Available online at http://rjas.rsu.ac.th

Rangsit Journal of Arts and Sciences, July-December 2017 RJAS Vol. 7 No. 2, pp. 173-180
Copyright © 2011, Rangsit University ISSN 2229-063X (Print)/ISSN 2392-554X (Online)

Integrated municipal solid waste management for the highland rural area: case study Patueng sub-district in Chang Rai, Thailand

Pannipha Dokmaingam[1*] and Panate Manomaivibool[2]

[1]School of Health Science, Mae Fah Luang University, Chiang Rai 57100, Thailand.
[2]School of Science, Mae Fah Luang University, Chiang Rai 57100, Thailand.
[1]Email: pannipha.dok@mfu.ac.th; [2]Email: panate.man@mfu.ac.th

*Corresponding author

Submitted 11 July 2016; accepted in final form 24 April 2017
Available online 22 December 2017

Abstract

Effective municipal solid waste management (MSWM) is a challenge for local governments in the highland. Models from urbanized areas focusing on waste collection and advanced centralized disposal systems might not be applicable in their contexts. The purpose of this study was to develop an integrated MSWM system with Patueng Sub-district Administrative Organization (Patueng SAO) in Chiang Rai Province. The participatory process started with problem identification and quantification. MSW was identified as the most urgent environmental problem. The SAO could not find the site to landfill all of the 107.87 ton of MSW estimated to be generated in a year. An integrated system was designed in the second round based on the result of waste composition analysis and participation from stakeholders. A combination of strategies to manage MSW at source and incineration was proposed. Home composting targeted organic waste, which accounted for 65% of the total waste. The other 17% that had re-sellable values could be recycled. Incineration reduced the amount of waste going to final disposal. An economic and environmental assessment showed that this model could reduce disposal costs and environmental impacts because it lowered the demand on the SAO to collect MSW for disposal.

Keywords: *fertilizer, highland area, incinerator, municipal solid waste*

1. Introduction

Effective municipal solid waste management (MSWM) is an essential element to promote community health and well-being. According to the Public Health Act, B.E. 2535, waste management is the responsibility of the local governments. But, this is a challenging task for Sub-district Administrative Organizations (SAO) in rural areas. Many SAOs have not provided any waste removal services and households have to get rid of their waste by open burning or dumping in vacant land.

Many previous researches study the appropriated MSWM methods for the urban community which located in flat area (Chiemchaisri, Juanga, & Visvanathan, 2007; IPCC, 2006a; Kerdsuwan, Laohalidanond, & Jangsawang, 2015). However, we might not be able to apply these models directly in rural communities. They must be modified taking into consideration the local context, climate and other related parameters. Unlike municipalities in the urban areas, only few SAOs have a designated department or trained personal for public health and environmental works. It is also difficult for SAOs to copy the services that municipalities provide. The challenge is even more daunting for SAOs in the highland.

This work presents a participatory process for the development of MSWM in a rural area. Previously, villagers in Patung sub-district disposed of their waste in open-dump sites or simply burned it at their own backyard. However, these caused eyesore and air pollution contributing to smog which was a major problem in northern Thailand. Therefore, Patung SAO worked with researchers to improve the situation. For Patung SAO with communities both in the lowland and in the highland, a trial and error was needed for the development of an effective MSWM.

2. Objectives

The objective of this participatory action research (PAR) was to develop an integrated MSWM system for a rural area with high- and lowland. Patueng SAO was selected as the case study. The participatory process consisted of three rounds. First, the problems were identified and quantified. This was followed by a selection of waste management processes that matched with the waste generated based on environmental and economic consideration. Finally, the system was implemented and evaluated. Recommendations were proposed to further improve the efficiency of the system.

3. Methodology

Vučijak, Kurtagić, and Silajdžić (2016) developed a methodology for multi-criteria decision making in the case of solid waste management optimization. The method had six steps: describing a baseline situation, defining scenarios, defining criteria, evaluating criteria for all scenarios, evaluating criteria weights, and ranking alternatives. Previous research also suggested various indicators to assess MSWM systems that could be grouped into three categories: material recovery, energy recovery and economic costs (Bueno, Latasa, & Lozano, 2015; da Cruz, Simões, & Marques, 2012; Grosso, Motta, & Rigamonti, 2010; Rigamonti, Sterpi, & Grosso, 2016; Menikpura, Sang-Arun, & Bengtsson, 2013; Vučijak et al., 2016; Bashkin, 2002).

According to a review by Kaosol (2009), the most common MSW disposal methods in Thailand were sanitary landfill, composting, open dumping, incineration, and others. However, out of 480 existing disposal sites run by local governments, there were only 97 that could be classified as safe disposal (i.e., 91 sanitary landfills, 3 incinerators, and 3 integrated-system facilities). For more efficiency of MSW, the review suggested an integrated MSWM system includes (i) waste selection (ii) material recovery facilities, (iii) incineration and energy recovery, (iv) biological treatment of organic waste (v) landfill of final inert waste. This process could prolong the lifetime of a landfill. Similarly, Udomsri, Petrov, Martin, and Fransson (2011) found that an integrated system was needed because MSW could not be disposed of with only one method. Although the analysis showed that the CO_2 emission from MSW incineration was lower than the landfilling without gas recovery process, it could not handle all of solid waste in Bangkok Metropolitan area. Landfill remained the most preferred process for final disposal due to the characteristic and quantity of MSW.

Menikpura et al. (2013) studied the quantity of greenhouse gas (GHG) emissions from the integrated MSWM in the case of Muangklang Municipality. Life cycle assessment (LCA) showed that the integrated system could considerably reduce GHG emissions from recovered nutrients, materials, and energy and the saving from landfill disposal of organic and recyclable waste compared to conventional landfill disposal. Among the individual technologies assessed, material recycling was found to offer the largest reductions in GHG emissions. The calculations indicated that a properly designed integrated system with high but fully realistic recovery rates can drastically reduce the climatic impact of waste management. Similarly, Kerdsuwan et al. (2015) suggested that with a separation efficiency of 25% a novel hybrid incineration and gasification technology could bring about improvements compared to the business-as-usual scenario where all of the MSW was treated as mixed waste.

The data collection and analysis in this study were divided into the following phases. First, general data related to solid waste in Patueng were gathered, including the population during 2009-2015, solid waste composition, solid waste quantity, and existing waste management facilities. The knowledge and behaviour of waste separation in this community was also studied. After which, the amount of solid waste can be predicted and a feasible Waste Management System would be analyzed base on solid waste quantity, proposed energy recovery, environmental impact and cost.

3.1 Forecast of the quantity of MSW

Because of Patueng's geography, and the migration behaviour of people in the highland, we used the population data from the Patueng District Health Promotion Hospital (2013-2015) and compared with the house register which showed a great increase of 1,500 people between 2009 and 2015. A random sampling was performed in a parallel study to gather information on the rate of generation of MSW from 11 villages which covered 45.3 % of the population (Jiaphasuanan, 2015). The amount of MSW was then predicted by using the Eq. 1 (IPCC, 2006a)

$$Mass_{MSW,i} = 0.453 \times Pop_{patueng} \times MSW\ rate_{patueng} \quad (1)$$

Where $Mass_{MSW,i} = Amount\ of\ MSW\ in\ year\ i\ (kg)$

$Pop_{patueng} = Population\ in\ Patung\ subdistrict\ (person)$

$MSW\ rate_{patueng} = Generation\ rate\ of\ MSW\ in\ Patung\ subdistrict\ (kg/person)$

3.2 Forecast of the catalog of MSW population

In this study, the composition of MSW was identified by using the Quartering method (Robinson, 1986). The types of MSW were grouped according to the available waste management technologies in Thailand. It should be noted that the forecast of each MSW catalog was extended from the predicted quantity, Eq. 2.

$$Type_{MSW,n} = \%\ of\ MSW_n \times Mass_{MSW,i} \quad (2)$$

Where $Type_{MSW,n} = Amount\ of\ MSW\ type\ n\ (kg)$
$\%\ of\ MSW_n = percentage\ of\ MSW\ type\ n\ (\%)$

3.3 MSW disposal technology

In order to select the appropriate MSW disposal technology for Patueng two main factors were considered for this study; the environment and the economy. The forecasted quantity of waste is used to calculate the environmental impact, Eq. 3 (IPCC, 1996), and cost, Eq. 4-7 (Douglas, 1988; IPCC, 2006b)

$$CH_4emission(Ton/year) = (MSW_T \times MSW_F \times MCF \times DOC \times DOC_F \times F \times 16/12 - R) \times (1 - OX) \quad (3)$$

where $MSW_T = total\ MSW\ generated\ (Ton/year)$
$MSW_F = Fraction\ of\ MSW\ disposed\ to\ solid\ waste\ disposal\ sites$
$MCF = methane\ corection\ factor\ (fraction)$
$DOC = degradable\ organci\ carbom\ (fraction)$
$DOC_F = fraction\ DOC\ similated$
$F = fraction\ of\ CH_4\ in\ landfill\ gas\ (default\ is\ 0.5)$
$R = recovered\ CH_4\ (Ton/year)$
$OX = oxidation\ fration\ (default\ is\ 0)$

$$Amortized\ total\ capital\ investment = Amortized\ tot.inv. + Amortized\ O\&M \quad (4)$$

$$\text{Amortized tot. inv.} (฿/Ton) = \left(\frac{\exp(0.08 \times lifetime)}{\sum_{j=0}^{19} \exp(dis.rate \times j)}\right) / (365 \times \text{capacity})\ Tot.inv.cost \quad (5)$$

where j = operating time (year)

dis.rate = discount rate which is 2% (CIA, 2015)
Tot.inv.cost = Total investment cost (฿)

$$Amortized\ O\&M\ (฿/Ton) = \left(1.031(Utility\ Cost) + 0.186\ \left({ins\ cost}/{lifetime}\right) + 2.31(labor\ cost)\right)/capacity \quad (6)$$

where ins. cost = installation cost (฿)

$$Total\ capiatal\ cost\ (฿/Ton) = \text{Amortized tot. inv.} (฿/Ton) + Amortized\ O\&M\ (฿/Ton) \quad (7)$$

As also found in previous work (Kerdsuwan et al., 2015), other considerations were also mentioned in the participatory process including:

- Practicability and performance, including efficiency, reliability, safety, operator-skill;
- Maturity of technology ; and,
- Technological self-reliance.

4. Results

4.1 Basic information of solid waste in Patueng

Patueng was one of the largest sub-districts in Mae Chan district. It had 220 km^2 of land and 20 villages with a total population of 25,522 people and occupies both low- and high-land areas at the time of study. People in Patueng consisted of nine ethnic tribes which resulted in a variety of native traditions within the area. A majority of the area was covered by agricultural land and forest which is the origin of the Jan River and other rivers in the area. There was also a hot spring that can be developed for eco-tourism.

Basic information regarding Patueng was collected using a "world café" technique and community forums. It was found that the most urgent environmental problems in this sub-district are MSW, waste-water, air pollution and the use of chemicals. The waste generation rate was estimate to be around 0.54 kg per person*week. Based on the population data from Patung Distric Health Promotion Hospital (2013-2015), we estimated an average waste generation in Patueng at 107.87 ton/year.

A survey revealed that people lacked the knowledge or skills to reduce and recycle waste. Based on the data collected from 220 households, they only separated waste that could be sold to junk shops. On the other hand, the waste composition in Figure 1 showed that the two largest components were organic waste and plastic bags, respectively. Based on a list of saleable recyclables in Table 1, the materials with re-sellable value counted only 17%. The survey results were also in line with physical observations and community forums. This information was useful for the design of a MSWM system.

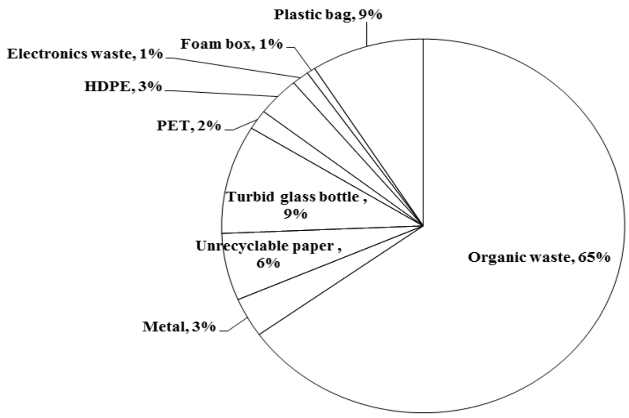

Figure 1 MSW composition of Patueng sub-district in 2015

Table 1 Selling price of recyclable material in Chang Rai Province (EREM, 2015)

Type of Materials	Catalog	Cost (Baht/kg)
Paper	Printed while paper	7.00
	Newspaper	4.00
Glass	Transparent	2.00
	Turbid	0.95
Metal	Aluminum	35.00
	Iron	4.00
Plastic	PET	11.00
	HDPE	19.00
	Mix plastics bottle	9.00
	Cleaned plastic bag	1.00

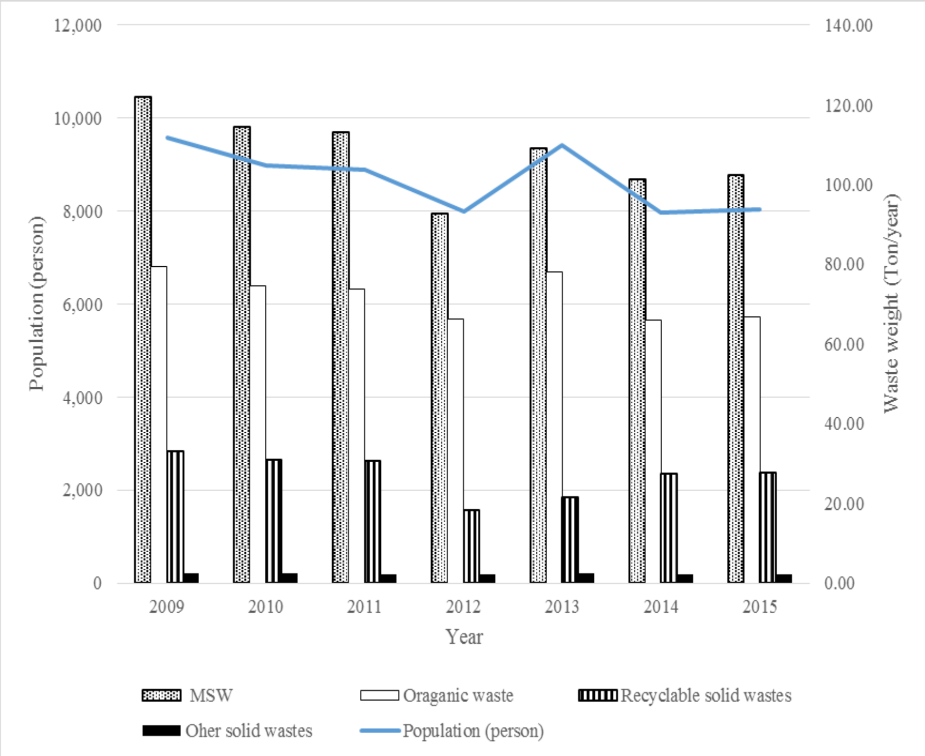

Figure 2 Forecasted population and quantity of solid waste in Patueng sub-district

4.2 Appropriate MSW disposal technology

According to quantity and composition of waste, two alternative MSW management models were proposed in this study, they were as follows:

- Base case: the MSW could not be separated and all of the MSW sent to landfill.
- Alternative Case: All saleable recycles were separated and sold; then the 50% organic waste could be separated for composting, and the remaining MSW would be sent to the incinerator.

Based on the current MSW collection practices, approximately 295.6 kg per day of MSW was collected and transferred to the disposal sites of Patueng. According to Utsaha (2010), the cost of waste disposal in Change Rai province was around 175.4 Baht/ton. Therefore, the Patueng SAO had to allocate a budget of 18,907 Baht/day. Landfilling resulted in the release of 3.24 ton of methane per year or around 81 CO_2eqTon /year (Bogner et al., 2008).

The alternative case was proposed by considering the selection criteria mentioned above, together with the exiting waste disposal method in Thailand. Home composting was deemed suitable for the disposal of organic waste because it was an uncomplicated, widely used, and reliable practice. Furthermore, the compost could be reapplied in agricultural land. This technique should also be applicable in other rural areas of Thailand. From an environmental stand-point, greenhouse gas emissions could be reduced as much as 81 CO_2eqTon/year. From an economic stand-point, the compost could be produced in each household, without cost.

17% of the remaining MSW could be separated to sell at the recycling center. Incineration was selected by the SAO with the approval of the local council as the preferred technology since it saved space for waste dispsoal (Kerdsuwan et al., 2015). However, incineration facilities require fossil fuel and electricity in order to operate and were more complex than conventional landfills (Kaosol, 2009). The costs for this waste capacity were listed in Table 2. The capital cost for waste incineration was estimated to be around 61,684 Baht/ton. It should be noted that the cost of MSW transportation was omitted because no location had been chosen to install the incineration system. The conceptual design of the overall process for the MSW disposal technology, focusing on the compositing process for food waste, is illustrated in Figure 3. The recycled material could be sold at approximately 322.7 Baht/day.

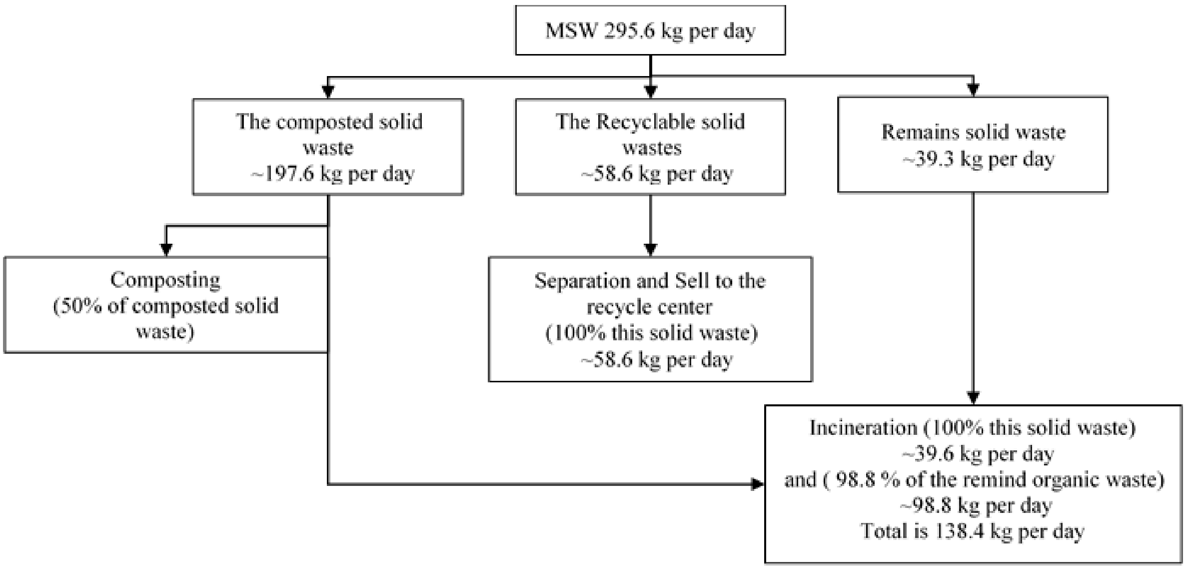

Figure 3 Conceptual design of the overall process for MSW disposal technology focusing on the composting method and incineration technology

Table 2 Costs for solid waste incineration process for Patueng SAO

Item	Capacity	Amount (unit)	Cost (unit)
Investment cost			
- incinerator	5 Ton/8hrs.	1	5,000,000 (Baht)*
- rear-loaded compact garbage truck	Capacity 12 m^3	1	3,000,000 (Baht)*
Operating cost			
- labor cost	-	4 (man)	300 (Baht/man/day)
- Fuel for start up	-	10 (liter/day)	26.8 (Baht/liter)**

*this cost is averaged from the SAOs nearby Patueng SAO
**the cost is averaged from the selling price of gasohol91during 2558 (Bangchak Petroleum PCL, 2558)

5. Discussion

Patueng SAO should implement campaigns to increase waste reduction/separation awareness within the community, continuously. Currently only saleable recyclables were separated but they only accounted for 17% of the MSW generated. However, organic waste which was less separated could result in methane emissions that contributed to global warming. If this could have been used as fertilizer, it would benefit the environment and the agricultural sector. Home composting would also be suitable for the rural area with a vast amount of agricultural land. The separation of these two fractions could reduce the greenhouse gas emission by 81 CO2eqTon/year. The rest of the solid waste could be incinerated at the cost of 61,684 Baht/ton to reduce the amount of waste going to final disposal.

6. Conclusion

Patueng sub-district represented the general issues regarding MSWM in rural, highland areas. The quantity of solid waste was estimated to be 295.6 kg per day. Although the amount of solid waste was still lower than in urban areas, it posed a major environmental problem and was expected to rise with a projected increase in population. As the highest composition of solid waste was organic, composting would be the most suitable method because the final product could be directly utilized in agriculture. Moreover, it could be done in each household reducing the transportation need in waste collection. The high technology such as incineration might be flexible for mixed waste after composting and recycling.

7. Acknowledgements

The authors would like to thank Mea Fah Laung Unversity, Thailand, for their financial support.

8. References

Bangchak Petroleum PCL. (2558). Historical retail oil prices. Retrieved 15/01/2016, from http://www.bangchak.co.th/th/oil-price-history.aspx?mode=download

Bashkin, V.N. (2002). The Combination of Analysis for Estimating Quantity of Solid Waste and Optimal Solid Waste Management a Case study 1: Samut Songkhram Province, Thailand. *Journal of Health Science*-วารสารวิชาการสาธารณสุข *11*(3), 339-349.

Bogner, J., Pipatti, R., Hashimoto, S., Diaz, C., Mareckova, K., Diaz, L., . . . Gao, Q. (2008). Mitigation of global greenhouse gas emissions from waste: conclusions and strategies from the Intergovernmental Panel on Climate Change (IPCC) Fourth Assessment Report. Working Group III (Mitigation). *Waste Management & Research, 26*(1), 11-32. DOI: 10.1177/0734242X07088433

Bueno, G., Latasa, I., & Lozano, P. J. (2015). Comparative LCA of two approaches with different emphasis on energy or material recovery for a municipal solid waste management system in Gipuzkoa. *Renewable and Sustainable Energy Reviews, 51*, 449-459. DOI: http://dx.doi.org/10.1016/j.rser.2015.06.021

Chiemchaisri, C, Juanga, J. P. , & Visvanathan, C. (2007). Municipal solid waste management in Thailand and disposal emission inventory. *Environmental monitoring and assessment, 135*(1-3), 13-20. DOI: 10.1007/s10661-007-9707-1

CIA, Central Intelligence Agnacy. (2015). Central bank discount rate. Retrieved 15 Dec 2015, from https://www.cia.gov/library/publications/the-world-factbook/fields/2207.html

da Cruz, N. F., Simões, P., & Marques, R. C. (2012). Economic cost recovery in the recycling of packaging waste: the case of Portugal. *Journal of Cleaner Production, 37*, 8-18. DOI: http://dx.doi.org/10.1016/j.jclepro.2012.05.043

Douglas, J. M. (1988). *Conceptual design of chemical process*. New York, USA: McGraw-Hill.

Grosso, M., Motta, A., & Rigamonti, L. (2010). Efficiency of energy recovery from waste incineration, in the light of the new Waste Framework Directive. *Waste Management, 30*(7), 1238-1243. DOI: http://dx.doi.org/10.1016/j.wasman.2010.02.036

EREM. (2558). MFU Good Bank (pp. 19): Institute for the study of Natural Resources and Environmental Management (EREM), Mea Fah Luang University.

IPCC, Intergovernmental Panel on Climate Change. (1996). IPCC Guideline for National Green House Gas Inventories Workbook (Volume 2). Retrieved 27 October, 2015, from http://www.ipcc-nggip.iges.or.jp/public/gl/invs5.html

IPCC, Intergovernmental Panel on Climate Change. (2006a). *2006 IPCC guidelines for national greenhouse gas inventories*: Intergovernmental Panel on Climate Change.

IPCC, Intergovernmental Panel on Climate Change. (2006b). *2006 IPCC GUIDELINES FOR NATIONAL GREENHOUSE GAS INVENTORIES* (B. L. Eggleston H.S., Miwa K., Ngara T. and Tanabe K. Ed.). IGES, Japan The National Greenhouse Gas Inventories Programme.

Jiaphasuanan, T. (2015). *Solid waste management design and planing project: a case study of Patung Subdistrict Administrative Organization, Mae Chan District, Chang Rai Province* (pp. 78): Public Policy Studies Institute Foundation, Thai Health Promotion Foundation.

http://en.thaihealth.or.th/WHO_WE_ARE/THAIHEALTH_INTRO/

Kaosol, T. (2009). Sustainable solutions for municipal solid waste management in Thailand. *World Academy of Science, Engineering and Technology*, *4*(12), 399-404. scholar.waset.org/1307-6892/6576

Kerdsuwan, S., Laohalidanond, K., & Jangsawang, W. (2015). Sustainable development and eco-friendly waste disposal technology for the local community. *Energy Procedia*, *79*, 119-124. DOI: http://dx.doi.org/10.1016/j.egypro.2015.11.493

Menikpura, S. N. M., Sang-Arun, J., & Bengtsson, M. (2013). Integrated solid waste management: an approach for enhancing climate co-benefits through resource recovery. *Journal of Cleaner Production*, *58*, 34-42. DOI: http://dx.doi.org/10.1016/j.jclepro.2013.03.012

Patueng Distric Health Promotion Hospital. (2013-2015). Aunnual Report.

Rigamonti, L., Sterpi, I., & Grosso, M. (2016). Integrated municipal waste management systems: An indicator to assess their environmental and economic sustainability. *Ecological Indicators, 60*, 1-7. DOI: http://dx.doi.org/10.1016/j.ecolind.2015.06.022

Robinson, W. D. (1986). *The solid waste handbook: A practical guide*. New York, USA: Wiley.

Udomsri, S., Petrov, M. P., Martin, A. R., & Fransson, T. H. (2011). Clean energy conversion from municipal solid waste and climate change mitigation in Thailand: Waste management and thermodynamic evaluation. *Energy for Sustainable Development*, *15*(4), 355-364. DOI: http://dx.doi.org/10.1016/j.esd.2011.07.007

Utsaha, E. (2010). *A study of costs and benefits of Garbage Collection for Chiang Rai Municipality.* (Master of Accounting Independent Study), Chiang Mai University, Thailand.

Vučijak, B., Kurtagić, S. M., & Silajdžić, I. (2016). Multicriteria decision making in selecting best solid waste management scenario: a municipal case study from Bosnia and Herzegovina. *Journal of Cleaner Production*, *130*, 166-174. DOI: http://dx.doi.org/10.1016/j.jclepro.2015.11.030