MUNICIPAL SOLID WASTE RECYCLING FACILITIES IN MALANG RAYA, INDONESIA

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ABSTRACT
The new paradigm of solid waste treatment that accentuate in reducing solid waste was applied in Malang Raya, Indonesia through 15 solid waste recycling facilities of different types. The objectives of this research were to identify types of the solid waste recycling facilities, and to determine solid waste recycling potential. Solid waste volume was measured according to load-count analysis method. Sampling for solid waste composition analysis was done randomly at solid waste recycling facilities with quarterly method. Total volume of solid waste input at solid waste recycling facilities was measured according to the amount and volume of various kinds of collecting vehicle. The results of this research showed that there were 4 types of solid waste recycling facilities in Malang Raya, which comprised 66.67% composting units, 20% Recycling and Compost Production Units (UDPK), 6.67% Integrated Solid Waste Treatment Facility (TPST), and 6.67% 3R Solid Waste Treatment Facility (TPST 3R). According to mass balance analysis, the recycling potential of solid waste was 76.77-88.92%.

Keywords: Malang Raya, recycling facility, municipal solid waste.

INTRODUCTION
The idea of integrated solid waste treatment was applied to reduce solid waste in its source. Solid waste that was produced must be recovered by reused and recycled, so that only the residual would be discarded into the landfill. Output from the treatment was used as input in process or converted to be added value of input for the other processes, to maximize resource consumption and to increase eco-efficiency [1].

The Indonesian Government Regulation Number 18/2008 concerning solid waste treatment stipulates the importance of basic paradigm change in solid waste treatment that accentuate in reducing and handling of solid waste [2]. Activity of reducing solid waste implied so that all of the society, including government, businessman and community do limitation on solid waste generation, also do recycle and reuse activity. That activity was known as 3R, Reduce, Reuse and Recycle. According to global trend, the solid waste treatment system was oriented to sustainability issue, especially through the combination of 3R technology [3]. Based on 3R principle, a lot of programs were implemented with the collaboration of government and private sector from social, technology, economy, public health and political perspective aspect [4].

There were various kinds of technologies to reduce solid waste accumulation in landfill, such as incineration followed by energy production, compost production from compostable solid waste, and material recovery through recycle. Those technologies had a potential to be sustainable method. However, with 55% of solid waste composition consisted of composted solid waste, composting was considered in many places in the world as a method to reduce solid waste in landfill [5].

Malang Raya Region covered Malang City, Batu City and Malang Regency administration region. Population growth of Malang City at 2013 was 840,803 people or the average growth was 0.86% per year [6], with the average waste generation rate in Malang City was 3.2 L/person/day [7]. Population growth of Batu City at 2013 was 196,951 people or the average growth was 1.17% per year [8], with the average waste generation rate in Batu City was 3.1 L/person/day [9]. Population growth of Malang Regency at 2013 was 2,506,102 person or the average growth was 0.85% per year [10], with the average waste generation was 2.09 L/person/day [11].

The objectives of this research were to identify types of the municipal solid waste recycling facilities in Malang Raya and to determine the recycling rate of municipal solid waste in each solid waste recycling facility for operational strategy reference in the future.

MATERIALS AND METHODS
The types of municipal solid waste recycling facilities were determined according to field survey about type and operational pattern, type of municipal solid waste, treatment method, people who did the treatment process, treatment capacity, cost of capital, operation cost and maintenance. The calculation of solid waste volume that entered recycling facility was done according to load-count analysis method by calculating total volume of solid waste that was received [12]. Measurement of solid waste composition was done with sampling method using minimum sample as much as 100 kg [13] and the composition sampling was done with quarterly method. The measurement of solid waste’s specific weight was done randomly in various types of collector vehicles. Recovery factor’s value was determined by measuring the weight of solid waste component which could be recycled and
calculated against total weight of solid waste. The recycling rate of solid waste was measured according to mass balance analysis.

**TYPES OF SOLID WASTE RECYCLING FACILITY AND FLOW PROCESS PATTERN**

According to survey’s result, it could identified some types of solid waste recycling facilities in Malang Raya, these were:

1. Recycling and Compost Production Unit (UDPK). There were two kinds of integrated activity in that unit, i.e. recycling secondhand goods and making of compost. Both of these activities were done with the same raw materials that were household waste in the city [14].

2. Composting Unit. Composting unit was a small scale commercial unit that was functioned to process garbage into compost and to sell recycling product [15].

3. Integrated Solid Waste Treatment Facility (TPST). Solid waste was separated, processed and restored in order to be used as raw material in TPST. The raw material would be reprocessed [16].

4. Reduce Reuse Recycle Solid Waste Treatment Facility (TPS 3R). Collecting, sorting, reuse and recycling activities for region scale were implemented in TPST 3R [17].

The types of solid waste recycling facilities in Malang Raya were showed in Table-1 and the location of these recycling facilities can be seen in Figure-1.

<table>
<thead>
<tr>
<th>The types of municipal solid waste recycling facilities</th>
<th>Total of recycling facilities</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Malang city (unit)</td>
</tr>
<tr>
<td>Recycling and Compost Production Unit (UDPK)</td>
<td>3</td>
</tr>
<tr>
<td>Integrated Solid Waste Treatment Facility (TPST)</td>
<td></td>
</tr>
<tr>
<td>Composting Unit</td>
<td>10</td>
</tr>
<tr>
<td>Reduce Reuse Recycle Solid Waste Treatment Facility (TPS 3R)</td>
<td></td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>15</strong></td>
</tr>
</tbody>
</table>

**Figure-1.** The location of municipal solid waste recycling facilities in Malang Raya.

UDPK facility in Malang City was built and managed with top-down model by Dinas Kebersihan dan Pertamanan (Cleaning and Landscaping Agency) Malang City. Each UDPK also functioned as TPS. Cost of capital, operational and maintenance of UDPK was subsidized by city government. There were 3 location of UDPK which had been operated since 1999. UDPK processed compostable solid waste to compost in compliance with the processing capacity.

Whereas, non-compostable waste that still had economic value would be sorted and packaged, furthermore would be sold to collectors. Solid waste that couldn’t be processed would be transported to the available container, furthermore would be discarded into
landfill. Flow chart of solid waste handling in one of UDPK, i.e. Gadang UDPK, Malang City was showed in Figure-2.

There were 10 location of composting unit in Malang City. Similar with UDPK, composting unit was built and managed with top-down model by Dinas Kebersihan dan Pertamanan (Cleaning and Landscaping Agency), Malang City. Composting unit only processed compostable solid waste to compost in compliance with the processing capacity. Meanwhile, the sorting of non-compostable solid waste which still had economic value would be done by informal sector or scavengers. Flow chart of solid waste handling in one of composting unit, i.e. Jatimulyo composting unit, Malang City was showed in Figure-3.

Mulyoagung TPST had been built since 2011 and was managed by self-support group community (KSM). Mulyoagung TPST was located at Mulyoagung Village, Dau Subdistrict, Malang Regency. The initial capital of this TPST was a grant land as big as 0.34 hectare [18]. Mulyoagung TPST didn’t get operational and maintenance cost from the government. TPST processed some kind of solid waste, i.e. yard waste which was processed to compost and food waste which was used as animal feed. Meanwhile, non-compostable solid waste which still had economic value would be sorted and packaged, furthermore would be sold to collectors. Mulyoagung TPST also processed PET plastic waste which would be processed to plastic ore before it would be sold. This TPST model was bottom-up because the idea and motivation was emerged by the community and it became the successful point of Mulyoagung TPST. Process flow pattern at Mulyoagung TPST, Malang Regency can be seen in Figure-4.

**Figure-2.** Process flow pattern at Gadang UDPK, Malang city.

**Figure-3.** Process flow pattern at jatimulyo composting unit, Malang city.
Pandanrejo TPS 3R was 0.129 hectare, located at Pandanrejo Village, Bumiaji Subdistrict, Batu City. It was recycling unit at village scale which was managed by self-supported community of Pandanrejo Village since 2009. Initial capital cost for this TPS 3R was a grant. Pandanrejo TPS 3R also didn’t get operational and maintenance cost from the government. The compostable solid waste would be processed into compost in Pandanrejo TPS 3R. Meanwhile, non-compostable solid waste which still had economic value would be sorted and packaged, furthermore would be sold to collectors. Process flow pattern at Pandanrejo TPS 3R can be seen in Figure-5.

RESULT OF SOLID WASTE ANALYSIS IN RECYCLING FACILITY

The measurement result of solid waste volume was total input volume from various types of collector vehicles. The result of solid waste volume and specific weight could be used to calculate solid waste weight. The
analysis result of solid waste average weight that was entered the recycling facility could be seen in Table-2.

<table>
<thead>
<tr>
<th>Location</th>
<th>Average weight (kg/day)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gadang UDPK</td>
<td>11209.07</td>
</tr>
<tr>
<td>Tlogomas UDPK</td>
<td>5042.26</td>
</tr>
<tr>
<td>Velodroom UDPK</td>
<td>7559.40</td>
</tr>
<tr>
<td>Jatimulyo Composting Unit</td>
<td>4544.94</td>
</tr>
<tr>
<td>Pandanwangi Composting Unit</td>
<td>3844.88</td>
</tr>
<tr>
<td>Polowijen Composting Unit</td>
<td>6414.25</td>
</tr>
<tr>
<td>Muria Composting Unit</td>
<td>9465.26</td>
</tr>
<tr>
<td>Manyar Composting Unit</td>
<td>4504.36</td>
</tr>
<tr>
<td>Narotama Composting Unit</td>
<td>3514.22</td>
</tr>
<tr>
<td>VEDC Composting Unit</td>
<td>4801.52</td>
</tr>
<tr>
<td>Asahan Composting Unit</td>
<td>9489.90</td>
</tr>
<tr>
<td>Sawojajar Composting Unit</td>
<td>2893.07</td>
</tr>
<tr>
<td>Supiturang Composting Unit</td>
<td>2135.00</td>
</tr>
<tr>
<td>Mulyoagung TPST</td>
<td>11864.40</td>
</tr>
<tr>
<td>Pandanrejo TPS 3R</td>
<td>3503.50</td>
</tr>
</tbody>
</table>

The analysis result of average composition in recycling facilities could be seen in Figure-6. The largest composition was compostable solid waste (food waste and yard waste) with the average 69.12%. Plastic waste (HDPE, LDPE, PET and plastic composite) with percentage reached 11.54%. Diapers waste 7.18%, paper waste (office paper, newspaper, magazine, book, cardboard and paper composite) with percentage 6.44% also the other kind of solid waste (cable, wood, hazardous waste, fabric/textile, glass, rubber, can, metal, leather, styrofoam, rock/sand, bone, hair) with percentage 5.72%. It could be known that input solid waste not only from household waste but also from the other kind of solid waste such as yard waste from agriculture product.

ESTIMATION OF RECYCLABLE SOLID WASTE

The recovery factor of each component of solid waste is shown in Table-3.

<table>
<thead>
<tr>
<th>Solid waste composition</th>
<th>Average recovery factor (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Compostable Solid Waste</td>
<td></td>
</tr>
<tr>
<td>Food Waste</td>
<td>99.47</td>
</tr>
<tr>
<td>Yard Waste</td>
<td>99.25</td>
</tr>
<tr>
<td>Plastic</td>
<td></td>
</tr>
<tr>
<td>HDPE</td>
<td>90.20</td>
</tr>
<tr>
<td>LDPE</td>
<td>58.93</td>
</tr>
<tr>
<td>PET</td>
<td>88.96</td>
</tr>
<tr>
<td>Plastic Composite</td>
<td>81.40</td>
</tr>
<tr>
<td>Paper</td>
<td></td>
</tr>
<tr>
<td>Office Paper</td>
<td>83.05</td>
</tr>
<tr>
<td>Newspaper</td>
<td>84.93</td>
</tr>
<tr>
<td>Magazine</td>
<td>35.62</td>
</tr>
<tr>
<td>Books</td>
<td>36.39</td>
</tr>
<tr>
<td>Paper Composite</td>
<td>65.19</td>
</tr>
<tr>
<td>Cardboard</td>
<td>58.46</td>
</tr>
<tr>
<td>Glass</td>
<td>76.26</td>
</tr>
<tr>
<td>Rubber</td>
<td>84.70</td>
</tr>
<tr>
<td>Can</td>
<td></td>
</tr>
<tr>
<td>Aluminum Can</td>
<td>87.46</td>
</tr>
<tr>
<td>Steel Can</td>
<td>46.67</td>
</tr>
<tr>
<td>Metal</td>
<td>72.96</td>
</tr>
<tr>
<td>Leather</td>
<td>69.05</td>
</tr>
</tbody>
</table>

Based on the recovery factors as shown in Table-3, the mass balance analysis was applied for measuring the recycling rate of the solid waste. Mass balance analysis at one of the Recycling and Compost Production Unit (UDPK), i.e. Tlogomas recycling and compost production unit (UDPK Tlogomas) could be seen in Table-4.

According to solid waste input weight in each of recycling facility, total residue that would be transported to landfill was 11.08-23.23% from total solid waste. So that, estimation of solid waste recycling rate was 76.77-88.92% with the calculation as could be seen in Table-5.
Table 4. Mass balance analysis at UDPK Tlogomas, Malang city.

<table>
<thead>
<tr>
<th>Solid waste composition</th>
<th>Average weight</th>
<th>Recovery factor (%)</th>
<th>Estimation of solid waste recycling rate (kg/day)</th>
<th>Residual weight (kg/day)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Compostable Solid Waste</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Food Waste</td>
<td>14.50</td>
<td>731.13</td>
<td>99.00</td>
<td>723.82</td>
</tr>
<tr>
<td>Yard Waste</td>
<td>59.67</td>
<td>3008.72</td>
<td>98.00</td>
<td>2948.54</td>
</tr>
<tr>
<td>Plastic</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>HDPE</td>
<td>5.14</td>
<td>259.17</td>
<td>54.30</td>
<td>140.73</td>
</tr>
<tr>
<td>LDPE</td>
<td>3.01</td>
<td>151.77</td>
<td>57.83</td>
<td>87.77</td>
</tr>
<tr>
<td>PET</td>
<td>1.49</td>
<td>75.13</td>
<td>57.47</td>
<td>43.18</td>
</tr>
<tr>
<td>Plastic Composite</td>
<td>1.43</td>
<td>72.10</td>
<td>59.93</td>
<td>43.21</td>
</tr>
<tr>
<td>Paper</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Office Paper</td>
<td>0.30</td>
<td>15.13</td>
<td>65.84</td>
<td>9.96</td>
</tr>
<tr>
<td>Newspaper</td>
<td>0.69</td>
<td>34.79</td>
<td>62.15</td>
<td>21.62</td>
</tr>
<tr>
<td>Magazine</td>
<td>0.02</td>
<td>0.50</td>
<td>33.33</td>
<td>0.34</td>
</tr>
<tr>
<td>Paper Composite</td>
<td>3.67</td>
<td>185.05</td>
<td>68.15</td>
<td>126.17</td>
</tr>
<tr>
<td>Cardboard</td>
<td>0.43</td>
<td>21.68</td>
<td>77.99</td>
<td>16.91</td>
</tr>
<tr>
<td>Diapers</td>
<td>4.65</td>
<td>234.47</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Cable</td>
<td>0.01</td>
<td>0.50</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Wood</td>
<td>0.93</td>
<td>46.89</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Hazardous Waste</td>
<td>0.12</td>
<td>6.05</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Fabric/ Textiles</td>
<td>1.33</td>
<td>67.06</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Glass</td>
<td>0.87</td>
<td>43.87</td>
<td>100</td>
<td>43.87</td>
</tr>
<tr>
<td>Rubber</td>
<td>0.09</td>
<td>4.54</td>
<td>100</td>
<td>4.54</td>
</tr>
<tr>
<td>Can</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Aluminum Can</td>
<td>0.07</td>
<td>3.53</td>
<td>100</td>
<td>3.53</td>
</tr>
<tr>
<td>Steel Can</td>
<td>0.06</td>
<td>3.03</td>
<td>100</td>
<td>3.03</td>
</tr>
<tr>
<td>Metal</td>
<td>0.03</td>
<td>1.51</td>
<td>100</td>
<td>1.51</td>
</tr>
<tr>
<td>Leather</td>
<td>0.16</td>
<td>8.07</td>
<td>32.51</td>
<td>2.62</td>
</tr>
<tr>
<td>Styrofoam</td>
<td>0.12</td>
<td>6.05</td>
<td>0</td>
<td>0.00</td>
</tr>
<tr>
<td>Rock/Sand</td>
<td>1.21</td>
<td>61.01</td>
<td>0</td>
<td>0.00</td>
</tr>
<tr>
<td></td>
<td>100</td>
<td>5042.26</td>
<td>4221.34</td>
<td>820.92</td>
</tr>
</tbody>
</table>
Table-5. Estimation of solid waste recycling rate at solid waste recycling facilities in Malang Raya.

<table>
<thead>
<tr>
<th>Recycling location</th>
<th>Average weight (kg/day)</th>
<th>Estimation of solid waste recycling rate</th>
<th>Residual</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>kg/day</td>
<td>%</td>
</tr>
<tr>
<td>Gadang UDPK</td>
<td>11209.07</td>
<td>8855.43</td>
<td>79.00</td>
</tr>
<tr>
<td>Tlogomas UDPK</td>
<td>5042.26</td>
<td>4221.34</td>
<td>83.72</td>
</tr>
<tr>
<td>Velodroom UDPK</td>
<td>7559.40</td>
<td>6239.88</td>
<td>82.54</td>
</tr>
<tr>
<td>Jatimulyo Composting Unit</td>
<td>4544.94</td>
<td>3734.04</td>
<td>82.16</td>
</tr>
<tr>
<td>Pandanwangi Composting Unit</td>
<td>3844.88</td>
<td>3257.86</td>
<td>84.60</td>
</tr>
<tr>
<td>Polowijen Composting Unit</td>
<td>6414.25</td>
<td>5474.22</td>
<td>85.34</td>
</tr>
<tr>
<td>Muria Composting Unit</td>
<td>9465.26</td>
<td>7596.40</td>
<td>80.26</td>
</tr>
<tr>
<td>Manyar Composting Unit</td>
<td>4050.36</td>
<td>3570.04</td>
<td>79.26</td>
</tr>
<tr>
<td>Narotama Composting Unit</td>
<td>3514.22</td>
<td>2962.43</td>
<td>84.30</td>
</tr>
<tr>
<td>VEDC Composting Unit</td>
<td>4801.52</td>
<td>3961.32</td>
<td>82.50</td>
</tr>
<tr>
<td>Asahan Composting Unit</td>
<td>9489.90</td>
<td>7697.86</td>
<td>81.12</td>
</tr>
<tr>
<td>Sawojajar Composting Unit</td>
<td>2839.07</td>
<td>2179.58</td>
<td>76.77</td>
</tr>
<tr>
<td>Supiturang Composting Unit</td>
<td>2135.00</td>
<td>1836.25</td>
<td>86.01</td>
</tr>
<tr>
<td>Mulyagoang TPST</td>
<td>11864.40</td>
<td>10525.69</td>
<td>88.72</td>
</tr>
<tr>
<td>Pandanrejo TPST 3R</td>
<td>3503.50</td>
<td>3115.22</td>
<td>88.96</td>
</tr>
</tbody>
</table>

Mulyagoang TPST was the recycling facility with highest productivity and continuously increasing its service area. At 2011, Mulyagoang TPST only served one village and it increased to 5 villages in 2014. The amount of treated solid waste in that TPST also higher than the other recycling facilities, i.e. average was 11864.40 kg/day with estimation of recycled solid waste was 88.72% and only 11.28% residual.

CONCLUSIONS

There are four types of solid waste recycling facilities in Malang Raya, which comprised 66.67% composting unit, 20% recycling and compost production unit (UDPK), 6.67% integrated solid waste treatment facility (TPST) and 6.67% 3R solid waste treatment facility (TPS 3R). The analysis result of the largest solid waste weight average at Mulyagoang TPST was 11,864.40 kg/day. Meanwhile, the biggest composition in each of recycling facility was compostable solid waste with average percentage 69.19%. According to mass balance analysis, the estimation of solid waste recycling rate was very high about 76.77-88.92%.

ACKNOWLEDGEMENTS

The author acknowledge to Directorate General of Higher Education Republic of Indonesia for Doctoral Dissertation Grant that was used in this research. The gratitude was also delivered to M. Darmawan, Mardan I., Y. Sabon Raga, M. Catarina, Dimas S., Wilhelmina M. Bia for technical assistance in field collecting data, and Ms. Deqi Rizkivia Radita for proof reading this manuscript.

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