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Original Article

Implementation of a new composting technology, *serial self-turning reactor system*, for municipal solid waste management in a small community in Thailand

Praj-ya Sungsomboon[1], Taweep Chaisomphob[1], Tetsuya Ishida [2], and Chira Bureecam[1]

[1] *Department of Civil Engineering and Technology, Sirindhorn International Institute of Technology, Thammasat University, Khlong Luang, Patum Thani, 12120 Thailand.*

[2] *Department of Civil Engineering, the University of Tokyo, Tokyo, Japan.*

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Abstract

"Serial Self-turning Reactors" (STR) is an innovative technology, which was developed to be an alternative organic waste treatment for small communities in Thailand. It is a vertical-flow composting system which consists of a set of aerobic reactors sandwiched with a set of self-turning units. Combination of those components results to a high performance composting with capacity flexible. The pilot-scaled prototype of the new technology has been tested to ensure its effectiveness. This paper focuses on the implementation of STR technology. The study consisted of four parts: 1) selection of a target community and investigation of its current MSW practice, 2) preparation of a proposal which STR incorporated would and submit to the university's administration for approval, 3) establishment of a demonstration plant and trial on actual practice, and 4) discussion and evaluation of the new technology in general and economical aspects. Thammasat University Rangsit campus was selected to be the target community to approach the new technology. An improvement program, namely "Recycling and Composting Pretreatment Program" (RCPP) was proposed and implemented. Trial operation on plant-scale performed effectively with low running costs. An economic evaluation of STR was carried out to generalize the system.

Keywords: municipal solid waste management, composting technology, serial self-turning reactor, implementation program

1. Introduction

Disposal of 14 million tons of municipal solid waste (MSW) will be handed over to local governments (LGs) responsibility regarding to the decentralization policy in Thailand (PCD, 2006). It is empowering LGs to be fully responsible on MSW management in a foreseeable future. While, the same report has mentioned that most of LGs do not own appropriate treatment sites. Hitherto their MSW practices are conveying all waste to the central disposal facilities right away without reduction activities. This figure leads to three problems, 1) MSW operation cost would depend on oil price, 2) increase of the Not-In-My-Backyard (NIMBY) problem, and 3) increase of unsanitary waste treatment sites because of LGs will try to solve the problem by built their own treatment station under the limitation of availability technology and budget. PCD (2006) also mentioned that composting was overlooked because of the operation difficulties, lack of skills, and unpleasant conditions even though it was accepted (Huag, 1993, US EPA, 2000) as the most appropriate treatment for the organic-rich MSW, with lesser environmental impact and low operation cost.

The Joint-research Project on Composting Technology (JPCT) was an academic cooperation between Sirindhorn International Institute of Technology at Thammasat University (TU) Thailand and the Department of Civil Engineering

* Corresponding author.
Email address: praj@siit.tu.ac.th

at 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 communities, which are generating MSW less than 50 ton per day.

2. Background of STR Technology

The new composting core unit, named '*Serial Self-turning Reactor System*' (STR) was originally invented by Bongochgetsakul and Ishida and has been registered for Thai patent no. 26147 (Reference here needed). 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 a square box fabricated with PVC sheet and stainless frame. It contains vertical aeration through perforated pipes. Rotation doors located at the bottom of each reactor was installed to control composted mass flow through the self-turning units below. The doors can be closed and opened to adjust the period of composting in the reactor (Bongochgetsakul *et al.*, 2007). The self-turning unit was the new feature of STR. This technology was developed based on the concrete mixing unit 'MY-BOX' proposed by Matabee (1998). A set of the self-turning units were 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 gravity, which then resulted in mixing process of the loaded material (Figure 1).

A mixture of compost material was loaded in the top-most reactor. After the composting period in the reactor was over, the bottom doors were opened, let the composted mass flew passed the adjacent self-turning unit to the next reactor below in consequential order. After the compost mass had passed all the unit sequences, compost by-product was obtained. The STR technology has been prototyped and

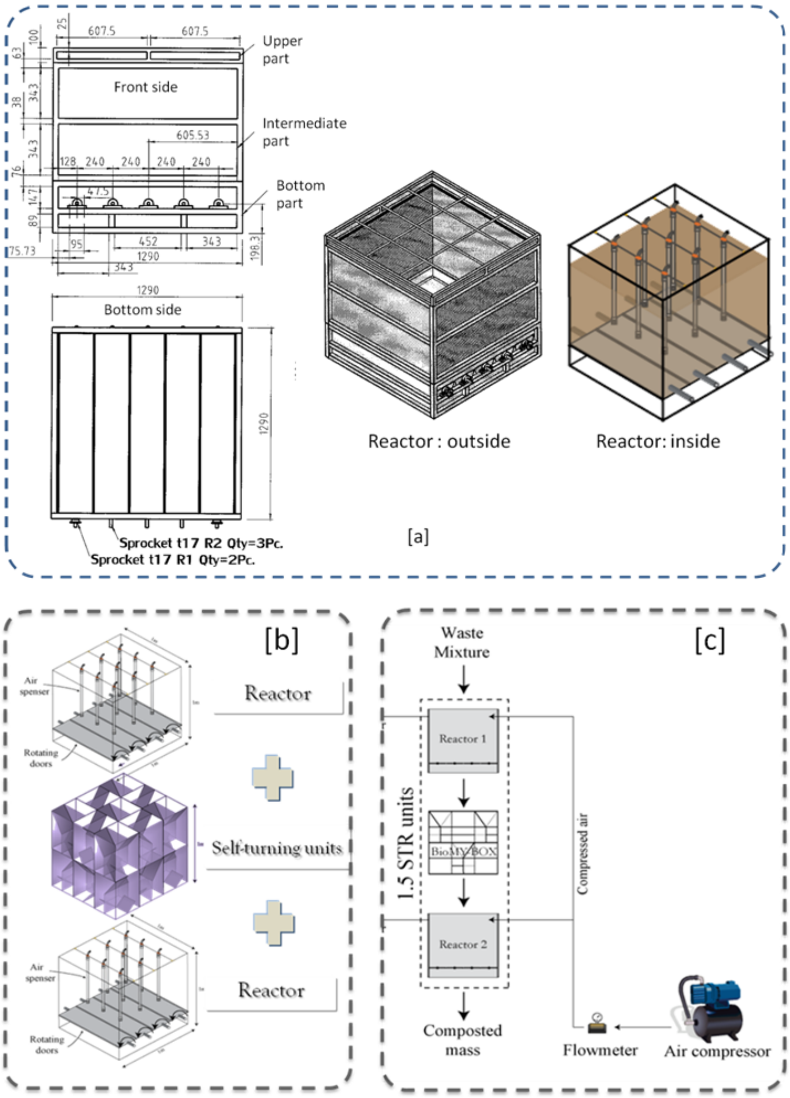

Figure 1. Aerobic reactor (a), self-turning units (b), and overall STR technology (c).

tested, implementation of the technology was need to be studied regarding to the main target of the project.

3. Methodology

This study consists of four parts; 1) selection of a target community and investigation of its current MSW practice, 2) preparation of a proposal which STR incorporated would and submit to the university's administration for approval, 3) establishment of a demonstration plant and trial on actual practice, and 4) discussion and evaluation of the new technology in general and economical aspects.

4. Investigation of the Target Community

In the first stage, a community would be considered to implement STR technology to MSW management system. The current state of the target community was investigated. The target community in this study was Thammasat University Rangsit Campus (TU Rangsit). It was chosen as its population of 15,000 in 2003. According to the university's plan, population in the campus has been rapidly increased to 25,000 by the year 2007 due to the migration plan from the old campus. After the year 2008, it has gradually increased (Wisetsumon, 2004), as shown in the Figure 2.

It was also reported (Wisetsumon, 2004) that MSW composition in TU Rangsit was similar to common communities in Thailand, as shown in Figure 3.

The report also mentioned that TU Rangsit generated MSW 1,997 tons totally in 2005. The amount of MSW was increased 13% from 4.8 ton/day in 2003 to 5.5 ton/day in 2005. The waste generation rate is nearly stable at 0.31 kg/day/capita. The largest part of the waste was general garbage, which was collected from regular 2-bin scheme, 1) dry waste or rubbish was 48% approximately by weight, which accounted to 2.63 ton/day, 2) organic waste was about 34% by weight including the food remains from the university's canteens, which was 1.86 ton/day. Average moisture content of unsorted MSW was 48.8% by weight. While, dry waste from yellow bin, and wet garbage from green bin have moisture contents 30.5% and 66.7%, respectively. Another type of MSW was the garden waste from landscaping and ground maintenance on the campus, which was 0.93 ton/day or accounted to 17% by weight. It was collected and sent to the university's garbage station separately. It was burnt periodically to clear space. The last part is hazardous waste, which was less than 1% of the total weight. This type of waste is needed to be collected and treated separately by outsourcing. Hence, it was out of this scope of work.

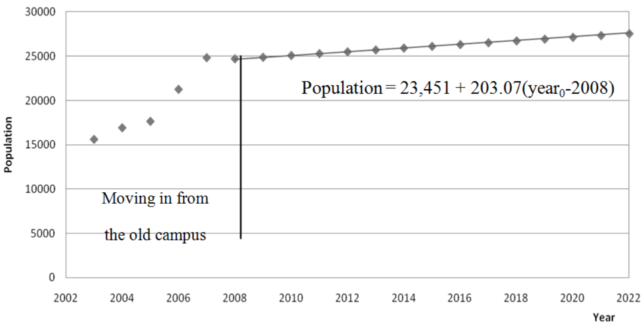

Figure 2. Population growth at TU Rangsit.

The two types of MSW, dry and wet garbage, were collected altogether and were re-sorted for recyclable material to re-selling. Remain garbage was transported out to the central landfill site by LG. It was indicated that current MSW practice in TU Rangsit did not have pre-treatment activities except hand sorting which was done without proper record, as represented in Figure 3.

5. Proposed Implementation Plan

Even thought, MSW practices in TU Rangsit have not systematically been organized, it has not yet exhibited a serious problem. If this is the case, the proposal would be made based on the common MSW management problems, which occurred in other communities, and which are summarized into four topics: 1) existing landfill sited are filled up, opening the new site is difficult, 2) MSW operation cost depends on the transportation cost. It could be reduced by reducing the amount of waste and reducing the number of the trips, 3) NIMBY problem from unpleased odor and flies, and 4) pollution and contamination from the operation, as exhibited in Figure 4.

In accordance to solve above problems, a new MSW pre-treatment program at community level, namely the Recycling and Composting Pre-treatment Program (RCPP) was drawn up. It consisted of two main parts, enhanced waste separation and recycling in community level and composting at community level, which included the STR as an alternative

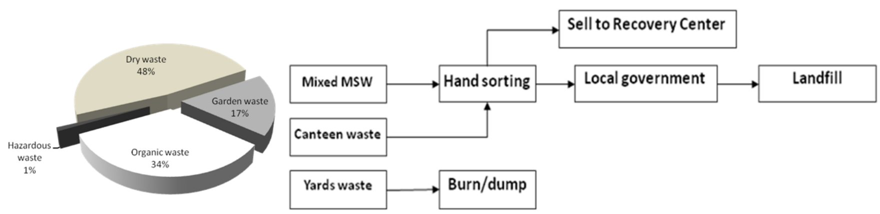

Figure 3. MSW composition and current practice in TU Rangsit before implementation of the program.

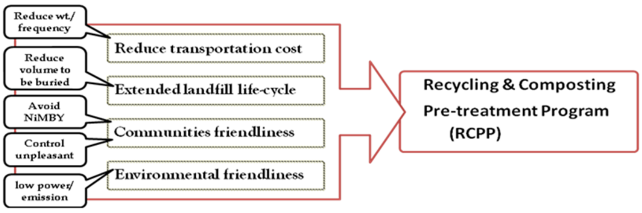

Figure 4. Formulation of the recycling and composting pretreatment program (RCPP).

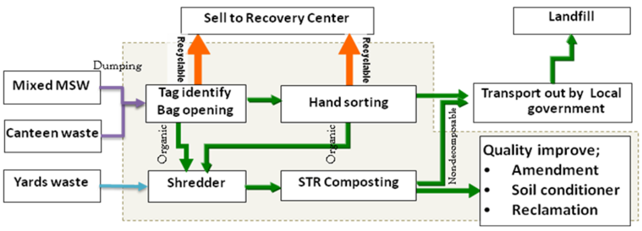

Figure 5. Proposed MSW management at TU Rangsit including STR technology.

technology. RCPP was implemented into the current practice, as represented in Figure 5.

According to the proposal, mixed MSW would be collected and delivered to the community's separation station. Waste from 2–bins scheme came in the same type of garbage bags. Type of waste would be identified in terms of color or tags on those bags, otherwise, the workers have to open all bags to separate them into three types, 1) recyclable material, which will be stored and sold to material recovery centers, 2) organic waste, which will be send to composting station, and 3) combined garbage, which will be sorted again by hand. Canteen waste or food remains from canteens would be sent to the garbage station in separate ways, and contained in the buckets. However, some of canteen waste was taken to feed animals in the farms nearby. Yard waste from the university's gardening would be sent to composting station directly, to be chipped for the composting process.

The STR implementation plan as a part of RCPP proposal was proposed to the university's working committee. According to the plan, the implementation program was divided into two phases. The beginning phase was subjected to study the implementation issue on approaching STR into the actual MSW management system. In the second phase, the system will be expanded to be able to treat about 1.6 ton per day of organic wasted that would be generated from 25,000 inhabitants in 2007.

In this study, the implementation program was commissioned on waste collected from the regular evening market which is set twice a week on every Mondays and Thursdays. The garbage from the market has been separated at source. It was classified as the "market waste" consisted of food wastes, raw food scraps, fruit peels, etc, with a highly moisture content between 60–80% by weight. It has an amount of about 600–1,000 kg/day during the regular term period.

6. The Demonstration Plant And Trial Operation

The demonstration composting plant or so-called 'Rangsit Plant' has been established on the area 10 m. x 20 m next to the TU sorting & recycling station. Four boxes of 1.3 m x 1.3 m x 1.0 m reactors with two sets of 18-cells self-turning units were installed onto two towers. The demonstration plant also included a mixing tower and a vertical conveyor, which were subjected to service all towers in the plant, as shown in Figure 6.

The operation process is shown in Figure 7. The presorted organic waste was delivered from the sorting and recycling station to reduce the particle size by shredder. Shredded garbage was mixed with woodchips using the mixing tower and bucket conveyor. The mixture was loaded to the first reactor, and left for 14 days, with pile-turning once on day 7.

Sawangpanyangkura (2004) recommended that aeration at 0.03 m^3/ kg/hr is optimal for organic degradation in Thailand. While, Tchobanoglous (2002) has suggested optimum aerate at 0.023-0.026 m^3/ kg/hr. Hence, aeration in this project was set at 0.03 m^3/ kg/hr. Haug (1993), Tchobanoglous *et al.* (2002), and Sawangpanyangkura (2004) have recommended the optimal conditions for the rapid composting as tabulated in Table 1.

Although, literature reviews and previous researches would provide a practical range for composting conditions, experiments on actual waste were required subjected to optimize those recommendations.

7. Results of Trial Operation

The trial operation showed that the whole system worked effectively according to the design. The demonstration plant required only two unskilled workers to operate the whole process. Workers rarely have direct contact with the organic waste. There was also no complaints about unpleasant odor or flies from the demonstration plant. The temperature record from the composting batches reached a

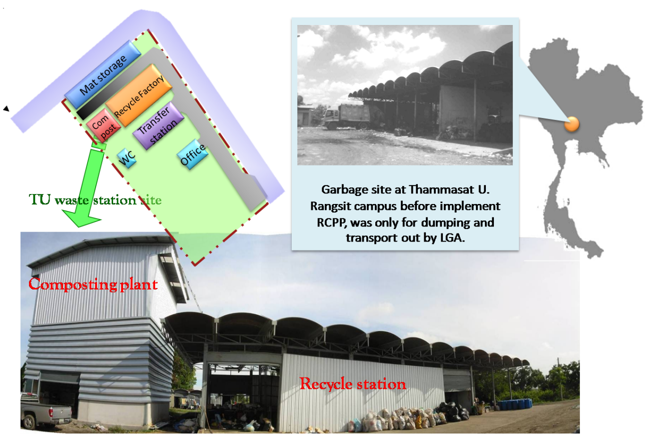

Figure 6. Demonstration plant and STR composting units at TU Rangsit.

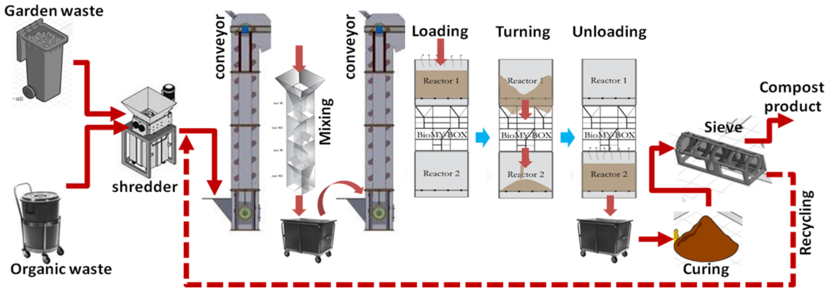

Figure 7. Trial operation process at the demonstration plant at TU Rangsit.

Table 1. Composting conditions for the trial operation

		Operation conditions	Moisture	C/N
Substrate (W)		Market waste, fruit peel, food scrap	70%-80%	10-15
Amendment 1(A1)		Woodchip (garden waste)	20%-30%	40-50
Amendment 2(A2)		Cow manure	10%-15%	29
Proportion W:A1:A2 (by vol.)		1 : 2.5 : 0.5	45%-60%	25-35
Initial condition setting	Value	Unit		
Real-scale reactor volume	V_0	1.56	m^3	
Aeration	Air	0.03	m^3/ hr/kg	
Composting + curing period	T	14+14	Days	

maximum of more than 55ºC and retained long enough to kill pathogens and harmful germs, as shown in Figure 8. The primary stage of composting took a short time on digesting the recycle waste. After 14 days of the primary stage, the volume has reduced over 30% of the original loading. The product from primary stage was dry, and bulky, and easy to handle.

After the primary stage of composting in the STR the compost mass was unloaded and transferred to be cured outside. It required about 2-3 weeks for maturation. Matured compost would be dry enough for screening with a sieve of 12 mm mesh size to remove oversized particles and impurities. It was discovered that a full load of 600 kg produces 200 kg of final compost. Off-screened material was about 200 kg with woodchips to be more than 80% and with uncompostable material, i.e. plastics, papers, bones, and rubber straps that

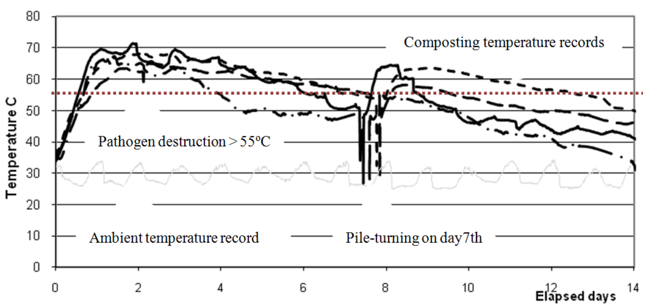

Figure 8. Examples of the temperature profiles recorded during trial operation.

could be reused as amendments or reclaimed material. It has a high heating value of 2,658 kcal/kg, so that it could be used as refused derived fuel (RDF). The final product has been sent for nutrient determination to the National Land Development Department's central lab. The results showed that the product has a quality similar to a standard organic fertilizer, as shown in Table 2.

During three months of the trial the operation costs of the STR have been recorded, including the power consumption of equipments, as indicated in Table 3. At full capacity, we found that operation costs of the system were 1.50 baht per kilogram of loading waste, and it produced good compost that is about 30% of the original loading.

8. Discussion

8.1 Economic evaluation on the STR operation

Operation records from the trial were taken to the economic analyze for evaluation. This stage was carried out in two parts, first, determination of the scale of production that gives the lowest operation cost; and second evaluation of the STR technology using economical analysis. The analysis was conducted for a 20-year period within following assumptions: Population increases linearly with waste generation rate constants at 0.31 kg/day-cap; Waste collection rate is 95%, sorting performance rate is 50%, and organic waste composition is 34%; Final product is classified as organic fertilizer, yield at 25% of loaded mass. The organic fertilizer's

Table 2. Quality of the compost products from trial operation

Item	Properties	Average	Max.	Min.	Range	Standard*
1	Particle size (sieve #12mm)	pass	n/a	n/a	n/a	<12.5x12.5 mm.
2	Moisture content	29.125	32	25.5	6.5	< 35% w/w
3	Impurities	None	None	None	0	None
4	Organic matter	49.97%	60.74%	30.10%	30.64%	> 30% w/w
5	pH	7.7	8.3	6.8	1.5	5.5-8.5
6	C/N ratio	16.5	24	13	11	< 20:1
7	EC; Electrical conductivity	6.082	7.28	4.58	2.7	< 6 dS/m
8	Total Nitrogen	2.05%	2.71%	1.12%	1.59%	> 1.0%
9	Total Phosphorous P_2O_5	1.00%	1.29%	0.65%	0.64%	> 0.5%
10	Total Potassium K_2O	1.83%	2.43%	0.57%	1.86%	> 0.5%

o Heavy metal (As, Cd, Cr, Cu, and Pb) were found within the standard range

Table 3. The operation cost estimation based on the trial operation

Description	Quantity For 1.5 m^3	Unit cost (Baht)	Amount (Baht)
Operation Expense			
Material cost; Cow dung	4 sacks	30	120
Miscellaneous (soap, lubricant, bag, etc.)	Ls	80	80
Labor cost;	2.5 m.d.	200	500
Electricity; Air compressor (¼ hp 14 days)	62.64 kw.hr	4	250.56
Electricity; Conveyor (1 hp x 3 hrs)	2.24 kw.hr	4	8.96
Electricity; Shredder (5 hp x 2 hrs)	7.46 kw.hr	4	29.84
Electricity; Sieve (1 hp x 3 hrs)	2.24 kw.hr	4	8.96
Total			998.32
Income			
Garbage and garden waste disposal fee	600 kg	1	600
Compost product 30% of loaded	200 kg	2	400
Total			1,000

market price is 2,500 baht/ton; Distance to the landfill site is 70 km from the community, a garbage truck consumes 15 liter of gasoline for one round trip, and oil price is 28.5 baht/liter; economical benefit from landfill cost reduction based on the landfill cost at 761 baht/ton; CO_2 emission from STR is 42.7 kg-CO_2/ton of waste, which were cost 420 baht/ton-CO_2; the discount rate is 6.25%.

It was shown in Figure 9 that the STR operation cost-per-unit would be lowered when the scale of production is expanded. At the production level of 1 ton/day, direct operation cost (material, labor, and electric cost) was 1.50 baht/kg, and the total operation cost-per-unit (including constructions and equipments depreciation) was 3.00 baht/kg, while at the production level of 5.0 ton/day direct operation cost was reduced to be about 1.00 baht/kg, and the total operation cost-per-unit was about 2.50 baht/kg.

For a 20-year period the economic forecasting showed that the STR would have composted 24,664.47 ton of organic waste and produced 6,166.12 ton of organic fertilizer as a by–product. On the one hand, a financial analysis which focused on direct financial outcome such as transportation cost reduction and by-product, the system has a net present value (NPV) of -20,431,545.64 B aht and a benefit to cost ratio (B/C) of 0.936. The negative value of NPV on the financial evaluation was expected for this case. Most of new MSW facilities feasibility study requires subsidization respect to the public health and environmental concerns. If this is the case, the economic analysis which includes intangible incomes from less emission of the green house gas (GHG) that could claim for 'Carbon Credit' has resulted in a NPV of 133,058,207.02 Baht and a B/C ratio of 4.157. Although the financial analysis indicated that the results were losses, the economical analysis has favorable results.

8.2 Evaluation on RCPP program

In this part, the whole RCPP practice will be monitored; the results could be represented by mass balance dia-

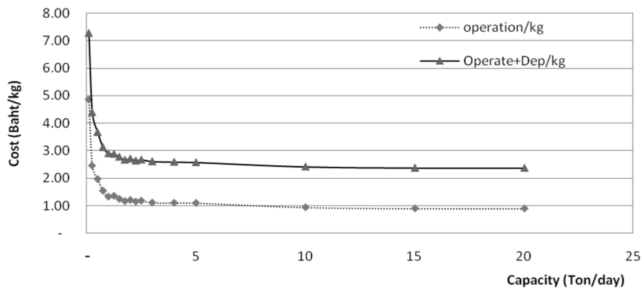

Figure 9. Estimation for STR operation cost at varied scale of production.

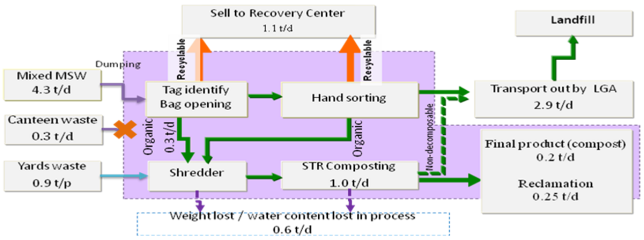

Figure 10. MSW mass balance on RCPP at TU Rangsit.

gram, as shown in Figure 10.

It was discovered that the 5.5 ton/day total waste has been reduced according to the pretreatment to 2.9 ton/day to be disposed by LG. This accounted for about 52.7% of the daily weight. STR has run at the full capacity to contribute to RCPP during the period. However, the demonstration plant has limited capacity. Extending its scale would result to increase the reduction rate of RCPP effectively. It was also indicated that the separation has a limited output rate of only 1.07 ton/day that accounted for 40.8% of the recyclable wastes. It was operated by 6-8 workers, which expected to sort up to 8 tons during 8 working hours (Diaz *et al.*, 1993). Meanwhile, revenue from selling recyclable materials was enough to sustain the operation cost of the garbage station.

9. Conclusion

Thammasat University Rangsit campus was considered for voluntarily implement STR technology. The size of the population and composition of the MSW were similar to small communities in Thailand. STR was incorporated in the MSN pretreatment program, namely the Recycling and Composting Pre-treatment Program (RCPP), which was implemented into the university's MSW practice. The implementation and trial in actuality showed its efficiency on digestion of recyclable garbage within a short time, with low operation cost, less space required, and environmental friendly. Although the financial analysis indicated that STR operation requires subsidization, the economical analysis, which includes intangible revenue such as CO_2 emission has showed benefical result. Even though, the trial operation on the plant-scale STR solely has a favorable result, it was recommended that the implementation of STR should be incorporated with the waste separation activity for a higher performance.

Acknowledgments

This study is a part of a joint-research project to introduce a new composting technology and to present an implementation of the technology to a real community in Thailand. The authors would like to thank Maeda Corporation who supporting the self-turning unit technology. We also would like to thank to M. Koichi and O. Hajime as the pioneers of the project. Moreover, we wish to express gratitude to the Rector of Thammasat University for the great cooperation.

References

Bongochgetsakul, N. 2006. Integrated Analytical System for Optimizing Design of Large-scale composting and Development of Serial Self-turning Reactor System, University of Tokyo, Japan.

Bongochgetsakul, N., Ishida, T., Sungsomboon, P. and Chaisomphob, T. 2007. an innovative composting: self-turning reactor system and gravitic mixing technology. Proceedings of the 21st International Waste Management and Landfill Symposium, October 1-5 2007, Sardinia, Italy.

Diaz F. L. 1993. Composting and Recycling Municipal Solid Waste, Lewis Publisher, USA

Haug, R.T. 1993. The practical handbook of compost Engineering, USA: Lewis Publishers.

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

Sawangpanyangkura, T. 2004. Composting in commercial scale by local community using aerated static pile system Proceedings of KMITL International Conference On Integration Of Science And Technology For Sustainable Development, Bangkok, Thailand, 25-26 Aug 2004 (vol 2), p.157-159

Tchobanoglous, G. and Frank, K. 2002. Handbook of solid waste management. McGraw-Hill Inc.

Department of Agricultural Extension. 2009. Biofertilizer Standard. (Online, Printed in Thai) http://www.doae.go.th/spp/biofertilizer/or4/htm (Dec. 2009)

US EPA. 2000. In-vessel composting of Biosolid. Biosolid technology fact sheet. http://www.epa.gov/owm/mtb/invessel.pdf (Apr. 2008)

Wisetsumon, U. 2004. The study on the improvement of solid waste management of Thammasat University Rangsit Campus Research paper for the TU development funding, Thammasat University, Pathum Thani, Thailand (Printed in Thai)