IGES Policy Report 2012-02

A Guide for Sustainable Urban Organic Waste Management in Thailand:

Combining Food, Energy, and Climate Co-Benefits




Sustainable Consumption and Production Group, Institute for Global Environmental Strategies (IGES)

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A Guide for Sustainable Urban Organic Waste Management in Thailand: Combining Food, Energy, and Climate Co-benefits

The Institute for Global Environmental Strategies (IGES) is an international research institute conducting practical and innovative research for realising sustainable development in the Asia-Pacific region.

The Sustainable Consumption and Production (SCP) Group aims to contribute towards sustainable patterns of consumption and production in Asia, with a focus mainly on low and middle income countries in the region. Special attention is given to the flows of materials through society, activities by consumers and producers, and the environmental impacts associated with material flows. The group's research is based on life-cycle thinking and explores how different actors, institutions, and policies can influence society's utilization of natural resources in a more sustainable direction.

Sirindhorn International Institute of Technology (SIIT) is a semi-autonomous international institute established under the statute of Thammasat University. SIIT is a well-known institute in terms of modern curriculum and research work that strongly responds to the needs of society, including environmental related issues. The faculty members at SIIT work in close proximity with government, private sectors, and citizens toward sustainable development of the country.

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Foreword

The Institute for Global Environmental Strategies (IGES) is an international research institute conducting practical and innovative research for realising sustainable development in the Asia-Pacific region. During 2009-2011, IGES received funding from the Asia-Pacific Network for Global Change Research (APN) through the APN CAPaABLE Programme for the project *Promoting Sustainable Use of Waste Biomass in Cambodia, Lao People's Democratic Republic and Thailand: Combining Food Security, Bio-energy and Climate Protection Benefits*. This multilateral, collaborative project aims to promote the use of climate-friendly technology for waste biomass conversion for food and energy production in Cambodia, Lao PDR, and Thailand.

In the three studied countries, the problem of managing urban organic waste is more severe than agricultural waste management, while the situation and progress on solid waste management varies significantly. The idea of country-specific publications to facilitate the implementation of urban organic waste utilization technology was thus born. Through these publications, it was envisioned that experiences and lessons learnt in Thailand, which is more advanced in waste biomass utilization, could be shared with and transferred to neighbouring countries in the form of South-South cooperation.

In this report, the authors describe and analyze the current situation of urban organic waste management in Thailand through field surveys and interviews with local stakeholders, including national and local governments, the private sector, and non-governmental organizations. In addition, the authors introduce various organic waste utilization technologies that are implemented in Thailand. In the latter part of the report, the authors provide a comparative analysis of urban organic waste utilization technology. They emphasise that careful selection of technology and proper implementation is required to ensure successful adoption by local governments, and they provide a practical guide for technology selection and proper implementation in the latter part of this report.

I congratulate the authors for completing this challenging assignment and believe that the findings will have value for local governments, policy makers and practitioners responsible for organic waste management, not only in Thailand, but also in other countries at a similar stage of economic development and facing similar waste management challenges.

Hideyuki Mori

President
Institute for Global Environmental Strategies

Foreword

Sirindhorn International Institute of Technology (SIIT) is an international educational institute in Thailand that emphasizes producing high-quality graduates and research of faculty members that responds to social needs. Cooperation between IGES and SIIT under APN CAPaABLE Programme, not only means an expansion of research networks, but also an answer to the needs of society to improve well-being and quality of life.

In Thailand, solid waste has been identified as one of the major environmental problems due to the fact that the waste generation rate has increased drastically together with a lack of awareness of local citizens. Local governments who are responsible for the management of solid waste often lack the capability to solve problems as a result of financial and personnel constraints.

One common problem for local governments is to select appropriate waste treatment technology. It is, therefore, important for most local governments to understand the differences between various types of technology available. The authors of this report have reviewed the status of solid waste management issues and also intensively studied country specific waste management technology being used. Such information is made available to local governments both in English and in local languages in order to strengthen clear understanding of the technology available. The implementation of solid waste management projects, especially those that deal with organic waste, is made easier by leaning from practices of other cities that are included in this report.

Apart from being able to select appropriate technology for each locality, the local governments are now equipped with the knowledge of the benefits of proper solid waste management, which include food, energy, and climate benefits. Extension of this knowledge to local citizens, together with other organizations will progressively lead the countries toward sustainable consumption and production.

I wish to express my sincere appreciation to the authors for their dedication to produce high quality report that will assist all stakeholders in solid waste management to reach national goals for sustainable waste management.

Prof. Chongrak Polprasert

Director
Sirindhorn International Institute of Technology

Preface

The objective of this report is to facilitate local governments in decision making and implementation of urban organic waste utilization projects that can contribute to sustainable solid waste management and national agendas on food, energy, and climate change. This report provides an overview of national policy, regulations, and institutions related to municipal solid waste management, and examples of municipal solid waste management practices in some cities. Furthermore, this report reviews advantages and disadvantages of each technology. In the latter part, this report provides guidance for technology selection and implementation of technology that is selected.

Organic waste is the major composition of municipal solid waste in developing Asian countries. Most of this waste is being discarded by means of open dumping and landfill. Thus, it is generally known as a food source of pest and disease carriers such as houseflies and rodents. In addition, it degrades rapidly and generates foul odor and polluted areas.

On the other hand, this waste can be used as a source of nutrients for soils and bio-energy. In addition, proper management of this waste can significantly contribute to climate change mitigation. Some municipalities see these benefits as an opportunity to improving their waste management practices. Some of them implement organic waste utilization projects such as composting and anaerobic digestion. However, many implementers confront challenges and constraints during the implementation. Therefore, other municipalities hesitate to implement similar activities.

Thailand, a developing Asian country, set a national goal to promote 3R (reduce, reuse, recycle) and increase utilization of organic waste. There are many pilot projects funded by various donors that are implemented by local governments. Lesson learned from these projects would be beneficial for not only other local governments in Thailand but also for other developing countries which have similar local circumstance and socio-economic conditions.

The earlier version of this report was published in Thai and distributed to local governments and other stakeholders participating in the workshop "Capacity Building on Accounting and Utilizing GHG Emission Reduction Measures for Local Waste Management Actor in Thailand" held on 25-27 January 2012 in Bangkok, Thailand. The workshop was co-organized by the Institute for Global Environmental Strategies (IGES), Sirindhorn International Institute of Technology (SIIT), and Pollution Control Department (PCD) with financial support from the Ministry of Environment of Japan (MOEJ) and Asia-Pacific Network for Global Change Research (APN). The organizers are impressed with positive responses from participants and their willingness to implement urban organic waste utilization projects.

The authors believe that this guide would also be useful for other local governments in Thailand and other countries that could not attend the workshop. Therefore, the authors revised the document, rearranged the story-line, and brushed-up the language. The Thai version is also being revised according to this English edition which will be useful for many local governments that are not familiar with a foreign language.

In addition to this report, there is guidance for promoting urban organic waste utilization projects that reflect local conditions and capacities of local governments in Cambodia and Lao PDR, which are also available in both the local language and English.

The authors welcome feedback and comments on this guide, which can be sent to Dr. Janya Sang-Arun (*sang-arun@iges.or.jp or janyasan@gmail.com*) and Dr. Alice Sharp (*alice@siit.tu.ac.th*).

Janya Sang-Arun

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Preface

Selection of solid waste management technology in Thailand has proved to be one of the difficulties for local governments since the municipality officers may not be able to make such decision by themselves. Consequently, many municipalities tend to end up with very advanced technology that does not fit with the characteristics of the waste that they have to deal with. This report focuses on treatment technology for organic waste as the authors believe that proper treatment of organic waste, which is the major component of solid waste in Thailand, will help reduce the quantity of waste entering final disposal sites. Additional benefits from the treatment of organic waste are also emphasized in order to provide incentives and raise awareness of local citizens.

This report covers five main types of technology: composting, anaerobic digestion, mechanical-biological treatment, biodigestion, and landfill gas recovery from sanitary landfill. The authors have travelled to various cities that operate each type of technology to collect waste management data as well as to collect baseline information for each technology.

Technologies were then compared based on a set of 12 criteria such as suitable waste characteristics, products from treatment technology, contribution to food security, contribution to energy security, and contribution to climate change mitigation. Each of the studied technologies has different advantages and disadvantages, thus it is not possible to rank the priority of technologies to be used. Decision makers should make use of information provided in this report as a guideline and ensure that the selected technology corresponds to local conditions and provides the highest combined benefits.

The authors are well aware that technology development is progressing at a very high speed, therefore, this report shall be used as the status quo of organic waste management in Thailand. Other countries that share the same social characteristics may also apply the knowledge from Thailand to their specific conditions. Additional comments, suggestions, best practices, and lessons learned from all related parties are all welcome for the benefit of global society.

Alice Sharp

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Acknowledgement

The authors owe a debt of gratitude to the Asia-Pacific Network for Global Change Research (APN) for funding the development of *A Guide for Sustainable Urban Organic Waste Management in Thailand: Combining Food, Energy and Climate Co-benefits* through the APN CAPaBLE Programme in FY2009 and FY2010. We are also grateful to the Ministry of Environment, Japan for providing the necessary financial support to publish the report and organize the capacity building workshop for local governments in Thailand.

The authors are also grateful to all stakeholders in Thailand who kindly donated their time, providing us valuable information which was useful for development of this document. Furthermore, the authors would like to thank Dr. Magnus Bengtsson (IGES) and Ms. Ainhoa Carpintero (UNEP.IETC) and Prof. Chettiyappan Visvanathan (AIT) for their substantial comments on the drafts of the report.

Last but not least, we sincerely thank the Pollution Control Department (PCD) for their great support as co-organizer of the workshop in Thailand.

15 May 2012

The authors

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Acronyms

1 Baht	Thai currency, equivalent to 0.0334 USD
3Rs	Reduce, Reuse, Recycle
AD	Anaerobic digestion
AFP	Area-Function-Participation
B.E.	Buddhist Era
BMA	Bangkok Metropolitan Administration
BOD	Biological oxygen demand
CBM	Community based solid waste management
CDM	Clean Development Mechanism
C/N Ratio	Carbon per Nitrogen Ratio
DOLA	Department of Local Administration
FET	Front-End Treatment
GHG	Greenhouse gas
GTZ or GIZ	Deutsche Gesellschaft für Internationale Zusammenarbeit
I-TEQ	International-Toxicity Equivalents
JBIC	Japan Bank for International Cooperation
JOECF	Japanese Overseas Economic Cooperation Fund
Kg	Kilogram
$Kg_{VM}/day.m^3$	Kilogram volatile matter per cubic meter per day
Km	kilometer
Km^2	Square kilometer
kWh	Kilowatt-hour
LFG	Landfill gas
MBT	Mechanical-biological treatment
MEA	Metropolitan Electricity Authority
MoIND	Ministry of Industry
MoINT	Ministry of Interior
MoNRE	Ministry of Natural Resources and Environment
MoPH	Ministry of Public Health
MSW	Municipal solid waste
Mt	One million tons
NCM	Nakhon Ratchasima City Municipality

NEB	National Environmental Board
NEQA	Enhancement and Conservation of National Environmental Quality Act
ng	1/1,000,000,000 gram
NGO	Non-governmental organization
Nm^3	Normal cubic meter
PAO	Provincial Administration Organization
PCD	Pollution Control Department
PCOA	Public Cleanliness and Orderliness Act
PPP	Polluter Pay Principles
RCM	Rayong City Municipality
RDF	Refuse Derived Fuel
SWM	Solid waste management
TAO	Sub-district Administration Organization or Tambon Administration Offices
tCO_2eq	Ton carbon dioxide equivalent
Ton	1,000 kilograms
UNFCCC	United Nations Framework Convention on Climate Change
USD	U.S. dollar

Executive Summary

Organic waste utilization in Thailand

- Most waste in Thailand has high organic composition, similar to other Asian countries. It has potential for utilisation for food and energy production. However, these wastes are being dumped into landfills and they release pollutants, including greenhouse gas into the environment.

- Some municipalities have initiatives on diversion of waste from final disposal site (e.g. composting in BMA, anaerobic digestion in Rayong, MBT in Phitsanulok). In addition, BMA installs landfill gas recovery systems to utilize methane gas for electricity generation.

- Organic waste separation at source is being promoted in some cities. However, it is not sustained due to various reasons such as the system to receive waste for further treatment is not well maintained, markets of products are not well established, or economic incentives are not significant.

- Increasing utilization of urban organic waste can significantly contribute to improve the urban solid waste management, and minimize environmental impacts from the final disposal site in Thailand. In addition, depending on the technology employed, it can contribute to increasing crop productivity, provide alternative energy, reduce greenhouse gas emissions, enhance resource efficiency, and generate income. Urban organic waste utilization can contribute to a national policy on creating a recycling society.

- To strengthening the 3R implementation, the Pollution Control Department (PCD) drafted the National 3R Strategy and the 3R Act to promote and support the 3Rs implementation in Thailand. The 3R Strategy aims to increase organic waste utilization by 50% before 2026. This target can greatly contribute to climate change mitigation by avoiding landfill gas emissions, supply organic fertilizer for cultivation, and generating alternative energy. Unfortunately, these drafts were not yet approved or entered into force.

Organic waste utilization technologies employed in Thailand

- Each municipality employs a different waste management system but all of them, to some extent, implement urban organic waste utilization technology. Technologies listed in this report include centralized composting and landfill gas recovery, as used in the Bangkok Metropolitan Administration, anaerobic digestion (AD) system of the Rayong City Municipality, mechanical biological-treatment (MBT) at Phitsanulok City Municipality, integrated solid waste management technology of Nakhon Ratchasima City Municipality, and community composting and bio-digestion at Kradangnga Municipality.

- Composting, anaerobic digestion and bio-digestion are suitable for sorted organic waste while MBT and sanitary landfill with gas recovery are appropriate for unsorted waste.

- Composting technology is varied from a simple one like windrow composting that is applied on a small scale at household and community levels to a complicate one like in-vessel composting that is implemented in BMA. Composting can contribute to food security and climate change mitigation. Compost can be sold for financial revenue. However many municipal composts are distributed as incentives for waste separation.

- Anaerobic digestion is a complicated and expensive treatment compared to composting. However, it can contribute to food, energy and climate co-benefits. Under good management, anaerobic digestion releases a smaller amount of GHG emissions than composting. In addition, anaerobic digestion can treat liquid waste efficiently, while compost requires a proper adjustment of moisture content. However, an anaerobic digestion system requires enough quality waste input to ensure sufficient gas for energy use.

- Bio-digestion is a new technology in Thailand. Therefore it is very expensive in terms of capital investment per ton of waste. However, the cost is affordable by small municipalities as the system is designed for a small scale treatment facility. This system can be considered as pre-treatment prior to composting and anaerobic digestion as a system can efficiently separate solids and liquids. The solid fraction can be applied directly as soil additive. The liquid fraction can be processed by either anaerobic digestion or bio-extraction (fermentation). The discharge after fermentation can be used as a soil additive, thus increasing crop productivity. There is no concise investigation on GHG emissions reduction; however it can be assumed that it is similar to in-vessel composting.

- MBT is an alternative to pre-treatment for unsorted waste prior to landfill. It can contribute to extending the lifetime of landfills, enhancing resource efficiency, and avoiding greenhouse gas emissions. The GHG emission reduction potential of MBT is similar to composting.

- These four organic waste treatment technologies are preferable to sanitary landfill with a gas recovery system in terms of effectiveness of enhancing resource efficiency, reducing environmental impacts, and mitigating climate change. However, sanitary landfill gas recovery is a desirable option where the municipality does not have an organic waste separation program and the Central Government provides a feed-in tariff for power generation.

Guides for technology selection and successful implementation of urban organic waste utilization projects

- As the size of local administrative offices varies, the ability in solid waste management is also different. Common constraints that can be found include lack of trained personnel, and financial constraints as technology can be expensive for a local government to purchase.

- Appropriate technology for one locality does not mean that it is appropriate for other places. Selection of technology should be made based on local conditions, budget availability, personnel skill requirements, users, or marketing of the products, and so on.

- In the selection of appropriate urban organic waste utilization technology for each locality, there are at least two main groups of criteria that the local government authorities should take into consideration: technical criteria (e.g. characteristics of municipal solid waste, effectiveness in waste utilization, land area required, operation and maintenance procedure, flexibility of the system, environmental impacts) and economic criteria (e.g. capital investment, operation and maintenance costs, income/by-products from the treatment). Sometimes, the most environmental friendly technology may not be selected due to the constraints on technology and economic issues. Public hearings should be carried out prior to technology selection in order to minimize risk of: termination of the project, due to strong public opposition, or failure in implementation due to lack of public cooperation.

- Even though an organic waste utilization project is introduced, waste reduction should be promoted to maintain or decrease the total waste generation because the waste collection capacity of local governments is limited.

- Once the selected technology acquires sorted organic waste input, such as composting, anaerobic digestion and bio-digestion, the local governments should establish supporting mechanisms which includes improving waste separation and collection systems, encouraging public participation and increasing local capacity (both local government and communities). Otherwise, the local governments will confront various constraints and may have to terminate the project.

1.
Introduction

1. Introduction

1.1 Background of the Report

Municipal solid waste management in Thailand has long been considered as one of the most severe environmental problems. As the country grows economically, the quantity of solid waste has also increased while many of the existing disposal sites have reached carrying capacity. Obtaining new disposal sites faces several constraints. First of all it is difficult for a local government to secure a budget to buy a large land area to be used as a solid waste disposal site. Secondly, even if there is a resource to buy new disposal site, there is also a problem of public opposition, to construct a solid waste disposal site near their communities. Lastly, when a local government selects technology to be used at a disposal site, they do not have sufficient scientific information to support their decision making process. Consequently, some technology used may not be suitable with the characteristics of the solid waste produced.

In terms of the agency responsible for solid waste management, local governments are usually designated to be responsible for providing solid waste management services. They also have the sole ownership right over waste once it has been placed outside a home or building for collection. However, not all local governments can properly manage their solid waste as they do not have sufficient trained staff or there is a lack of budget for investment in solid waste management. Immediate solutions to solid waste problems thus, are open dumping and landfill as these are cheap disposal methods with minimum skills required. The complexities of solid waste management become the challenges for authorities as each type of waste requires a unique treatment and management scheme.

Realizing that the mismanagement of solid waste could bring about other irreversible damage to human health and ecosystems, the Government of Thailand has given priority to the problem and aims to promote effective and appropriate technology to be used in solid waste management.

When solid waste is properly managed, various benefits can be derived from the action. For instance, pressure on environmental quality will be minimised and human health will be protected as direct benefits. Other benefits include job creation and income generation for communities and obtaining by-products such as feed for animals, compost for soil improvement and crop production, as well as biogas and fuel briquette for energy use, at the local levels. On the global level, appropriate solid waste management can contribute to the reduction of greenhouse gas (GHG) emissions.

It is widely accepted that the emissions of GHG have increased the degree of impacts of global warming. Municipal solid waste (MSW) is one of the important sources for GHG emissions. A study on GHG emissions from MSW in ten Asian countries suggested that per-capita GHG emissions from MSW have increased substantially (Sang-Arun and Bengtsson, 2009; Sang-Arun et al, 2011a). This is the result from increasing waste generation and improper waste management systems employed in those countries.

Regarding GHG emissions from various types of waste, organic waste has contributed the most in this aspect. In most developing countries, where organic content of waste is high, improper management of waste (e.g. open dumping and landfill of organic waste without gas recovery and open burning of plastic waste) may lead to higher GHG emissions in the future. Thailand is no exception. Due to its MSW containing a high proportion of organic waste, it is also facing the problem of GHG emissions from landfill, while most local governments do not have sufficient budget and staff with technical and managerial skills to administer and improve the waste management systems.

On the global level, a solid waste management system that may reduce GHG emission has widely gained public acceptance. International funding agencies as well as the national government have allocated a certain amount of budget for local capacity building for GHG emission reduction programs. Local government offices, should, therefore, perceive appropriate solid waste management with the aim to reduce GHG emissions as their priority, in order to secure a budget and increase capacity of local government staff.

This study covers the review of various types of urban organic waste treatment and utilization techniques, ranging from a technique that transforms waste to energy to a technique that promotes the utilization of waste, and a technique that reduces the quantity of waste entering disposal sites. Also covered in this study are techniques currently available in Thailand as well as a comparison of the feasibility of each technique. The report intends to facilitate local government authorities and decision makers to select an appropriate technique for each locality. Thus, urban organic waste can be properly treated; thus reducing its impacts on environment and climate.

The report consists of four main sections. The first part presents national policies and plans relevant to solid waste management, and legislative and institutional frameworks on solid waste management in Thailand.

The second part reviews the current situation of solid waste generation and management in Thailand. Data from various cities are presented in order to give a clear picture of the situation on municipal solid waste management systems employed. Cities covered in this study are Bangkok Metropolitan Administration (BMA), Nakhon Ratchasima, Koh Samui, Rayong, and Phitsanuok. Selection of cities were based on reviews of secondary data on existing available technology.

The third part disseminates organic waste utilization technology employed in Thailand. Technologies included in this part are composting, anaerobic digestion, bio-digestion, mechanical biological treatment (MBT), and sanitary landfill with gas recovery. Comparison of the technologies studied and criteria for selection of appropriate technologies are presented as a decision-making tool for local government authorities, private sectors, and other stakeholders.

The last part presents guidance for improvement of urban organic waste management including discussion of barriers, recommendations to improve waste separation and collection services, encouragement of public participation, and local capacity building.

2.
Existing municipal solid waste management policy, legislation and institutional framework in Thailand

2. Existing municipal solid waste management policy, legislation and institutional framework in Thailand

2.1 National Environmental Policies and Plans

According to the Natural Resources and Environmental Policy (1997-2016), the Government has implemented an environmentally sound waste disposal system and improves waste disposal capacity of local government agencies. The Government also encourages the role of private sector in research and development for recycling of raw material and clean technology. Additionally, the Government will strictly control the trans-boundary waste to prevent Thailand from becoming an end receiver of waste.

In response to the Natural Resources and Environmental Policy, the National Environmental Quality Management Plan has been developed every four years. The current plan is effective during 2007-2011. Targets of the policy on solid waste management are summarized as follows:

- Reducing municipal solid waste generation rate to not more than 1kg/person/day;
- Utilizing municipal solid waste by at least 30%;
- Increasing coverage of sanitary disposal of municipal solid waste by at least 40%;
- Separating municipal hazardous waste and safely disposing of it by at least 30%;
- Establishing a center for municipal hazardous waste management in each region.

To achieve these targets, integrated waste management is included in the national agenda.

2.2 National Integrated Waste Management Policy

Solid waste management in Thailand has moved toward national environmental policies and plans. The policy is developed mainly for integrated solid waste and wastewater management (UNEP, 2012).

The national integrated waste management policy aims to minimize waste generation by promoting 3Rs hierarchy including promotion of waste reduction and separation at source, waste materials recovery for composting, materials and energy uses. As for waste treatment facilities, the country will promote an establishment of central solid waste management disposal facilities with appropriate technology to be shared among municipalities. Privatization of waste management services is also needed in order to high efficiency as well as to attract investment from the private sector.

Concerning policy implementation, solid waste management shall employ Polluter Pay Principles (PPP) for all waste generators. Databases for waste management systems shall be updated and distributed to all parties involved. Law and regulation should be updated and revised when appropriate. Example of matters that should be regularly updated are service fees, subsidy schemes for waste reduction, and the program for local community to participate in solid waste management and monitoring of environmental quality.

Apart from the above mentioned measure, there are also other potential implementation measures including the promotion of environmental education, research and development in environmentally sound technologies, capacity building for government officers and related stakeholders, and raising environmental awareness among citizens and the local public.

2.2.1 *National municipal solid waste management policy*

In general, the national policy on municipal solid waste management has aimed at the control of waste generation rate, waste segregation, material recovery, and waste disposal technology that will have minimum impacts on local residents. The policy can be grouped into five major categories.

i) Monitoring of waste generation situations including waste characteristics and sources of waste generation.

ii) Assistance to local government authorities both financially and technically. The assistance shall cover the whole waste management hierarchy starting from source separation, collection, transportation, material recovery, and disposal.

iii) Awareness raising for both local government authorities and public.

iv) Development of appropriate municipal solid waste management regulations and implementation guidelines.

v) Involvement of stakeholders in municipal solid waste management.

The policy can be achieved through two means of implementation, which are the national waste management plan and the provincial environmental quality management action plan.

2.2.1.1 *National waste management plan*

The national waste management plan was developed as a result of the cabinet resolution on January 21, 2003. The Ministry of Natural Resources and Environment (MoNRE) is designated as the responsible agency for municipal solid waste management. The plan was approved in 2004, and was adopted as a national agenda to emphasize the importance of appropriate municipal solid waste management. In general, the plan aims to fulfill two main objectives;

i) To effectively manage municipal solid waste following an integrated waste management concept. The plan emphasizes maximizing material recovery and minimizing the quantity of waste to be disposed of. The management scheme shall not have adverse impacts on environment and local communities.

ii) To promote participation of all stakeholders in municipal solid waste management in order to achieve the target set for waste generation rate and waste disposal.

2.2.1.2 *Provincial environmental quality management action plan*

The provincial environmental quality management action plan is prepared based on the concept of Area-Function-Participation (AFP), which has aimed for a management system that is suitable with the situation, problems, and resources of the locality. However, it is not limited to the development of a separate plan for each municipality or Sub-district Administration Organization (TAO), but also includes action plans for adjoining areas that may share both problems and resources.

2.3 National 3R strategy

The Pollution Control Department (PCD) has finalized the draft of the National 3Rs Strategy to achieve the targets of integrated solid waste management that focus on the 3Rs (reduce, reuse, recycle). The 3Rs strategic plan aims to reduce waste generation and enhance waste segregation, reuse, and recycling in every community.

The strategies include promotion of resource - efficiency, sustainable consumption, waste reduction and recycling, and technology - based treatment and disposal. The strategies cover whole stages of resource life cycle:

i) Production and distribution – enhance proper designing of goods and packages, promote manufacturing and distribution of eco-friendly products, etc.;

ii) Consumption - increase public participation in using reusable, recyclable, and eco-friendly products, etc.;

iii) Reuse, recycling, treatment, and disposal - promote waste separation at source, enhance the use of biodegradable waste for soil amendment and energy use, encourage the use of non-recyclable waste for thermal recovery, etc.

The national targets for reduce, reuse, and recycle under the national 3Rs strategy are shown in Table 2.1. The government aims to increase recovery rate from 22% to 30% by 2016, 62% by 2021, and 90% by 2026. Currently, organic waste utilization is not widely practiced. Therefore, the target was set to 5% by 2016. However, it is expected that Thailand could achieve a higher organic waste utilization rate of 30% by 2021.

2.4 National Climate Change Strategies

Thailand reported to the United Nations Framework Convention on Climate Change (UNFCCC) that GHG emission from the solid waste treatment in 2000 was 4.89 $MtCO_2$ equivalents which were approximately 2.1% of total GHG emissions (ONEP, 2010). Emissions from solid waste management tend to increase over time due to population growth and changes in consumption patterns. Sang-Arun and

Table 2.1 Targets for reduction, reuse, and recycling

Strategies	Reduction targets (%)		
	1-5 years (2012 – 2016)	5-10 years (2017 – 2021)	> 10 years (2022 – 2026)
1. Waste reduction	1	3	5
2. Utilization of solid waste and recycling materials			
2.1 Material recycling	20	22	25
2.2 Waste to energy (thermal recovery)	5	10	15
2.3 Biodegradable recovery (composting, anaerobic digestion)	5	30	50
3. Total recovery	30	62	90
5. Total achievements (targets 1, 2)	31	65	95

Source: Draft of National 3Rs Strategy, PCD, 2011

Bengtsson (2009) roughly estimated GHG emissions from landfill of food and paper waste in Thailand and found that the current GHG emissions can be as high as 5.3-13.2 $MtCO_2$ equivalents due to the increase of waste generation, increase of waste collection services, and upgrading of open dumping to landfill.

Due to the growing GHG emissions from the waste sector, the National Climate Change Strategies (2007-2011) put the waste sector as the second priority after the energy sector. The National Climate Change Strategies include reducing organic waste composition in waste for disposal, upgrading waste disposal technology from open dumping to sanitary landfill, and promoting the 5Rs (reduce, reuse, recycle, refill, repair) for waste management. Waste separation is promoted to enhance waste utilization and resource recovery. Waste to energy and composting are recommended.

2.5 Overview of legislative framework

The regulations related to municipal solid waste management (SWM) in Thailand can be stratified into three levels; national, provincial, and local levels. At each level, there are a number of Laws/Acts, Regulations, Standards, and Technical Guidelines overseeing the supervision of solid waste generated in the country. Significant legislation is summarized in Table 2.2. The Public Health Act is the main law that local governments are obliged to follow.

In general, these laws at the national level are focused on controlling the disposal of waste that is generated, which is not associated with the national policy on resource recovery and 3Rs. Therefore, PCD drafted a master law to promote waste reduction, reuse, and recycling.

Details description of some legislation can be found in Appendix I[1].

2.6 Institutional framework

Institutions involved in SWM are distributed into three administrative levels; national, provincial, and local levels.

2.6.1 *National level*

There are four ministries: the Ministry of Natural Resources and Environment (MoNRE), the Ministry of Public Health (MoP), Ministry of Industry (MoIND), and the Ministry of Interior (MoINT), involved with agencies under each of the ministries to oversee the issue of solid waste management.

Principally, the ministries set the national environmental policy and the departments and agencies under the ministries are responsible for implementing the provisions of the law through regulations and technical guidelines. The diagram showing central government organizations related to the SWM is presented in Figure 2.1.

In respond to NEQA 1992, the National Environmental Board (NEB) has been formed to oversee the management of the country's natural resources and environmental quality. However, under Section 18 of the Public Health Act of 1992, the disposal of sewage and solid waste in the area of any local government shall be the mandate and duty of such local government.

2.6.2 *Provincial and local levels*

Local administration is classified into five classes of local self-government units:

- Provincial Administration Organization (PAO)
- Bangkok Metropolitan Administration (BMA)
- City of Pattaya
- Municipalities (with three sub-classes: City, Town, Sub-district)
- Sub-district Administration Organization (TAO)

These local government authorities are given their legal status by the Parliament. Forms and characteristics of local government are summarized in Table 2.3. Details regarding institutional framework can be found in Appendix II.

At the provincial and local levels, the Provincial Administrative Organizations (PAO), municipalities and Tambon (Sub-district) Administrative Organization (TAO) are primarily responsible for waste collection, transport, treatment, and disposal. During the last few years, the government has implemented the Decentralization Action Plan in order to transfer functions, budget, and personnel from the central government to nearly 8,000 local governments.

[1] Parts of Summary of Regulatory Framework appearing in Table 2.2, Appendix 1 and Institutional Framework in Appendix 2 were previously published in many reports under UNEP Waste Management Focal Area. Detailed reports can be downloaded from http://www.unep.or.jp/ietc/spc/activities/GPWM/table3_projects.asp under waste plastic project for Bangkok and Chiang Mai.
It should be noted that the translation of Thai laws can be found in many websites such as:
http://www.mekonglawcenter.org/download/0/thai.htm
http://www.pcd.go.th/info_serve/en_reg_relatedlaw.html
http://www.env.go.jp/earth/coop/oemjc/thai/e/thaie3.pdf

Table 2.2 Summary of regulatory framework related to SWM in Thailand.

Focal Area in Waste Management Stream	Policies/Plans	Laws/Acts	Regulations/Standards
Overall	National Solid Waste Management Policy	The Constitution of the Kingdom of Thailand B.E.2550 (2007)	None
	Framework for Country's Environmental Quality	The Enhancement and Conservation of National Environmental Quality Act (NEQA), 1992	• Notification of the Ministry of Science, Technology and Environment, Issued under the NEQA, and published in the Royal Gazette Dated 7 August, 1997 • Notification of the Ministry of Science, Technology and Environment #3, Issued under the NEQA, and Published in the Royal Gazette Dated 13 February, 1996 • Notification of the Ministry of Science, Technology and Environment, Re: Specifying Conditions, Procedures and Guidelines for Preparing Reports on Environmental Impact Assessment.
Sanitation and disposal of solid waste	None	Public Health Act, 1992	
Household waste management	None	Public Cleanliness and Orderliness Act (PCOA), 1992	• BMA Ordinance: Disposal of Garbage, Refuse, and Unclean Things 1978 • BMA Ordinance: Specifying Requirements for Construction of Building and Public Utilities 1996 • BMA Ordinance: Control of Waste Collection, Haulage, or Elimination Business which is made for Consideration as Service Fee 1998
Industrial Waste	National master plan on the cleaner production and cleaner technology	Factory Act, 1992	• Notification of the Ministry of Industry Concerning Factory Wastes 1988
Hazardous Waste Management		Hazardous Substance Act, 1992 Hazardous Substance Act, 2001	• Notification of Ministry of Industry Concerning Storage and Disposal of Toxic Substances 1982 • Poisonous Substances Act 1967, amended in 1973 • Notification of Ministry of Industry Concerning Industrial Effluent Standards 1982 • Notification of Ministry of Industry concerning manufacture and use of toxic substances 1982 • Notification of Ministry of Industry Re: Hazardous waste manifest system B.E. 2547 (2004)

Table 2.2 (continue)

Focal Area in Waste Management Stream	Policies/Plans	Laws/Acts	Regulations/Standards
Source Reduction	Strategic Plan on Packaging and Packaging Waste Management	Industrial Estate Act, 1979	• Solid waste management standard, DOLA • Manual of strategy and basic regulation for waste reduction and utilization, PCD
	None	Construction Building Control Act, 1979	
	None	City Planning Act 1975	
Segregation of waste	National 3Rs Strategy (draft)	3R Act (draft)	• Solid waste management standard, DOLA • Manual of strategy and basic regulation for waste reduction and utilization, PCD
Waste Collection	National 3Rs Strategy (draft)		• Solid waste management standard, DOLA • Manual of strategy and basic regulation for waste reduction and utilization, PCD • BMA's Technical Guideline for Solid Waste Operator
Landfills	None	Factory Act, 1992	• Notification of Ministry of Industry Concerning Storage and Disposal of Toxic Substances 1982
Incinerator	None		• Notification of the Ministry of Science, Technology and Environment B.E.2540 (1997) dated June 17, B.E.2540, published in the Royal Government Gazette, Vol. 114 Part 63, dated August 7, B.E. 2540 (1997) • Notification of Ministry of Natural Resource and Environment : Emission Standard for Infected Waste Incinerator published in the Royal Government Gazette, Vol. 120 Special Part 147 D, dated December 25, B.E. 2546 (2003) • Notification of Ministry of Natural Resource and Environment : Infected Waste Incinerator is designated as Pollution Point Source which its emission must be controlled published in the Royal Government Gazette, Vol. 114 Special Part 147 D, dated December 25, B.E. 2546 (2003)
Recycling	• Integrated waste management scheme • National 3Rs Strategy (draft)	3R Act (draft)	
Resource Recovery	• Integrated waste management scheme • National 3Rs Strategy (draft)	3R Act (draft)	

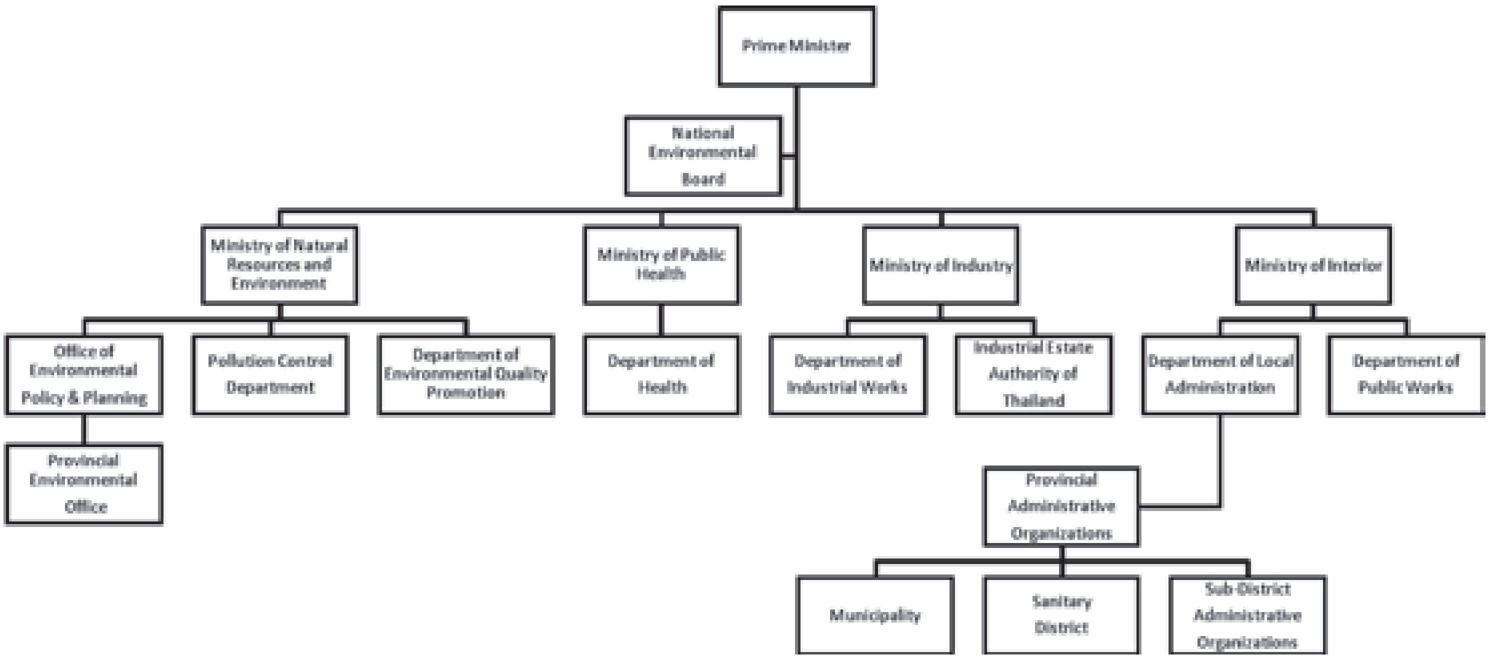


Figure 2.1 Central government organizations related to solid waste management

Table 2.3 Summary of forms of local governments in Thailand.

Form of Local Government	Population Size	Chief Executive	Legislative Body
1. Provincial Administrative Organization (75 Provinces)	300,000 – 1,700,000	Chief Executive, elected by popular votes	Assembly elected for a 4-year term, size varies with population
2. Bangkok Metropolitan Administration (BMA)	8,249,117 (2010)	Governor, elected by popular votes	One council member elected by votes in each electoral area
3. City of Pattaya	104,318 (2007)	Mayor, elected by popular votes	24-member council elected for a 4 year term
4. Municipality (1,619 municipalities in 3 categories)	Urban Population 7,000 – 300,000	Mayor, elected by popular votes	Council elected by popular votes
4.1 City Municipality (23 municipalities)	50,000 – 300,000	Mayor, elected by popular votes	24-member council elected for a 4 year term
4.2 Town Municipality (140 municipalities)	10,000 – 150,000	Mayor, elected by popular votes	18-member council elected for a 4 year term
4.3 Tambon Municipality (1,456 municipalities)	7,000 – 100,000	Mayor, elected by popular votes	12-member council elected for a 4 year term
5. Tambon Administration Organization (TAO) (6,157 organizations)	Rural population 200 – 40,000	Chief, elected by popular votes	Minimum 6-member council, consisting of 2 elected members from each village

Each office is independent in making decisions within legal boundaries. With reasonable cause, the local government may entrust any person with the solid waste management tasks on its behalf under the control and supervision of the local government or may permit any person to operate the disposal of sewage or solid waste.

In response to the national solid waste management plan and policy, the Department of Local Administration (DOLA) in collaboration with the Engineering Institute of Thailand under H.M. the King's Patronage published a Solid Waste Management Standard aiming at enabling local governments to implement the national policy effectively. The standard provided a framework, guidelines and recommendations to local authorities on solid waste administration, waste management plan, public participation, facility development, involvement of private sector, and technologies for solid waste treatment.

Based on this standard, composting is highly recommended for organic waste treatment, but compost quality control is required. Waste to energy is also promoted in the form of electricity generations and to be sold to the public grid with a premium price which can be calculated from the base-price of electricity plus an adder or feed-in tariff. As of 2008, the adder tariff from different raw materials varies; the adder tariff for biomass was 0.30-1.30 Baht/kWh while the adder tariff for waste was equal to 2.50-3.50 Baht/kWh.

2.7 Discussion on existing policy, legislation, and institution framework

The Government in Thailand intends to promote sustainable solid waste management by promoting the 3Rs and improving final disposal site. However, most local governments put more attention on improvement of final disposal sites as they experience negative environmental impacts and social resistance blocking accessibility to a disposal site. In addition, the local governments are more familiar with the end-of-pipe solution as it has less interaction with citizens.

The authors found that the implementation of the waste management measures may have not been carried out effectively despite the fact that the responsible authority for solid waste management is clearly specified by laws. This is due to various factors such as limited number of personnel and budget, political conflicts, capability of municipality staff, and lack of awareness and cooperation from residents. In order to increase efficiency of solid waste management, capacity of municipality staff must be built at all levels while providing an education on waste awareness for citizens to create appropriate behavior regarding waste and environment among stakeholders.

3.
Current municipal solid waste management in Thailand

3. Current municipal solid waste management in Thailand

3.1 Waste generation

In general, waste generation in Thailand has increased during 2000-2008 (Figure 3.1). However, there is fluctuation of waste generation in Bangkok, within the municipality and outside the municipality area. Waste generation in Bangkok has decreased after 2004 due to the implementation of the 3Rs policies for waste reduction, reuse, and recycling. Waste generation in municipalities increased continuously even after the 3Rs policy was introduced due to the increasing numbers of municipalities and increasing population in the municipality area. Consequently, the population and quantity of waste produced outside municipalities decreased.

On average, waste generation rate in Thailand is 0.63 kg/day/capita: 1.5 kg/day/capita in Bangkok, 1.0 kg/day/capita in municipalities and Pattaya city, and 0.4 kg/day/capita outside municipality areas (PCD, 2011).

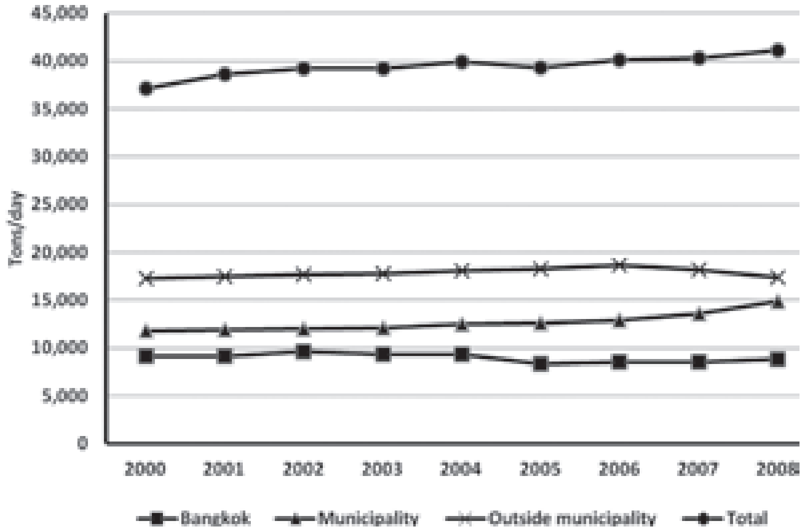


Figure 3.1 Trends of waste generation in Thailand during 2000-2008 (Compiled from Summary of State of Thailand's Pollution, Pollution Control Department)

3.2 Municipal solid waste characteristics

Geographical location, living style, consumption patterns, and regulation affect quantity and composition of the waste generated. However, most municipal solid waste in Thailand shares the same characteristics of high organic content followed by recyclable waste (Table 3.1 and Table 3.2).

It can be seen that the major component of waste in Thailand is of organic nature. A reduction in organic components of waste can drastically reduced the quantity of waste to be disposed of. Thus it is important to implement appropriate organic waste treatment technology in a way that waste components are utilized and eventually reduce the emission of greenhouse gases that is affecting humankind at the global level.

3.3 Municipal solid waste management practices

As it is stated in the nation's waste management policy, an integrated waste management system shall be implemented where appropriate; many local governments in the country have improved their waste management system to comply with the national policy.

An integrated waste management system is implemented in order to reduce the quantity of waste to be disposed of by the minimization of waste generation, utilization of waste (both reuse and recycling), and effective disposal technology to convert waste into valuable products. In general, there are four main components to be considered; waste reduction mechanisms, recycling systems, transportation, and disposal systems. However, the components can be modified in accordance to locality.

- *Waste reduction mechanisms*: campaigns on waste minimization should be implemented. Campaigns may include

Table 3.1 Waste compositions of different regions in Thailand in 2003.

Waste Components (% of wet weight)	Regions of Thailand					
	North	Central	North-East	East	South	Average
Organics and Food	63.81	64.49	69.55	59.34	59.10	63.258
Paper	7.18	7.31	6.01	8.40	10.24	7.828
Plastic	18.52	17.62	15.26	18.58	18.14	17.624
Glass	3.11	19.0	3.19	3.31	4.37	6.596
Metal	1.59	1.54	1.81	2.60	2.27	1.962
Wood	0.85	1.30	0.44	0.91	0.43	0.786
Rubber/Leather	0.32	0.36	0.49	0.57	0.63	0.474
Cloth	1.22	1.51	1.00	1.89	1.40	1.404
Other waste	3.40	3.99	2.28	4.43	3.44	3.508
Total	100	100	100	100	100	100
Waste Density (kg/m^3)	179.47	185.28	176.82	167.28	209.40	183.65

Source: PCD, 2003

Table 3.2 Waste compositions of selected municipalities (PCD, 2003)

Local Government	Waste composition (% of wet weight)									No. of households	Population	Waste generation tons/day
	Food	Paper	Plastic	Glass	Metals	Rubber/ leather	Cloth	Wood/ leaf	Others			
Chiang Mai City	54.00	11.00	15.10	9.60	2.10	0.90	2.60	1.20	3.50	67,010	174,235	265.00
Nakorn Sawan City	79.76	4.07	13.17	0.81	0.36	0.28	0.41	0.30	0.84	16,790	65,043	81.95
Nakorn Pathom City	76.90	4.64	13.65	0.46	0.97	–	0.91	1.82	0.65	28,279	93,554	196.46
Pathum Thani Town	69.00	6.46	13.95	5.53	0.71	0.36	2.72	–	1.27	5,324	18,916	34.05
Nonthaburi City	63.55	4.86	14.92	10.21	1.12	0.32	2.07	0.84	2.11	95,179	270,077	260.00
Samut Songkram Town	57.40	8.92	11.29	2.03	1.61	0.77	3.39	11.42	3.17	8,676	35,672	26.75
Phuket Town	65.64	6.56	19.28	4.09	0.35	0.03	0.64	–	3.41	*	67,164	144.40
Studied Cities												
Bangkok Metropolitan	42.68	12.09	10.88	6.63	3.54	2.57	4.68	6.90	10.04	1,625,438	5,759,726	8,897.00
Nakorn Ratchasima City	68.87	7.49	19.16	1.87	0.85	–	–	–	1.76	31,569	174,057	176.00
Rayong City	48.73	18.03	17.27	10.51	0.88	0.10	0.41	0.10	3.97	21,657	55,240	78.44
Koh Samui Town	58.83	8.07	13.61	10.04	1.93	–	2.29	0.76	4.47	15,476	38,380	47.98
Phitsanulok City	68.59	2.53	20.59	1.61	1.45	0.29	1.51	0.89	2.54	27,014	90,386	84.06

the reduction of packaging materials, utilization of environmental friendly products, minimization of the use of non-degradable materials, and education and awareness campaigns, for instance.

- *Recycling systems*: a system should be designed to cover all aspects related to recycling starting from waste separation at the source for reuse and recycling. Containers to promote waste separation and waste collection system should be arranged to support the recycling activities of the public. Recycling centers and other voluntary base activities should be promoted.
- *Transportation*: for short distances, waste should be transported directly to the disposal site. On the other hand, when longer distances are involved, transfer stations should be used to reduce the transportation costs.
- *Disposal systems*: an integrated system for waste disposal should be employed. Current disposal site can be transformed into a waste disposal center by including waste separation and a mixture of waste treatment systems such as composting, anaerobic digestion, and sanitary landfill equipped with landfill gas utilization systems.

Due to budget and personnel constraints, an integrated waste management practice is successful to some extent in some municipalities where local authorities put effort on mainstreaming education and awareness raising campaigns.

The practices of integrated waste management system to handle waste being generated include three major components: waste segregation at the source, waste collection and transportation, and waste disposal technology.

i) Waste separation at source

Waste separation is considered as an important component in an integrated waste management system. Separation can be done manually, mechanically, or both at the generation point. Equipment to support appropriate separation includes waste bins with proper labels and plastic bags of different colors to make it possible for waste collectors to segregate waste correctly.

At present, waste segregation at source is not formally carried out, although guidelines on a separation procedure exist (Figure 3.2). Most of the practices are at community level and the segregation is mainly for recyclable materials that have market value.

ii) Collection and transportation

A general MSW collection and transportation system consists of three main components: (1) household/building waste containers, (2) waste collection trucks, (3) waste collectors.

In order to have an effective waste collection system, waste collection stations should be identified, especially in highly populated areas such as housing estates, cafeterias, and movie theaters. Transfer stations may be needed when a large amount of waste is expected, together with a long distance to the MSW facilities. A typical transfer station consists of temporary MSW storage unit, transfer point, vehicles and equipment for MSW transfer and the procedures for operating and maintaining these facilities and equipment.

Figure 3.2 Waste segregation at the source is not generally practiced in BMA

In Thailand, local government offices such as municipalities and Tambon Administration Offices (TAO) are responsible for collection, transportation, and disposal. Waste collection in Bangkok is higher than 90% in contrast to 37% collected in municipality areas and 6% collected outside municipality areas (Kaosol, 2009).

iii) Waste disposal

In Thailand, open dumping is the most commonly used method of MSW disposal as a result from unavailable waste collection systems in many municipalities and TAO. Other commonly employed methods are landfill and sanitary landfill. As of 2009, there are 97 disposal facilities including 91 sanitary landfills, 3 incinerators, and 3 integrated-system facilities that are properly designed (Kaosol, 2009).

3.4 Examples of municipal solid waste management in studied cities

This study covers 5 cities which are Bangkok Metropolitan Administration (BMA), Nakhon Ratchasima City Municipality (NRM), Koh Samui town Municipality, Rayong City Municipality (RCM), and Phitsanulok City Municipality. Map and location of each city is shown in Figure 3.3.

3.4.1 Bangkok Metropolitan Administration (BMA)

Bangkok Metropolitan Administration (BMA), the capital city of Thailand, is located in the center of the country on the plain of the Chao Phraya river basin. The city is divided into 50 districts and 154 sub-districts. Urbanization has expanded to cover almost half of the city area. There are three main types of land use; residential area (23%), agricultural area (23.58%), and the remaining area for commercial, industrial, and government use.

With an area of 1,568.74km^2, the total registered population in Bangkok as of

Figure 3.3 Location of studied cities in Thailand

Source: http://www.nationsonline.org/oneworld/map/thailand_map2.htm

2008 was 5,710,883, which corresponded to approximately 9% of the total population of Thailand.

3.4.1.1 Solid waste generation and composition

The volume of municipal solid waste generated in BMA increased by 10% during 1980-1997 as a result of economic development and immigration of rural population to the city. BMA has introduced waste reduction and source separation program which reduced the waste generation figure by 1.5% during 2003-2007 (Figure 3.4).

In 2008, waste collection in BMA was 8,780 tons/day, which accounted for 21% of the urban solid waste generated in the country (PCD, 2009). In 2009, waste collection in BMA increased to 8,787 tons/day. The study on waste composition from the three disposal sites during 2000 to 2009 indicated that more than 60% of waste could be processed for reuse and recycling (Table 3.3). However, not all the recyclable waste is being utilized.

3.4.1.2 Solid waste management practices

In order to improve waste management of BMA, the office has divided waste management activity into four programs, which are 1) Waste reduction and separation, 2) Waste collection 3) Waste transfer and transportation, and 4) Waste treatment and disposal.

1) Waste reduction and waste separation for recycling
   BMA promotes waste reduction and separation for resource recovery, including campaigning for public awareness and cooperation. Waste separation at the source is promoted by introducing three waste bins for different types of waste as shown in Figure 3.5. The containers provided can be classified

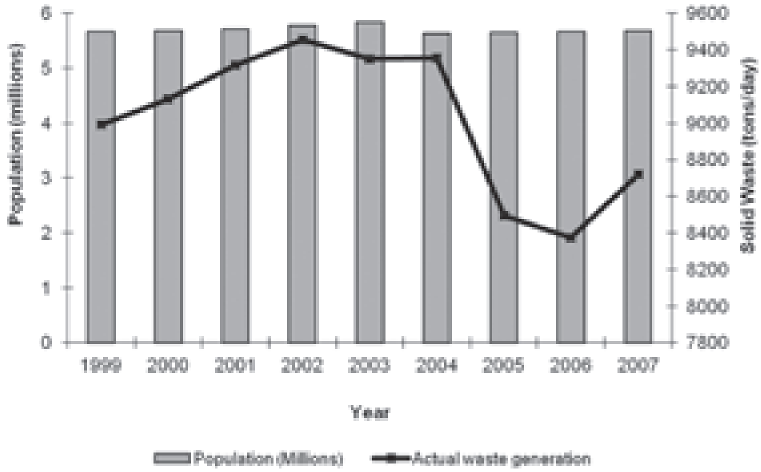


Figure 3.4 MSW generation in Bangkok in relation to the population growth and waste generation rate during 1999-2007 (Department of Environment-BMA, 2007)

Table 3.3 Composition of waste collected by BMA (Unit: percent)

Waste category/Use	Fiscal Year									
	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Composting Category	**60.41**	**61.00**	**49.32**	**49.25**	**54.51**	**50.53**	**51.06**	**49.66**	**50.02**	**50.01**
Food waste	46.88	46.92	34.16	30.59	34.74	44.32	44.99	42.11	41.95	44.34
Sticks and leaves	6.77	7.52	6.59	8.53	6.17	5.11	6.07	7.55	8.07	5.67
Others	6.76	6.56	8.57	10.13	13.60	1.10	0.00	0.00	0.00	0.00
Recyclable category	**6.38**	**5.85**	**15.08**	**10.62**	**8.13**	**9.69**	**10.44**	**13.68**	**9.93**	**10.29**
Recyclable paper	0.00	0.00	2.44	1.86	0.89	0.72	1.96	2.32	0.35	1.19
Recyclable plastic	1.73	1.49	4.37	3.53	2.42	2.55	3.77	4.87	3.86	3.25
Foam	0.59	0.42	1.02	1.35	0.98	1.20	1.44	2.01	1.22	1.44
Glass	2.57	2.30	5.07	2.55	2.97	3.16	1.65	2.72	2.55	2.70
Metal	1.49	1.64	2.18	1.33	0.87	2.06	1.62	1.76	1.95	1.71
Landfill category	**33.21**	**33.15**	**35.60**	**40.13**	**37.36**	**39.78**	**38.50**	**36.66**	**36.66**	**36.66**
Non-recyclable paper	8.66	8.58	11.14	11.55	9.51	8.93	9.83	9.40	10.62	10.70
Non-recyclable plastic	17.15	17.50	15.37	18.30	21.68	24.46	21.26	19.63	20.00	19.18
Leather and rubber	0.11	0.78	2.19	0.58	0.22	0.83	1.03	0.95	1.93	1.95
Clothes and textiles	6.43	4.00	4.58	8.10	4.77	4.58	5.2	5.28	5.31	5.52
Rocks and ceramics	0.51	1.00	0.58	0.68	0.34	0.53	0.26	0.61	0.99	0.81
Bones and shells	0.35	1.29	1.74	0.92	0.84	0.45	0.92	0.79	1.21	1.54
Total	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**

Source: BMA, 2010

into three types; food waste, recyclable waste, and household hazardous waste. However, as a result of low enforcement on waste segregation program, very limited number of community adopted the segregation program. A survey done by BMA indicated that 30% of residents in the metropolis are cooperating with the waste separation program.

Waste management at disposal sites is shown in Figure 3.6. It can be seen that the BMA could not recover the entire amount of waste appropriate for composting and recycling because waste separation at source is not efficiently practiced by residents.

BMA started to implement a policy to reduce waste by 10% per year from 2005. The city launched variety of campaigns to reduce and separate wastes at source. Consequently, the amount of waste collected was relatively constant, especially from 2007 to 2009. When comparing the amount of waste collected to the expected waste generated, it can be seen that the quantity of waste that was generated decreased. Costs saved are averaged at 1,000 Baht/ton. Estimated cost saved during the implementation years is shown in Table 3.4.

In total during this five years period, the BMA reduced the quantity of waste

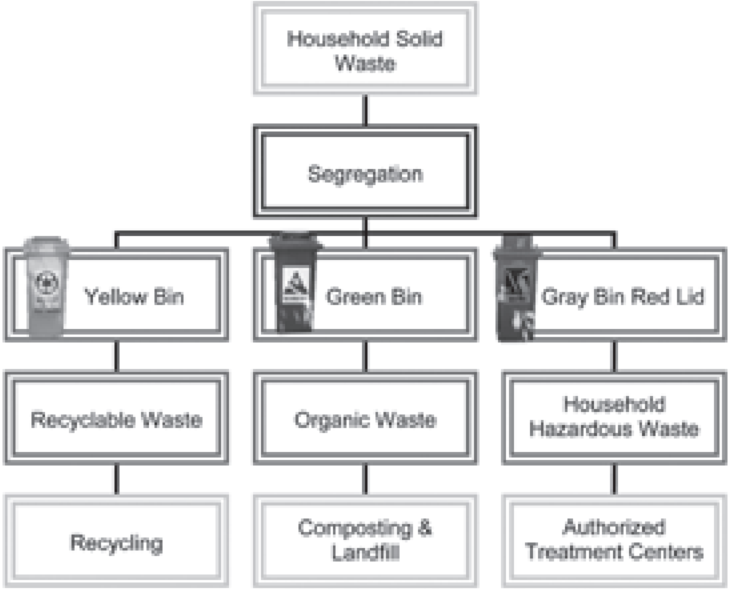


Figure 3.5 Sorting and management of solid waste in BMA (Department of Public Cleansing, 2002)

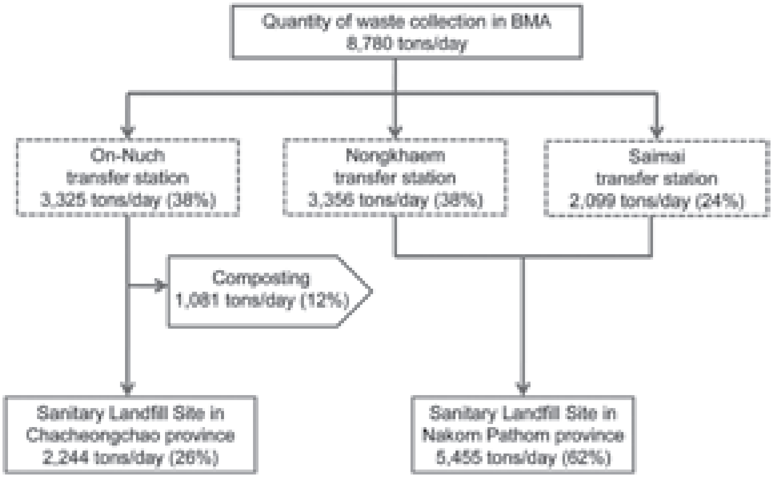


Figure 3.6 Flows of waste management in BMA in 2008 (PCD, 2009)

generated by more than 5,000 tons per day. The total cost saved during the period was approximately 1.9 Billion Baht.

The waste reduction campaigns contain three main principles to ensure suitability with each target group.

i) 3Rs Principles: These principles were used to encourage people

Table 3.4 Quantity of waste reduced after waste reduction campaigns and estimation of costs saved

Year	Expected waste generated (Tons/day)	Collected waste (Tons/day)	Waste reduced (Tons/day)	Estimated cost saved (Baht/day)	Total cost saved (Million Baht/ year)
2005	9,388	8,496	892 (9.60%)	892,000	325.58
2006	9,546	8,377	1,169 (12.30%)	1,169,000	426.68
2007	9,706	8,718	988 (10.20%)	988,000	360.62
2008	9,847	8,780	1,067 (10.84%)	1,067,000	389.45
2009	10,000	8,787	1,213 (12.13%)	1,213,000	442.75

Source: BMA, 2010

to make uses of food waste, sticks and leaves, as well as recyclable waste. The campaigns aimed for awareness raising and participation; encouragement in reusable waste separation; waste reduction to relieve the waste load transferred to disposal site; and resource uses and pollution minimization towards sustainable development.

ii) Zero waste management: It is based on the concept that "waste has its economic value where it can be reused". It aims to minimize waste and to eliminate the rest with efficient technologies. The concept implies the key messages, to choose raw materials that can be mostly recycled, to minimize waste volume, to produce environmental friendly goods, to encourage uses of items composed of recycled material, to collect a tax integrated with the raw material price, to improve local business development and to increase local job opportunities.

iii) Community based solid waste management (CBM): It relies on participatory activities in discussing and selecting the community solid waste management methods as well as in implementing and separating waste at the local level. In general, the recyclable waste was firstly screened out and sold. Food waste, sticks, and leaves were collected for composting with dry leaves as an input ingredient, for liquid biological fertilization, or feeding animals. There are also some encouragement measures such as the preparation of 2 bins for food waste and non-reusable waste, leading to keeping the area in front of the house clean, and a clean landscape. Waste collection of public services was also at a lower frequency due to smaller volume and odorless waste (no containers of food waste). Sometimes a community needs the waste collection service just once a week.

Many activities have been conducted to promote recycling and reduction of waste, both by public and private sectors and NGOs. The implementation of activities has shown improvement in waste recovery and recycling. The recovery rate of municipal solid waste has increased from 7% in 2000, to 22% in 2005.

In BMA, recycling practices are dominated by informal participation. An effort on recycling has been put on encouraging communities to establish waste banks (Figure 3.7) and composting facilities. A waste bank is a form of community or school activity that collects and sells recyclable waste in the same manner as a financial cooperative system. Under the waste bank program, households who participate in waste bank activities will receive the benefits, both in the form of money and improving environmental quality. Management of waste bank programs varies from place to place, however. A general waste separation campaign will be implemented, and recyclable materials were collected and stored at a community center. Separated waste will be sold regularly. Monetary benefits arising from selling of recyclable materials are returned to members of the project.

In general, waste separation for reuse and recycling is practiced throughout the waste stream due to its economic incentive. There are various stakeholders involve in this process: waste generators, waste pickers, and authorized waste collection personnel, as well as BMA's waste collection workers.

(a) Residents

Some residents separately store and sell the valuable items in their waste stream. In 2000, it was estimated that the residents of BMA separated and sold 1,500 tons/day of recyclable waste to junk shops.

(b) Waste pickers and tricycle waste buyers in towns.

Apart from household separation, remaining waste can be sorted for valuable items by informal sector such as waste pickers and tricycle waste buyers. Waste pickers search for valuable item and sell them to tricycle waste buyers or directly to the waste trading shops. Tricycle waste buyers purchase materials directly, both from waste generators and waste pickers. The Pollution Control Department has estimated that the number of tricycle waste buyers could be as high as 2,100 tricycles in Bangkok alone. The study also estimated that each tricycle waste picker/buyer can collect 158 kg/tricycle/day. Therefore, the amount of recyclable materials collected can be as high as 332 tons/day.

(c) Collection workers

BMA's collection workers also separate

Figure 3.7 Community Waste Bank for recyclable waste collection (Photo by Dr. Alice Sharp)

recyclable materials from the waste collected during their regular waste collection route. Each truck may stop during the trip to transfer station to sort out materials and sell these materials to waste traders located nearby to the transfer station. BMA's collection trucks can recycle an estimate of 413 tons of waste per day.

(d) Waste pickers at the transfer stations
Once waste has reached a transfer station, there are waste pickers who collect recyclable materials from waste temporally piled at the transfer stations and sell these to waste traders or sell directly to end-users.

2) Waste collection
BMA focuses on effective collection to minimize uncollected waste. The collection of solid wastes is done with a 2,610 vehicles fleet, and over 7,000 staff. Collection trucks are rented to solve vehicle unavailability and problems of vehicle maintenance. In fiscal year 2007, almost 65% of garbage trucks were rented. The maintenance operations of the fleet are managed separately by most of the 50 districts.

Effective waste collection requires public cooperation on proper time and places for dropping waste, to reduce uncollected wastes. Appropriate routing for collection trucks is required. The approaches employed are:

i) Assigning of waste dropping and collection schedule
- Main streets, minor streets and market places:
  a) 08:00 p.m. to 03:00 a.m.
  b) Collection completed by 06:00 a.m.
- Collection is made daily for communities, small roads and lanes. For areas inaccessible by collection trucks, volunteers collect waste at source and take it to a collection point.

ii) Waste collection by types and increase collection frequency.
- General wastes - Daily or every other day based on location.
- Recyclable wastes - Every Sunday
- Hazardous wastes - 1st and 15th of the month

At present, BMA has estimated that 99% of wastes generated were collected and transferred. The areas where waste is not collected are mainly new settlement areas. These areas normally have very narrow roads, which cannot be accessed by car or collector trucks, thus, leaving a huge quantity of solid waste in communities. In one of the studies on the waste management situation, it was found that the quantity of waste uncollected can be as high as 23% of waste generated in communities. In order to solve the problem of uncollected waste, the new settlement areas should be surveyed and recorded, and appropriate collection methods to be used with these areas should be identified to improve the efficiency of waste management system. In addition, to further improve waste collection, collection route maps should be re-arranged and information technology such as the Global Positioning System should be introduced.

3) Waste transfer and transportation
BMA contracted private operators to dispose of the waste at the sanitary landfill. The disposal site is located further from BMA. Therefore, three waste transfer

stations are established to reduce cost of transportation and public nuisance caused by waste transportation.

Each of the transfer site has the responsibility related to the solid waste transportation, sanitary landfill, repairing and maintenance of buildings, vehicles, machinery and equipment, providing equipment to facilitate and support for cleansing of collection trucks and other duties[2]. The names of the stations are as follows:

- On Nuch Solid Waste Disposal Center;
- Nong Khaem Solid Waste Disposal Center ; and
- Sai Mai Solid Waste Disposal Center

Waste collection trucks arrive in these transfer sites on a daily basis. Waste is shared among the three transfer stations. Three private firms were hired to take solid waste from transfer stations to be disposed in the nearest sanitary landfills (Table 3.5). The On Nuch Solid Waste Disposal Center has added the process of compaction and plastic wrapping before sanitary landfill. Each project is done based on contract agreement to transport solid waste from each transfer station to designated sanitary landfill sites.

Environmental conditions of the three transfer stations were found to be unsanitary due to piles of waste accumulated at the sites.

4) Waste treatment and disposal

Waste arrived at the transfer station will be classified based on their potential utilization (Table 3.6) as follows:

- Waste to be composted or fermented (50%),
- Waste to be recycled (10%), and
- Waste to be disposed of by landfill or incineration (40%)

The BMA could not recover the entire amount of waste appropriate for composting and recycling because waste separation at source is not efficiently practiced by residents. However, since 2005, BMA contracted a private company to operate a composting and material recovery facility that receives approximately 1,200 ton/day of unsorted waste. The facility is located at

Table 3.5 Summary of hiring the private sector to treat and dispose of solid waste

Treatment/Disposing Method	Transfer site	Sanitary landfill site	Term of Contract (Years)	Starting date
Sanitary landfill by compaction and plastic wrapping	On Nuch	Phanomsarakham, Chachoengsao	10	December 2005
Composting	On Nuch	Phanomsarakham, Chachoengsao	5	December 2010
Sanitary Landfill	Sai Mai	Kamphangsan, Nakornpathom	10	November 2005
Sanitary Landfill	Nong Kheam	Kamphangsan, Nakornpathom	10	November 2005

[2] http://office.bangkok.go.th/environment/pdf/swdisposaldiv.pdf

On Nuch waste transfer station. This facility can recover approximately 80 ton/day of recyclable waste and can produce around 300 ton/day of compost available for soil fertilization (Figure 3.8). Compost produced at On Nuch transfer station has been sold to households and agricultural farms at 250 Baht per 40 Kilograms of compost. The BMA compost has been used widely due to the quality control of compost product. The compost has been tested for desired compost quality.

The waste that cannot be composted is

Table 3.6 Waste composition bases on utilization capacity at BMA in fiscal year 2008

Type of Waste Utilization	Percent of waste at transfer Station			Average(%)
	On Nuch	Nong Khaem	Sai Mai	
Ferment Type	*52.04*	*51.49*	*46.53*	*50.02*
Food	45.65	41.29	38.90	41.95
Wood & Leaves	6.39	10.20	7.63	8.07
Others	–	–	–	–
Recycle Type	*10.74*	*7.97*	*11.09*	*9.93*
Paper (Recycled)	0.86	0.18	–	0.35
Plastic (Recycled)	3.27	2.67	5.65	3.86
Foam	1.18	1.35	1.12	1.22
Glass	3.79	1.49	2.38	2.55
Metal	1.64	2.28	1.94	1.95
Landfill type	*37.22*	*40.54*	*42.38*	*40.05*
Paper (non-recycled)	11.66	10.16	10.03	10.62
Plastic (non-recycled)	18.74	20.34	20.91	20.00
Leather and Rubber	0.38	1.21	4.20	1.93
Cloth and Textile	4.38	4.59	6.95	5.31
Stone and Ceramic	0.68	2.15	0.14	0.99
Bone and Shell	1.38	2.09	0.15	1.21

Source: BMA, 2010

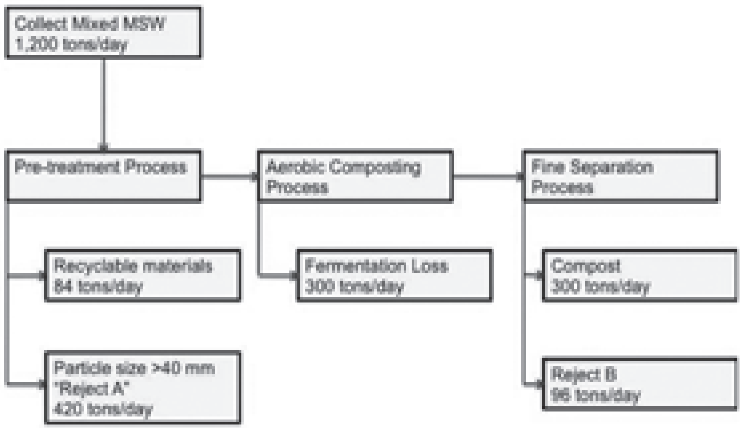


Figure 3.8 Mass balance of compost production processes (Nithikul, 2007)

transferred to two sanitary landfill sites located at Phanom Sarakam district, Chacheongchao province (2,244 ton/day) and Kampaengsaen district, Nakorn Pathom province (5,455 ton/day) (Figure 3.6).

3.4.2 Nakhon Ratchasima City Municipality (NCM)

The Nakhon Ratchasima City Municipality (NCM) covers an area of 37.50 sq. km. It is located 255 kilometers to the northeast of Bangkok. The municipality total population as of 2010 was 164,206 from 33,487 households (77,968 males; 86,238 females). In addition to registered population, a non-registered population in NCM city can be over 90,000 as of 2007 estimation.

The high number of population of NCM and associated large service sector and growing industrial activities contribute to a large volume of solid waste generated. This creates two distinct problems: (i) a lack of cleanliness around the city due to uncollected waste and (ii) appropriate solid waste disposal. Accumulations of garbage around the city have resulted from unsystematic littering by the residents and workers.

3.4.2.1 Solid waste generation and composition

Solid waste in the NCM is generated from local communities, government offices, commercial districts, and industrial zones. As the city has been growing rapidly, the quantity of waste generated has also grown at an alarming rate. The quantity of waste collected within the NCM is approximately 182 ton/day. It has been estimated that the waste generation rate per capita for citizens in NCM was equal to 1.05 kg/capita/day in 2004 (DEE Foundation 2005).

The main component of municipal solid waste in NCM is organic waste, which contributes to more than 60% of total waste generated (Table 3.7). The second and third largest components are plastics (21.0%) and paper (6.4%).

Table 3.7 Waste composition of NCM

Waste items	Percentage of Waste (%)
Organic waste	61.1
Plastics	21.0
Paper	6.4
Glass	2.2
Metals	1.3
Polystyrene	1.2
Others (rubber, cloth, wood, ceramics)	6.4
Hazardous waste	0.4

Apart from municipal solid waste, there are also other waste streams including separated food waste, market waste, night soil, and garden waste. The total quantity of waste expected to enter the treatment system is 240 tons of waste per day.

3.4.2.2 Solid waste management practices

1) Waste reduction and waste separation for recycling
   The NCM introduced a public participation program in solid waste management in 2001. Starting from 2004, the NCM continuously runs the organic waste separation campaign at the source, resulting in the reduction of organic waste (both for direct and indirect utilization) of up to 26 ton/day from approximately 110 tons/day. However, as the treatment system for organic waste was not in place at the time, the quantity of organic waste

entering landfill site bounced back again.

In 2005, the NCM emphasized on expanding the network by involving more stakeholders to include 29 communities, 19 academic institutes, 7 markets, and 3 department stores. The activities included training for waste separation, competition for green city symbol, production of compost and liquid fertilizer and so on. The NCM aimed to reduce waste to be disposed of by 8 tons/day at the end of the campaign, even though the potential for waste reduction can be as high as 16 ton/day. By the end of the campaign 71% of the participants gained a better understanding on waste separation and waste reduction activities.

NCM experienced difficulty in promoting waste reduction and waste separation for recycling as follows:

- Waste Banks – the number of waste banks and recyclable waste separation projects are increasing, especially in schools. However, it is difficult to continue the program at the community level as there is no personnel from the community to take charge of the project.
- Liquid fertilizer - Residents of NCM consider the production of liquid fertilizer as a burden, especially in terms of production cost, as they need to buy starter for making liquid fertilizer, and there is no certain market for liquid fertilizer yet.
- Food Waste Separation - The project actually received a lot of cooperation from local residents; however, the NCM has not yet established a system to manage the food waste that is separated.

2) Waste collection

Collection method for solid waste in NCM can be categorized into 3 main types.

i) Door to door collection - household owners will collect their own waste and put it into plastic bags or waste bins in front of their houses.

ii) Curb-side collection - there will be locations for community's waste bins where local residents bring their waste for disposal to be collected by waste collector trucks later.

iii) Waste Stations - waste stations will be constructed with walls on three sides and placed with large containers for waste collector trucks to collect. The area for waste stations is normally in busy business areas such as markets, hospitals, and hotels.

Waste collection still cannot be done completely within the NCM. The collection trucks are not able to collect waste at every collection point and the schedule of collection also cannot be specified. The capacity of waste collector trucks is approximately 72% of the total waste generated. Trucks have to repeat the same route more frequently in order to collect all waste, which increases the cost of fuel and reduces the lifetime of the vehicles.

3) Waste treatment and disposal

Waste disposal in NCM, up to the present, relies on landfill with an environmental protection system such as control of the quantity of waste to be disposed of, prevention of dust and odor contamination, treatment of leachates, and separation of infectious and hazardous waste.

The landfill is located at an experimental farm of the Royal Military II and has an area of 302,000m^2. Onsite management of solid waste first involves sorting by scavengers, followed by regular covering of waste layers with soil.

In addition to solid waste generated within the NCM, 7 other municipalities and sub-district offices of smaller size and capacity also transport their waste of 19 tons/day to be treated at the landfill facility of NCM. In total, 201 tons of waste are disposed daily at the landfill site of NCM.

3.4.2.3 *Plan for improvement of waste management practice*

The current sanitary landfill site has almost reached its capacity. Therefore, NCM plans to implement an integrated solid waste treatment system to enhance waste and resource recovery. The system under construction since August 2008 consists of 5 main sub-systems as follows:

i) Front-end facility to separate wastes that have not been separated from the generator

ii) Biological treatment for organic components:

- Anaerobic Digestion (AD) system: The AD system is for recovery of energy and nutrients from food waste and market waste. Waste entering the system will be homogenized before entering the reactor for the fermentation process to take place, and
- Composting system where the raw materials will come from garden and yard waste, branches, and the sludge from the AD system.

iii) Electricity generation system

iv) Refuse derived fuel system (RDF)

v) Sanitary landfill

A process diagram of new designed solid waste integrated treatment system is shown in Figure 3.9. There are five sources of waste, which are 180 tons of mixed municipal waste, 15 tons of food waste, 30 tons of market waste, 10 tons of night soil, and 5 tons of garden waste where each type of waste has its own pretreatment. The end products for the system include RDF pellets, electricity, and compost. RDF pellets will be sent to an external incinerator or be used in industrial processes, to substitute for other fuels such as coal. Electricity will be used within the treatment facility, and compost can be sold to private sectors or used within the waste treatment facility.

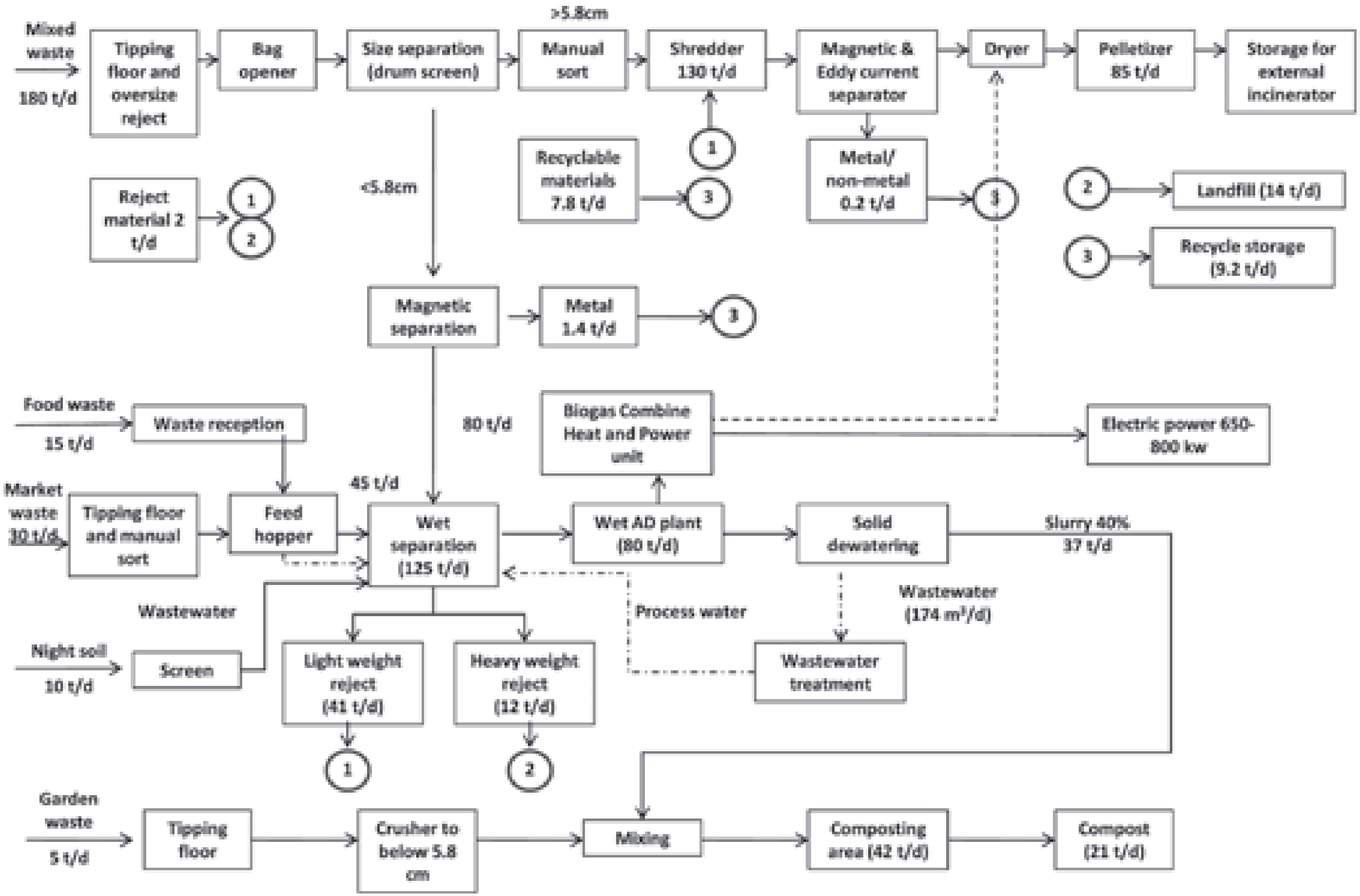


Figure 3.9 The proposed design (process flow diagram) of an integrated solid waste treatment system in NCM, which can manage the MSW up to 240 tons/day

3.4.3 Koh Samui Town Municipality

Koh Samui is an island on the east coast of Surat Thani Province, Thailand. It is Thailand´s second largest island, with an area of 228.7km^2 (see footnote[3]). The island is about 35km northeast of Surat Thani town (9°N, 100°E). The island measures 21 km at its widest point, and 25 km at its longest. The island is surrounded by sixty other islands, which are part of the Ang Thong Marine National Park.

Koh Samui has a population of about 55,000 and the economy of the island is based primarily on the tourist industry, and exports of agricultural products such as coconut and rubber. Economic growth from tourism has brought both prosperity and environmental and cultural impacts.

There is no appropriate planning document for the development and growth of Koh Samui as a tourism destination. This lack of planning has caused the deterioration of the natural environment, depletion of available water resources, and accumulation of waste, and other pollutants.

3.4.3.1 Solid waste generation and composition

As a result of high population and visitors, over 120 tons of solid wastes have been generated daily on the island.

Tourists are accountable for producing a large portion of Koh Samui's total waste. The Department of Public Work for Koh Samui reported the quantity of waste generated by each Thai resident of Koh Samui and a single hotel room at around 1.2kg of trash per day and 2.9kg per day, respectively. Therefore, 8,625 hotel rooms (in 2004) generated about 26 tons per day, about a third of the total garbage generated on the island for that year (IPEN, 2006).

Table 3.8 shows an average quantity of solid waste generated from 1998 to 2008. It can be seen that the waste generation rate has increased dramatically, almost doubling in 5 years.

Table 3.8 Quantity of waste generation in Koh Samui Town Municipality

Year	Average Quantity of Waste (tons/day)
1998	30
2003	66
2004	80
2005	96
2006	118
2007	116
2008	124

As the design and budget requirements for solid waste treatment depend on seasonal variation of waste quantities, it is worth noting that seasonal variation of waste quantity on the island is high. The ASEAN Center for Energy (2004) reported that the quantity of waste generated has notably increased during the high season for tourism (December – January).

It can be seen from Table 3.9 that the quantity of non-degradable waste is greater than that of other types. The largest portion of waste is plastics, comprising about 30%. The combustible content was high, contributing to approximately 75% of wet weight.

[3] http://en.wikipedia.org/wiki/Ko_Samui

Table 3.9 Waste compositions of Koh Samui at the disposal site.

Item	Percentage of waste
Food	28.15
Plastics	31.55
Paper	6.59
Cloth	5.90
Rubber, film	3.23
Wood	3.18
Other burnable type	1.26
Refuse that cannot be burned	20.14

Source: ASEAN Center for Energy (2004)

3.4.3.2 Solid waste management practices

1) Waste reduction and separation for recycling

Household waste segregation as well as other informal sectors' contributions in waste collection and disposal were not evaluated. However, after waste has been through primary separation at the source, the garbage collection workers sort through the waste for valuable materials such as paper, plastics, metals and other items to be sold to junk shops or waste traders, normally located along the truck routes or near the disposal sites.

The waste separation program is in its initial stage and has not yet been widely practiced. However, in 2007 the Green Island Project was launched. The project aims to establish a network and develop environmentally awareness among Koh Samui stakeholders. As human activities have impacts on the environment, activities should be carried out carefully, both to preserve and improve the natural environment. Participants of the project include individuals, businesses, local organizations, government, the Tourism Authority of Thailand, NGOs, and tourists.

Later, the Thai Hotel Association and the Koh Samui Town Municipality initiated a Low Carbon School project, supported by the Green Island program, under which a buddy system between the schools and hotels on the Island, was developed. For the first year, the pilot project has been done with 10 schools to set up recycling banks, composting, and organic gardens to create environmental awareness among the children toward their future and how they can help their hometown become a green island. At each school, different kinds of garbage bins have been set up (recycling waste, kitchen waste, paper waste, and garden waste). Compost and liquid fertilizer making projects were introduced in order to have children understand the utilization of biomass waste. Composts produced will be applied to school vegetable/flower beds. Each school will have a hotel that practices green management to guide them through the implementation of all activities.

2) Waste collection

Approximately 80% of waste generated is collected daily. Wastes are then transferred to a solid waste incineration plant. It was estimated that, in order to collect 80% of waste each garbage truck has to make 2-3 trips a day.

Waste collection and transportation has been a problem on the island. Thus the Koh Samui Town Municipality has developed a waste collection plan by grouping the type of waste generators into two types; local residential areas and commercial buildings. For local residential areas, measures include separate waste bins provided for each household and waste bins provided at the collection areas in local communities, especially where the road is too narrow for collector trucks to enter.

For commercial buildings such as hotels, department stores and restaurants, each building shall have their own waste collection system that the waste collector trucks can access easily.

Increasing quantity of municipal solid waste on the island has seriously constrained the waste collection system. The island's tourism businesses have added a large quantity of solid waste to be collected by authorities.

3) Waste treatment and disposal

A major disposal method of solid waste generated on the island is based on incineration. Koh Samui Town employs a stoker-type incinerator in the solid waste management system. The Incineration Plant is located in the area of Kok Khanoon Village, Nah Muang sub-district, Koh Samui (IPEN, 2006).

The construction was funded by the Japanese Overseas Economic Cooperation Fund (JOECF) or presently known as Japan Bank for International Cooperation (JBIC). The construction was completed in 1998 and started its operation in 1999.

At first, the municipality hired the Thai French group Palcon-Montaney to manage the incinerator. This cost the government an additional 50 million Baht per year.

The incinerator has a capacity to burn waste at 140 tons/day (two furnaces of 70 tons/day each) and can run at a minimum of 75 tons per day. In the beginning, the island did not generate waste at its maximum capacity; therefore the incinerator used only one furnace to burn garbage once every 10 days. The periods between burning were used for maintenance of the furnace.

The two furnaces were supposed to run alternatively (one operates while the other is under maintenance), however, later on they were run 24 hrs a day and 7 days a week, to cope with the quantity of waste generated. This has resulted in low maintenance for both of the furnaces, which eventually broke down. The landfill area that was supposed to be used for fly ash and bottom ash is now used as a landfill site for fresh waste.

There were several problems encountered in the operation of the incinerator. First, as the waste was not treated properly and there was a lack of waste separation practice, the incinerators have deteriorated before their expected operational lifespan. This has pressured the Koh Samui Town Municipality Office to spend a huge amount of budget on repairing and maintenance of the incinerators. Additional to budget problems, since both incinerators are to be shut down for maintenance, the municipality has to rely on the use of landfill. At present, the landfill site has reached its capacity and creates further environmental problems, such as odor and leachate contamination to lowland communities.

The nature of MSW, with high water content, leads to a high volume of leachate, 10 – 12m^3/day. The biological oxygen demand (BOD) concentration of leachate is approximately 50,000mg/L and only a portion of the leachate produced can be treated. Approximately 5m^3/day of leachate is used for controlling of temperature in the combustion chamber. Thus, this untreated leachate, with high BOD and low pH, accelerates the corrosion of the combustion chamber.

The original air emission control equipment did not include the control of dioxin emission. In 2006, the emission of dioxin problem was solved by the installation of an activated carbon injection unit. Injection of 1.6 kg activated carbon per ton of waste will reduce the concentration of dioxin in flue gas to that of less than 0.08 ng I-TEQ/Nm^3. The standard in Thailand is set for 30 ng I-TEQ/Nm^3 for an incinerator of capacity larger than 1 ton per day.

Approximately 35 – 42 ton/day of ash is produced from the combustion process. Due to limited landfill area of 1.6 ha (10 rai), the landfill site has reached its capacity. There is also concern over ground water contamination from the disposal of ashes.

Finally, the incinerators are not equipped with electricity generation because the size of the incinerators is small and the energy conversion efficiency of the boilers is less than 40%. The inadequate power supply in the island was the main reason for the frequent shutdowns of the incinerator.

3.4.4 Rayong City Municipality

Rayong City Municipality (RCM) covers an area of 16.95km^2 in four sub-districts; Tha Pradu, Pak Nam, Nuen Phra, and Cheang Nuen. It is located 179 kilometers to the east of Bangkok. The municipality total population in Rayong city area as of 2010 was 59,625 from 29,443 households (28,359 males; 31,266 females). In addition to registered population, Rayong city also accommodates as high as 30,000 from nearby areas and non-registered laborers.

3.4.4.1 Solid waste generation and waste composition

As Rayong province is one of the most popular tourist destinations, as well as a location for various industries, leading to increasing quantity of solid waste, which has caused serious environmental problems.

A study conducted in 2002 indicated that there are three major waste generators in RCM: community, markets and local businesses, and department stores. The contribution of waste generated by each generator is shown in Table 3.10.

The quantity of general solid waste increased from 71 ton/day in 2001 to 85 ton/day in 2005. However, the amount of waste delivered to landfill site has significantly

Table 3.10 Contribution of waste generation from major generators.

Waste Generator	Waste Quantity (%)
Community	81
Markets and local businesses	17
Department Stores	2

Source: DEE Foundation, 2006

decreased from 68 tons per day in 2001 to 62 tons per day in 2005 due to the implementation of organic waste separation for composting and anaerobic digestion (Wanapruek et al, 2007).

Most of municipal solid wastes are organic waste, followed by plastics and recyclable materials and others (Figure 3.10).

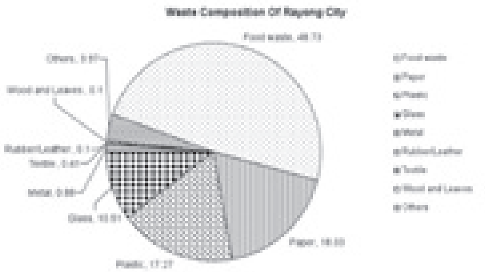


Figure 3.10 Waste compositions (Percent) of Rayong City Municipality (RCM, 2004)

3.4.4.2 *Solid waste management practices*

1) Waste reduction and separation for recycling

As a result of increasing municipal solid waste, the original landfill site has reached its capacity. To extend the life span of the landfill, source separation initiatives were introduced in 1999. The initiatives include education for the local community to separate recyclable waste and food waste, production of liquid fertilizer from food waste, and the utilization of liquid fertilizer produced. Citizens of RCM have come to understand the concept of waste separation, types of waste, and utilization of waste separated. Figure 3.11 shows food waste separation activities implemented in RCM.

Figure 3.11 Food waste Separation and collection activity in RCM (RCM, 2004)

2) Waste collection

Concerning the quantity of organic waste feedstock to be used in the anaerobic digester tank, the RCM has developed a waste management model to ensure a smooth feed of the waste to the system by involving all stakeholders in various kinds of activities. The activities were implemented with three pilot communities, consisting of 3,500 households. Recyclable waste dealers were brought into the program to deal with recyclable waste that accounted for almost one third of the total waste. Activities such as school waste bank, community waste bank, and waste trading for eggs were introduced in communities.

As food waste is the major component of organic waste, a food waste separation and collection system was developed. The Rayong City waste management model is shown in Figure 3.12. It can be seen that with proper implementation activities, more recyclable waste can be separated. Expansion of pilot communities will also increase both recyclable material and also organic waste feed stock for the AD system.

Figure 3.12 Rayong city waste management model (RCM, 2004)

3) Waste treatment and disposal

RCM established an anaerobic digestion and composting facilities to treat organic waste. The anaerobic digestion system applied in RCM is explained in section 4. Biogas generated by anaerobic digestion is used for electricity generation and sold to the provincial grid. Slurry of fermented waste is compressed and mixed with compost.

Composting is applied for green waste and some of the food waste that is not suitable for the anaerobic digestion process. Compost is distributed to residents from pilot communities as an incentive for waste separation at the source.

Waste that cannot be treated by means of anaerobic digestion and composting is disposed of in a sanitary landfill adjacent to the organic waste treatment facility.

3.4.5 Phitsanulok City Municipality

Phitsanulok City Municipality is located at the lower northern part of Thailand. The municipality covers an area of 18.26 km^2 with a registered population of approximately 90,000 people.

3.4.5.1 Solid waste generation and composition

The quantity of waste generated is approximately 84 tons/day and waste generation rate is 0.93kg/person/day.

Typical fresh municipal solid waste characteristics of Phitsanulok city contains high organic content, more than 47% of the whole waste are food waste. The average water content of the waste is also relatively high.

Phitsanulok city employed a mechanical biological treatment (MBT) process to reduce the volume of waste prior to landfill. The inert waste after MBT process, with nine months of static aeration pile composting, was 38.7% compost and 55.8% plastics (ERC, 2006). The remaining residues from composting suggested that the materials should be used in energy recovery.

3.4.5.2 *Solid waste management strategies and practices*

1) Waste reduction and separation for recycling
   In 1999, the Municipality aimed to reduce the quantity of waste for disposal by introducing the 3Rs and pretreatment of waste before disposal. The Municipality introduced various activities to promote the 3Rs in both midstream (consumption stage - waste generation) and downstream (final disposal site). At the consumption stage, the Municipality aimed to avoid waste generation by promoting use of biodegradable and reusable materials, encouraging waste separation for sale, and supporting composting at household and community levels. At the post-consumption stage, the Municipality aimed to improve final disposal by the pretreatment of waste through mechanical biological treatment (MBT) prior to landfill.

   As a result of these efforts (Figure 3.13), the quantity of waste transported to the disposal site decreased sharply from 142 ton/day in 1996 to 82 ton/day in 1999 (Phitsanulok Municipality, 2005). The quantity of waste to disposal site was maintained thereafter.

   At the disposal facility, recyclable materials are removed by waste pickers and sold to private recycling shop dealers. Therefore, most input to the MBT is organic and low market value waste, such as plastic bags.

2) Waste treatment and disposal
   The city has one disposal site. The landfill site is located in Bangrakam district where it is 40km away from the city. The concept of sanitary landfill was introduced in 1999 and after that, the application of pre-treated process or mechanical biological treatment (MBT) prior to landfill was introduced.

   Once the fresh waste arrived at the landfill facility, waste is shredded to smaller size and homogenized at the treatment process by the mobile rotary drum. Inside the drum, sprockets are installed to tear open the plastic bags. As for the biological treatment, the homogenous waste is heaped onto a layer of wooden pallets on the landfill. The windrow composting pile is covered with

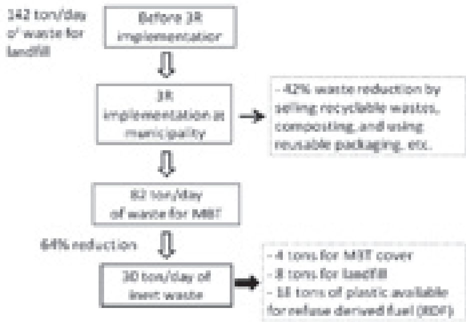


Figure 3.13 Waste reduction through 3R practices in Phitsanulok Municipality (Sang-Arun and Bengtsson, 2012)

coconut shells as bio-filter to minimize odor and vermin. The pile is then left for an average of 9 months for completing the degradation process. Final residue that has no market value is placed in the sanitary landfill. More details of this system are explained in section 4.

3.5 Discussion of municipal solid waste management in Thailand

Waste generation in Thailand has slightly increased due to the impact of the 3R promotion that resulted in increased waste generation. However, its implementation is not as efficient as in Japan which experienced decreasing waste generation. Only some cities, where the mayor takes strong leadership and implemented the 3Rs in a systematic way, such as BMA and Phitsanulok could achieve the gross waste reduction, to some extent.

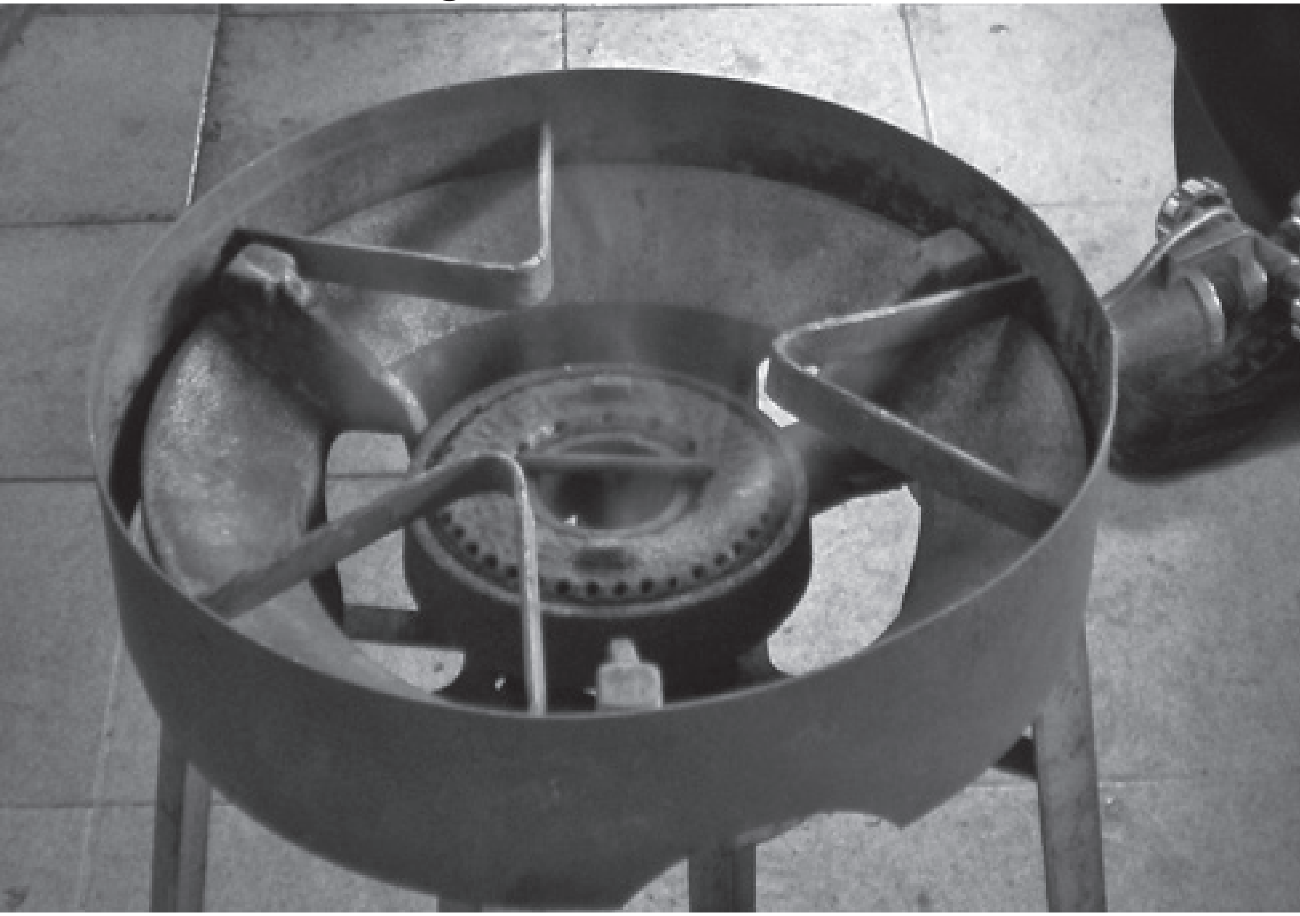
The major composition of waste in Thailand is organic, which has potential for utilisation for food and energy production. However, these wastes are being dumped into landfills and release pollutants including greenhouse gases to the environment. Some municipalities implement diversion of waste from final disposal site (e.g. composting in BMA, anaerobic digestion in Rayong, MBT in Phitsanulok). In addition, BMA installed a landfill gas recovery system to utilize methane gas for electricity generation. For the case of an island, incineration is being used, as land is scarce.

Waste separation at source is successful where economic incentives are significant, such as recyclable waste separation for sale. However, a system to receive and treat the separated waste is important to sustain the public participation.

Organic waste separation at source is being promoted in some cities. However, it is not sustained due to various reasons, such as the system to receive waste for further treatment is not well maintained, markets for products are not well established, or economic incentives are not significant.

Local governments are confronted with challenges and constraints in implementation of any solid waste management system, especially in terms of budget, personnel, and public participation. Therefore, many of them are not interested in shifting their on-going landfill practices to an advanced system, unless grants are available.

4.
Urban organic waste utilization in Thailand



4. Urban organic waste utilization in Thailand

At present, there are many initiatives on organic waste management which include composting, anaerobic digestion, integrated bio-digestion, mechanical biological treatment, and sanitary landfill with gas recovery. The technologies employed range from technology for metropolitan and big cities, to that for community and household levels.

In some cases, large-scale SWM alone may not be that effective. Instead, local groups of citizens were formed, with or without the support from local government or NGOs, which seems to be more effective in their operation. This section provides examples of urban organic waste treatments that are being implemented in Thailand.

4.1 Composting

From the characteristics of MSW in Thailand, composting tends to be the most appropriate technology for waste disposal and treatment. A high percentage of organics makes waste suitable for composting (Table 3.2 and 3.3). Composting also generates valuable fertilizer or soil conditioners for agricultural and horticultural uses.

To promote composting of urban organic waste, PCD published a guideline on composting in 2004. However, the composting activity shares less than 1% of waste generated, except for BMA where a mega-composting facility is established. The reason for low composting rates might be due to the living patterns of urban population where the need for compost is low and the citizens do not see incentives in producing their own compost. As for rural areas, the market for compost is small compared to chemical fertilizer. Therefore the level of waste conversion to compost is still low.

The scale of composting activities in Thailand can range from large scale to household composting. Examples of composting projects in Thailand are disseminated as follows:

4.1.1 Large scale composting at Bangkok Metropolitan Administration

A large scale composting plant is located at On Nuch waste transfer station. The technique used is in-vessel composting. This facility can receive 1,200 tons of unsorted waste input per day.

The composting process consists of 3 main units, namely, pre-treatment, aerobic composting, and maturing plant, and fine compost separation. The diagram of the process together with mass balance is shown in Figure 3.6.

1) Pre-treatment process

The pre-treatment step is actually a mixture between manual separation of waste and other physical/mechanical separation of waste. It is divided into 4 main steps (Nithikul, 2007) as shown in Figure 4.1.

1.1) Manual separation: Waste is put on the conveyor belt while workers sort out big and recyclable materials such as electrical appliances, plastics, glass bottles, and aluminum cans. At this step, approximately 83 tons of materials can be recovered daily.

1.2) Magnetic separation: magnetic separator, installed at the end of conveyor belt, will separate ferrous metals from the remaining waste. Metals can be recovered at this step at about 1 ton/day.

1.3) Bag breaking/homogenization: Waste that has been through magnetic separator will be sent to a horizontal cylindrical drum to break open the plastic bags and at the same time, homogenize the waste. The drum is rotating slowly to facilitate bag breaking and homogenizing of waste. The retention time of the drum is about 12 hours, in which decomposition of organic materials has started to take place.

1.4) Screening: Homogenized waste is sent to the screen with a mesh size of 40 mm, where oversize materials will be separated and sent to landfill (Reject A). Materials smaller than 40 mm will be sent to the aerobic composting process.

Waste that has been through the pre-treatment process contains lower organic contents (Table 4.1), which suggested that the pre-treatment process can effectively separate organic components of waste and, when possible, pretreatment can be employed to collect most of the organic materials before the treatment process.

2) Composting process

During the aerobic composting process, waste is aerated from the bottom of the pile for 40 days. The aeration process can be divided into two sub activities: intensive aeration and slow aeration.

3) Grading process

The composted product is then passed through a fine separation process to separate compost from materials with high calorific value (Reject B).

4.1.2 Small scale composting

Several communities in Thailand have formed environmental conservation groups that work on a voluntary basis. Activities of such groups are normally generated within community members with or without the support from local government authorities. Most groups formed have recognized the importance of waste separation at source. Thus, activities such as a recyclable waste bank and composting are commonly found.

Local group composting can easily be implemented by finding a common area and installing containers made of any materials that are available in the area (e.g. cement, bamboo, wood). Separated organic waste can be dumped into the container. Volunteers or persons-in-charge can then

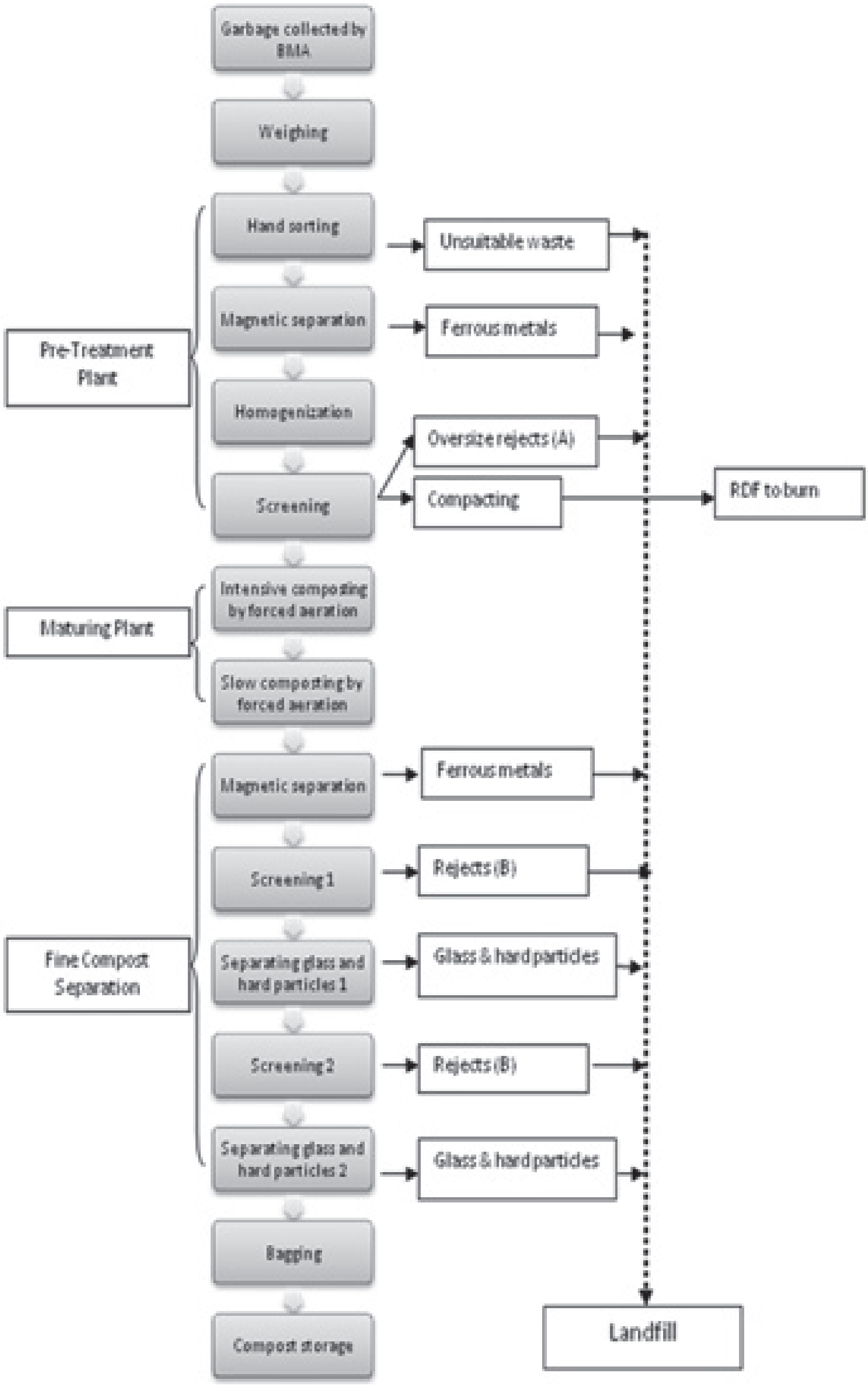


Figure 4.1 Process flow chart of BMA composting plant

Table 4.1 Comparison of waste characteristics of collected waste, Reject A, and Reject B (Nithikul, 2007).

Parameters	Collected Waste (% by weight)	Reject A (% by weight)	Reject B* (% by weight)
1. Waste composition			
Food waste	42.11	9.48	N/A
Wood and leave	12.72	27.28	N/A
Paper	14.04	9.61	N/A
Plastic	16.23	41.06	N/A
Leather and rubber	5.26	0.39	N/A
Cloth	3.07	4.21	N/A
Bone and shell	0.44	0.08	N/A
Stone and ceramics	0.44	6.23	N/A
Metal	0.44	1.01	N/A
Glass	2.19	0.65	N/A
Hazardous waste	1.52	Not Detected	N/A
Others	1.54	Not Detected	N/A
Total	100	100	N/A
2. Bulk Density (kg/m^3)	405	141	N/A
3. Moisture Content (%)	50.8	60	6.2
4. Ash Content (%)	10.8	11.8	15.1
5. Calorific value (MJ/kg) dry basis	6.0	21	29.5

* From Siam City Cement Public Co., Ltd., 2006

turn the pile of organic materials until the composting process has completed and compost product is formed (Figure 4.2).

Different techniques of composting can be employed locally. Commonly used techniques are windrow composting, aerated pile composting, and compost bin systems.

Details for composting methodology can be found from the publication of the Pollution Control Department (PCD)[4]. The PCD has published detailed information on theory behind composting, small scale composting for rural area, household composting, and examples of composting projects in Thailand.

4.2 Anaerobic Digestion (AD)

The anaerobic digestion process has been viewed as a technology appropriate to the characteristics of Thai solid waste, which contains high organic content. Organic compounds in waste components can be separated and fed into the digestion tank where anaerobic fermentation takes place. As a result, methane gas is generated and can be collected for various kinds of application. At present, there are a few municipalities employing this technology. Rayong and Nakhon Ratchasima Municipalities are two examples.

[4] More information can be accessed from: http://infofile.pcd.go.th/waste/waste_Composting.pdf?CFID=6073453&CFTOKEN=56977045

(a) (b)

Figure 4.2 local community composting system: (a) community composting site at Kradangnga municipality, (b) Household composting in Phitsanulok town municipality.

4.2.1 Large scale anaerobic digestion at Rayong City Municipality

Due to the successful implementation of the public participation program, the RCM decided to request for funding from the Energy Conservation Promotion of Waste to Energy Policy, Ministry of Energy to establish an anaerobic digestion facility that will transform food waste and other organic waste to energy and organic fertilizer.

The construction of the facility was commenced in 2002 and completed by July 2004. The plant consists of front-end treatment, anaerobic digestion tank, biogas utilization system with its generator, and all necessary auxiliary equipment at a total budget of 142,011,030 Baht (4,437,844 USD). The energy produced in forms of heat and electricity are used for internal consumption at the facility. The surplus electricity is sold to the Provincial Electricity Authority (PEA). The process flow diagram of the facility is shown in Figure 4.3. The technical design and installed capacity are shown in Table 4.2.

Major Processes at the AD Facility

i) The Front-End Treatment (FET)
The front-end treatment was designed to accommodate 70 tons of municipal solid waste per day or 25,000 tons/year. The area of this unit is approximately 1,000 m^2. Waste entering the front-end treatment consists of waste separated at source (20 ton/day) and general waste (50-60 tons/day).

FET consists of the following major components and equipment: waste receiving floor, drum screen, conveyor belts, recyclable waste separation belts, bag opener, magnetic separator, fragmentizer, and suspension tank. The most important part is the fragmentizer as the smaller size of organic waste will help bacteria to digest waste particles faster and produce more gas.

ii) Anaerobic Digester System
The system was designed to treat 70 tons/day (40 tons from waste separated at the FET, 20 tons from waste

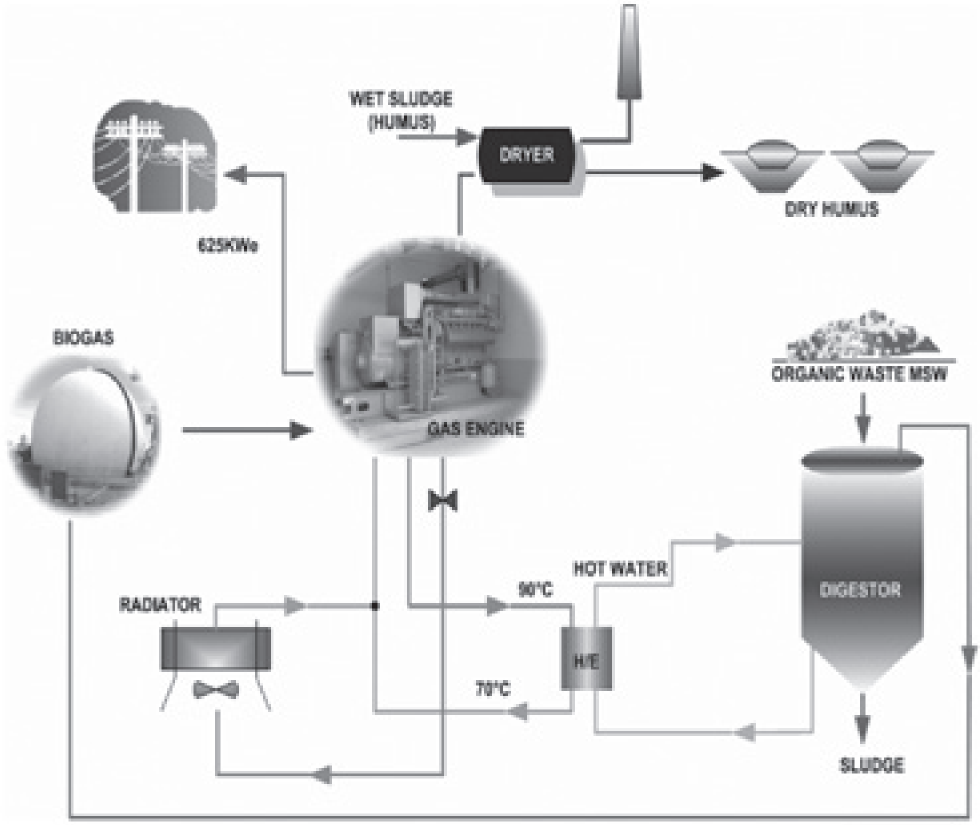


Figure 4.3 Process flow diagram of RCM anaerobic digestion facility (Muller, 2007)
Source: http://www.cogen3.net/final/docs/RayongMunicipalitypowerpoint.pdf

separated at the source, and 10-14 tons of night soils). The system comprises 8 processes as follows:

- Feed preparation of anaerobic digester process including addition of water, removal of undesirable materials, and homogenization of the waste to ensure effective digestion and avoid failure of the system.
- Anaerobic digester in bioreactor: Feedstock will be kept in the bioreactor for 18 days. Volatile solids will be converted to biogas in the tank. Within the reactor, there will be mixing devices to homogenized waste feedstock that is constantly fed into the reactor to ensure well mixing with bacteria in the reactor.
- Mechanical dewatering of digested slurry
- Thermal treatment and hygiene for humus mass
- Odor control
- Process water system
- Wastewater treatment system
- Biogas utilization system: The biogas produced from the digestion tank is composed of approximately 65-70% methane and the rest is carbon dioxide. However, this

Table 4.2 Technical design and installed capacity of anaerobic digestion facility at Rayong City

Attribute	Process	Unit	Design capacity	Installed capacity
Waste type	Source separated organic waste	Tons/day	20	12
	Mechanical sorted organic fraction of solid waste	Tons/day	50	3.3
Organic waste property	Total solids	%	30	18
	Volatile solids	%	70	86
Pre-treatment	Bag opener	Tons/hr	7	No data
	Drum screening	Tons/hr	7	6
	Magnetic separator	Tons/hr	3.50	3.50
	Shredder	Tons/hr	8.50	No data
	Fragmentizer	Tons/hr	7.50	3
	• Low-riddle	mm	<10	±10
	• Solid content	%	15	5
	Input to the digester	m^3/day	120	45
	Reject	Tons/day	10	3
Anaerobic Digestion	Digester volume	m^3	2,100	2,100
	Temperature	°C	30-36	25-31
	Organic loading rate	Kg/m^3d	6	1.3
	Retention time	Day	18-20	33
	pH		6.7-7.4	6.7-7.4
	Biogas generation rate	Nm^3/m^3d	2.85	0.3 (0.2-0.4)
	Biogas yield	Nm^3/ton organics	100	76 (40-80)
Post treatment	Belt press	m^3/h	16	No data
	Pasteurized rotary drum	Ton/h	7.50	No data
Product	Electricity	kWh/ton org	230	181 (100-220)
	Compost	Tons/ton organics	0.26	0.2 (0.1-0.3)

Source: Wanapruek et al, 2007

composition may vary depending on the characteristic of waste fed into the system. Gas produced from the process will be kept in a gas holder before being sent to the power generator. Excess gas will be burnt at the excess biogas burner. Cooling water from the power generator is sent back to warm the waste feedstock.

In order to effectively promote the separation of solid waste at the source, the RCM has set up 3 pilot communities of approximately 3,500 households to run a waste separation campaign. Once the communities had successfully separated their waste, the collection and transportation system were then developed to accommodate the separated waste.

Cost and Income from system operations

The investment cost for the Rayong model AD system was 172 million Baht. The operation and maintenance cost is approximately 23 million Baht per year (Wanapruek et al, 2007). The cost can be broken down as shown in Table 4.3.

Income generated from the operation

Table 4.3 Investment cost for anaerobic digestion system

Job Description	Cost (million Baht)
Construction cost	142
Land	27
Consultancy	3
Total	**172**
Operation and maintenance cost (per year)	23

Source: Wanapruek et al, 2007

of the AD system can be grouped into 3 categories; recycled material, electricity, and fertilizer. Details of the expected income, if the system is operating at full capacity, are shown in Table 4.4. However, due to several reasons, the system is not operating at design capacity. This is partly because of the quantity and quality of organic waste feed stocks and also the operation and maintenance of the equipment itself that is quite complicated.

As a result of the discontinuity of operation, the expected income, both in terms of electricity generation and compost production, does not meet the estimation shown in Table 4.4. Instead, the operation has been done at a loss of approximately 240,000 Baht per month.

The system has contributed to saving space and the cost of landfill. It was estimated that the savings from avoided landfill is approximately 10.5 million Baht per year, if the AD system is operating at full capacity (Wanapruek et al, 2007). This contribution is remarkable as new landfill development is very difficult due to social resistance.

Obstacles of the anaerobic digestion project in RCM are explained as follows:

i) Insufficient quantity of waste feedstock: At present the quantity of waste feedstock supply to the AD system has reached its operational capacity. The quantity of waste that enters the AD system has increased from approximately 500 tons/month in October 2006 to 2400 tons/month in March 2007. The quantity of organic waste separated has slightly increased from 360 tons/month in October 2006 to 550 tons/month in March 2012.

ii) The designed bag opener cannot open some types of materials. Additionally,

Table 4.4 Estimated income from operation of anaerobic digestion system if the system is operating at full capacity

Description	Unit	Quantity	Price/unit (Baht)	Income/year (Baht)
Recycle waste				
• Paper	Tons/year	621	–	–
• Plastic	Tons/year	1,314	–	–
• Metals	Tons/year	73	–	–
• Glass	Tons/year	543	–	–
Electricity	MWh/year	3,826	1,500	5,793,000
Fertilizer	Tons/year	5,562	1,000	5,562,000
Total income	Baht/year			11,355,000
Average income per ton	Baht/ton			444

the magnetic separator cannot separate non-ferrous metals such as aluminum and stainless steel, or even ferrous materials under a pile of waste. Thus, reducing the quality of waste feedstock results in the rejection of a whole lot of waste when the metal detector can detect contamination of metals in the feedstock.

iii) Damage to machinery: The AD system lacks continuity of operation due to damage caused to the machines. The fragmentizer is the machine that has the most problems as the blades cannot cut open all plastic bags. The belt press is leaking and the pipeline under the bioreactor is often clogged due to seafood waste residues, stones and gravel.

iv) Less participation of communities: Apart from the design failure, the participation level of communities is also low (40% of households join the activity) and the project areas are limited to only 3 communities out of 9 in total.

v) As the production of electricity depends on the quantity of gas generated from the AD system, the power generation facility sometimes has to stop its operation due to problems with the machinery and also the quantity of gas generated.

4.2.2 *Small-scale anaerobic digestion project promoted by the Ministry of Energy*

The Ministry of Energy together with the BMA launched a project to promote the production of biogas from school organic waste and to educate children on source of alternative energy. In the first phase, the project has installed organic waste digestion tanks at 40 schools around Bangkok (Figure 4.4). The tanks were funded by the BMA while the Ministry of Energy was responsible for school selection for the project and provided training courses on biogas production using food waste to teachers and students.

As of January 2012, there are 540 digestion tanks installed in schools and local administrative offices in Thailand. The system could remove more than 7,884 tons of food waste per year while producing 492,750 cubic meters of biogas per year, which is equivalent to 226.6 tons of LPG (LPG price as of March 2012 equal to 1200 USD/ton). In addition, this technology can reduce environmental impacts such as unpleasant odor without expanding the use

Figure 4.4 A small-scale anaerobic digestion tank

of landfills. However, not all the digestion tanks are operated continuously due to the complexity of the system, and insufficient gas supply for heating.

4.3 Integrated bio-digester

An integrated bio-digester was invented by Thai Central Mechanics, Ltd. The company has designed its equipment to convert biomass waste into more valuable products within 24 hours. The general characteristics of the digester can be summarized as follows.

The bio-digester comes in three different sizes suitable for different quantities of waste generated. The management capacity varies from 1.5 tons/day to 15 tons/day.

- Liquid fertilizer generated during its operation can be used as microbial feedstock to the system, repeatedly.
- In the large system, with a high amount of liquid fertilizer generated, it can be used to feed an anaerobic bioreactor to produce methane gas, or used as nutrient feedstock for algae culture, and it can produce animal feed.
- Operation cost can be as low as 0.60 Baht per 1 kg of fresh organic waste.

However, it should be noted that the bio-digester is in the development process and can work effectively as designed when organic contents are properly segregated. Process diagram of the bio-digester is shown in Figure 4.5. The bio-digester is only employed at the pilot project at Kradangnga Municipality.

The bio-digester has been implemented at the Kradang-Nga Tambon Municipality.

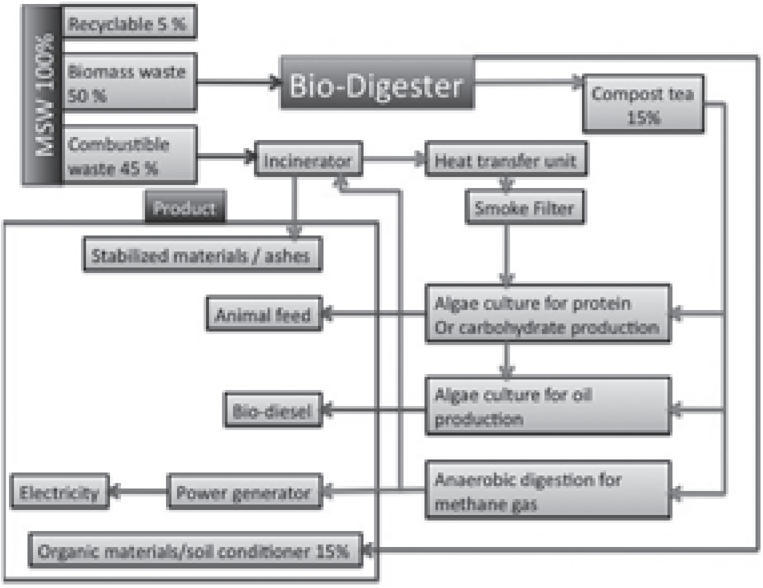
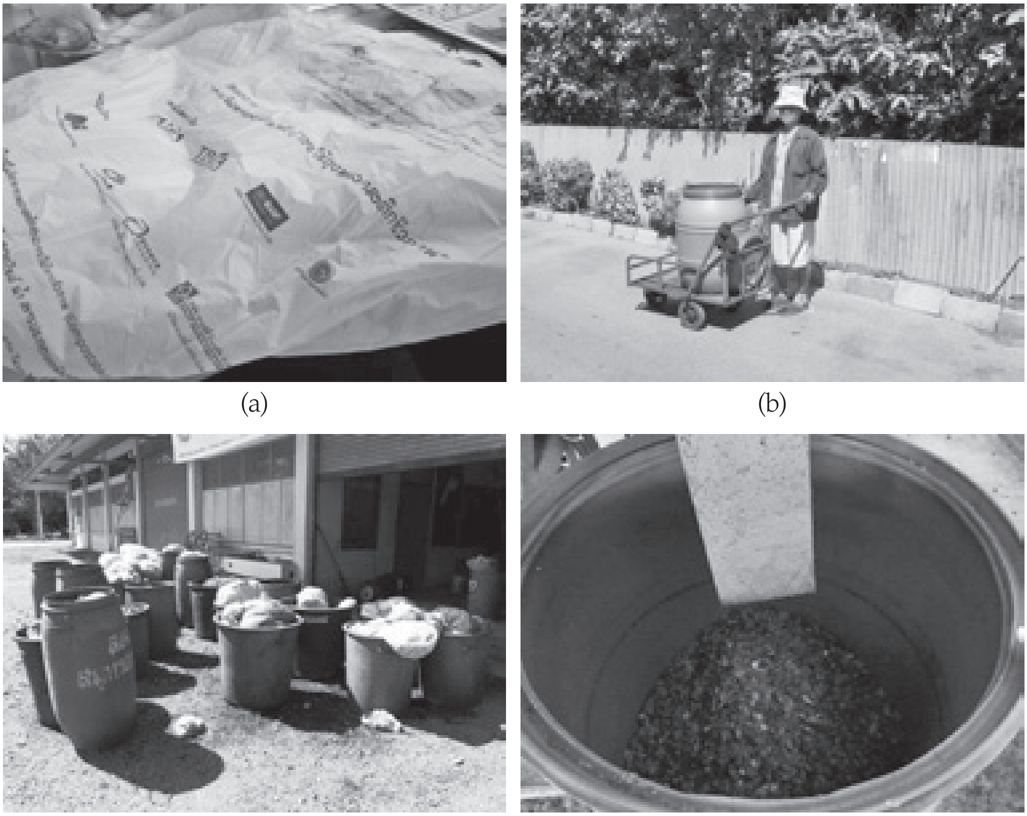


Figure 4.5 Example process diagram of bio-digester.
Source:Modified from http://www.tcm1989.com/biodigestor/Bio-Digester%20Technology%20for%20thailand.pdf

This project has been used as a pilot project in the utilization of biodegradable plastic bags for food waste separation. Households in the municipality were given bio-plastic bags and bins in order to promote waste segregation at the source. Bags are then collected and sent to the bio-digester to be processed (Figure 4.6). At present the municipality can collect approximately 450 kg of waste daily. The produced product is distributed to farmers and residents upon requests, as an incentive for waste separation.

4.4 Mechanical-Biological Treatment for unsorted organic waste

The nature of waste entering landfills in Thailand is mixed-waste packed in plastic bags. As a result it takes longer time to be decomposed. The MBT process employed in Thailand aims to homogenize and shred waste into smaller pieces. Therefore, the decomposition of organic components can be done faster. Since 2001, the Phitsanulok City Municipality has employed this technology and it has been used as the study site for the process in Thailand.



(a) (b) (c) (d)

Figure 4.6 Bio-plastic bags (a), waste collection from households (b), collected waste for digester (c), and digested materials/soil conditioner (d) at Kradangnga Municipality

The solid waste management program of the Phitsanulok City Municipality has been widely recognized as one of the best MSW management practices in Thailand. The management scheme starts with a waste separation campaign at the community level in which over 40% by weight of waste has been reduced. The remaining waste is then transported to the landfill facility in Bangrakam district. To prolong the life of the existing landfill site, the municipality together with GTZ has introduced a pre-treatment process before final disposal into the landfill. The pre-treatment process employed is the Mechanical-Biological Treatment (MBT) designed by Faber Thailand Company, Limited.

The MBT system in Phitsanulok Municipality has a capacity of 100 tons/day of waste received. It comprises four major steps (Figure 4.7).

Step 1: Waste receiving and pre-treatment: Collected waste is placed on the receiving floor where oversize objects, contaminated or hazardous items

(a)

(b)

(c)

(d)

Figure 4.7 MBT process at Phitsanulok Landfill site: (a) waste being placed at the receiving floor; (b) sorted waste is put into rotary drum; (c) homogenized waste is placed to form composting piles; and (d) separation of compost from non-degradable waste.

and other recyclable materials are manually removed. Oversize items are shredded before undergoing the next step.

Step 2: Mechanical treatment: Waste is mixed in a rotating vessel to homogenize materials. The moisture content is adjusted at this step.

Step 3: Biological degradation: The mixed waste from step two is placed on top of wooden pallets to allow aerobic composting conditions. In addition, the wooden pallets enhance drainage of rainfall. Coconut shells are used as a bio-filter material to control odor and other vermin. Moisture content of the windrows is controlled by the watering of compost piles to ensure effective decomposition of organic content. Gas emission and temperature are monitored. The desired temperature for the composting process is in the range of 50 - 70 °C. The time applied for this process is 9 months, but it is possible to shorten the duration to 5 months. However, the Municipality prefers to keep it for 9 months to ensure the maturity of the composting.

Step 4: Landfilling of the remaining residues: After the composting process, most organic contents were degraded and could be used as compost or as cover material for the next batch of composting processes. Inert waste that is not economically viable for recycling is disposed of in landfill.

4.5 Sanitary landfill of unsorted waste for gas recovery

Landfill is the most commonly used technology in managing MSW in Thailand. Slightly more than 45% of landfill sites in Thailand are managed properly and can be considered as sanitary landfill with leachate collection and the lining of landfill floor. More than 50 % of landfill sites are not properly managed.

The operation of sanitary landfill in Thailand involves the spreading of waste in a landfill area and pressing the waste content with a compaction tractor until the waste layer has the density specified in the design. Once the required density is reached, a thin layer of soil is placed on top of the waste layer. The process is done repeatedly until the landfill area is fully packed with waste and soil layers. The area is covered with top soil, and the area is converted to serve other purposes such as recreational areas. Landfill gas recovery is not an obligation for landfill operation in Thailand.

Although operation of sanitary landfill is simple, the environmental impacts it may cause are not simple to deal with. During the decomposition of waste, leachate, and landfill gases are produced. A sanitary landfill pipeline will be laid out at the bottom of the landfill to collect all leacheat for further treatment. Most of the gases produced from the decomposition process are methane (40-60%) and CO_2 (30-50%). The release of these gases to the atmosphere will contribute to rising GHG accumulation.

Capture of methane for energy use is an alternative to reduce climate impact from landfills. A landfill that installs a landfill gas collection system covering all areas within one year after the waste is deposited can achieve 60-85% collection efficiency (with 75% on average) (EPA, 2010). The recovery rate in Thailand can be much lower due to budget constraints and rapid degradation of organic matter.

Utilization of LFG can offset the dependency on fossil fuel. The heating value typically is equivalent to half of the heating value of natural gas (Table 4.5) (SCS Engineers, 1994).

Table 4.5 Fuel Equivalents of Landfill Gas (LFG with 50% methane)

Fuel	Equivalents to 1 m^3 of LFG
Natural gas	0.502 m^3
Propane (liquid)	0.738 L
Butane (liquid)	0.656 L
Gasoline	0.522 L
No. 2 fuel oil	0.481 L
Bituminous coal	0.593 Kg
Medium-dry wood	1.271 Kg

Source: interpreted from SCS Engineers, 1994

Landfill gas recovery project in Rachatewa landfill site

The Rachatewa landfill site is located at Rachatewa Sub-district, Bangpli District, Samut Prakarn Province, 30 km east of Bangkok. It is an old dumpsite of the Bangkok Metropolitan Administrative (BMA).

The landfill occupies some 40 ha and is divided into two sites. Site 1 has operated since 1999 and was closed at the end of 2001. It covered an area of 8 hectare at the west end of the landfill area. The area contains approximately 2.5 million tons of newly disposed solid waste together with 2.2 million tons of old solid waste relocated from the On Nuch landfill site. The base of the site is located 18 meters below ground level. Site 2 has operated since the end of 2001 and was closed in 2006. It was estimated that this site contains approximately 6 million tons of solid waste.

The landfill gas recovery project is implemented at site 1. The construction was started in 2004 and completed in 2005. The LFG collection system is based on horizontal lines and wells which is more appropriate for Thai MSW and the country's climate conditions than a vertical system. The 60% collection efficiency has also been further confirmed by the feasibility study conducted.

This is the first CDM (Clean Development Mechanism) from landfill gas recovery project applied in Thailand. Recovered LFG is utilized as a fuel source for the generator. The capacity of electricity generation is 1 MW. Excess gas is flared under an open system because it is cheaper than a closed one. The generated electricity is sold to the Metropolitan Electricity Authority (MEA) under a power purchase agreement. GHG emissions are expected to be reduced by approximately 470,000 tCO_2eq over ten years (2008-2017) through combustion of the collected methane and displacement of grid electricity produced by fossil fuel based plants (Mitsubishi UFJ Securities, 2009).

4.6 Analysis of Technology from the viewpoints of food and energy security and climate change mitigation

In order to compare different types of urban organic waste management technologies, there are certain numbers of attributes to be considered. Table 4.6 compares five types of technology discussed in this study: composting, anaerobic digestion, bio-digestion, MBT, and sanitary landfill with gas recovery. The first three technologies are suitable for sorted organic waste while the latter two are appropriate for unsorted waste.

Composting technology is varied from a simple one like windrow composting that is applied in a small scale at households and community levels to a complicated one like in-vessel composting that is implemented in BMA. Composting can contribute to food security if farmers are satisfied with the quality of compost produced. However, in some areas where farmers refuse to use compost for food production, the compost can be used for soil improvement in public parks. Compost can be sold for financial revenue; however, much municipal compost is distributed as incentives for waste separation. Making compost can generate a small amount of greenhouse gas emissions; however it only contributes approximately 80% of net greenhouse gas emissions on a lifecycle perspective (in comparison to landfill of organic waste). Unfortunately, composting cannot contribute to energy generation.

Anaerobic digestion is a complicated and expensive treatment compared to composting. However, it can contribute to food, energy and climate co-benefits. Biogas generation from the anaerobic digestion process can be easily collected and used as cooking gas or converted to electricity. However, the system requires enough quality waste input to ensure sufficient gas for energy use. Discharge from anaerobic digestion is useful for soil improvement, and thus can contribute to food production. Under good management, anaerobic digestion releases a smaller amount of GHG emission than composting. It can reduce greenhouse gas emissions by 99% compared to landfill of organic waste (based on a lifecycle assessment). In addition, anaerobic digestion can treat liquid waste efficiently, while composting requires a proper adjustment of moisture content.

Bio-digestion is a new technology in Thailand. Therefore it is very expensive in terms of capital investment per ton of waste. However, the cost is affordable by a small municipality as the system is designed for small scale. This system can be considered as pre-treatment prior to composting and anaerobic digestion, as a system can efficiently separate solid and liquid composition. Solid fractions can be applied directly as soil additive. The liquid fraction can be processed by either anaerobic digestion or bio-extract (fermentation). The discharge after fermentation can be used as soil additive, thus contributing to food production. There is no concise investigation on GHG emission reduction; however, it is assumed to be similar to that of in-vessel composting.

MBT is an alternative to pre-treatment of unsorted waste prior to landfill. It can contribute to extending the lifetime of a landfill, enhancing resource efficiency, and contributing to climate change mitigation.

Compost from MBT can be contaminated with heavy metals; therefore its contribution to food production is questioned. The degraded organic matter from MBT can be used for an energy source if it is processed in a gasification system. However, this technology has not been implemented in Thailand. GHG emission reduction potential of MBT is similar to composting, approximately 80% reduction compared to sanitary landfill.

These four organic waste treatment technologies are preferable to a sanitary landfill with gas recovery system in terms of their effectiveness in reducing GHG emissions, enhancing resource efficiency, and minimizing environmental impacts. Sanitary landfill does not provide co-benefits to food production. However, it can contribute to energy security and climate change mitigation once the landfill gas is collected and used for electricity generation. Sanitary landfill with gas recovery is a desirable option where the municipality has a lack of organic waste separation programs and the Central Government provides a feed-in tariff to power generation.

Based on the aforementioned, it is recommended that local governments should prioritize waste separation at source to maximise utilization of organic waste. A combination of technology such as the combination of composting and MBT, or the combination of composting, anaerobic digestion, and MBT are recommended where resources (budget and personnel) are available.

Table 4.6 Comparison of different types of urban organic waste management technology.

Attributes	Composting	Anaerobic Digestion	Bio-Digester	MBT	Sanitary landfill with gas recovery
1. Suitable waste characteristics	Sorted organic waste: suitable with a certain mixture ratio of wet and dry organic matter	Sorted organic waste: suitable for either wet or dry waste depending on type of AD system	Sorted organic waste	Unsorted waste that contains non-hazardous nor infected waste	Unsorted waste
2. Products	Compost for soil amendment	Biogas as alternative energy and soil additive materials	Soil additives materials (both liquid and solid forms) Possible for energy generation if AD system is installed	Refuse derived solid fuel (RDF), compost-like products that are available for covering of the composting pile and inert waste	Biogas as alternative energy
3. Contribution to food security	Possible with use of compost for cultivation	Possible with use of discharge for cultivation	Possible with use of liquid and solid fertilizer for cultivation	Uncertain, depending on quality of compost-like product, which should meet the heavy metal contamination standard	Almost none. Landfill mining is not practical. The degraded organic matter might contain high heavy metal concentration.
4. Contribution to energy security	Negligible	Possible with power generation	Possible if AD system is installed	Possible with utilization of RDF and gasification of compost-like product	Possible with landfill gas recovery for power generation
5. Contribution to climate change mitigation*	Avoided GHG emissions by approximately 80% per ton of organic waste treated	Avoided GHG emissions by approximately 99% per ton of organic waste treated	Not yet investigated, but assumed to be similar to in-vessel composting	Avoided GHG emissions by approximately 85% per ton of waste treated	Minimizing landfill emission by 12.5% (Rachatewa landfill) and can be up to 50% per ton of waste treated
6. Potential negative environmental impacts	Odor and insect problems can occur under improper management	Leakage of methane gas under improper management	Almost none	Odor and insect problems can occur under improper management	• Methane emission to atmosphere • Limited recovery efficiency of recyclable materials • Foul odors and insect outbreaks under improper management • Leachate pollution to environment under ineffective treatment system

Attributes	Composting	Anaerobic Digestion	Bio-Digester	MBT	Sanitary landfill with gas recovery
7. Capital investment	Low for windrow composting but medium for in-vessel composting	High	Very high	Low	Medium
8. Example of capital investment in Thailand**	Approximately USD 27.97 million for in-vessel composting of 1,000 tons/day in BMA (USD 28,000 per capacity of one ton/day of waste)	Approximately USD 4.53 million for 70 tons/day of waste input in Rayong (USD 64,700 per capacity of one ton/day of waste)	Approximately 1.5 million Baht for handling 0.5 ton/day at Kradangnga (100,000 USD per capacity of one ton/day of waste)	Approximately USD 1.6 million for 100 tons/day of waste input (USD 16,000 per capacity of one ton/day of waste)	Approximately USD 2 million for sanitary landfill without gas recovery of 85 tons/day (USD 23,500 per capacity of one ton/day of waste). Landfill gas recovery system and power generation engine can increase cost.
9. Operational cost	Medium for windrow and high for in-vessel	High for automated system but medium for manual system	Medium-high	Medium	Medium
10. Personnel skills	Skillful personnel required with additional training from supplier when in-vessel composting is selected	Skillful personnel required with additional training from supplier	Skillful personnel required with additional training from supplier	Skillful personnel required with additional training from supplier	Skillful personnel required with additional training from supplier
11. Land requirement	Medium for windrow but low for in-vessel	Low	Low	Medium	High
12. Technology Development	Widely used in many countries, several small sites in Thailand	Widely used in many countries, several small sites in Thailand	Pilot project being implemented	Widely used in Europe, one site in Thailand	Widely used in developed countries, a few sites in Thailand

* Sang-Arun et al, 2012
** Sang-Arun et al, 2011b

5.
Guidance for implementation of urban organic waste utilization project

5. Guidance for implementation of urban organic waste utilization project

Thailand intends to promote the 3Rs for sustainable solid waste management. This policy could significantly contribute to food and energy security as well as climate change mitigation. There are some municipalities implementing organic waste utilization. However, the extension of this practice is very slow due to various constraints and questions on its applicability in other municipalities.

This report provides an analytical framework and guides for local governments on selection of technology and implementation of such technology successfully in their municipalities.

5.1 Overview of barriers in urban organic waste utilization

Information gathered from all studied cities shows that in order to have successful implementation of organic waste management, there are certain types of barriers that local governments should overcome before forming and implementing any action plan. When these barriers are not taken care of, the achievement of the program is unlikely to happen. Some barriers need to be solved by the national government, but some need to be handled by local governments. The barriers are as follows:

- **Institutional barriers:** There are many agencies, both nationally and locally, that play different roles in SWM. Each of the organizations have different functions and responsibility. When they are not coordinating with each other or with the private sector, work cannot be carried out in the same direction. For the case of organic waste utilization, cooperation among related Ministries on unifying the national goals is important to encourage local governments to implement the alternative technology for organic waste utilization.
- **Policy barriers:** Sometimes policies of different Ministries work against each other. For instance, premium price adder to landfill gas recovery or a waste-to-energy project discourages 3R implementation as local governments or investors would like to have more waste for processing.
- **Technical barriers:** Some of the organic waste utilization technologies such as anaerobic digestion are advanced technology. Such technology requires skillful personnel in operation and maintenance. Additionally, as the technologies are new in Thailand, it will take some time to gain acceptance from

the local public. There is also a lack of standards on some of the technologies. Altogether, the commercialization of technology is hard to achieve.

- **Financial barriers:** Since most technologies are new to the market, they normally have higher capital investment, compared to that of conventional technologies. Subsidy from the Central Government is required. In addition, subsidy for conventional sanitary landfill development should be minimized.
- **Information barriers:** In order to gain trust from private investors, and commercialize a technology, a successful pilot project is essential. However, at present, only a limited number of successful projects can be found. Additionally, data from pilot projects, in some cases, are not properly collected and hinder the significance of such data sets. Detailed information for each system should be collected in a scientific manner with appropriate interpretations. Such data should be available to public and private sectors. More effort should be made to compile meaningful information. Information sharing through capacity building and awareness raising should be prioritized.
- **Public support barriers:** In relation to information barriers, the public often lack awareness and confidence in technologies available, resulting in misperception of such technologies and thus leading to conflict between government agencies and local communities. Sometimes, it can stop implementation of a project. Nowadays, this barrier is stronger and tends to be the key driver for improving solid waste management in Thailand.

5.2 Selection of appropriate technology

As described in the previous section, each technology has advantages and disadvantages. In the selection of technology, local governments need to consider local circumstances in terms of budget, personnel, users or marketing of the products, and so on.

In the selection of appropriate technology for each locality, there are at least two main groups of criteria that the local government authorities should take into consideration: technical criteria and economic criteria. The local governments should go through Table 4.6 prior to selection of technology. Sometimes, the most environmental friendly technology may not be selected due to the constraints on technology and economic issues. Public hearings should be carried out prior to technology selection in order to minimize risk of: termination of the project, due to strong public opposition, or failure in implementation due to lack of public cooperation.

5.2.1 *Technical criteria*

- *Characteristics of MSW*: Information on waste composition, waste quantity and other characteristics can strongly influence the technology selection process. Composting, anaerobic digestion, and bio-digestion require waste separation at source, otherwise front-end separation must be installed. MBT and sanitary landfill with gas recovery are appropriate with all types of waste, except for hazardous and infectious waste.
- *Effectiveness in waste utilization*: In terms of waste utilization, anaerobic digestion

has advantages over bio-digestion, over composting. Sorted waste treatment has advantages over unsorted waste treatment. MBT has advantages over sanitary landfill, in terms of overall resource efficiency once RDF and compost-like products are used for energy generation. Landfill gas recovery can provide alternative electricity and resource recovery can be increased if the local governments plan for landfill mining.

- *Land area required*: Space required for each technology is different; anaerobic digestion requires less space than other technology. Working space for MBT and sanitary landfill with gas recovery would be the same in the short term; however the lifetime of an MBT site can be twice that of a landfill site. Technology that requires a large area of operation would create other challenges such as the location of project site, price of property, distance from sources of waste generation, impacts on capital investment, and acceptance of the local public in the area.
- *Operation and maintenance procedure*: Automated systems require higher skilled personnel than a manual system. Once advanced technology is selected, the technology providers should provide training for a certain number of personnel.
- *Flexibility of the system*: In this case, flexibility refers to the ability to adjust the system to make it suitable for wastes of different characteristics, i.e., variation of waste from different seasons. Automated systems may need to be shutdown due to problems with advanced machines or routine maintenance procedures. Each time that a system cannot be operated causes damage to the reputation of the waste utilization technology and also creates further problems in finding alternative solutions to solve problems.
- *Environmental impacts*: All technologies have impacts on the environment at different degrees depending on pollution control measures employed. However, composting, anaerobic digestion, bio-digestion and MBT tend to generate less environmental impact than sanitary landfill.

5.2.2 Economic criteria

- Capital investment: In this case, capital investment include cost of property, machinery, vehicles, construction of plants and other materials important to the installation of the treatment systems. Imported anaerobic digestion, automated composting facility, and bio-digestion have higher cost of capital investment due to advanced machines and operation system, when compared to a simple designed local facility.
- Operation and maintenance cost: This category includes, salary and personnel cost, fuels and materials and supplies, as well as other costs that may be incurred from the operation and maintenance of the system. In Thailand, operation cost of a manual system seems to be cheaper than an automated system.
- Income/by-products from the treatment: In operating the treatment system, there can be income generated as well as other by-products that may have commercial value. Recyclable waste segregated from a composting facility and MBT can be sold. Slurry from anaerobic digestion facility is applicable for soil improvement. The use of by-products or income generated from selling them

can offset the operation costs that have to be paid.

In general, anaerobic digestion is recommended for municipalities that can secure funding for capital investment and hire skillful personnel for operation because this technology can provide various benefits. For municipalities that do not have sufficient funds, windrow composting at a community level is appropriate as it requires very small investment. MBT is recommended to treat unsorted waste delivered to a final disposal site. In recent years, global warming is a serious concern. Therefore, MBT is recommended as an effective measure for climate change mitigation. However, a supporting system to utilize by-products of MBT should be established to ensure effective resource utilization.

A combination of technology implementation is recommended where budget and personnel are available because each type of technology is suitable for a specific type of waste. For example, anaerobic digestion is good for liquid and soft waste while composting is suitable for garden waste. Organic waste that is contained in general waste should be treated by MBT. Segregated valuable materials from MBT such as recyclables, RDF, and compost-like products should be further utilized by means of material, nutrient and/or energy recovery.

5.3 Improvement in waste separation and collection

Even though an organic waste utilization project is introduced, waste reduction should be promoted to maintain or decrease the total waste generation because the waste collection capacity of local governments is limited by the number of collection trucks.

Once anaerobic digestion, composting, or bio-digestion is selected, a specific organic waste separation and collection system should be introduced to ensure sufficient quantity of waste. Contamination of a non-organic waste, especially hazardous and infectious waste, will interfere with the system and give an inferior quality product.

Water should be drained before disposing at the collection bins to minimize working load of the vehicles and avoid foul wastewater on roads or public spaces. In addition, a transfer station should be established when the utilization facility is far from a source of waste generation. Small vehicles may be used for collection from communities, and then waste is transferred to bigger trucks. However, the small vehicles may go directly to the utilization facility if this is economically viable.

It is recommended that the local governments should start a program with large organic waste generators such as restaurants, hotels, food markets, and schools and expand the activity to communities that have strong interest in participation in the projects. A mainstream promotion of waste separation at source could fail easily as a local government may not have enough staff to follow-up and provide sufficient guidance to residents.

Some local governments that have problems with promoting waste separation at source need to introduce a front-end waste separation system. This system is expensive and may generate health hazards for workers. However, a successful case is found in Muangklang Municipality where a locally made conveyor belt is employed for the front-end separation.

Separation of recyclable waste for sale by households is a good initiative that other local governments can follow as it could reduce the work load at the front-end separation. Selling of recyclables is a source of income for the front-end separation system. The local government needs to decide what approach is desirable and easier for the project implementation.

Additionally, the local governments may follow the Solid Waste Management Standard of Department of Local Administration (DOLA) which classifies waste into four categories: i) general waste that is not economically viable for recycling, ii) organic waste, iii) recyclable waste and iv) hazardous waste. Furthermore, the local governments may use different color waste bins or bags to clearly identify type of waste to be disposed of. These waste separation strategies are not beneficial, if the local government does not have a supporting facility to treat this sorted waste.

Organic waste that is sorted by households should be collected separately from other types of waste and directly transported to the utilization facility. When a separation program is promoted, waste collection frequency and routes may need to be adjusted to comply with the separation strategies employed.

Local governments that select to implement MBT and sanitary landfill with gas recovery do not need to employ a specific organic waste separation system.

5.4 Encouraging public participation

Effective organic waste utilization and waste reduction cannot be accomplished unless the project has received support from the local community. As proposed in the previous section, improvement in waste separation and collection systems is an essential factor. However, separation can hardly be done without cooperation from local communities.

Several local government authorities have tried to implement waste separation programs in a top-down manner, excluding local needs. Programs that were designed in such a way will not be able to answer the needs of local people, or the differences in waste compositions from different localities. Most successful waste separation programs have involved local residents in the decision-making process, and the campaigns were then designed according to local characteristics.

Problems concerning public participation in Thailand are rooted in several reasons. Some factors that prevent public participation programs to be implemented effectively are discussed below.

- *Beliefs of local government authorities*. Some of the waste separation campaigns were implemented with the prejudice of local authorities that waste separation is not applicable to Thai behavior and implementation of such policy is ineffectual. However, cases of successful implementation suggested that behavior can be changed and Thais can adapt themselves to waste separation systems.
- *Assessment of the programs*. Many waste separation programs were carried

out without proper evaluation of the implementation. Consequently, weak points of the programs cannot be corrected and improved. Eventually, local communities lost their interest in practicing waste separation.

- *Inadequate supporting systems*. When waste separation programs are being promoted, it is essential for local government authorities to modify their working system to support the program. For example, when households separate their wastes, different types of waste should be collected separately at appropriate time intervals. Food waste, if not routinely collected, can accumulate and generate other environmental problems and reduce the attractiveness of cooperation. This factor seems to be critical for non-participation in waste separation programs of residents.
- *Legal enforcement and incentives*. Waste separation is not legally binding in Thailand. As a result, all types of waste can be mixed together and disposed of. Legal enforcement for illegal dumping violations is low or almost nonexistent. Incentives for waste separation programs are also one of the problems. When there is no incentive or unclear incentive, not necessarily in terms of money, local communities see no reason to support the program. As for this reason, local governments with a waste separation campaign should also adopt ordinances related to waste separation at the source and design clear incentives to cooperate with the program. For example, reduction of waste collection fee for households that separate waste, offering certification to volunteers to promote environmental quality, can be used.
- *Communications*. In this case communications include both communication between local government authorities and citizens and also communication between different agencies related to SWM. Effective communications can reduce misunderstandings and overlapping in performing SWM tasks. A good example is Phitsanulok Municipality, where the government officials regularly communicate with residents, and thus significantly received positive responses from them.

All the factors mentioned above, when combined together can have a fatal effect on the programs. It is, therefore, necessary for local government authorities to recognize the importance of public involvement and include these issues in their consideration of all solid waste management plans including organic waste utilization projects.

5.5 Local capacity building

Even though this report focuses on the promotion of organic waste utilization, local capacity building should cover the entire solid waste management framework to ensure successful implementation of projects.

5.5.1 Institutional capacity building

Solid waste management is a municipal responsibility. Thus, when the municipalities are not equipped with appropriate capacity, they cannot perform their tasks effectively. In some cases, institutions responsible for services may need to be restructured for more accountability and transparency to the residents and business they serve. The units responsible for solid waste management should be promoted to department level and placed directly under the management of trained engineers for the design and operations rationalization, especially when advanced organic waste utilization technology is selected.

Apart from the restructuring of the institution, there should also be an organizational development support provided. Supports can be in forms of clear job descriptions, training, understandable operational procedure, and reduction of low skilled labor idleness. There should be involvement from the private sector in order to introduce competitive forces that increase productivity.

5.5.2 Financial capacity building

Government financial capacity building programs should consider processes that provide adequate cost recovery, or lower the cost by improving the management capacity of the municipalities. Systems that will allow full cost accounting must be developed to provide sufficient information on cost recovery for local authorities. The full accounting systems must include the following detailed information: costs of operation and maintenance, billing, project management, depreciation, etc. While providing SWM services to citizens, local government offices can also generate revenues through implementation of the polluter pay principle. The municipality can apply user charges to recover a portion of the costs of solid waste management services from waste generators. Appropriate charges should be designed and imposed at proper stages of solid waste management. However, charging the full cost of SWM to generators may not be possible and may result in littering and illegal open dumping if the enforcement is weak. Capacity building on incentive generation is also important for successful implementation of waste separation and organic waste utilization programs.

5.5.3 Communities capacity building

As for communities, environmental awareness raising campaigns and environmental education should be in place, in order to generate clear understanding of impacts of improper SWM as well as to get involvement and support from local communities.

Promotion of organic waste separation is more difficult than recyclable waste separation, as organic waste degrades rapidly and generates foul odors. Therefore, awareness is a key driver for public participation on this kind of project.

6. Conclusion

6. Conclusion

The solid waste management policy in Thailand is aligned with the 3Rs and resource efficiency. However, many local governments do not introduce technologies to implement these concepts as they lack the necessary technical capacity and they are unsure whether the technologies can be implemented in their area.

Some municipalities have established urban organic waste utilization programs as it could contribute to the national agenda on sustainable development including food, bio-energy, and climate change issues. Examples include household composting, centralized composting, anaerobic digestion, MBT, and landfill gas recovery. The successes and constraints of these programs provide important lessons for scaling-up and replication in other parts of Thailand, though local governments need to modify technologies and design management systems to reflect their capacities and local circumstances.

Selecting appropriate technology is not easy for local governments. They face budgetary and personnel constraints and the problem of service providers presenting only positive information about their technologies. The guidance on technology selection criteria and recommendations for successful implementation, including improving waste separation and collection systems, encouraging public participation and increasing local capacity (both local government and communities) provided in this report will help local governments make these decisions.

Each technology has advantages and disadvantages. For instance, composting is a simple and cheap technology that can be implemented by any municipality, but it does not provide the opportunities for energy generation that anaerobic digestion and landfill gas recovery do. The best technology for each locality depends, inter alia, on the local conditions, local needs, budgets, human resources, marketability, and preferences of residents. For cash-strapped municipalities, composting provides the best option for organic waste utilization, whereas for municipalities with larger budgets, a combination of anaerobic digestion, and composting would be the best option.

Once they have selected an urban organic waste utilization technology, local governments must pay attention to a range of social and financial issues, such as the willingness of local people to co-operate, improvement of the waste collection and separation system to ensure quality control of the waste inputs, training of residents on waste separation and disposal, training of government officers on project management and public relations, and mainstreaming of waste management throughout the local government departments.

Local governments should not expect great achievements in the first few years of implementation. Local residents need time to become accustomed to the urban organic waste utilization system and to understand how they can contribute to the project and environmental improvements in general. Campaigns involving the mayor and making use of public events, such as having compost making demonstration booths at festivals, are useful tools to encourage public participation, both at the beginning of the program and from time to time after implementation.

Keys to successful implementation include strong commitment of the mayor and senior administrator(s), continuity of the program, and stakeholder participation. Local governments must be prepared to respond to problems, which invariably arise at some stage during implementation, and to innovate as necessary. Periodic public consultations can uncover problems and their causes, before they get out of hand, and provide solutions.

Finally, local governments should develop their urban organic waste utilization program within a comprehensive strategy for waste management that sets waste reduction as a top priority.

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Appendix I

Summary of Regulatory Framework on Solid Waste Management

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Summary of Regulatory Framework on Solid Waste Management

1. National Level

1.1 National Regulatory Framework

The Constitution of the Kingdom of Thailand B.E.2550 (2007)

According to The Constitution of the Kingdom of Thailand B.E.2550 (2007), environmental management is different from the previous constitutions. This law provides the public right to participate in the prevention and elimination of any actions that can deteriorate natural resources and pollute the environment, some of the sections related to this statement are as follows:

- **Section 57** A person shall have the right to receive data, explanations and reasons from a Government agency, a State agency, a State enterprise or a local government organization prior to the approval or the operation of any project or activity which may affect the quality of the environment, health and sanitary conditions, the quality of life or any other material interest concerning such person or a local community and shall have the right to express his or her opinions to agencies concerned, for assisting further consideration of such matters.
- In planning social, economic, political and cultural development, or in undertaking expropriation, town and country planning, zoning and making by-laws likely to have impacts on essential interests of the public, the State shall cause to be held comprehensive public hearings prior thereto.
- **Section 66** Persons so assembling as to be a community, a local community or a traditional community shall have the right to conserve or restore their customs, local knowledge, good arts and culture of their community and of the nation and participate in the management, maintenance, preservation and exploitation of natural resources, the environment and the biological diversity in a balanced and sustainable fashion.
- **Section 67** The right of a person to give to the State and communities participation in the conservation, preservation, and exploitation of natural resources and biological diversities and in the protection, promotion and preservation of the quality of the environment for regular and continued livelihood in the environment, which is not hazardous to his or her health and sanitary condition, welfare or quality of life, shall be protected as appropriate.
- **Section 85** The State shall pursue directive principles of State policies in

relation to land, natural resources and the environment, as follows:

(1) to prescribe rules on land use which cover areas throughout the country, having regard to the consistency with natural surroundings, whether land areas, water surfaces, ways of life of local residents, and the efficient preservation of natural resources, and prescribe standards for sustainable land use, provided that residents in areas affected by such rules on land use shall also have due participation in the decision-making;

(2) to distribute land holding in a fair manner, enable farmers to have ownership or rights in land for farming purposes thoroughly through land reform or otherwise, and provide water resources for sufficient use of water by farmers in a manner suitable for farming;

(3) to provide town and country planning and carry out the development and action in the implementation of town and country plans in an efficient and effective manner in the interest of sustainable preservation of natural resources;

(4) to provide a plan for managing water resources and other natural resources systematically and in a manner generating public interest, provided that the public shall have due participation in the preservation, maintenance and exploitation of natural resources and biological diversity in a balanced fashion;

(5) promote, maintain, and protect the quality of natural resources in accordance with the sustainable development principle, control and eradiate polluted conditions affecting health, sanitary conditions, welfare and the quality of life of the public, provided that members of the public, local residents and local government organizations shall have due participation in determining the direction of such work.

- **Section 290** A local government organization has powers and duties in connection with the promotion and maintenance of the quality of the environment as provided by law. The law under paragraph one shall at least contain the following matters as its substance:

(1) the management, preservation and exploitation of the natural resources and environment in the area of the locality;

(2) the participation in the preservation of natural resources and environment outside the area of the locality only in the case where the livelihood of the inhabitants in the area may be affected;

(3) the participation in considering the initiation of any project or activity outside the area of the locality which may affect the quality of the environment, health or sanitary conditions of the inhabitant in the area;

(4) the participation by local communities.

The Enhancement and Conservation of National Environmental Quality Act (NEQA) 1992

At the national level, the NEQA of 1992 is the basic environmental protection law for the country and establishes the role of Ministry of Natural Resources and Environment (MNRE) in environmental planning, standard setting, and monitoring. Key points in the NEQA 1992 include the following points.

- the provision of the right of individuals to information, compensation and redress against violators, and the duty of individuals to assist and cooperate in enhancing and protecting the environment;
- a recognition of the role and standing of environmental NGOs;
- the provision for the Prime Minister or the delegated provincial governor to deal with emergencies or public danger arising from natural disasters or environmental pollution;
- the creation of a high-level multi-representational National Environmental Board (NEB) to oversee the coordinated response of ministries inter se and between central and provincial authorities;
- the reconstruction of environmental related agencies by setting up the Office of Environmental Policy and Planning (OEPP), Pollution Control Department (PCD), the Department of Environmental Quality Promotion (DEQP);
- the establishment of an Environmental Fund from which resources will be drawn to combat environmental incidents and to enhance environmental protection efforts like research and training, disbursements of loans and grants, education, NGO funding, etc. The fund provides grants to governmental agencies and low-interest loans to the private sectors who are engaged in the activities related to the improvement of the environment;
- the formulation of a National Environmental Management Plan and the subsequent duties of government agencies to implement the Plan and of provinces to draw up corresponding Provincial Action Plans, if required;
- the provision for the NEB to declare Pollution Control Areas (PCAs) in localities where particularly serious pollution concerns have arisen - contingent upon the declaration of a PCA, special measures may be taken to redress the problem in the area concerned, and a duty is henceforth imposed upon the provincial governor to draw up a Provincial Action Plan to redress the situation;
- the provision for the declaration of Conservation and Environmentally Protected Areas in environmentally-fragile areas where special measures can be taken to protect sensitive natural ecosystems and wherein a Provincial Action Plan would have to be formulated by the provincial governor to address the concerns;
- the provision for the NEB (instructing the MOSTE) to assume jurisdictional competence over provinces where the provincial authorities demonstrate an unwillingness or incapacity to deal with a particular incident or to come up with suitable provincial plans;
- the prescription of a fairly-detailed environmental impact assessment (EIA) process which incorporates public participation and views of experts in

decision-making;
- the establishment of a multi-agency Pollution Control Committee to oversee pollution control matters, including the enactment of discharge standards;
- the regulation of air, noise, water and hazardous waste pollution, as well as other forms of pollution;
- the duty to use central waste treatment facilities, the expense for which is borne by the user (pursuant to the "polluter pays" principle);
- the prescription of various civil, criminal and administrative remedies for environmental violations.

When focusing on solid waste management issue, it specifies the role of the municipality in: managing solid waste management, contracting out solid waste management services to the private sector where needed, and charging fees in accordance with ministerial regulations. The environmental fund can be used to finance solid waste investments proposed by local governments. As for industrial and hazardous wastes, the management is emphasizing environmental planning and environmental quality standards and monitoring as well as the establishment of EIA system, which applies to industrial waste disposal sites. Examples of related section in NEQA 1992 are shown below.

- ***Section 78*** The collection, transport, and other arrangements for the treatment and disposal of garbage and other solid wastes; the prevention and control of pollution from mining both on land and in the sea; the prevention and control of pollution from the exploration and drilling for oil, natural gas, and all kinds of hydrocarbon both on land in the sea; and the prevention and control of pollution resulting or originating from the discharge of oil and the dumping of wastes and other matters from sea-going vessels, tankers, and other types of vessel, shall be in accordance with the governing laws related thereto.
- ***Section 79*** In case there is no specific law applicable thereto, the Minister shall, with the advice of the Pollution Control Committee, have the power to issue ministerial regulations specifying the types and categories of hazardous wastes generated from the production and usage of chemicals or hazardous substances in the production process of industry, agriculture, sanitation, and other activities which shall be brought under control. For this purpose, rules, regulations, measures and methods must also be prescribed for the control of collection, storage, safety measures, transportation, import into the Kingdom, export out of the Kingdom, and for proper and technically sound management, treatment and disposal of such hazardous wastes.

A numbers of ministerial regulations were issued or revised in accordance to the revision of the NEQA, 1992. Following are the selected ministerial regulations related to the management of solid waste.

- Notification of the Ministry of Science, Technology and Environment, Issued under the NEQA, and published in the Royal Gazette Dated 7 August, 1997. This Notification sets standards of effluents from waste incinerators. Under this notification: the waste incinerator shall be divided into two sizes:
  - With the capacity rate of waste incineration: from 1 ton per day, but

not more than 50 tons per day.
  - With the capacity rate of waste incineration: more than 50 tons per day.
- Notification of the Ministry of Science, Technology and Environment #3, Issued under the NEQA, and Published in the Royal Gazette Dated 13 February, 1996. This Notification sets industrial effluence standards controlled by the Pollution Control Committee (PCC).
- Notification of the Ministry of Science, Technology and Environment, Re: Specifying Conditions, Procedures and Guidelines for Preparing Reports on Environmental Impact Assessment. This Notification governs the conditions, procedures, and guidelines for preparing reports on Environmental Impact Assessment. Central waste treatment plants are governed by this Notification. It specifies that, if the waste treatment project is not required to be approved by the Thai Cabinet, the EIA reports can be submitted during the application for the establishment or the expansion of the factory. On the other hand, if the waste treatment project is required to obtain prior approval from the Thai Cabinet, the EIA reports must be submitted prior to the filing of the request for the Thai Cabinet's approval.

1.2 Laws and Regulations Related in SWM

Public Health Act (PHA), 1992

These are the most comprehensive laws dealing with solid waste management. The PHA specifies that local government must provide disposal facilities for infectious and industrial non-hazardous waste and that health-care facilities can treat and dispose of infectious waste with approval from the local government. They emphasize the roles of the municipality in solid waste management described in NEQA. The PHA Act designates sewage and solid waste management the responsibility of local authority.

Public Cleanliness and Orderliness Act (PCOA), 1992

The main content of this act is to forbid any activity that is likely to cause dirtiness to streets and public places all over the country. It specifies how households should store solid waste and place it for collection. The act is one of several that prohibit dumping of solid waste and littering.

Factory Act, 1992

The Act mainly controls and regulates the establishment and the operation of factories in Thailand by paying attention to the impacts of a factory on the environment. Generally, factories are required to be kept clean and free from garbage and refuse at all times. It authorizes the Department of Industrial Works (DIW) to issue standards and specify methods for the control, handling, and disposal of waste by a factory and to license, permit, and inspect factory operations, including waste management. It also governs the licensing, permitting, and inspection of waste treatment, disposal, and recycling facilities. Also, according to Section 8 in the Act, PCD has authority to establish standards and criteria to control the factory operations, specially the standards and methods to control the disposal of waste, pollution or any contaminants caused from factory operation that impact the environment.

Hazardous Substance Act, 1992

The act governs a broad range of hazardous materials, including hazardous and infectious waste. It also allows the handling, storage, transport, and disposal of hazardous waste to be specified in a ministerial decree. The act describes hazardous substance control criteria for import, production, transportation, consumption, disposal, and export, and not to influence and be dangerous to humans, animals, plants, properties, or the environment. The Ministry of Industry (MOI) categorizes the hazardous substances into 4 types for use to control correctly and appropriately, and designates the Hazardous Substances Information Center to coordinate with other government agencies on hazardous substances information and stipulation of the criteria and methods to register hazardous substances.

Industrial Estate Act, 1979

The Act oversees the powers of the Industrial Estate Authority of Thailand, including enforcement of regulations and taking action on hazardous waste practices within industrial estates.

Construction Building Control Act, 1979

The Construction Building Control Act of 1979 controls the design, construction, renovation, remove and utilization of buildings. The construction of a waste treatment plant shall be considered as the construction of a building under this Act.

1.3 Code of Penalty

There are some Sections in the Penal Code of Thailand, which relates to the management of waste and refuse: those are as follows:

- Under Section 237 of the Penal Code of Thailand, it states that whoever introduces a poisonous substance or any other substance likely to cause injury to health into food or water in any well, pond or reservoir, and such food or water has existed or has been provided for public consumption, shall be punished with imprisonment of six months to ten years and a fine of one thousand to twenty thousand Baht.
- Under Section 238, it states that if the offences committed according to Sections 226 to 237 causes death to another person, the offender shall be punished with imprisonment for life or imprisonment for five to twenty years and a fine of ten thousand to forty thousand Baht. If it causes grievous bodily harm to another person, the offender shall be punished with imprisonment of one to ten years and a fine of two thousand to twenty thousand Baht.
- Under Section 239, its states that if the offences mentioned in Sections 226 to 237 are committed by negligence and result in imminent danger to the life of another person, the offender shall be punished with imprisonment not exceeding one year or a fine not exceeding two thousand Baht, or both.

2. Provincial Level

All national level Laws, Regulations, Ordinances and Guidelines relevant to SWM are applicable at the provincial level.

3. Local Level

All National level Laws, Regulations, Ordinances, and Guidelines relevant to SWM are applicable at the local level.

Additionally, municipalities, and BMA have the authority to grant licenses to private solid waste operators and in creating local by-laws that govern SWM. Each municipality and BMA have the authority to issue Regulations and Ordinances relevant to SWM. Selected BMA Ordinances are as follows.

BMA Ordinance: Disposal of Garbage, Refuse, and Unclean Things (1978)

Under this Ordinance: *Garbage* means waste from paper, cloth, food, merchandise, ash, animal droppings or carcasses, including things swept from streets, market places, animal stalls, or other places. *Refuse* means excrement or urine and shall include anything which is unclean and has foul odor. Articles of this Ordinance are as follows:

- Article 5: The person who is in possession of a premises, building, or dwelling place is required to provide garbage containers and use them to contain garbage within the premises, building, or dwelling place possessed by him.
- Article 8: No person shall discharge, dump, discard, or create refuse or unclean things in public places or ways such as a street, passage, lane, river, canal, ditch, pond, or well, except at the places the setting up of which is permitted by a Public Health Official or a Local Official, or is specially provided.
- Article 14: No person other than the officials of BMA shall haul, scavenge, or dig garbage in garbage containers, garbage hauling automobile or vessel, or at any garbage-dumping sites of the BMA.

BMA Ordinance: Control of Water Sewage System (1991)

This Ordinance controls the water sewage systems in general types of buildings.

BMA Ordinance: Specifying Requirements for Construction of Building and Public Utilities (1996)

This Ordinance controls the construction of building and public utilities systems in Bangkok.

BMA Ordinance: Control of Waste Collection, Haulage, or Elimination Business which is made for Consideration as Service Fee (1998)

This Ordinance controls the waste collection, haulage, or elimination business, which is engaged by a private sector that provides the said waste collecting, hauling or eliminating service in consideration of service fees. It requires that any person, who wishes to provide the said services, must firstly obtain a license from BMA. The licensee shall enter into the agreements with BMA in accordance with the standard agreements drafted by BMA. It also states the obligations and responsibilities of the licensee.

Technical Guidelines

In addition to the laws and regulations, there are also technical guidelines prepared by relevant agencies covering several managerial aspects of various types of waste. Some are listed as follow;

- BMA's Technical Guideline for Solid Waste Operator.
- BMA's Guideline and Procedures for service fee collection.
- Guide to the Implementation of the

Notification of Ministry of Industry on Hazardous Waste Manifest System Notification B.E. 2547 (2004).
- Guidelines for Waste Management in Hospitals.

Appendix II

Institutional Framework of Solid Waste Management in Thailand

Appendix II Institutional Framework of Solid Waste Management in Thailand

1. Overview of Institutional Framework

Institutions involved in SWM distributed into three administrative levels: national, provincial, and local levels. At the national level there are four ministries involved with agencies under each of the ministries to oversee the issue of solid waste management.

However, under Section 18 of the Public Health Act of 1992, the disposal of sewage and solid waste in the area of any local government shall be the power and duty of such local government. With reasonable cause, the local government may entrust any person with the solid waste management tasks on its behalf under the control and supervision of the local government or may permit any person to operate the disposal of sewage or solid waste.

As for BMA and municipalities, there are several institutions involved in solid waste management. However, as they are one of the organizations under the Ministry of Interior, they have their own solid waste management scheme. The decision-making processes are agreed upon within the BMA and municipalities and mostly do not have to be approved by the central government.

2. Roles and Responsibilities of Relevant Authorities, Institutions, and Organizations

2.1 National Level

In respond to NEQA 1992, the National Environmental Board (NEB) has been formed to oversee the management of the country's natural resources and environmental quality. Components and functions of NEB are described in the next section.

There are four ministries at the national level that are responsible for SWM, namely, the Ministry of Natural Resources and Environment (MNRE), the Ministry of Public Health (MoP), Ministry of Industry (MoIND), and Ministry of Interior (MoINT). Principally, the ministries set the national environmental policy and the departments and agencies under the ministries are responsible for implementing the provisions of the law through regulations and technical guidelines.

(A) National Environmental Board

The NEB consists of the following members;

- Prime Minister as the Chairman,
- Deputy Prime Minister designated by

the Prime Minister as the first Vice Chairman
- Minister of Science, Technology and Environment as the second Vice Chairman
- Minister of Defense
- Minister of Finance
- Minister of Agriculture and Cooperatives
- Minister of Transport and Communications
- Minister of Interior
- Minister of Education
- Minister of Public Health
- Minister of Industry
- Secretary-General of the National Economic and Social Development Board
- Secretary-General of the Board of Investment
- Director of the Bureau of the Budget
- Experts in environmental matters: not more than eight persons of which no less than half shall be representatives from the private sector
- Permanent Secretary of the Ministry of Science, Technology and Environment as member and secretary

The appointment of qualified members shall be made by drawing from persons who are knowledgeable and known for their expertise, contributions and experiences in the matters concerning the enhancement and conservation of environmental quality.

The National Environment Board shall have the power and duty as follows;

- To submit policy and plan for enhancement and conservation of national environmental quality to the cabinet for approval.
- To prescribe environmental quality standards pursuant to section 32.
- To consider and give approval to the Environmental Quality Management Plan proposed by the Minister according to section 35.
- To consider and give approval to the Provincial Action Plan for environmental quality management according to section 37.
- To make recommendations to the cabinet in respect of financial, fiscal, taxation and investment promotion measures for the implementation of the policy and plan for enhancement and conservation of national environmental quality.
- To propose for amendment or improvement of laws relating to the enhancement and conservation of environmental quality to the cabinet.
- To consider and give approval to the action plan for prevention and remedy of danger caused by contamination of pollutants or spread of pollution proposed by the Pollution Control Committee pursuant to section 53 (1).
- To consider and give approval to the setting of emission or effluent standards proposed by the Minister pursuant to section 55.
- To supervise, oversee and expedite the enactment of royal decrees and issuance of ministerial regulations, rules, local ordinances, notifications, bye-laws and orders which are necessary to ensure systematic operation of the laws relating to enhancement and conservation of environmental quality to the fullest extent possible.
- To submit opinion to the Prime Minister for his/her directions in case it appears that any government agency or state enterprise infringes or refrains from complying with the laws and regulations for environmental protection, which

may cause extensive damage to the environment.

- To specify measures for the strengthening and fostering of co-operation and co-ordination among government agencies, state enterprises and the private sector in matters concerning the promotion and conservation of environmental quality.
- To supervise the Fund management and administration.
- To submit reports on national environmental quality situation to the cabinet at least once a year.

(B)Ministry of Natural Resources and Environment

The ministry has been set up in 2002, following the Restructuring of Ministries, Bureaus and Departments Act of B.E. 2545 (2002). The responsible agencies for SWM within the Ministry of Natural Resources and Environment are the Pollution Control Department (PCD), Office of Natural Resources and Environmental Policy and Planning (ONEP), and the Department of Environmental Quality Promotion (DEQP).

(C)Ministry of Public Health

The Restructuring of Ministries, Bureaus and Departments Act of B.E. 2545 (2002) provides that the Ministry of Public Health has powers and responsibilities related to the promotion of health, prevention/ control and treatment of diseases, and rehabilitation of people's health, as well as other official functions as provided by laws which indicate that such functions are under the responsibility of the Ministry of Public Health.

Its principal purpose is to make all Thai citizens healthy, physically and mentally, with good quality of life, to be able to live a happy life in society and to be valuable resources of the country. Regarding SWM, the Department of Health (DOH) under the Ministry of Public Health is responsible for medical waste and infectious waste management.

(D)Ministry of Industry

The Department of Industrial Works (DIW) and the Industrial Estate Authority of Thailand (IEAT) under the Ministry of Industry are responsible for all hazardous wastes generated from industries.

DIW has the capability to supervise, promote, and support industrial business operation for its sustained development and acceptability to the international community. Its major responsibilities include the supervision and coordination of industrial business operation activities by following the guidelines of environmental preservation, safety, hygiene, and energy economization.

The Industrial Estate Authority of Thailand (IEAT) is a state enterprise under the Ministry of Industry; the Industrial Estate Authority of Thailand is responsible for the development and establishment of industrial estates, where factories for various industries are orderly and systematically clustered together. The enterprise is to provide an environmental management system, along with industrial accident prevention and relief systems.

(E)Ministry of Interior

The Ministry is given wide ranging responsibilities over many aspects. For example the Ministry has responsibility over:

the Royal Thai Police, local administrations, internal security, citizenship, disaster management, land management, issuing national identity cards and public works. The Ministry is also responsible for appointing 74 Governors of the Provinces of Thailand.

2.2 Provincial and Local Levels

At the provincial and local levels, the provincial administrative organizations (PAO), municipalities and Tambon (Sub-district) Administrative Organization (TAO) are primarily responsible for waste collection, transport, treatment, and disposal. These local governments can contract the private sector to undertake some of the services. During the last few years, the government has implemented the Decentralization Action Plan in order to transfer functions, budgets, and personnel from the central government to nearly 8,000 local governments.

(A)Provincial Administrative Organization (PAO)

After the act of PAO in 1997 was approved by the Parliament, it started enforcement on 1 November 1997. This act is about the administration of PAO, which is a local administration, rather than a provincial administration.

(1)Administrative structure

The president of PAO is Chief of Administrative Office (previously, a Provincial Governor), Vice President of PAO is an Assistant, and Deputy of PAO is a Supervisor. The Royal Decree on PAO Officers in 1998 describes the division of PAO as follows;

1. Administrative Department
2. PAO Affair Department
3. Planning and Budget Department
4. Financial Department
5. Engineering Department
6. Others

(2) City Council of PAO Structure

City Council of PAO consists of memberships who are elected from people who have the right to vote and have 4 year terms for administration. The amount of memberships in each province will not be the same, depending on the number of people in a previous year's house registration.

(3) Roles and Responsibility

Under the Act of Decentralization Section 17, Provincial Administrative Organization (PAO) has a responsibility to administrate public service as here:

- Provide local development plan and other development plans assigned by the Interior Minister
- Support the development of local administrative organizations
- Co-operate with other local administrative organizations
- Allocate budget to local administrative organizations
- Protect, take care of, and preserve forest, land, natural resources, and the environment
- Support educational systems
- Uphold democracy, equality, liberty, and rights of people
- Support each community to participate in local development
- Support the development of technology
- Set up wastewater treatment systems

- Clean up waste and garbage
- Reduce pollution and environmental problems
- Administrate land and water transportation
- Promote tourism
- Support investments and corporate investment
- Set up and preserve land and water transportation among other local organizations
- Establish middle markets
- Uphold sports, customs, and culture in communities
- Provide Provincial Hospitals, treatments, and contagious disease prevention and control
- Establish and preserve museums and archives
- Uphold mass communication and traffic engineering
- Prevent and decrease public hazards
- Set up security systems
- Promote and create activities for other local administrative organizations to work together and launch projects for local organizations to work out by themselves
- Support and assist government sections and other local administrations
- Service the government sector, private sector, state enterprises, and other local administrative organizations
- Uphold public welfare for children, women, elderly, and people who are disadvantaged
- Promote and provide projects, using the criteria of PAO law
- Uphold and support other projects which can enhance life for people in a community.

(B)City Municipality Office

According to Municipal Act B.E. 2496 (1953) review to be the twelfth issue B.E. 2546 (2003), it stated duties and functions of municipality as follows:

- Law and order maintenance
- Provision and maintenance of land and water resources.
- Cleanliness of streets, pathways and public places as well as disposal of solid waste and sewage.
- Prevention and control of communicable diseases.
- Provision of fire-extinguishers and fire-engines.
- Providing public training courses to educate local people.
- Provision and maintenance of social welfare for mothers, children, youth, old people, and handicapped people.
- Maintenance of local arts, tradition, local wisdom, and local culture.
- Provision of water supply or clean water.
- Provision of abattoir or slaughter houses.
- Provision and maintenance of hospitals.
- Provision and maintenance of drainage systems.
- Provision and maintenance of public toilets.
- Provision and maintenance of electricity or other means of lighting.
- Provision of pawn shops or local finance.
- Provision and maintenance of mothers and children.
- Other tasks for public health.
- Controlling safety, order, and sanitation in food shops, theatres and public places.
- Improvement of slum settlements and housing management.
- Provision of markets, ferries, and

parking lots.
- City planning and building control.
- Tourism promotion.
- Other duties specified by other specific laws.

In terms of management structure, the City Municipality Office has the following management structure.

1)Mayor of Municipality

The mayor, the highest executive, is directly elected by eligible voters in the municipal area and has a term of 4 years. The mayor will be assisted by deputy mayors who are appointed by the mayor (not more than 4 deputies). The mayor will also be able to appoint 1 advisor and 4 secretaries.

2)Deputy Mayors

The deputy mayor is empowered to make decisions and administer the matters assigned to him/her by the mayor. Matters are reported directly to the mayor, as specified by laws or regulation, as the authority of the deputy mayor.

3)Advisor and Secretary to Mayor

Their tasks are specified by the mayor.

4)Municipal Council

The municipal council is the legislative body of the municipality. It has the power to issue ordinances by law, which must not be contradictory with the laws of the country. The municipal council applies to all people living in municipal areas. The City Municipality comprises elected members who will serve for 4-year terms. Among those members, one of them is elected to be the chairperson of the municipal council and one of them is elected to be the vice-chairperson of the municipal council. An example of organizational structure in Thailand is shown in Figure A2-1.

(C)Sub-District (Tambon) Administrative Organization (TAO)

A tambon is usually translated as sub-district in English. It is the third administrative subdivision level after a district and a province. Following the Tambon Council and Tambon Administrative Authority Act BE 2537 (1994) and later by the constitution of 1997, tambons were decentralized into local government units with an elected Tambon Council. Depending on the size and tax income a tambon may either be administrated by Tambon/Sub-district Administrative Organization (TAO) or a Tambon Council (TC). The TAO or TC consists of two representatives from each village within the jurisdiction of that Tambon. The Tambon area, which belongs to a municipality, is administrated by the city council. In the case only a part is within a municipality, the remaining part is administrated by a TAO. Adjoining Tambons of a single Amphoe (district) can also have a joint TAO responsible for more than one Tambon.

2.3 Private Sectors and Civil Society

Due to the fact that not all solid wastes are collected in several TAOs, communities in a province contribute greatly to the control of solid waste management problems. Society conducts awareness raising programs and promotion of recycling efforts. Both the Decentralization Action Plan of the government and the 1997 Constitution mandate greater public participation in environmental planning and implementation of environmental services. Effective waste management will rely upon active involvement of the public in activities such as reporting open dumping of industrial waste, disposal site planning as well as reduction of waste generated via reuse, recycling, and composting initiatives. Civil society organizations will continue to play a key role in bringing about this involvement through awareness building and encouraging local initiatives.

Figure A2-1 Organization Chart of a City Municipality Office.

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