and biofertilizer production showed that Municipal organic waste has a great potential as substrate for bioenergy such as hydrogen and methane or substrate for biofertilizer. The biofertilizer could be either as compost or liquid biofertilizer which are rich with growth promoting substances produces by specific bacteria during municipal organic solid waste fermentation.

Key words: Municipal, organic solid waste, management, bioenergy, biofertilizer

INTROSPEKSI


Kata Kunci: Perkotaan, limbah padat organik, manajemen, bioenergi, biofertilizer

INTRODUCTION

Indonesia is the third largest country in Asia after China and India and comprises a population of 214.4 million people (BPS 2002). The population varies, with the most densely populated island being Java, housing about 60 % of Indonesia's total population on 7 % of the total land. Most people live in urban areas of e.g. Jakarta or Bandung with 14465 or 11158 inhabitants per square kilometer,
respectively. The rapid urban and industrial
development caused major environmental
problems, such as wastewater treatment, urban
runoff-management, solid waste disposal,
leachates management and air pollution. Bad
effects for human beings in both, health, hygiene
and aesthetic sides are consequences. Solid waste
management, which is only collection and
transportation of all kinds of wastes to open
dumping sites, continues to create major problems
since most disposal sites are occupied 70 - 80 %, the
residual capacity being exhausted in 3 - 6 years,
and people now refuse to have sanitary landfills in
their neighborhood.

During the year of 2007 and 2008 the
amount of Municipal Solid Waste (MSW) arrived
at the open dumping site is increased. The amount
of MSW from Bandung City come to the open
dumping site increased averagely about 15005.367
m³ per month (Sriwuryandari and Sembiring,
2009). The solid waste amount increased about 25%
delivered to open dumping site which is an
alarming situation for the government.

Waste management could be by
incineration but waste incineration is too
expensive and most of the wastes are too wet for
thermal treatment. Special treatment of wet waste
fractions would reduce significantly the amount
for disposal and make sanitary landfills safer.

In Bandung 2495.4 m³ of wastes are
generated per day. The highest amounts come
from households, followed by commercials and
industry and then already by market residues
(see Table 1). The wastes have a high organic
content of 80 - 90 %, that predestination them for
biological stabilization processes such as
anaerobic digestion or composting. The capacity
for waste collection in Bandung is available for just
about 50 % and only in Jakarta a higher proportion
of more than 60 % of domestic wastes is collected.
The limiting factor is transport capacity from
temporarily collection points to the sanitary
landfills. Organic solid waste collected from
markets is one of the substrates that enable to
generate biogas and a nutrient-rich residue
without toxic compounds (Sembiring et al. 1998,
Ariani, 2003) or to use as substrate for biofertilizer,
either as compost or liquid bio fertilizer.

Efficient plant nutrition management is
becoming the most challenging issue to modern
agriculture. Due to increased energy cost, and
intensive agriculture, the fertilizer inputs are
becoming less feasible for the farming community
which demands the use of alternative sources of
plant nutrients. The tremendous economic
growth, industrialization and urbanization during
the last couple of decades are resulting in
generation and accumulation of organic wastes in
huge amounts which is also playing havoc with
the environments severely. However, if properly
recycled, these rich sources of organic matter
could successfully supplement plant nutrition for
sustainable, low-cost and environment friendly
crop production. The soil application of composites
after their enrichment/blending with nutrients,
plant growth regulators (organic fertilizer) and/or
plant growth promoting rhizobacteria (bio-
fertilizer) at substantially lower rates (250 kg ha⁻¹)
have produced very encouraging result

Study on the utilization of municipal
organic waste as substrate for bioenergy or
biofertilizer was firstly doing with survey to the
market in the city of Bandung. Market waste was
taken to be use as substrate for the experiments.
Market waste firstly separated into organic and
non organic materials. The composition of
traditional Market waster from Bandung city
shown in figure 1.
More than 80% of market waste, precisely 84.6% is organic matter. The rest of 15.4% is plastics, paper and others such as metals, glass and, sands, woods etc. Meanwhile the chemical analyses of market waste of traditional market in Bandung shown that the C/N ratio of organic market waste around 25-40. (See Table 1.)

Table 1: Analyses of Chemical Composition of Organic Market waste (Nasution 2009)

<table>
<thead>
<tr>
<th>No.</th>
<th>Parameters</th>
<th>Percent (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Water Content</td>
<td>88.52 - 92.19</td>
</tr>
<tr>
<td>2</td>
<td>Total Solid</td>
<td>7.81 - 11.48</td>
</tr>
<tr>
<td>3</td>
<td>Organic Total Solid</td>
<td>90.05 - 97.54</td>
</tr>
<tr>
<td>4</td>
<td>Ash</td>
<td>0.25 - 1.56</td>
</tr>
<tr>
<td>5</td>
<td>Carbon (gravimetrical)</td>
<td>54.69 - 55.42</td>
</tr>
<tr>
<td>6</td>
<td>Nitrogen</td>
<td>1.35 - 2.20</td>
</tr>
<tr>
<td>7</td>
<td>C/N</td>
<td>25.20 - 40.51</td>
</tr>
</tbody>
</table>

The detailed composition of each fruit and vegetable collected are shown in table 2 below.

Table 2: Composition of some fruits and vegetables collected in the marked waste. (Susilorukmi et al 2008)

<table>
<thead>
<tr>
<th>Sample</th>
<th>pH</th>
<th>Moist Content (%)</th>
<th>Total Solid (%)</th>
<th>OTS (%)</th>
<th>Ash (%)</th>
<th>Total Carbon (%)</th>
<th>COD (mg/l)</th>
<th>N total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Total</td>
<td>Filtrate</td>
</tr>
<tr>
<td>Apples</td>
<td>4</td>
<td>88.52</td>
<td>11.48</td>
<td>97.54</td>
<td>0.25</td>
<td>55.42</td>
<td>35093.57</td>
<td>21630.00</td>
</tr>
<tr>
<td>Guavas</td>
<td>4</td>
<td>87.96</td>
<td>12.04</td>
<td>96.03</td>
<td>0.40</td>
<td>55.33</td>
<td>30844.82</td>
<td>25235.00</td>
</tr>
<tr>
<td>Tubers</td>
<td>4</td>
<td>84.58</td>
<td>15.42</td>
<td>93.89</td>
<td>0.64</td>
<td>55.20</td>
<td>29134.29</td>
<td>14898.21</td>
</tr>
<tr>
<td>Brassica</td>
<td>6</td>
<td>97.12</td>
<td>2.88</td>
<td>71.84</td>
<td>2.84</td>
<td>53.98</td>
<td>28913.57</td>
<td>27478.93</td>
</tr>
<tr>
<td>Bushbeans</td>
<td>5</td>
<td>95.07</td>
<td>4.93</td>
<td>88.40</td>
<td>1.17</td>
<td>54.91</td>
<td>27589.29</td>
<td>18760.71</td>
</tr>
<tr>
<td>Pumpkins</td>
<td>5</td>
<td>95.63</td>
<td>4.37</td>
<td>64.13</td>
<td>1.86</td>
<td>54.52</td>
<td>27478.93</td>
<td>21630.00</td>
</tr>
<tr>
<td>Curcumas</td>
<td>4</td>
<td>93.11</td>
<td>6.89</td>
<td>79.79</td>
<td>2.11</td>
<td>54.38</td>
<td>25051.07</td>
<td>14125.71</td>
</tr>
<tr>
<td>Green-peas</td>
<td>6</td>
<td>90.31</td>
<td>9.69</td>
<td>93.94</td>
<td>0.63</td>
<td>55.21</td>
<td>24113.04</td>
<td>11862.39</td>
</tr>
<tr>
<td>Oranges</td>
<td>5</td>
<td>90.09</td>
<td>9.91</td>
<td>94.41</td>
<td>0.56</td>
<td>55.24</td>
<td>23947.50</td>
<td>14832.00</td>
</tr>
<tr>
<td>Solanum</td>
<td>5</td>
<td>93.27</td>
<td>6.73</td>
<td>87.71</td>
<td>1.24</td>
<td>54.87</td>
<td>22788.75</td>
<td>14898.21</td>
</tr>
<tr>
<td>Zuurzaks</td>
<td>4</td>
<td>90.60</td>
<td>9.40</td>
<td>92.85</td>
<td>0.72</td>
<td>55.16</td>
<td>22568.04</td>
<td>10925.36</td>
</tr>
<tr>
<td>Fruit-trees</td>
<td>4</td>
<td>93.21</td>
<td>6.79</td>
<td>92.59</td>
<td>0.74</td>
<td>55.14</td>
<td>21795.54</td>
<td>17657.14</td>
</tr>
<tr>
<td>Chillies</td>
<td>4</td>
<td>92.19</td>
<td>7.81</td>
<td>90.05</td>
<td>1.56</td>
<td>54.69</td>
<td>21740.36</td>
<td>10925.36</td>
</tr>
<tr>
<td>Cucumbers</td>
<td>4</td>
<td>96.55</td>
<td>3.45</td>
<td>89.60</td>
<td>0.88</td>
<td>55.07</td>
<td>19091.79</td>
<td>12028.93</td>
</tr>
</tbody>
</table>

Figure 1. Composition of Market Waste from Traditional Market in Bandung (Susilorukmi et al 2008)
Preparation of municipal organic solid waste as substrate

Organic solid waste in the municipal mainly from markets and households. Before use as substrate for the bioenergy production or biofertilizer/compost, it should be prepared to have a certain physical condition which is suitable for the process. Organic solid waste firstly separated from inorganic refuse and other wastes which could be recycled. Secondly the wastes should be grinded and blended to have a smaller size of organic waste sludge. The sludge later on could be use directly as substrate for composting/liquid biofertilizer or biogas production either hydrogen or methane generation. Schematic of one stage diagram of fermentation process is shown in Figure 2 and two stage process of fermentation is operated due to schematic diagram in Figure 3.

![Figure 2. Schematic diagram of One stage municipal organic solid waste fermentation for Bioenergy generation and fertilizer production](image)

![Figure 3. Schematic diagram of two stage anaerobic fermentation process for energy generation and fertilizer production.](image)
Bioenergy from Municipal Organic Waste

Bioenergy from municipal organic waste could be in the form of hydrogen gas or methane. Both of these gases are products of anaerobic fermentation using microorganisms. In the hydrogen generation, the solid substrate would be fermented in acidic condition using hydrogen generating microorganisms which have enzyme to ferment long chain polymer such as protein, carbohydrates or fat. Clostridium sp is one of species could be use as microorganism on the hydrogen fermentation. As source could be a mixed of pure culture of clostridium or by using heat treated garden soil as the source of microorganisms. Accelerating of hydrogen production could be done by the recycling the fermented sludge mixed with new substrates before feeding to the bioreactor Fig 4.

In this case, a heater for substrate treatment is needed to minimize the population of other microorganisms. The problem of hydrogen fermentation is the storage of hydrogen. It's not easy to build a big stable hydrogen gas container, because of the reactivity of hydrogen to ward oxygen especially if the ambient temperature increase. This is one of interesting area of research namely to store concentrated hydrogen as metal-hydrates. It is the reason of the pursued of anaerobic fermentation to produce methane which is more stable than hydrogen although methane is one of green house gases. As effluent of the hydrogen fermentation process we find a high concentration of organic acids. The effluent could be later use as substrate in the methane generation or direct to the composting process.

Methane generation or biogas production is known by two process namely one stage or two stage process. One stage process of municipal organic waste could be operated in three fermentation system namely by separating solids and liquid for fermentation or by using the sludge slurry directly as substrates. (Sembiring, 2008). Solid fermentation take long time process because of the lack of water as supported in the media fermentation.

Fermentation of organic sludge suspension in one stage gas compressed bioreactor as shown in Fig. 5 was done. A 40 liter effective volume of stainless steel bioreactor equipped with a regulator pump and double compressor for feeding and biogas re-compressed respectively. Gas production was measured by using a gas meter. Organic matter converted to soluble organic materials and biogas. Biogas production Fig. 6 during the experiment was analyzed for its methane content. Methane content was more than 60% and the rest is Carbon dioxide (35%), sulfide, nitrogen and others. Purification of methane from carbon dioxide and hydrogen sulfide would be better to have higher energy value and to inhibit the bad effects of hydrogen sulfide to the equipment and combustor.
Figure 5. Schematic diagram of bioreactor used in the study operated at ambient temperature. (Sriwuryandari and Sembiring, 2009)

Figure 6. Running of bioreactor A; initial total solid 2%; B; initial total solid 4% and C; initial total solid 6% (Susilorukmi et al, 2008)
Biofertilizer from Municipal Organic Waste

Bioconversion of municipal organic waste from sludge of organic suspension was done with inoculation of the substrate with non pathogenic polymers degrading microorganisms such as Lactobacillus sp, yeasts and others. The leachates produced from the fermentation process later on mixed with animal manure. The mixture later than transferred to fermentation tank for further fermentation using mixed of selected specific microorganisms such as Pseudomonas fluorescens, Azospirillum sp., Azobacterium sp, Lactobacillus sp, Yeasts etc. There after, the fermented broth transferred to storage container for further use in the farm. Nutrient value of fermented broth is shown in Table 3.

Application of liquid biofertilizer Fig. 6 for growing of vegetables were used for chili, cucumber and kidney bean, planting in the bare/poor soils field. The plants have a good product and the bare soils turn to the soil rich of nutrient as a side effect of the use of biofertilizer. In almost all cases, the crop growth, yield, nutrient use efficiency/saving and product quality were superior.

Table 3. Nutrient Value of Fermented broth of organic leachetes and chicken manure.

<table>
<thead>
<tr>
<th>No.</th>
<th>Amount of manure</th>
<th>Nutrient Value</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>C</td>
</tr>
<tr>
<td></td>
<td></td>
<td>S (%)</td>
</tr>
<tr>
<td>1</td>
<td>10 %</td>
<td>20.28</td>
</tr>
<tr>
<td>2</td>
<td>20 % *</td>
<td>22.22</td>
</tr>
<tr>
<td>3</td>
<td>30 %</td>
<td>25.34</td>
</tr>
</tbody>
</table>

L = liquid; S = Sediment; * No leachate of organic solid waste
Figure 7. Application of liquid biofertilizer in the poor soil fields / bare land

Solid part of organic wastes which have inoculated with plant growth promoting bacteria later on turn to be a rich compost and known as a good biofertilizer for planting in the farm (Arshad et al, 2007). Figure 8. shown the ripe composts of municipal organic solid wastes.

Figure 8. Ripe compost inoculated with plant growth promoting microorganisms.

The composting has changed the ratio of the nutrient. It was found that the ratio of nutrient was better than non composted organic solid waste (as shown by Arshad et al, 2007) in the study on the composting of fruit and vegetable waste using for farm. It was found also that the inoculated compost with plant growth promoting bacteria was effective as fertilizer.

Table 4: Analysis of raw (non-composted) and composted fruit and vegetable wastes (Arshad, 2007).

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Organic waste before composting (crushed &lt;2.0 mm)</th>
<th>Composted organic waste material</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carbon (%)</td>
<td>36.2</td>
<td>23.4</td>
</tr>
<tr>
<td>Nitrogen (%)</td>
<td>1.44</td>
<td>2.26</td>
</tr>
<tr>
<td>Phosphorus (%)</td>
<td>0.30</td>
<td>0.48</td>
</tr>
<tr>
<td>Potassium (%)</td>
<td>1.22</td>
<td>1.55</td>
</tr>
<tr>
<td>Copper (mg kg⁻¹)</td>
<td>1.06</td>
<td>1.29</td>
</tr>
<tr>
<td>Zinc (mg kg⁻¹)</td>
<td>48.0</td>
<td>62.0</td>
</tr>
<tr>
<td>Manganese (mg kg⁻¹)</td>
<td>40.0</td>
<td>53.0</td>
</tr>
<tr>
<td>Iron (mg kg⁻¹)</td>
<td>546.0</td>
<td>655.0</td>
</tr>
<tr>
<td>CN ratio</td>
<td>25.1</td>
<td>10.4</td>
</tr>
<tr>
<td>CP ratio</td>
<td>121.0</td>
<td>48.8</td>
</tr>
<tr>
<td>CK ratio</td>
<td>29.7</td>
<td>15.1</td>
</tr>
</tbody>
</table>

By the using of organic solid waste as raw material, the value addition of recycled organic wastes either in the form of organic fertilizers or biofertilizers proved to be a useful soil amendment for sustainable farming.
SUMMARY

Bioconversion of municipal organic waste into energy and fertilizer by using microorganisms either mixed or selected culture for bioenergy and biofertilizer could be done in the communal by using low costs of appropriate technology.

These appropriate technology offers a practical solution to manage organic wastes by their conversion into bioenergy and biofertilizer which are cost effective, value added soil amendments, and can feasibly and safely to be applied to the soil for sustainable crop production and environment promotion.

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