Research and Development on Novel Organic Waste Composting Technology Using “Serial Self-Turning Reactor (STR)”: Case Study at Thammasat University, Rangsit Campus, Thailand

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Executive summary
Composting was admired as the most environmental friendliness treatment of municipal solid waste, however, several composting facilities in Thailand has faced operation problems. It was found that the level of adopted technology and the scale of facilities were unsuitable for small- and medium-size communities which generate daily solid wastes less than 100 tons. These communities are accounted to be 80 percent of communities in Thailand. This paper deals with a research and development on a novel composting technology. The present study is divided into 3 stages: 1) Investigate and review available technology and users’ requirements, 2) Develop a novel composting technology, and 3) Implement the plant-scale technology in the actual condition. The proposed composting technology, namely, “Serial Self-Turning Reactor (STR)”, i.e. a vertical-flow composting system which consists of a set of aerobic reactors sandwiched with a set of self-turning units. In-vessel bioreactor technology enables to control composting conditions. A tower-like STR resulted in flexibility on scale and composting duration. The implementation and trial operation at a Thammasat University, Rangsit Campus, located in Thailand, showed that the high performance of system which requires comparatively lesser energy and space.

Keyword; Composting technology, Organic solid waste, “Serial Self-turning Reactor”

Introduction
Over 14 millions tons of municipal solid waste (MSW) was generated in Thailand in the year 2006
Disposal of that waste will fall onto the Local Government Administrations (LGAs) hands regarding to the decentralization policy (section 281 & 283 of the Thai Constitution 2007) which will empower LGAs to be fully responsible on MSW management in a foreseeable future. While, the same report has mentioned that most of LGAs were not own appropriate treatment sites, and they conveyed their waste to the central waste disposal station right away without reduction activities. This figure may lead to 2 problems; 1) increasing of the disposal cost due to oil price, and Not-In-My-Backyard (NIMBY) problems, and 2) increasing of unsanitary waste treatment sites because of LGAs tried to solve the problem by built their own treatment station under the limitation of availability technology and budget.

It also reported by PCD (2006) that about two thirds of the chosen disposal methods were open-dumping and burn on open land. About 34% of LGAs used sanitary landfill as their disposal methodology. However, existing landfill sites were filling up while new sites were difficult to establish. Incineration was also chosen as the third place at 1% due to its quickest process. Meanwhile, social concern on air pollution and the global worming leaded to higher technical standard which became very burdensome. Composting, which was agreed (Amin, 2005, Huag 1993, US EPA, 2000) to be the most appropriate treatment for the organic-rich MSW, with lesser environmental impact and low operation cost, however, came as the last place at less than 1%. It was overlooked because of the operation difficulties, lack of skill, and unpleasant conditions (PCD, 2006). Those problems could be solved using an appropriated technology which was the statement of the problem of this research project. It was also preparing for the new coming decentralization of MSW management task, with predetermining of the threaten transportation rising cost, social against and NIMBY problem. Hitherto unsuccessful composting projects were reviewed and discussed, together with requirements from LGAs' staffs as the target users.

The Joint-research Project on Composting Technology (JPCT) was an academic cooperation between Sirindhorn International Institute of Technology at Thammasat University (TU) Thailand and Department of Civil Engineering, the University of Tokyo, Japan. It has been established in the year 2005. The aim of this research was to develop a new composting technology for small and medium communities which were generating MSW lower than 100 ton per day.

This article was a part of the joint-research project to propose an alternative composting technology that has been developed to solve above problems and to present the case of implement new technology to the real practice.

Methodology

The research and development methodology of the project consists of 3 stages: 1) Investigate and review available technology and users’ requirements. In this stage, literature reviews and sites visiting to the waste treatment centers focusing on the composting plant in Thailand and other countries would be carried out. The results from this part would be discussed to set criteria for the system designing. 2) Develop a new composting technology regarding to the criteria and user requirements. And 3) implement the plant-scale technology in the actual conditions which would
subjected to establish a plant-scale composting station and operate the new system within the target community as a pilot case study of the project.

Stage 1) Review and data collection
In this stage, 12 real composting sites and some alternative treatment sites were observed, together with relevant literature review and discussed. The findings of this stage could be summary in to 4 headings;

i. Current practice of the MSW composting in Thailand are the most likely to be promised on open-pile types, e.g. windrows and static pile. It was agree on low technology and flexible, but many complaints on land and labor intensive, odor and flies, and takes long time. Some closed systems such as static bed reactor and bio-cell were also utilized in some urbanized communities. It was chosen due to its higher performance and enables to control odor and flies. However, the system inflexibility is the limitation of this type.
ii. The survey found that the major part of the communities in Thailand generates waste less than 100 tons per day. Those communities were defined as small and medium sizes which account to be about 80 percents of about 7000 communities in Thailand.
iii. LGA's staffs who were responsible on MSW management agreed that the most difficult part was putrescible organic waste with high moisture content. This type of MSW needs to be collected frequently and needs to be treated before it gone rot. Amount and properties of MSW also varies depend on many factors. Many LGAs have tried composting practice but have problems on operation cost, labor scarcity, and complaint from nearby houses.
iv. In 2004, PCD (2006) has launched the master plan, so-called 'MSW Clustering Plan'. This plan was subjected to establish about 306 very-large-scale waste disposal centers throughout the country. Hitherto 116 sites were contracted. This policy was the reason to the declined of grant on the LGA's proposal to establish their own treatment site outside the clustering plan. However, there was another channel for LGAs to apply government funding through the Office of Local Government Authority Promotion. The proposal has to meet the following criteria;
   1) MSW generation rate 5-10 tons per day
   2) Overall budget would not excess 50 million baht
   3) Use appropriate level of technology cooperate with waste reduction program
   4) The proposed site must have distance more than 70 km from the clustering treatment center

Stage 2) Design of the new composting technology
The conclusion from review and data collection was similar to the suggestion from Amin (2005) that a set of medium-scaled treatment plant operated by LGA would be more appropriated for the transitional communities (refer to urban-industrial middle-income societies in the developing countries). The treatment facilities would be able to locate and operate in or nearby the community. If this was the case, unfavorable conditions such as odor and flies must be controlled and contained.
Therefore, an in-vessel composting system was considered as it was a closed system, and requires less area (Huag 1993, US EPA 2000). This basis technology has been picked up to be improved regarding to the 4 keywords; high performance, low cost, flexible, and environmental friendly.

**Serial self-turning Reactor sytem; STR**

The new composting core unit, namely ‘Serial Self-turning Reactor System’ (STR) was registered for Thai patent no. 26147. The system consists of vertically aeration-type reactors and sets of self-turning units. These two types of units are connected vertically making a series of composting and turning processes in alternate sequence.

The reactor was assembled by several vertical reactor clusters for adjusting the total reactor capacity. It contains vertical aeration through perforated pipes and odor venting passage. Reactor doors mechanism located at the bottom of each reactor was installed as for controlling the composted mass flowing through the self-turning units below. The doors were able to be closed and opened to adjust the period of composting in the reactor.

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**Overall operations**

Figure 1. Design concept of the STR technology (Bongothgetsakul, et al, 2007)
The self-turning unit was the new feature of STR. Nattakorn and Ishida have developed this technology based on the concrete mixing unit ‘MY-BOX’ which has been proposed by Matabee and his research team in 1998 (Matabee, et al, 1998). The self-turning units were next below the reactor unit. It contained no mechanical hardware but only complicated passages to direct flows of different types of material while falling down and impacting the unit walls due to earth gravity, which then resulted in mixing process of the loaded material.

Mixture of compost material will firstly be loaded in the topmost reactor. After composting period in the reactor was over, the composted mass would passed to the adjacent self-turning unit and then next reactor below in consequential order. After the compost mass has passed all the unit sequences, compost product will be obtained.

**Stage 3) Implement on a Case study:**
After the data collection, theoretical studying and designing of the composting core unit, the demonstration pilot-plant has been established at Thammasat University (TU) Rangsit Campus. The university were considered as its size of population are about 15,000 people, generated daily waste 4.8 ton, and MSW composition was similar to general communities, as shown in figure 3.

Figure 3. Existing MSW management practice in TU rangsit campus and the implement proposal
MSW management practice in TU Rangsit campus could be represented by figure 3. The new MSW management proposal with incorporate STR system was made and proposed to the University's working committee. According to the plan the system will be expanded to be able to treat about 1.6 ton per day of organic waste that is generated from 20,000 populations in the 2009 (Wiriyasumon, 2004). However, at the beginning stage, the project was assigned to deal with MSW collected from the regular night market twice a week on every Mondays and Thursdays with capacity about 600 kg/day.

The demonstration composting plant or so-called ‘Rangsit Plant’ has been established on the area 10 m. x 20 m. next to TU sorting & recycling station, as shown in Figure 4. Four boxes of 1.3 m x 1.3 m x 1.0 m reactors with three sets of 18-cells BioMY-BOX were installed onto 2 STR towers associated with a mixing tower and a vertical conveyor which were subjected to service all towers in the plant.

The operation process was shown in Figure 5. The pre-sorted organic waste was delivered from
sorting & recycling station to reduce particle size by grinding machine. Grinded garbage was mixed with woodchip using the vertical conveyor and mixing tower. The mixture was loaded to the composting tower, to be left for 14 days, with pile-turning once on day 7th.

A part from pile-turning, solid waste decomposition rates are affected by all factors that commonly control microbial growth which are; moisture, pH, temperature, C/N ratio, and the composition of materials. The decomposing period required to reach maturity is a key parameter for the design of solid waste composting facilities.

Haug (1993) has recommended the optimal conditions for the rapid composting as tabulated in Table 1.

Table 1 Composting condition setting for the trial operation

<table>
<thead>
<tr>
<th>Operation conditions</th>
<th>C/N</th>
</tr>
</thead>
<tbody>
<tr>
<td>Substrate (W)</td>
<td>Market waste, fruit peel, food scrap</td>
</tr>
<tr>
<td>Amendment (A)</td>
<td>Woodchip + trace of cow manure</td>
</tr>
<tr>
<td>Proportion W:A</td>
<td>1:3 (v/v)</td>
</tr>
<tr>
<td>Initial condition setting</td>
<td></td>
</tr>
<tr>
<td>Real-scale reactor volume</td>
<td>$V_0$</td>
</tr>
<tr>
<td>Initial moisture content</td>
<td>$\theta_0$</td>
</tr>
<tr>
<td>Initial compost temperature</td>
<td>$T_0$</td>
</tr>
<tr>
<td>Avg ambient temperature</td>
<td>$T_{amb}$</td>
</tr>
<tr>
<td>Avg ambient RH</td>
<td>$RH_{amb}$</td>
</tr>
<tr>
<td>Aeration</td>
<td>Air</td>
</tr>
<tr>
<td>Composting + curing period</td>
<td>t</td>
</tr>
</tbody>
</table>

For the aeration, Haug (1993) noted that it is necessary for the aerobic decomposing in three ways; 1) it adds oxygen which is vital for microbial; 2) it reduces excess water; and 3) it controls the temperature in the compost pile. Tchobanoglous et al (2002) found that at 562-623 m$^3$/day/ton of waste is optimal for organic degradation. While, Sawangpanyangkura T., (2004) suggested that aerate at 0.03 m$^3$/kg/hr would have the optimal result for the MSW composting in Thailand. According to above literatures, the aerate level in this project was set at 0.03 m$^3$/kg/hr, as it was the limitation of the currently used air flow valve’s accuracy.

**Results**

After adjusted some mechanical parts of the prototype, the trial operation showed that the whole system worked effectively according to the design. The demonstration plant required only 2 unskilled labors to operate twice a week. There was no compliant on unpleasant odor or flies. The temperature record from the composting batches reached a high temperature and retained long time enough kill pathogens, as shown in figure 6. The primary biodegradation reaction took short time to stabilize by digesting putrescible organic waste and reduce volume and weight of the waste more than 30% of original. The product from the 14-days composting was dry, and bulky, easy to
handle. The product with 2 weeks cured (pile outdoor) and impurities removed using sieve #12mm. has been sent to Land development department central lab for nutrient check. The results showed that the product has quality similar to the standard organic fertilizer, as shown in Table 2.

Table 2 Quality of the composting product from trial operation

<table>
<thead>
<tr>
<th>Item</th>
<th>Properties</th>
<th>Sample I</th>
<th>Sample II</th>
<th>Standard</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Particle size</td>
<td>sieve#12 mm</td>
<td>sieve#12 mm</td>
<td>&lt;12.5 x 12.5 mm.</td>
</tr>
<tr>
<td>2</td>
<td>Moisture content</td>
<td>25.5% w/w</td>
<td>29.5% w/w</td>
<td>&lt; 35% w/w</td>
</tr>
<tr>
<td>3</td>
<td>Impurities</td>
<td>None</td>
<td>None</td>
<td>None</td>
</tr>
<tr>
<td>4</td>
<td>Organic matter</td>
<td>52.62%</td>
<td>56.43%</td>
<td>&gt; 30% w/w</td>
</tr>
<tr>
<td>5</td>
<td>pH</td>
<td>6.79</td>
<td>7.50</td>
<td>5.5-8.5</td>
</tr>
<tr>
<td>6</td>
<td>C/N ratio</td>
<td>13</td>
<td>16</td>
<td>&lt; 20:1</td>
</tr>
<tr>
<td>7</td>
<td>EC; Electrical conductivity</td>
<td>7.28</td>
<td>6.12</td>
<td>&lt; 6 dS/m</td>
</tr>
<tr>
<td>8</td>
<td>Total Nitrogen</td>
<td>2.34%</td>
<td>2.02%</td>
<td>&gt; 1.0%</td>
</tr>
<tr>
<td>9</td>
<td>Total Phosphorous</td>
<td>1.23%</td>
<td>0.81%</td>
<td>&gt; 0.5%</td>
</tr>
<tr>
<td>10</td>
<td>Total Potassium</td>
<td>2.43%</td>
<td>2.30%</td>
<td>&gt; 0.5%</td>
</tr>
</tbody>
</table>

- 14 days compost product with 14 days cured and removed impurities by sieve#12mm.
- Nutrient determination tested by Land Development Department
- Heavy metal (As, Cd, Cr, Cu, and Pb) were found in the standard range

The full capacity operation cost of the system was 1.5 baht per kilogram of waste loaded, and it produced the good compost about 35% of original weight.

**Conclusion**

The Joint-research Project on Composting Technology was an academic cooperation between Sirindhorn International Institute of Technology at Thammasat University, Thailand and the University of Tokyo, Japan. It was aimed to develop a new composting technology for small and medium communities in Thailand.
The reviews of current MSW treatment practice disclosed that composting was not likely to be used in Thailand. It was also found that the current composting technology was unsuitable for scale of coming waste. Criteria for developing the new system were come from comments which were collected from MSW operators. The new composting system was developed by integrating varied existing technology which has been adopted regarding to the 4 keywords; high performance, low cost, flexible, and environmental friendly.

The result came as a cutting-edge composting technology, so-called “Serial Self-Turning Reactor (STR)” a vertical-flow multi-stage composting system which consists of a set of aerobic reactors equipped with a set of self-turning units. In-vessel bioreactor technology enables to control composting conditions. A tower-like STR resulted in flexibility on scale and composting duration.

The implementation and trial operation at a Thammasat University, Rangsit Campus showed that the high performance of system which requires comparatively lesser energy and space.

Acknowledgment
The authors would like to thank Maeda Corporation who supported the self-turning unit technology. We also would like to thank to Prof. Maekawa Koichi and Prof. Okamura Hajime as the pioneers of the project. Moreover, we wish to express gratitude to the Rector of Thammasat University for the great cooperation.

References
Pollution Control Department (PCD). (2006) Municipal Waste Management; Manual for Local Administration (in Thai)
2004