MUNICIPAL SOLID WASTE MANAGEMENT AND FEASIBILITY STUDY OF COMPOSING TECHNOLOGY IN LOCAL GOVERNMENT

CASE STUDY SUB-DISTRICT MUNICIPALITY
SURATTHANI PROVINCE

BY

CHUTIMON SOMBOONMARK

A THESIS SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF MASTER OF ENGINEERING (ENGINEERING TECHNOLOGY)
SIRINDHORN INTERNATIONAL INSTITUTE OF TECHNOLOGY
THAMMASAT UNIVERSITY
ACADEMIC YEAR 2016

MUNICIPAL SOLID WASTE MANAGEMENT AND FEASIBILITY STUDY OF COMPOSING TECHNOLOGY IN LOCAL GOVERNMENT

CASE STUDY SUB-DISTRICT MUNICIPALITY
SURATTHANI PROVINCE

BY

CHUTIMON SOMBOONMARK

A THESIS SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF MASTER OF ENGINEERING (ENGINEERING TECHNOLOGY)
SIRINDHORN INTERNATIONAL INSTITUTE OF TECHNOLOGY
THAMMASAT UNIVERSITY
ACADEMIC YEAR 2016

MUNICIPAL SOLID WASTE MANAGEMENT AND FEASIBILITY STUDY OF COMPOSING TECHNOLOGY IN LOCAL GOVERNMENT

CASE STUDY SUB-DISTRICT MUNICIPALITY SURATTHANI PROVINCE

A Thesis Presented

By

CHUTIMON SOMBOONMARK

Submitted to

Sirindhorn International Institute of Technology

Thammasat University

In partial fulfillment of the requirements for the degree of

MASTER OF ENGINEERING (ENGINEERING TECHNOLOGY)

Approved as to style and content by

Advisor and Chairperson of Thesis Committee ____________________

(Assoc. Prof. Dr. Taweep Chaisomphob)

Committee Member and

Chairperson of Examination Committee ____________________

(Assoc. Prof. Dr. Alice Sharp)

Committee Member ____________________

(Assoc. Prof. Dr. Sandhya Babel)

Committee Member ____________________

(Prof. Dr. Kiyohiko Nakasaki)

December 2016

Abstract

MUNICIPAL SOLID WASTE MANAGEMENT AND FEASIBILITY STUDY OF COMPOSING TECHNOLOGY IN LOCAL GOVERNMENT

CASE STUDY SUB-DISTRICT MUNICIPALITY SURATTHANI PROVINCE

By

CHUTIMON SONBOONMARK

Bachelor of Science (Public Health): Thammasat University, 2013
Master of Engineering (Engineering Technology): Sirindhorn International Institute of Thailand, Thammasat University, 2016

This study was focused on the municipal solid waste management (MSW) of rural community by investigating the waste generation rate and evaluating the MSW produced from Thachi sub-district municipality, Suratthani Province, in order to study the feasibility for use of the composting technology "Serial-Self Turning reactors (STR)" by characterizing the putrescible waste.

Municipal solid waste consists of a high proportion of biodegradable materials especially food waste containing large reserves of nutrients. The composting technology is the option for processing the enormous quantities of biodegradable solid waste, and hence the volume of wastes placed in landfills can be reduced. For implementing the composting, source separated waste should be improved. Municipal solid waste by public participation was undertaken in term of the community-based waste management system. The source separation practice as recycling waste which biodegradable waste was used as a material for composting.

The small-scale composting was performed for study with the composite materials between kitchen waste include food and vegetable waste and the bulking agent were collected from the agricultural sectors such as dried leave, yard waste, empty palm fruit bunch and cow manure in order to find the best mixing proportion.

After that, the large-scale composting by STR technology was conducted. It was found that the best proportion from small-scale composting is 0.25: 1.0 : 0.5 which the waste combination consists of vegetable waste, cow manure and agricultural waste, respectively. Providing the final product properties of composting contains low nutrients (NPK) that did not meet the criteria of biofertilizer, determined by Department of Agricultural of Thailand.

Keywords: solid waste, municipal solid waste management, composting, MSW, serial self-turning technology (STRs)

Acknowledgements

I would like to thank you in research supported by the Advanced and Sustainable Environmental Engineering of TAIST-Tokyo Tech program, and Department of Common and Graduate Studies, Sirindhorn International Institute of Technology (SIIT), Thammasat University.

First and foremost thanks to my major advisor, Assoc. Prof.Dr. Taweep Chaisomphob, who always gives good advice and guidance, his suggestions and comments are very useful for my research. I would like to express sincere gratitude to my thesis committees, Assoc.Prof.Dr. Alice Sharp and Assoc.Prof.Dr. Sandhya Babel. They are a very great suggestion throughout my work. I also would like to thank Prof.Dr. Kiyohiko Nakasaki, thesis committee from Tokyo Institute of Technology, who give me very informative and useful suggestion to improve my thesis and composting in the future.

Many thanks to all correspondents and interviewees for the cooperation and valuable time, especially the mayor, official and staff of Thachi sub-district municipality sharing data, collecting waste samples and using the building for experimental study. Include, a neighboring district, local market of Bansong sub-district municipality providing the vegetable waste as we required. The authors would like to thank the faculty of science, Suratthani Rajabhat University permits us for using their laboratory, really grateful to laboratory of the faculty of Public Health, Thammasat University for their lab assistances train us to use Kjeldahl digester for total nitrogen analysis.

Special thanks to all friends and staffs at TAIST Tokyo Tech Thailand, NSTDA and SIIT for good suggestions, include my family for their good support, entirely care and encourage me to success.

Table of Contents

Table of Contents

Table of Contents

Chapter	Titles	Pages
3	Methodology	34

Table of Contents

Table of Contents

List of Tables

Tables **Pages**

List of Figures

Figures **Pages**

List of Figures

Figures **Pages**

List of Figures

Figures **Pages**

Chapter 1

Introduction

In 2013, the municipal solid waste generated about 26.774 million tons per year, the volume of solid waste generated in Sub-district Administrative Organizations (SAO) at about 12.396 million tons (46%) of MSW generated in Thailand. The solid waste is collected and delivered to suitable waste management facilities equal to 52% of the total volume. Thus, 48% of the total volume of the collected waste, especially in small LAOs, were unsuitable disposal by open burning or open dumping into old abandoned pits or undeveloped areas [1].

Municipal Solid waste management problems become a crisis because unsuitable dumpsites resulting in an accumulation of solid waste, causing the release of toxic substances and creating unsanitary conditions that are highly effect to human health and environment. As for the local administrative organizations did not provide an appropriate waste management system and they lack a long-term master planning and no cooperative planning on the MSW management [2]. People in this area need to be responsible for their household waste, and some of them might illegally dump the waste in public areas or by the roadside. The environmental problems posed by a contamination of soils, surface and subsurface water by pollutants present in the MSW leaching, odour problem from landfill and uncontrolled dump site. The practice of open dumping is a critical environmental issue that needs more the efficiency management. Moreover, The estimation of GHG emissions from landfill of food and paper waste in Thailand with the current GHG emissions as high as 5.3-13.2 Million tonnes of CO_2 equivalents due to the increase of waste generation, increase of waste collection services, and improving of open dumping to landfill [3].

Suratthani Province is in the fifth ranking of provinces facing the waste management crisis. Thachi sub-district municipality (Tambon) have several MSW management problems including the budget of the local government allocated for MSW management is not enough, lack of the materials and technology for coping with the MSW management problem and improper MSW management has found e.g. open dumped and open burning. Municipal solid waste generated by Thachi sub-district municipality is 4.32 ton/day, and they did not have the proper MSW collection and disposal system [4].

According to the municipal solid waste (MSW) stream in Asian countries which composed of a high fraction of organic materials more than 50% with high moisture content [5, 6]. Organic materials continue to be the largest component of MSW [1]. The organic fraction is often between 50 to 70 percent by weight of municipal solid waste in developing countries. High amounts of organic wastes are produced as well as some environmental and ecological problems, which have increased human health concerns and environmental awareness [5]. Therefore, composting technology is the option for processing the enormous quantities of biodegradable solid waste and the volume of wastes placed in landfills can reduce eventually.

In the current situation, saleable recyclable waste can clearly meet the approach in waste recycling system and only need some modification to improve for more efficiency. On the contrary, large amount fraction of biodegradable waste in the waste stream should be managed. Therefore, appropriate technology and environmental friendly should be taken. An alternative treatment especially composting and production of refuse derived fuel (RDF) were considered.

Municipal solid waste (MSW) consists of a high proportion of biodegradable materials, which were decomposed during dispose to landfill facility leading gas released and leachate. Concerns over the environmental impacts of landfill emissions have resulted in efforts to identify alternative management options for MSW instead of the incineration technology. However, composting of MSW are difficult to be conducted due to the heterogeneous of waste compositions, source separation of MSW at household is very important because the waste should be utilized by sorting organic waste such as food waste, vegetable waste, and fruits waste including agricultural waste in order to compost as a fertilizer. Thus, municipal solid waste management by public participation was undertaken in term of community-based waste management project. This is the sustainable way to tackle with the MSW management problems based on source separation practice as recycling waste, biodegradable waste for use as a material of composting. Furthermore, composting is a useful and desired technology for organic wastes treatment and generates a byproduct that can be utilized as a resource of organic fertilizer and soil nourishment[7]. The community can use for oil palm and rubber plantation or vegetable and fruit orchard; moreover they can sell as a compressed fertilizer as well.

The serial-self turning reactors (STR) using the composting technology is the appropriate treatment for the organic-rich MSW with less impact to environment, lower in cost operation and reduction in the weight of MSW sent to the disposal site. The STR plant can be located and operated near a community in closed system and requires less area, while unfavorable condition, odour and flies can be controlled [8].

1.1 Objective of this study

1.1.1 To initiate community-based MSW management system by waste recycling and source separation project

1.1.2 To study on the potential to use organic waste batch composting by experimental study of different materials

1.1.3 To perform the large scale composting experiment in serial-self turning composting plant at local government

1.2 Scope of this study

Study the municipal solid waste management systems of local government include the information on municipal solid waste (MSW) composition and characterization, recycling, and disposal. This study aims to apply the STR technology to the MSW utilization at Thachi sub-district municipality, Bannasan district, Suratthani province.

Chapter 2
Literature Review

2.1 Municipal solid waste (MSW)

Municipal solid waste is defined as unwanted materials and/or substances generated in a community or municipal, generally composed of food waste, organic waste, infectious waste, hazardous waste , electronic waste (WEEE), and packaging waste. MSW can be characterized by the source of waste generated from waste collection systems of the municipalities or other local authorities include the residential, households, schools or institution, healthcare service centers or hospitals, offices, shops and markets and that falls under the responsibility of local governments [9]. As the definition of MSW of Environmentally Sound Management Of Solid Wastes And Sewage-related of Agenda 21, solid wastes include all domestic refuse and non-hazardous wastes consist of commercial and institutional wastes, street sweepings and construction debris. In addition, some countries the municipal solid wastes also includes human wastes such as night soil, ashes from incinerators, septic tank sludge and sewage sludge from waste water treatment plants, which wastes was manifest as hazardous characteristics they should be treated as hazardous wastes.

However, the definitions of municipal solid waste in each region may be different. Also organic wastes are referring to discarded waste that can be easily biodegraded especially food, plants, animal residues and products that are made of these materials, such as paper include the biodegradable plastic [10].

2.1.1 Municipal solid waste sampling

Municipal solid waste consists of a variable materials composition depending on the community, lifestyle, and social status and economic. That’s why these could be estimates the MSW composition for a different community. In order to collect data, many issues should be addressed.

2.1.1.1 Direct sampling

Direct sampling of MSW, commonly use on a small scale for obtaining the information of municipal solid waste composition. The direct sampling includes physically sampling and sorting of MSW that generated at the source. To make an accurate sampling of composition, MSW sorting and analysis should be randomized several times and extensive location within the community. Waste sampling from single and multifamily households, commercial establishment (restaurant and businesses) and institution (school, healthcare service centers, and hospital) are encouraged. Another approach for the study on waste after placed at central waste collecting point or during in unloads area. For the area of unloading may include transfer station or disposal facility, the degree of sorting is a function of the types of materials categories should be identified. If the composting technology is to be instituted, a sorting practiced might include organic and inorganic material. Additionally, food leftover and yard wastes are the proper quality for use as a feedstock of composting which can be separated from commingled municipal solid waste. For recycling facility, waste should be separated into metals, glass, paper, cardboard, plastic bottle and etc.

2.1.1.2 Material flows

Materials flow methodology for MSW sampling, based on the data of the mass of materials and products (by weight) in the waste stream, to estimate the data on MSW generation and production of each material. Imports and exports need to be adjusted and for make the diversions from MSW such as plastic materials for building and paperboard that become construction and demolition debris. For food waste, yard trimmings, and a small amount of commingled inorganic wastes are accounted by collected data from the different of waste sampling studies [11]. For a specific municipality, input and output of materials are reduced and compared, if a community purchase 500,000 aluminium beverage cans in 1 week, it can be expected that about 500,000 of aluminium cans will end up in waste stream sometimes can increase and further. But, oversimplification standard, must be also considered that the community having numerous imports and exports [12].

2.1.1.3 Survey

Waste quantities and composition can be estimated by questionnaires distribution to the source of waste generators. This system appropriate to applies to commercial and industrial wastes generators but does not apply effectively for the domestic source. Questionnaires are attributed to the company with give questions concerning related the quantities of waste generated and its composition. This method can cause the variation by season in waste generation and any recycling programs. The disadvantage of this method is many companies do not maintain to record data of the amount of waste generation. Data on composition may be difficult to obtain because they concerns over the data of the company will release and for confidential information.

2.1.2 Solid waste quantification

The main aspect of solid waste management depend on the amount of waste to be managed, the determination of the functional units, size and number of the MSW and equipment are significant data for the waste management system. The amounts of waste were measured by use the data of weight and volume basis. The weight of waste is generally constant for setting up the waste disposal system, whereas the volumes quite high and vary by the types of waste and materials also source of waste generated especially packaging and also construction debris. Waste quantification is commonly estimated on the basis of past record of waste generation. The methods generally used to identify the quantities of waste including load count analysis, weight volume analysis and material balance analysis. Additionally, repetitive sampling and analysis would provide for more representative data [13]. Whether lacking on the data of MSW quantification caused by the non-availability of daily record of waste generation rate, they cannot access the total budget involved for MSW management system and facility.

2.1.3 Municipal solid waste (MSW) composition

The solid waste composition is important issue for waste management, which can affect the waste density, the proposed technology of disposal and is necessary for examining on waste reduction, reuse, and recycle. The MSW compositions of each component can be determined by the sampling method on a weight and volume basis. MSW composition is the influence factors for evaluate the MSW management, as in the waste stream which contain different types of materials. In Thailand, the MSW can be categories into different type of materials. The major types of MSW composition is food leftover, paper, wood, textiles, rubber, leather, plastics, metal, glass, stone, and others [14] .

The MSW fraction in Thailand composed of a large proportion of food waste followed by plastic and paper [5, 15]. From the survey on MSW composition in Thailand provide the average of MSW composition generated from whole reference area consists of 63.6 % organic or food waste, 16.8 % plastic, 8.2 % paper, 3.5 % glass, 2.1 % metal and 5.8 % miscellaneous [16] as shown in Figure. 2.1

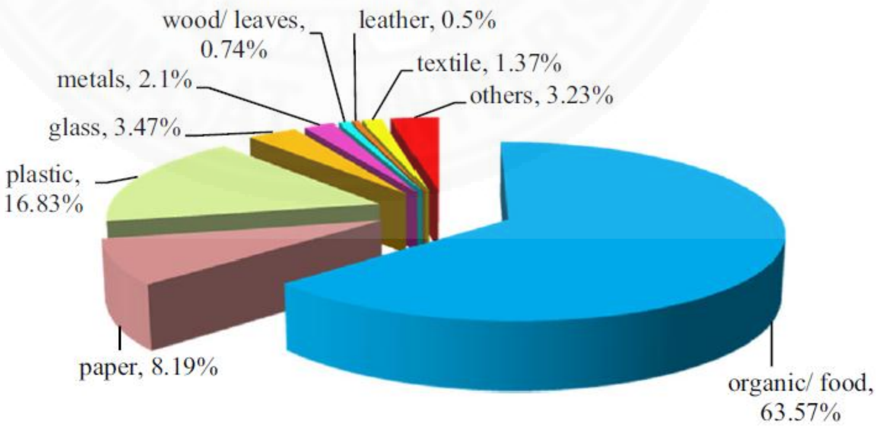


Figure 2.1 Composition of MSW in Thailand [16]

2.1.4 Municipal solid waste characterization

Municipal solid waste (MSW) quantification and composition is the fundamental for planning of the solid waste management systems[17]. For improving the MSW management system in the community, accurate and reliable data on municipal solid waste compositions and quantities are important. Waste compositions will provide the information on organic materials can be used in a composting facility or for produce gas fuel. Data of physical properties of municipal solid waste can design the transportation system, processing, and requirement. Without knowing on waste characterization resulting in the waste management systems are not operated effectively.

The chemical composition of municipal solid waste can help the engineers and scientists for make a decision of using fuel utility; predict gas emission after incineration, including can help in predicting leachate of MSW at the disposal site and landfill. That causes the environmental authorities can apply appropriate treatment technology for their community.

In the previous studies looked at the characteristics of municipal solid waste at the final disposal sites [18]. Municipal solid waste characterization including physical compositions is performed using quartering method, Hand sorting method is provided by segregating the different types of material from the miscellaneous MSW, particularly the MSW composition was studied according to the MSW composition is an important data for apply in the MSW management system and also for waste utilization. The main physical properties measured in MSW are described as below follows:

2.1.4.1 Bulk density (kg/m^3)

Bulk density can be defined by the weighting the material in term of weight per volume unit (e.g. kg/m^3 or lb/ft^3), refers to uncompacted waste. This value varies by the location, season, and storage time. Waste density can use for assess the volume of transportation technology, disposal site capacity and size of the landfill facility.

2.1.4.2 Moisture content

The percentage of moisture content can described as a percentage of the MSW material in wet weight. Moisture content is the important factor for estimate the MSW leachate and for implement composting facilities.[19]

For design the municipal solid waste management system, critical factors such as the current MSW compositions, the moisture content of waste, heating values, proximate and ultimate analyses was considered. The chemical properties analyses of MSW which are very important data to evaluate the alternative waste management technology and for design the waste recovery system.

2.1.4.3 Proximate analysis

(1) Moisture content: loss of moisture after dry at 105°C, 24 hr.

(2) Volatile solids: loss weight of volatile combustible material determined in the approximate of the percentage of organic matter available in the material.

(3) Fixed carbon: combustible residue after the mass of volatile material was removed from the original weight of the sample.

(4) Ash content: weight of remain waste sample after combustion.

2.1.4.4 Ultimate analysis

The ultimate analyses of waste components are determined by analyzing the percentage of carbon, hydrogen, oxygen, nitrogen, sulfur, and ash. The result of this analysis can be apply to the waste characterization and chemical composition of organic matter in MSW, generally used to define the proportion of mixed waste material in order to achieve the proper C/N ratios for biological treatment.

2.1.4.5 Heat content (calorific value)

MSW consists of water and hydrogen and when the MSW is burnt using latent heat while combusting. Heating value is released from MSW combustion, resulting in heating value decreases known as Lower calorific value **(**LCV**)**. It can be useful for considering the suitability of MSW disposal by incineration.

The physical characterization and chemical composition of municipal solid waste are influenced for the composting system. MSW consisted of more variation of sizes and shape. Hence, sufficient times are required to complete the waste degradation. Physical and chemical characteristics of MSW are significant for design the composting facility. For example, the percentage of moisture content, carbon content and C/N ratio of the MSW can be able to calculate the organic materials proportion and air requirement for complete degradation. However, the physical characteristic provides information of the waste density and particle sizes of waste can give the identification of waste degradation itself. In addition the chemical composition of MSW is useful for engineering design and decision making for implement the appropriate MSW treatment system such as incineration technology, calculation of gases that generated from dump site, includes for design composting technology, therefore the municipal solid waste composition analysis more significant for MSW management

2.2 Municipal solid waste management in Thailand

2.2.1 Municipal solid waste generation in SAOs

The municipal solid waste management strategies in Thailand commonly focuses on bulking waste collection and mass disposal [20]. According to Thailand State of Pollution Report 2013, a survey on the volume of solid waste generated by 7,782 Local Administration Organizations (LAOs) were conducted, 26.774 million tons per year of municipal solid waste was generated, the volume can be divided into the solid waste generated in municipalities and Pattaya City at about 10.241 million tons (38%), and the solid waste generated in Sub-district Administrative Organizations (SAO) at about 12.396 million tons (46%) (see Figure2.2). In contrast, only 37 % of waste is collected in municipality areas and 6 % of waste is collected in outside municipality areas [21].

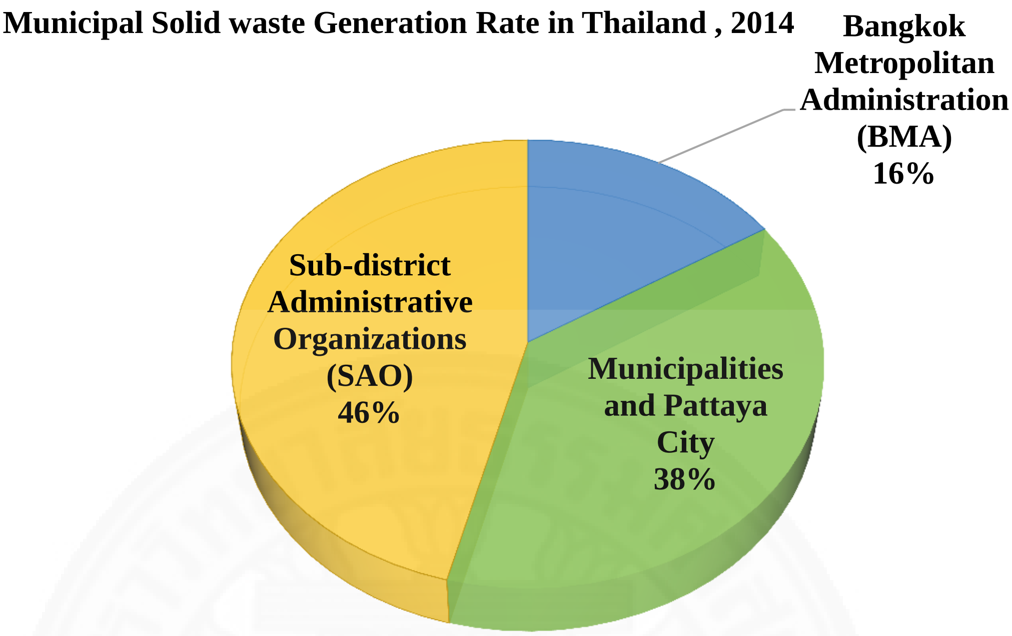


Figure 2.2 Municipal solid waste proportion in 2013 [1]

About 7.421 million tons or 20,332 tons a day, equal to 52% of the total volume of the collected waste is delivered to suitable waste management facilities. However, 6.938 million tons or 19,008 tons a day, equal to 48% of the total volume of the collected waste, especially in small LAOs, were unsuitable disposed of by open burning or open dumping into old abandoned pits or undeveloped areas. [1]

2.2.2 Municipal solid waste management practices in SAOs

In 2013, out of 26.8 Mil.Tonnes of MSW generated, only 7.3 Mil.Tonnes (about 27 %) was properly disposed, while 14.3 Mt (53 %) was improperly disposed at 2024 sites (i.e., open dumping or burning sites) and 5.2 Mil.Tonnes (19.5 %) was recovered. Waste was utilized in appropriated disposal sites is 466 which consist of landfilling (6.7 Mil.Tonnes), composting facilities (0.05 Mil.Tonnes), incineration technology (0.25 Mil.Tonnes) and other processes (0.27 Million Tones) [22].

According to the Thailand State of Pollution Report 2013, 78% open dumping is the most widely used waste disposal method [1]. This improper method is generally found in areas governed by local administrative organizations. Open dumping results in accumulation of solid waste, causing the release of toxic substances and creating unsanitary conditions that are highly detrimental to human health and effect to the environmental and neighborhood areas where people live near or around the area of the unsuitable dumpsites.

From the assessment of MSW generation and composition in SAOs in Thailand, providing and overview of the current state of municipal solid waste management analysis of the current problem. Resulting in the composition in the sub-district administrative organization (SAO) is dominated by a high organic content due to the concentration of food and kitchen waste in solid waste makes up the highest proportion in the waste stream. The study provided that only 25% of the household can access the waste collection and transportation services.

Households and local authorities reported producing a high level of food leftover including vegetable waste from kitchen and restaurant. Some household put waste directly in the pit, open space, along the roadside and opened spaces that can cause the environmental contamination increase the health risk to people in communities. Urgent and immediately improvement in the MSW management problem aimed to improve the management system related the appropriated technology for a different community. However, low level of waste segregation was generally reported in all sites mainly relating to inconvenience practice.

Solid waste management was a commitment, role, and responsibility of all that could be attending the stakeholder in the community. Participants recognizable are important for strengthening the accountability of local authority on solid waste management and the role of the community including household level, community levels and also for local community sector. Local authorities have taken direct action to reduce waste by encouraging people to participate in a recycling waste separation project. Most waste recycling activities in Thailand carried out by informal sector, which buying recyclables waste to facilities that exchange them for money.

For the target of municipal solid waste recovery in terms of material and energy is 30% and 40 % for appropriate disposal of the waste generation, and the government in the 10th National Economic and Social Development Plan (2007 to 2011) introduced to control the waste generation rate up to 1.0 kg/capita/day, however these plan have not been done [23]. Then, the targets have been change to the 11th National Economic and Social Development Plan (2012 to 2016), for the MSW recovery is 30 % and 50 % for an appropriate disposal [22]. Recently, material recovery has been emphasized for an integrated solid waste management system such as sources separation practice, pretreatment systems, waste to energy (WTE) technologies and other alternative technologies include composting [24-26].

2.2.3 Regulations and policies of solid waste management related to SAOs

2.2.3.1 Recycle communities were implemented by reducing unnecessary consumption to reduce solid waste and hazardous waste generation; promoting the use of environmental friendly products; encouraging waste separation and reuse of solid waste and hazardous waste to maximize practicality and efficiency.

2.2.3.2 Clustering of Local Administrative Organizations in order to implement the entire and centralized municipal solid waste, hazardous waste and infectious waste management system.

2.2.3.3 Promoting a research and development plan of appropriate technology to solve the problem on the solid waste management system. This included operation, maintenance, energy processing, cost efficiency and the management of Local Administrative Organizations.

2.2.3.4 Promote and encourage more public participation with the private sectors in Public Private Partnerships (PPPs) to enhance the efficiency of the proper management of solid waste, hazardous waste, and infectious waste from the collection, transportation, recycling, and disposal.

2.2.3.5 Allocate a budget for the treatment and disposal of pollution in according to civil law Section 96 of the Enhancement of Conservation of the Natural Environment Quality Act B.E. 2535 [27].

However, the Ministry of Public Health's Announcement is in the process of being issued in order to regulate waste relocation and disposal in all municipalities in accordance with the Public Health Act B.E. 2535 (1992) and to appoint Provincial Waste Management Committees in all 77 provinces. In addition, promote the discipline of waste management to the public such as the monitoring, expediting and ensuring that the local authorities implement on MSW management system that relate the Roadmap on Waste and Hazardous Waste Management towards. Includes promote the MSW management campaign to encourage people to have the public awareness on waste reduction and waste sorting, promoting the use of environmental friendly products, enhancing capabilities of municipal authorities in the management of solid waste and hazardous waste, promoting to produce refuse-derived fuel (RDF), demonstrating a working group to study the relevant regulation , as well as appointing a sub-committee and the private sector to consider and emphasize in the construction of appropriate power plants generated RDF from waste[28].

2.3 Community-based municipal solid waste management practice in SAOs

Municipal solid waste management practice by public participation can initiate in the community by contribute or involve of the community members. For example, it can even be the waste separation practice of at household before waste collected. Community participation in the MSW, have numerous benefits for municipal authorities by saving costs of collection and disposal systems. [29]. Municipal solid waste management project will not a success, if the lack of community-based cooperative and participation.

2.4 Municipal solid waste management problem in local government

Technical and environmental impacts posing by open dump site without the suitable controlled and found that can cause health and environmental risk and found the waste recovery rate is low. Financial and economic cost for dealing with these problems is required includes the investment, operational and maintenance cost is high while revenue as collection fee is low. Lack of community participated in MSW management, institutional and the organization has a scheme focus on the only disposal system while ignoring waste recycling system. These problems related to budget from decentralization was limited to allocate to local government while local government authorities are unable to manage the entirely solid waste generated from the community. Moreover, for some local community which the solid waste management system have not been planned and/or enforced properly because they lack of the significant information on waste generation and also community did not record and maintained the dada of the waste generation rate. Source specific solid waste quantification and characterization is very much required to access the quantities and quality of waste generated. However, it's difficult to keep a record of quantity of waste generated from each source; the waste is quantified on the basis of total waste generation rate in the community. That cause they should be the reliable information on waste generation rate and characterization, which is the important data required for the waste management systems. Due to non-availability of daily records on waste quantification, the community cannot assess the total budgets for solid waste disposal facility. There have been observed that 60% to 75% of the generated waste is disposed at the landfill site. Remaining part of the waste is either disposed into the illegal dump site or throw away in the abandoned area.

Most of the municipalities have less than 25% trained staff which revealed that most local government lack trained personal might because of inefficient of waste management authorities. In term of strategies or plan in MSW management of each local government administrative organization (LGAs) has its own plan and strategies. However, most plans focus only on waste collection and disposal system instead of the recycling facility.

Uncollected waste is dumped indiscriminately along the street and abandoned areas which drain to environment that contributing from flooding, increasing of insects and vectors can spread of harmful disease. Moreover, even the collected waste is often disposed to unsuitable dumpsite and/or opened burnt caused the environment pollution. Open dumpsite in the community, uncontrolled open burning lead to an environmental problem, odour, surface and groundwater contaminated that can cause an adverse effect on environmental and public health.

Strategies and plans for reinforcing the local government that should be considered with the monitoring and evaluating projects performance continuously, promoting the source separation first and setting up recycling project by providing supported budget, manpower and public participation in waste management practice, increasing the staff for cope with MSW management, improving the efficiency of waste collection and disposal services, reducing illegal dumpsite and waste utilization should be applied.

Contributing the solid waste recycling project that reduces a large quantity of waste transported to the disposal facility, which should focus on how to convince local government to initiate and implement successful recycling programs by promoting source separating at household.

However, due to a limitation in the budget was allocated, low accessibility of community and expensive technologies and low awareness concern in the environmental issues and public health impact including the application of inappropriate waste treatment and also unscientific methods like open dumping and open burning of solid waste in community parts has become common practiced. Therefore, integrated waste management which includes waste collecting, sorting and treatment methods such as recycling, composting, incineration, anaerobic digestion and landfilling was considered, which provide all resource are used for waste utilization with an environmental and economic acceptance.

Waste management not only concerns in the issue of public health and safety but also effective consumption of materials and energy and most importantly, environmental friendliness of suitable waste management planning. According to the waste management integration may adopt for more treatment technologies depending on waste characteristics, environmental conditions as well as social and economic acceptance. These have increased the concerning about the economic feasibility and environmental compatibility of the waste management methodologies.

2.5 Municipal solid waste composting

Municipal solid waste composting begins with separating the biodegradable material before disposed. MSW compositions from the agricultural parts of rural community are suitable for composting as a method for the organic wastes utilization. Furthermore, composting produces a valuable product as an organic fertilizer or a soil conditioner for agricultural uses. Applications of aerobic composting for MSW management include yard and agricultural waste, separated MSW, commingled MSW, and co-composting with sludge from waste water treatment facility include the animal manure from community farming. Also critical review of the study on composting technology work done at various places has been practiced.

2.6 Composting technology

Composting is an aerobic process which decomposed and the end product is the partially organic fraction. Composting is often promoted as a "natural" process of solid waste treatment [30]. The volume of waste are suitable for composting especially organic waste was about 48% of the entire MSW in Thailand, providing it a good choice for the sustainable MSW management system in Thailand. Furthermore, composting generates a valuable organic fertilizer or soil nourishment for agricultural used. Composting transforms the biodegradable organic materials into a final product as soil-like material, inactivate pathogens, and convert ammonia into a more stable form of nitrogen. Composting was admired as the most environmental friendliness treatment of municipal solid waste, can minimize the incineration technology and landfilling while promoting source reduction and recycling instead. At least 50% of the MSW stream is compostable material. Composting transform these materials from less beneficial disposal methods to the valuable product and maintains a more environmentally sound of MSW treatment technology. However, aerobic composting technologies have not been practiced effectively in Thailand due to the lacking on the specific expert of effective composting technology and the high cost of maintenance was required.

Material decompositions occur in a well-operated process to obtain the maturity condition create a valuable final product with a minimum of adverse effect to the environment.

There are many different ways of composting by use a variety of materials, method, and equipment for operating process.

Table 2.1 shows economic and environment motivation/reasons in waste recycling and composting performed in micro and macro level in terms of economic gain and environmental benefit [31]

Table 2.1: Economic and environmental motivations/reasons in waste recycling and composting

Economic gain	Environmental benefit
Micro level	*Micro level*
- provide work and opportunity to the poor community - Cost of manufacturing for composting plant gets reduced as cost of recycled material, less than only use of original or industrial raw material	- neighboring area and street clean - increase the community's happiness and enhance the quality of life - reduce extent energy consumption for the composting plant by self-produced energy from waste
Macro level	*Macro level*
- Reduce collection and disposal cost of municipal solid waste - Save cost for import expensive technology and machine from foreign country	- reduces the waste dispose at the landfill - reduces environmental pollution - reduce the additional environmental cost - improves sanitation - increases the aesthetic beautiful of the city - Saves resource if add significantly in a positive way to sustainable development

2.7 Fundamental of composting

Aerobic microorganisms extract the energy from organic matter through a series of exothermic reactions that break the material down to simple materials.

$$[\text{Organics waste}] + O_2 \xrightarrow[\text{Microorganism}]{\text{Aerobic}} CO_2 + H_2O + NO_3^- + SO_4^{2-} + [\text{Other less complex organics}] + [\text{heat}]$$

Composting is the microbiological process based upon the activities of diverse bacteria includes the actinomycetes, and fungi. The main product is rich in humus and plant nutrients; the by-products obtained from composting process are carbon dioxide (CO_2), water (H_2O), and heat [32]. During the decomposition the temperature increases to about 70°C (160 °F) in most well-operated composting operations. As the reaction develops, the early decomposers are mesophilic bacteria followed after about a week by thermophilic bacteria, actinomycetes, and thermophilic fungi. Above 70°C, spore-forming bacteria predominate.

As water evaporates, carbon breaks down and lost as carbon dioxide, the volume of compost was decrease, phosphorus, and nitrogen and other nutrients become more stable. Some of the nitrogen will be lost during composting in forms of ammonia and nitrate. It has been also estimating less than 15 % of nitrogen in compost pile, which appropriate for soil application.

Under optimal conditions, the composting process is divided into three phases include the mesophilic phase that moderate temperature phase occurred, thermophilic phase which provide high temperature, including the maturation phase which the temperature cooling down near ambient condition. During the decomposition process, the different microorganisms increase and act as decomposers. Later on, temperature increases and causes the temperature of the final product to increase. In this phase, other microorganisms that can act at higher temperatures (between 45 and 70 ºC) become active [33-35]

2.7.1 Composting phases

Composting process would be performed in three phases;

2.7.1.1 Active phase (thermophilic)

The materials most rapid breakdown in this phase , after the material are completely mixed and temperature of pile simultaneously rise (above 45ºC) and the decomposition is completed under aerobic condition created by thermophilic, microorganisms including bacteria, actinomyces, fungi, and protozoa.

The microorganisms which use oxygen to decompose the organic materials then release carbon dioxide gass. Temperature and moisture content exceed the optimum ranges (40-60 ºC and 50-60 % moisture respectively) while low oxygen levels reduce the biological activity. Also, a high percentage of moisture will reduce oxygen and low moisture levels made high temperature condition occurred. The appropriate conditions required for the active phase depend on the type of raw materials, ambient temperatures, and composting system. An in-vessel composting system with turning and aeration can complete in short times. On the contrary, the composting windraw which take a long time for composting process and needs a frequent turning for maintaining the active stage at least 1-4 months or up to 4-8 months for less turning.

2.7.1.2 Mesophilic phasing (Curing)

After the thermophilic phase was finished and pile turning process was done, temperature performed more stable usually less than 40ºC. In this stage, there is a transformed of microorganism that prefers low temperature. Turning process is no need but aerobic condition should be remained. In the curing phase, composting is not completely mature, the composting materials still have high in organic acid, C:N ratios, pH value extremely high which harm to seed and plants.

2.7.1.3 Maturing

In this condition identified the conversion of organic compounds to humic substance and resist to microbial breakdown. They have more testing method for composting maturity that can use the germinations test. Resulting in the immature compost may harm to seed and plants, while the maturing phase, size and quantities of piles would less than during active and curing phases. Later on, final product of composting can be moved from curing storage for distribution.

2.7.2 Composting factors

Composting is microbiological mechanism providing factors significantly effect to the composting process. The important factor for composting as follow;

2.7.2.1 Particle size

The organic fraction of composted materials from solid waste that include the different size and shape of material, irregular shape and different size of materials should be reduced by shredding the organic materials before composted. JICA (1982) proposed the appropriate particle size for composting is between 0.5 to 1.5 inch.

In addition, the particle sizes of materials have more significant effect to surface area while the microorganisms attack to the particles. The degradation rate of microbial attacking which perform in the ratio to mass resulting in the higher of ratio will increase the rate of material decomposition [36].

2.7.2.2 Moisture content

Moisture content between 40% and 60% is recommended range for composting. Moisture is the main influential needed for microbial activity; on the other hand, excess moisture can inhibit gas exchange between the composted materials lump and may cause anaerobic conditions in the pile. The compost mixture should feel moist when touching, but not wet. Therefore, extremely wet material may be dried before mixing, or adding dry bulking material which can be used to absorb moisture. Consider protecting the compost piles from the precipitation or natural water source. However, some moisture materials will be removed from the mixture during the composting process. During dry weather, the composting pile may need water added to maintain moisture in.

2.7.2.3 C/N ratio

The carbon to nitrogen (C/N) ratio in a substrate is important for implementing the proper mixing of the raw materials for composting in accordance with a proper C/N ratio. Microorganism use up carbon (C) in 25 to 30 times faster than using nitrogen [37]. The C/N ratio in the range between 20:1 to 30:1 is appropriate for agricultural wastes. UNEP (1981) mentioned that the optimal C/N ratios of various composting material with C/N ratio is 30:1 [37]. Higher C:N ratios decrease the decomposition rate of organic material, because low level of nitrogen limits the microbial activity while, lower C: N ratios may contain excessive nitrogen that may be volatilized as ammonia (NH_3^+) , as a result production of odour and nitrogen loss. If odour is a major concern, consider a feedstock mixture with a higher C: N ratio.

2.7.2.4 pH

Microorganisms tend to modify for living in varies environmental conditions of composting. Final products of organic composting which pH may change with time. Near neutral pH is preferred for the most effective for microbial activities. Due to the oxidative action of microorganisms, the temperature increases. Even though there is a drop in pH at the very beginning of the composting, caused by the formation of volatile fatty acids, the subsequent degradation of acids brings about an increase in pH. Furthermore, some food production and industrial generates wastes by exhibit levels of alkalinity or acidity of waste that inhibit nutrient availability or microbial activity. Chemical analyses of material samples should by identify whether pH or nutrients need to be adjusted.

2.7.2.5 Temperature

Due to the oxidation condition of microorganisms, the temperature will be increased but pH dramatically drop at the beginning of composting process, generates the formation of volatile fatty acids and the subsequent degradation of acids brings about an increase in pH and further. According to the temperature of a composting pile reaches to 45–50˚C, thermophilic microorganisms replace mesophilic. The second phase is called the thermophilic phase. This is the active phase of composting which most of the organic matter is degraded and hence most oxygen is consumed by the microorganism in this phase. While the temperature higher than 60˚C, these microorganisms cannot grow and lignin degradation is slowed down. [38]

2.7.2.6 Aeration rate and pile turning

Aeration can apply by the piping system, but the piles are usually provided with an air blower for more effective aeration control. The corrugated plastic pipe such as perforated polyvinyl chloride (PVC) pipe is used commonly for air supply. To apply the aeration system, aeration rate is controlled by adjusting the aeration rate (liter/minute). However, insufficient air distribution and unexpected composting condition can occur. Therefore, the aeration condition should be maintained continuously.

2.7.2.7 Bulking agent

The bulking agent should be added to the kitchen waste in compost mixed due to kitchen waste has a high moisture content with low C/N ratio. The efficient bulking agent is mixed with materials which provide a high moisture content and C/N ratio for maintain the suitable composting condition. For example, cornstalks can use for reduced the economic cost of bulking agent, which are common waste materials mostly found in China, adding this material to make more effective composting process are suggested. The major composite material in cornstalk are carbon and have a low density and low moisture content, making them suitable for use as a bulking agent for compost with kitchen waste.

2.8 Utilization of oil palm empty fruit bunch (EFB)

Oil palm empty fruit bunch (EFB) found a lot in the tropical region. The major source of oil palm EFB residue left after the fruit bunches is pressed at oil mills in the oil extraction process. Oil palm empty fruit bunch is commonly used as fuel, fertilizer and mulching material which the remaining of oil palm waste materials still make the environmental issue.

Large quantities of oil palm empty fruit bunch are generated, renewable, nontoxic and low cost materials, which the high amount of biomass is generated by palm oil industries. These wastes are the byproduct of oil palm processing and further transfer to industrial wastes. Furthermore, the solid residues and liquid wastes are generated, mainly solid residues is EFB, more than 20% of the fresh fruit weight [39].

During the palm oil extraction process, which byproducts are generated as the wastes include oil palm empty fruit bunch (EFB), palm oil mill effluent (POME), sterilizer condensate, palm fiber and palm kernel shell [40]

According to the large amount of oil palm empty fruit bunch commonly found in palm oil industry due to these waste was neglected for industrial application. However, some palm oil processing that use the empty fruit bunch for produce fuel and also creates an environmental impact to the local communities.

Oil palm empty fruit bunch is a suitable raw material for waste recycling application because performing large quantities of oil palm EFB in locality. In the past, it was often used as fuel to generate steam at the mills [41]. In the agricultural parts which EFB was mainly used as mulching material for covered under the palm trees, can helps to control the circumstances of oil palm plantation, prevent soil erosion and maintain the moisture content. Nowadays, the current labor is a shortage for EFB transportation and distributions to oil palm plantation tend to more expensive. Composting of EFB was interested, in terms of value adding, and also to reduce the volume for easy to the application [41-43].

2.8.1 Composting of empty palm fruit bunch

In the south region of Thailand, oil palm empty fruit bunch (EFB) is widely used as a substrate for mushroom cultivation and as an organic mulch as well as supplementary fertilizer for oil palm plantation. As a substrate for mushroom cultivation, EFB is pressed in a rectangular block and mushroom spores are inoculated into palm empty fruit bunch block (PEFB). Finally the block is covered by plastic sheet to maintain moisture content for limit sunlight. Mulching material on soil surface for oil palm plantation can reduce soil temperature and conserve soil moisture to improve growth and crop yield. The residue from mushroom cultivation or mulching material for oil palm plantation is the composting PEFB which can further be served as organic fertilizer. Another possibility is the utilization of EFB ash as fertilizer or soil conditioner. However, this method is non-preferable because white smoke caused from high moisture content in EFB has an aesthetic condition which can effect to the environment.

2.9 Final products properties of composting

Compost is any product of organic materials that decompose through natural processes or accelerated with the use of microbial with proper C/N ratio of substrates where traces of the original materials are reliable, or partly soil-like in texture, and can supply nutrients to plants. Organic fertilizer refers to any product of organic matter that has undergone substantial decomposition with free from any pathogens, soil-like in texture, contains not less than 20 % organic matter, and can supply nutrients to plants.

The completion of the composting period was determined by examining some physiochemical characteristics of the composted material to fulfill the following criteria:

2.9.1 Color of the compost was brownish black

2.9.2 Final temperatures in composting reactors ranged between 28 to 32 °C.

2.9.3 The final C/N ratios of the compost products of compost mixed should lower than 20:1

2.9.4 According to the previous study, a temperature of 53 °C or above for sufficient time for optimization to eliminate the pathogenic bacteria, enteric viruses, and Ascaris eggs [44].

2.9.5 Standard of organic fertilizer

The definition of organic fertilizer from THAI AGRICULTURAL STANDARD which determine as the fertilizers that are made from chopping up, grinding, fermentation, composting, sifting, or that have been made from organic material, biofertilizers, and not chemical fertilizers [45].

Table 2.2: Quality standard of biofertilizer [46]

Parameters	units	Biofertilizer Standard		
		Grade1	Grade2	High
Particle size	mm.	< 12.5 ×12.5		
pH		5.5-8.5	5.5-8.5	5.5-10
Electrical Conductivity (EC)	dS/m	≤ 10	≤ 10	≤ 15
Moisture Content	%	≤ 30	≤ 30	≤ 30
Total Nitrogen	%	≥ 1		
C/N		≤ 20:1		
Organic Matter	%	≥ 30		
Total Phosphate (P_2O_5)	%	≥ 0.5	≥ 0.5	≥ 2.5
Total Potassium (K_2O)	%	≥ 0.5	≥ 0.5	≥ 1.0
Arsenic (As)	mg/kg	< 50		
Cadmium (Cd)	mg/kg	< 5		
Chromium (Cr)	mg/kg	< 300		
Copper (Cu)	mg/kg	< 500		
Lead (Pb)	mg/kg	< 50		
Mercury (Hg)	mg/kg	< 2		

Source: Thailand agricultural standard of organic fertilizer

According to the Land Development Department of Thailand categorizes the compost into three grades as shown in Table 2-2, which consist of biofertilizer grade1 represent for a non-liquid organic fertilizer, organic matter content of not less than 30 percent by weight, made from organic materials. The composted materials decomposition was completed until converted from the original, while use with the plants will provide the necessary nutrients to the plants. The standard configurations as following;

1) The amount of organic matter (Organic Matter) not less than 30 percent by weight

2) The ratio of carbon to nitrogen (C / N Ratio) up to 20:1

3) The conductance (Electrical Conductivity) does not exceed 10 dS per meter.

4) The pH and alkalinity (pH) is between 5.5 to 8.5

5) Sodium (Na), not more than 1 percent by weight

6) Main nutrient

- Total nitrogen (Total N) is not less than 1.00 percent by weight
- Total Phosphate (Total P_2O_5) is not less than 0.50 percent by weight
- Total Potash (Total K_2O) no less than 0.50 percent by weight

7) Moisture content not more than 30 percent by weight

8) The particle size of fertilizer does not exceed 12.5x12.5 mm.

9) The amount of stones and gravel up to 5 mm in size from less than 2 percent by weight

10) Have no sharp shards of glass, plastic or metal

11) The amount of heavy metals

- Arsenic (As)	No more than 50 milligrams per kilogram
- Cadmium (Cd)	No more than 5 milligrams per kilogram
- Chromium (Cr)	No more than 300 milligrams per kilogram
- Copper (Cu)	No more than 500 milligrams per kilogram
- Lead (Pb)	No more than 500 milligrams per kilogram
- Mercury (Hg)	No more than 2 milligrams per kilogram

Note: These are minimum standard follow the Fertilizers Act, No. (2550).

12) The complete composting not less than 80 percent

For the compost grade 2 represent the non-liquid organic fertilizer which has organic matter content of not less than 20 percent by weight, get or made from organic materials, which produced by the fermentation process, crushed chopped, damp, heat, and extraction or by other related method . The organic material is decomposed by microorganisms or other living things, but not consisted of chemical fertilizers or fertilizer. The standard configurations are;

1) The amount of organic matter is not less than 20 percent by weight

2) The ratio of carbon to nitrogen (C / N Ratio) up to 20:1

3) The conductance (Electrical Conductivity) does not exceed 10 dS per meter

4) Sodium (Na), not more than 1 percent by weight

5) Main nutrient

- Total nitrogen (Total N) is not less than 1.00 percent by weight

- Total Phosphate (Total P_2O_5) is not less than 0.5 percent by weight

- Total Potash (Total K_2O) is not less than 0.50 percent by weight

The total amount of main nutrient no more than 2 percent by weight

6) Moisture content not more than 30 percent by weight

7) The size of fertilizer does not exceed 12.5x12.5 mm

8) The amount of stones and gravel up to 5 mm in size from less than 2 percent by weight

9) Have no sharp shards of glass, plastic or metal

However, the amount of heavy metal allowed detecting in compost similar to the properties of bioertilizer grade 1.

Finally, for the high quality of organic fertilizer represent non-liquid organic fertilizer which has macro-nutrient not less than 9 percent and not more than 20 percent by weight, obtained from organic materials or inorganic nature of agricultural nutrients through a fermentation process until complete dissolution. Or applying fertilizer through the complete dissolution and then mixed with organic or inorganic nature and agriculture with high nutrients. The standard configurations are;

1) The amount of organic matter is not less than 20 percent by weight

2) The ratio of carbon to nitrogen (C / N Ratio) up to 20:1

3) The conductance (Electrical Conductivity) does not exceed 15 dS per meter.

4) The pH and alkalinity (pH) is between 5.5 to 10

5) Sodium (Na), no more than 1 percent by weight.

6) Main nutrient

- Total nitrogen (Total N) is not less than 1.00 percent by weight
- Total Phosphate (Total P_2O_5) no less than 2.5 percent by weight
- Total Potash (Total K_2O) no less than 1.00 percent by weight.

The total amount of main nutrient no less than 9 percent and no more than 20 percent by weight

7) Not more than 30 percent by weight of moisture content

8) The size of fertilizer does not exceed 12.5x12.5 mm.

9) The amount of stones and gravel up to 5 mm in size from less than 2 percent by weight

Also, the amount of heavy metal in compost allowed detecting similar to the biofertilizer grade 1 and grade 2.

2.10 Recycling program

Waste recycling involves waste separation, collection, sorting or pre-treatment and conversion into useful products while, the informal sector plays a major role of resource recovery. Also ‘‘Salengs’’ who uses tricycles or motorcycles and collects recyclable waste directly from household, for private company, such as Wongpanit company Ltd, is the biggest recyclable wastes trader and service center which has several branches in nationwide, and in neighbor countries [47]. In addition, waste recycling project approach in term of waste bank of different levels such as school, institute, communities and sorting site which recycling program need to be promote [48, 49]. Recycling program implementation can be promoted by the community members include the volunteer or the leadership in the community and the sub-district municipality authorities should participate. The recyclable materials include paper (newspaper, cardboard, mixed paper, etc.), glass, cans (aluminum and ferrous), and plastics (PET, HDPE, PS, PVC, PP, LDPE, etc.), as well as other items. [50]

The recycling program initiation shown as the following:

- Drop boxes, drop-off centers, or buyback center for recyclable wastes
- Central recyclable waste collecting system of materials separated from household

- Central waste separation of commingled recyclables from household
- Waste recovery facilities for the separation of commingled recyclable materials by collected at central waste collection site in community, collection in drop boxes, or collected at special bin provide to household for the waste management system which using various level of mechanization for waste processing
- Mechanical equipment assisted hand sorting of recyclables waste from mixed waste in the front end processing
- Completely use mechanical equipment for separation of recyclable materials from the waste stream

The waste collection system can implement in many difference ways. Waste is collected at curbside in multi-compartment truck either with or without waste compacting system of segregated materials part or commingled waste is collected in either a waste dumping truck or a packing truck.

Material separation can be done itself by the houshold level, which waste is collected at curbside, or by workers at the central waste separated facility. When materials are mixed together, they must be separated at a processing facility before it be delivered to recyclable markets waste. For the source separation and waste collection programs, materials are obtained from the household and the curbsides collection center.

Typical source separation programs collect recyclable materials such paper, glass, different types of plastic and metals, and the remaining household waste. The more materials are generated, while the collection and processing problems are commonly found. As the number of materials collected from source separation increase, the carrying capacity of waste separation system is required to deal with the material seem to increase significantly. Different types of materials should be considered, which materials is implemented together with a recycling program, there are several methods of waste separation and collection, include the various types of processing and separation systems that are available. However, specific expert is required to evaluate the optimum method for transfer the knowledge to community, based upon its population, geographic location, and accessibility to markets.

2.11 Serial – self turning (STR) composting technology

The serial self-turning (STR) reactor which is the composting technology using aerobic composting system by transforms the biodegradable waste to a humus-like product, inactivate pathogens, and ammonia was converted into the most stable form of nitrogen. For adequate oxygen supplied for aerobic composting. In an enclosed composter, an effective way to achieve this is the mixing or turning of the organic material. In-vessel composting systems are also well known as "reactor" systems, are considered to more intensive designing and engineering than conventional systems. This helps in achieving better process efficiency, process control, and optimization.

The STR technology was developed based on the concrete mixing unit 'MY-BOX'. This composting technology was designed for small communities which municipal solid wastes were generated approximately 50 tons per day. Only using of gravitic mixing system, STR technology requires low fixed cost and low operating cost. Most interesting, only two unskilled workers can control the whole system. The major components of STR system include; 1) Reactors, 2) STR tower, 3) Bio-mybox and 4) aeration system. The STR operation process, which is demonstrated in Figure 2.3, had some potential changes to be the safest, simplest and easiest method to handle. For example, the ability of reactors' mobility makes the control and observation of parameters simply, it is a flexible system that can uses of many reactors at the same time with only one STR tower optimums the area.

STR composting technology can apply to small community although the location in or near the community, the unfavorable conditions such as odour and flies can be controlled. Therefore, an in-vessel composting technology was recommended, due to it is a closed composting system, and requires less area for system operated [44]. This is the improving of composting technology with regard to four indicators: high effective performance, low cost of construction and operation, flexibility and environmental friendliness.

The biodegradation process took a short time to digest the putrescible waste mass is reduced by more than 30% from the beginning. The final product from the 14 days composting was dry, bulky, odourless, and easy to handle. Self-turning reactor system has been applied to canteen waste, market waste, fruit peel, food scraps, vegetable waste, sewage sludge and animal manure.

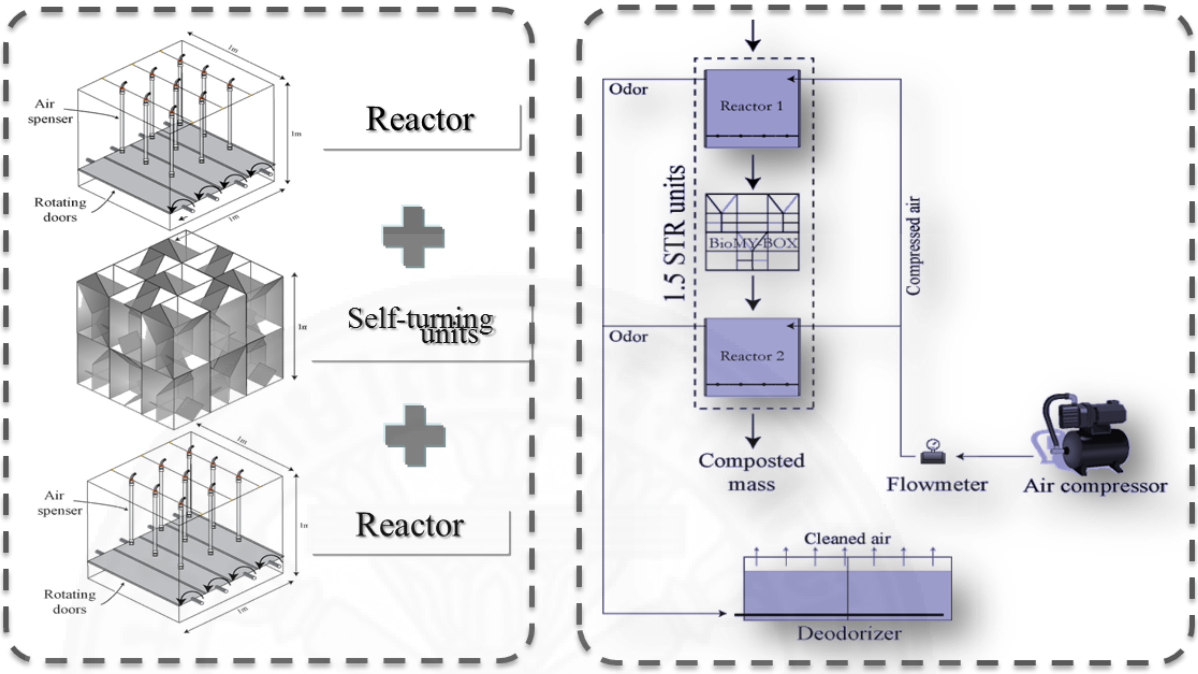


Figure 2.3 In-vessel composting system with serial-self turning (bio-mybox) [8]

Chapter 3

Methodology

3.1 Framework of this study

This study was focused on the municipal solid waste management of rural community by investigating the waste generation rate and evaluates the MSW produced from Thachi sub-district municipality, Suratthani Province in order to study the feasibility for the application of composting technology “Serial-Self Turning reactors (STRs)”

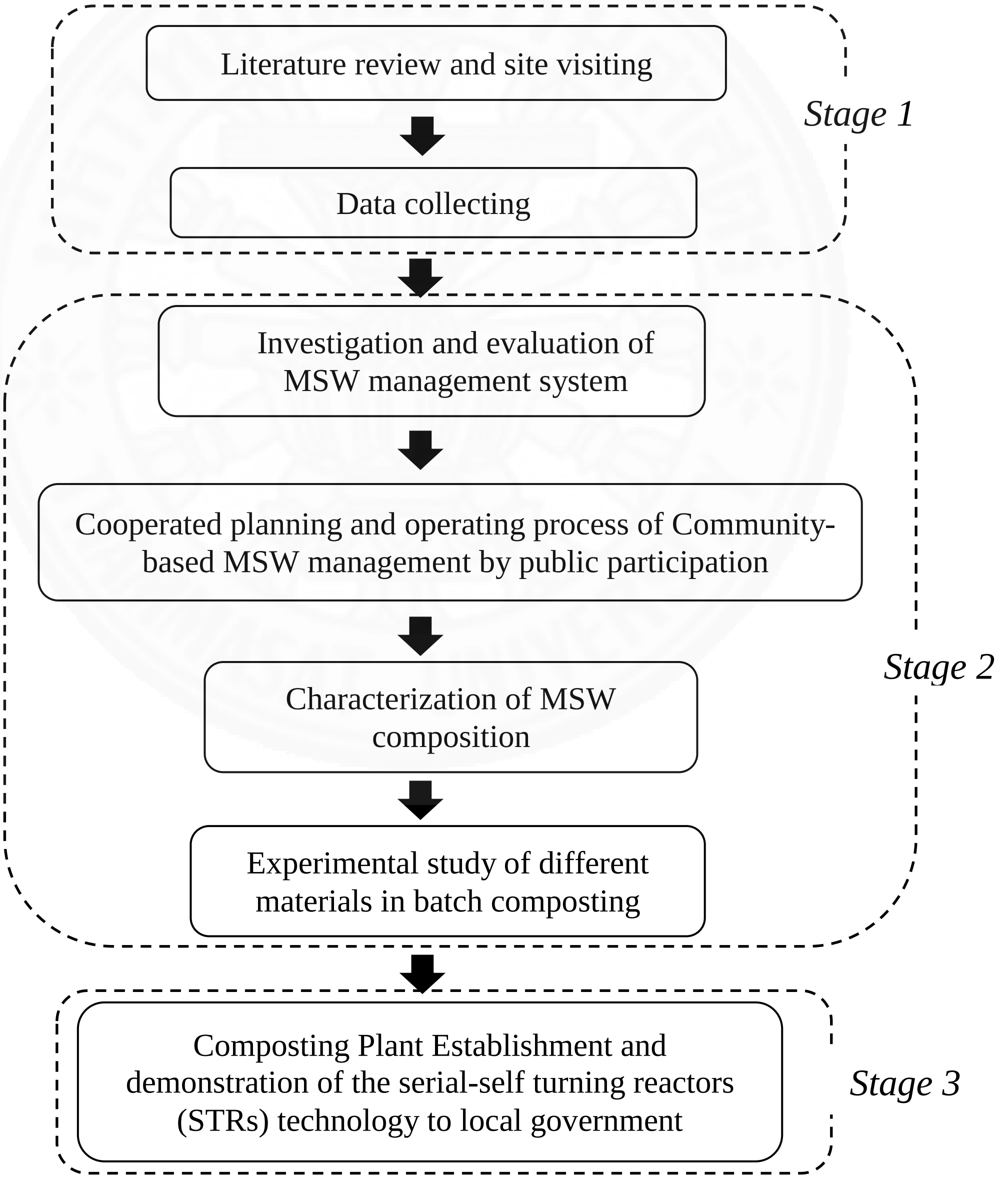


Figure 3.1 Study framework

The research framework is divided into 3 stages (see Figure 3.1);

1st Stage : Literature review, site visiting and data collecting

2nd Stage

- Investigation and evaluation of MSW management system
- Cooperated planning and operating process of community-based MSW management by public participation
- Study on the potential to use the composting technology by use organic waste as a material for composting experiment

3rd Stage: Composting Plant Establishment and preparing for setting up of serial-self turning reactors (STRs) technology on MSW management

- Design the handle capacity of organic waste materials for supply to STRs composting plant by analyzing from the MSW generation rate
- Demonstrate the operational system of STRs to Thachi sub-district municipality for a study on the mixing performance of the gravitic mixing.
- Large-scale experiments of Serial-self turning system

3.2 General information of study area

3.2.1 Location and administrative area

Thachi sub-district municipality, Bannasarn district, Suratthani province, located at the south of Thailand far from Muang Suratthani district 65 kilometers. There are 6 villages with total area 77.80 km^2. The maps is shown in Figure 3.2

3.2.2 Local geography

Thachi sub-district municipality is located on the low flat area along the Tapi riverside which branches to a creek, swamp, and canal. The three-quarters of the total area are suitable for farming, gardening, and local livestock includes for agricultural used especially for vegetables and fruits plantation. According to the forest area this area is a peat swamp forest abundant with various species of freshwater fish. Figure 3.3 shows the Geography Map of composting plant.

3.2.3 Population

According to the data of sub-district administrative organization in 2015, there are 1,426 households in Thachi sub-district municipality, the total population was including 4,931 [51]

3.2.4 Land using

Occupational intensity is agricultural parts including rubber and oil palm plantation, seasonal fruit cultivation, and farming. The most of the population is a farmer.

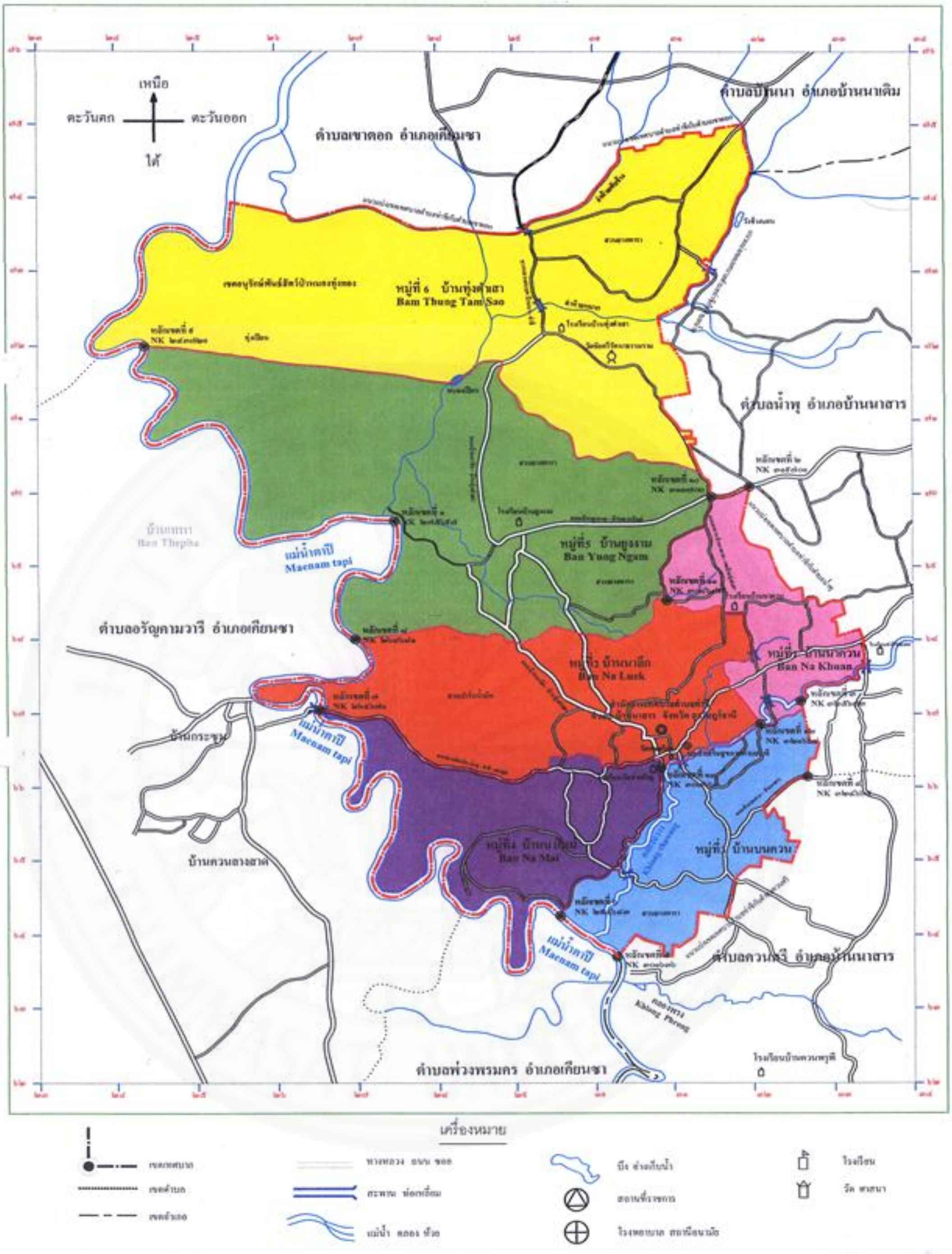


Figure 3.2 Location of study areas (Map), Thachi sub-district municipality, suratthani province

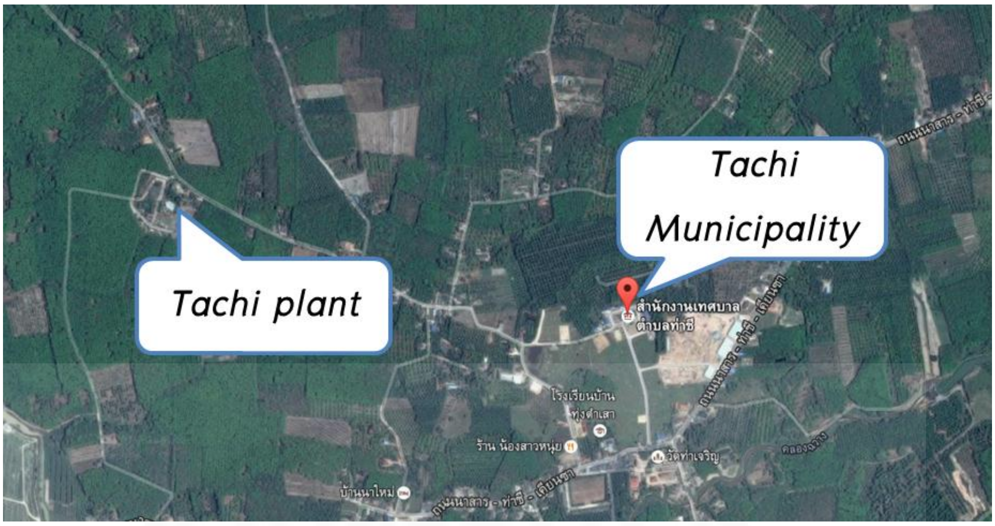


Figure 3-3 Geography map of composting plant, Thachi sub-district municipality, suratthani province [52]

3.3 Investigation and evaluation of MSW management system

Data collecting was performed by interview questionnaire, household survey, and field observation. This study explores the:

3.3.1 Quantity and types of municipal solid waste in Thachi sub-district municipality by waste sampling

3.3.2 Questionnaires survey by interviewing the community members. The content of questionnaires based on the waste management systems at their household and waste disposal facilities which consist of question 1.) General information of household, 2.) MSW management practice, 3.) Knowledge on waste utilization technology. In addition, visual inspection of the waste generated from community and the quantity of waste also the waste composition in the various season were determined (See Appendix 1 on Page 102)

3.3.3 Study the current situation of municipal solid waste and collect the secondary data personal interview methodology was particularly way to collect the data at source of study area on the municipal solid waste management system and also interview the knowledge and strategies of MSW management with sub-district municipal authorities.

3.4 Operated planning and operating process of MSW management by public participation

The community-based MSW management project leads by trained social innovator and leadership of each village with education on waste separation, recycling and reduces waste disposal by following processes (see Figure 3.4)

- Field observation, questionnaire interview
- Group discussion
- Workshop of community-based MSW management planning

Figure 3.4 Community-based MSW management planning and group discussion

3.4.1 Community-based participation process

Group discussion and workshop with the key members of the community were elucidated by the community participation**.** The awareness on waste management problems and the importance of recyclable waste project and source separation were promoted by the use of education-based communities. Descriptions of the practical methods were shown as follow**;**

3.4.1.1 Provides community-based education related to the 3Rs projects for the resident that includes reduces, reuse and recycle practice in community. The projects leads by the staffs of Tachi sub-district administrative municipality and the volunteer of each village form the groups as the social innovator which supported by the project of EGAT (See report "The Study of Social Capital for Sustainable Development in the Suratthani Province").

(1) Community meetings for group discussions and comments regarding community-based on waste management projects.

(2) Working groups of sub-district municipality staff and volunteer of each village for contributed organic waste for household composting practices, and designs the practical methods for apply on the waste recycling project in community. (See Figure 3.5)

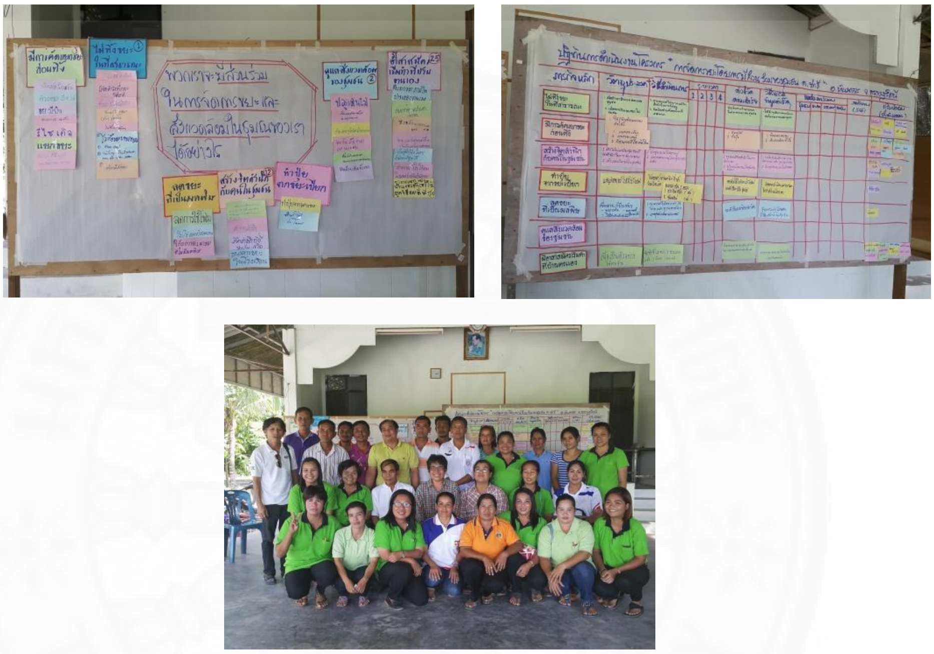


Figure 3.5 Group discussion workshop of municipality staff and volunteer

3.4.1.1 Educational activities of waste recycling project for student at primary school was undertaken by participate with the teacher and the expert on waste recycling from neighboring area, Bannasan's model**.** The activities provide the working groups on students by contributing the recyclable waste project and adding value in terms of the recycle waste bank at school. In addition, students can create the materials from recyclable waste such as handmade product from beverage carton. (See Figure 3.6)

Figure 3.6 Student working groups

In addition, community-based waste management projects received support from stakeholders of local government agencies , which provided technical waste management including non-profit organization from Bannasan' s model that support in waste recycling project. Moreover, educate in waste management to community members, which received a knowledge and share with other community.

3.5 Study on the potential to use STRs composting technology

Analysis of MSW composition may be also based on the source of waste. In this study focused on rural community, household and agricultural waste are analyzed in term of material types such as garbage, plastic, glass, paper, biodegradable waste and other.

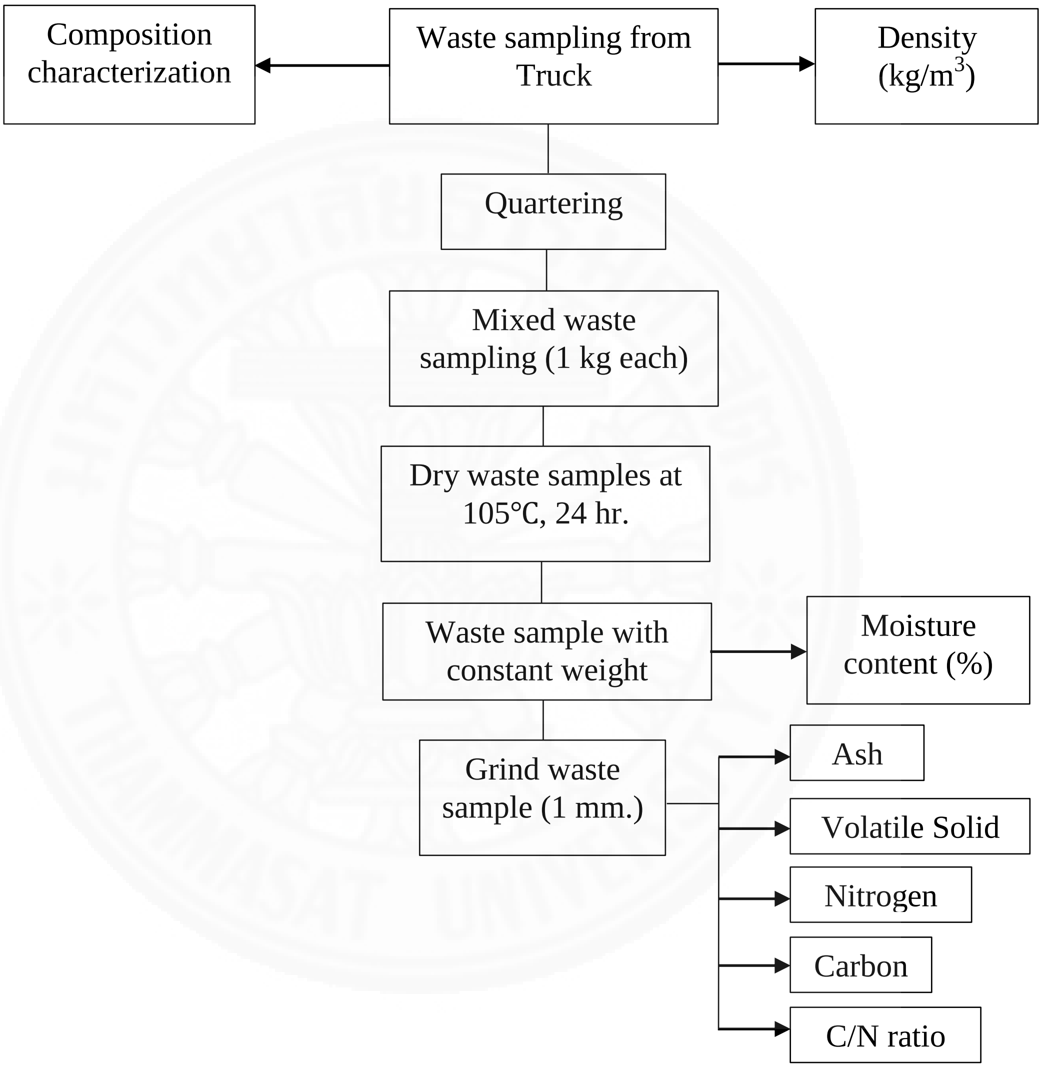


Figure 3.7 Municipal solid waste characterization process

3.5.1 Waste Sampling and MSW composited characterization

3.5.1.1 Size of sampling

For community waste generated from household, sample size of waste collected was a minimum of 100 kg and it was completely mixed on the floor and placed in a form of pile with 0.8 m. high. Then, coning and quartering by divide waste into four parts; waste sample was collected in 100 kg - 200 kg.

Accordingly the waste sample collected should be separated for physical characteristics into various compositions, such as paper, plastic, metal and etc. Each component is gathered and weight. The weights are identified as percent of waste samples.

3.5.1.2 MSW samples segregation

Municipal solid waste characterization methods had been studied by which the sorting area that should be protected from wind and leachate includes precipitation. Waste sorting can be initiated after the waste samples were collect from the truck before transport to disposal site. Quartering method of MSW was undertaken follow by the Ministry of Public Health and Welfare, 2000 and ASTM D5231-92, 2008 [13, 53] and further MSWs composition are separated, each types of MSWs are weighted and data are recorded , comparing the proportion of waste categories with the total MSW, give a result in the percentage of wet weight, the sorting methods described below; (See process in Figure 3.8 and 3.9)

- Preparing a copy of data record form
- Waste samples were unloaded and spread flat on a clean plastic sheet at the sorting area.
- Large types of waste (most of the yard and agricultural waste and plastic bag should be separated first from the waste sample pile and then weighting by using scale balanced and record the mass in kilogram.

- The types of waste is manually segregated into different components in the each container: Food waste, Leaves, Papers, Metals, Textiles, Plastics, Glasses, Leathers, Hazardous materials and miscellaneous materials.

- The container of each component was weighed and the mass of waste was calculated and recorded.

- 1 kg of composite samples of compostable and/or combustible fractions (leaves, food, soft papers and the miscellaneous) was collected in polyethylene bags and transported to Laboratory of Rajabhat Suratthani University, moisture content was analyzed immediately.

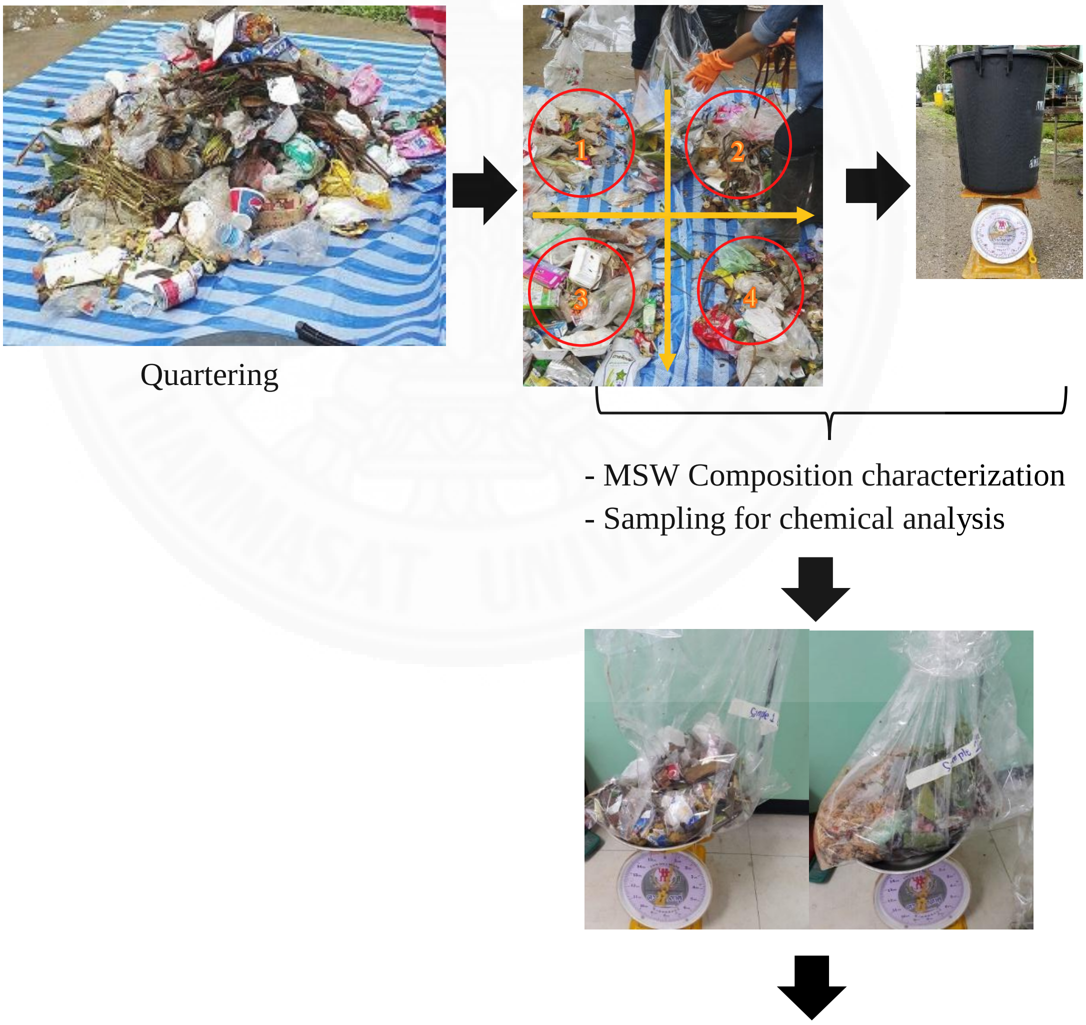


Figure 3.8 Municipal solid waste sampling

Figure 3.9 Municipal solid waste characterization

3.5.2 Chemical characterization of MSW

After waste sampling have done, the waste samples were packed in the zip lock plastic bag and temporarily collected at the temperature less than 4 °C. The waste samples for laboratory testing consisted of at least 1 kg of mixed waste for each day of sampling. Then those of the samples were delivered to the laboratory for chemical analysis.

3.5.2.1 Proximate analysis

According to the proximate analysis the following parameter should be determined, the percentage of moisture content, ash content, volatile solid content and calculate the percentage of fixed carbon according to ASTM standards D7582-12 [54].

(1) **Moisture content** (drying at 105 °C)

The percent moisture of the MSW samples was determined by weighing of samples before and after drying in an oven at 105°C to a constant weight [54]. The percent moisture content (%) was calculated as a percentage loss in weight before and after drying. The equation (1) provides the formulae for determine % Moisture. See analytical processes in Figure 3.10.

$$\%Moisture = \frac{[Wetweight - Drywight]}{Wetweight} \times 100\% \quad \text{………… (1)}$$

Figure 3.10 Moisture content analysis

(2) **Ash content** (combustible residue left after ignition)

Ash content identifies the mass (g) of incombustible material that remained in the crucible after burning, which given waste sample as a percentage of the original mass (g) of the waste sample. Practically, waste samples used for moisture content analysis was used for determine the ash content. Weight of samples are recorded before ignition and then samples are burned in furnace with operated the temperature at 550±50 ˚C for two hours. Eventually the remaining ash after ignited is let to cool down before record the ash weight (g) [55]. % Ash can calculate by use equation number (2) as follow;

$$\%Ash = 100 - \%Volatile \qquad (2)$$

Figure 3.11 Volatile and ash content analysis

(3) Volatile solid (%)

The volatile solid content is the amount of matter that volatilizes when heated the samples which determined by the method of ignition of the sample at 550 ± 50°C [54]. Volatile solid can calculate by equation (3). According to the volatile solid can be used for approximate the amount of organic carbon present in the sample by calculate using equation (4). After combustion, to determine the ash in dry weight (kg) the waste samples are weighed, with volatile solids being the difference between the dried solids and the ash. (see processes in Figure 3.11)

$$\%Volatile = \frac{[W_D - W_{Ash}]}{W_D} \times 100\% \quad \text{...........(3)}$$

$$\%Organic carbon = \frac{\%Volatile solid}{1.8} \quad \text{.........................(4)}$$

3.5.2.2 Ultimate analysis

Ultimate analysis includes determination of % content in Carbon (C) and Nitrogen (N). The chemical composition is the percent of carbon, and nitrogen, which were also used to define the proper MSW to achieve suitable C/N ratios for biological transformation processes.

Organic carbon was analyzed by the sample ignited at 550 ± 50 °C and then can calculate the carbon content (%) which estimated by equation (4) related to the volatile solid content of different mixing materials and final product samples by considering that the most biological materials have the carbon content between 45% and 60% of volatile solid fraction as shown in equation (2), Assume that;

$$\%\,\mathrm{Carbon} = \frac{(\%Volatile solid)}{1.8} \quad \text{.............................} \; (4)$$

Total nitrogen was analyzed by using total Kjeldahl nitrogen digester, distillation and titration analysis [56]. (See processes in Figure 3.12 and 3.13)

.

$$\%Nitrogen = \frac{\left|V_{Sample} - V_{Blank}\right| \times conc. of H_2SO_4(N) \times 1.4007}{weight_{Sample}(g)} \quad \text{......} \; (5)$$

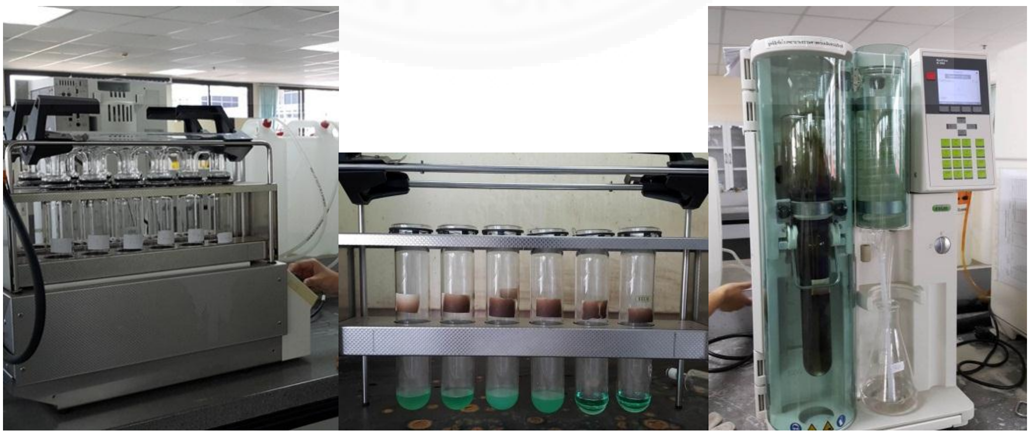


Figure 3.12 Total Kjeldahl nitrogen (TKN) digestion

Figure 3.13 Total Kjeldahl nitrogen (TKN) analysis (Titration)

3.5.3 Composting process monitoring

During operate of composting process; the temperature will be measure every five minutes by using data logger for record the temperature generated in composting pile. Later on, the controlled parameter for composting was measured at the end of composting process include , pH , moisture content (%) , C/N ratio, total organic carbon, total nitrogen, total phosphorus and total potassium, electrical conductivity (EC) and so on. The analytical method for determine the primary result of physical, chemical and biological properties of mixing material and final product of composting are described below;

3.5.3.1 pH and electrical conductivity

(1) Apparatus

- pH meter and Electrical conductivity meter, MettlerToledor
- beaker, stirring rod, distilled water

(2) Analytical procedure

The electrical conductivity and pH content was measured from the samples in distilled water perform by 1/10 of solid/liquid aqueous.

3.5.3.2 Moisture content (%) and total organic carbon

(1) Apparatus

- Moisture analyzer, hot air oven and muffle furnace
- Aluminum tray, aluminum dish and ceramic crucible
- Desiccators providing with colour indicators of moisture absorbent

- Electronic analytical balance (2 or 3 digits)

(2) Analytical procedure

The moisture content was determined by weighting the samples before and after drying at 105 °C and calculates by use equation (3) as follow;

$$\%\ \text{Moisture} = \frac{Weight_{initial} - Weight_{afterdry}}{Weight_{initial}} \times 100\% \text{ .... (3)}$$

Organic carbon was analyzed as mention in the ultimate analysis.

3.5.3.3 Nitrogen content

(1) Apparatus

- Digester machine which can adjust the temperature
- Condenser
- Erlenmeyer flask 250 ml.

(2) Chemical and reagents

- Catalyst mixture can obtain from mixed 5 g of $CuSO_4$ with 100 g of K_2SO_4
- Conc. H_2SO_4 (sulfuric acid)
- NaOH (Sodium hydroxide) 32 % was prepared by weight the NaOH 320 g and distilled water was added for adjust the volume to 1 liter, use in distillation process
- Boric acid 4% (H_3BO_3) was prepared by weighting the H_3BO_3 40g and gently dissolved into distilled water and adjust the volume to 1 liter
- Mixed indicator prepared by mixed bromocresol green with methyl red dissolved in 100 ml ethanol
- 0.1 N H_2SO_4 with standardized for titration was prepared by pipette the H_2SO_4 2.78 ml. and make the volume to 1 lit by use volumetric flask 500 ml.

(3) Analytical procedures

- Weight 1g of sample, record the weight (g)
- Add the mixed catalyst and add the 5 or 7 of glass beads
- Add conc. H_2SO_4 20 ml. cautiously
- Set the digester machine and place the digester tube in to the digestion blocks
- After digestion is completed, set aside to cool down in the fume hood
- Condense the digested sample by used distilled water and prepared NaOH 32% 80 ml.
- Place 250 ml. Erlenmeyer flask with 4% H_2BO_3 60 ml. was prepared and place under the condenser distillation for collect the dissolved distillate
- Add indicator 2 to 5 drops
- Titrate the distillate used the 0.1 N H_2SO_4 until reach the endpoint which the colour changes from green to pink

(4) Calculation

$$\%Nitrogen = \frac{\lfloor V_{Sample} - V_{Blank} \rfloor \times conc.of H_2SO_4(N) \times 1.4007}{weight_{Sample}(g)}$$

3.6 Experimental study of organic waste composting

This research study with the composite material mixed between agricultural waste with vegetable/food waste and cow manure by small-scale and large-scale experiments of composting.

3.6.1 Composted materials

For this study, biodegradable waste is used as a raw material for composting. Food waste was collected from restaurants in the community. Vegetable waste was taken from groceries store in the community and neighboring district, Bansong local market. Cow manure was taken from farming in the community; leaf compost was bought from the gardening shop, agricultural wastes including oil palm empty fruit bunch (EFB) and yard waste were used as a bulking agent. Figure 3.14 shows the example of raw materials for composting.

Figure 3.14 Materials for composting

3.6.1.1 Overview of oil palm empty fruit bunch (EFB) in Thaci sub-district municipality

According to the environmental problems from EFB residue was performed in the entire crude palm oil process does not need any chemicals as a processing aid. However, there are a number of environmental problems at the factories, such as high water consumption, the generation of a large amount of wastewater with a high organic content, waste generation from the crude palm oil industry in Thailand. In Thachi only need more area for EFB stocked and then use as a material for mushroom production, sometime especially in rainy season the EFB pile provide odour but did not directly effect to the human health due to it located in the abandon area far from residential area.

The application of oil palm residue in Thachi sub-district municipality is the agricultural area which occupied by oil palm planation, therefore amount of oil palm frond is very high compared to other residue of oil palm tree. Oil palm frond is commonly use as soil cover material or mulching material under the palm tree.

The EFB recycling only practice in the agricultural sector, EFB is used as a substrate for straw mushroom cultivation. Currently, EFB is bought by the farmer in local community and sell to factory in neighboring area, EFB is sold around 600 Baht/ton. However, some factory distributes the

EFB with no charge if the farmer transport EFB residue by themselves. Oil palm producers use EFB as a substrate for the cultivation of straw mushrooms in the oil palm plantation in community. In addition, the EFB is used as a material for composting.

3.6.2 Experimental set-up

Small scale (Cubic reactor)
Cubic reactor: 450 x 450 x 450 mm^3 (Figure 3-15)

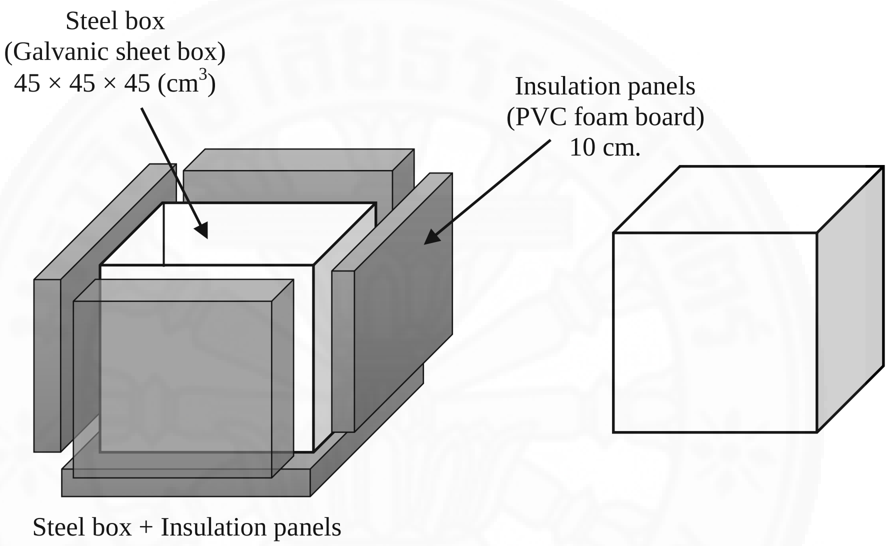


Figure 3.15 Small scale reactor

The experimental study was used small reactors with dimension 0.45x0.45x0.45 m^3 with 10 cm. the thickness of foam cover. The volume was designed to equal to one fourth of the serial-self turning reactor (STR). The aeration was supplied by air compressors through the air flow rate and the PVC pipes. Composting parameters are controlled by measurement of the parameter that can affect the condition of the composting process. The temperature was measured by thermocouple and data logger, to ensure a present temperature profile. After 28 days, for checking the chemical properties of the final product will be sent to the Central Laboratory of Thailand for testing.

3.6.2.1 Plan of experimental runs

To find the best compost materials, the different mixing ratio was required. Five small scale composting experiments were studied in semi batch composting as follow; Experiment 1 , Experiment 2, Experiment 3, Experiment 4 and Experiment 5. These experiments were carried out during a period of 5 months and 5 day, from 15 January to 20 May 2016. The details of the experiment shows in table 3.1

Primary testing of physical, biological and chemical characterization of raw materials are important for setting up the appropriate composting condition.

Table 3.1 Proportion of raw materials

	Materials proportion				
	Experiment 1	**Experiment 2**	**Experiment 3**	**Experiment 4**	**Experiment 5**
Mixing ratio Aeration rate 0.5 l/min/ kg OM	F: V: EFB	F : V : EFB : LC	F : V: RH : LC	F+V: CM : A	OM:CM: EFB
	0.5:0:0.5	1:0:0.5:0.5	1:0:0.25:0.25	0.25:1: 0	0:1: 0.25
	0.5:0.25:0.5	1:0.25:0.5:0.5	1:0.25:0.25:0.25	0.25:1: 0.25	0.25:1:0.25
	0.5:0.5:0.5	1:0.5:0.5:0.5	1:0.5:0.25:0.25	0.25:1: 0.5	0.5:1: 0.25
	0.5:0.75:0.5	1:0.75:0.5:0.5	1:0.75:0.25:0.25	0.25:1: 0.75	0.75:1: 0.25

F = Food waste LC = Leave compost A = Agricultural waste
V = Vegetable waste CM = Cow manure RH = Rice husk
OC = Organic commingled waste except food waste
EFB = Oil palm empty fruit bunch

(1) Experiment 1 (See Figure 3.16)

Organic waste material used in this experiment composed of vegetable scraps and food leftover which were collected from the local restaurant and local market of a neighboring district. Oil palm empty fruit bunch (EFB) was used as an amendment and a carbon source, and EFB was obtained from oil palm mill near the community. Raw materials were ground into 1 to 1.5 inch. Table 3.2 shows the raw material properties. Table 3.3 demonstrates the proportion of initial compost. Bulking agents were added for maintaining the composting condition.

Table 3.2 Raw material properties of experiment 1

Parameter	Food leftover	Vegetable scrap	Oil palm empty fruit bunch (EFB)
pH	6.25	6.44	7.6
Total organic carbon (%)	36.3	39.29	45.57
Total Nitrogen (%)	2.07	1.86	1.35
C/N ratio	17.53	21.15	34.33
Moisture content (%)	65.00	60.00	25.45

Table 3.3 Proportion of initial compost for experiment 1

Parameter	Food leftover : Vegetable scraps : EFB			
	Reactor 1 0.5 : **0** : 0.5	Reactor 2 0.5 : **0.25** : 0.5	Reactor 3 0.5 : **0.5** : 0.5	Reactor 4 0.5 : **0.75** : 0.5
Moisture (%)	58.12%	58.40%	58.61%	58.77%
Organic carbon	38.15%	38.34%	38.48%	38.58%
C/N ratio	19.85	20.06	20.21	20.32
Aeration rate (lit/minute)	0.042	0.043	0.043	0.043

Figure 3.16 Experimental study 1 (15 Jan – 5 Feb, 2016)

(2) **Experiment 2** (See Figure 3.17)

Organic waste combinations used in this experiment compose of food leftover, vegetable scraps, oil palm empty fruit bunch (EFB) and leaf compost. EFB was used as a carbon source. Raw materials were ground into 1 to 1.5 inch. , Table 3.4 and 3.5 show the raw material properties and proportion of initial compost for experiment 1.

Table 3.4 Raw material properties of experiment 2 and 3

Parameter	**Food leftover**	**Vegeta ble scrap**	**Oil palm empty fruit bunch (EFB)**	**Leaf compost**	**Rice husk**
pH	6.5	5.4	8.8	8.7	8.3
Total organic carbon (%)	46.3	39.38	50.47	10.3	41.21
Total Nitrogen (%)	2.072	1.862	1.352	0.763	0.33
C/N ratio	22.35	21.15	37.33	13.05	123.5
Moisture content (%)	78.00	69.80	33.33	15.8	8.2

Table 3.5 Proportion of initial compost for experiment 2

Parameter	Food leftover : **Vegetable scraps** : EFB : Leaf composted			
	Reactor 1 1:**0**:0.5:0.5	Reactor 2 1:**0.25**:0.25:0.5	Reactor 3 1:**0.5**:0.5:0.5	Reactor 4 1:**0.75**:0.5:0.5
Moisture (%)	66.04%	66.50%	66.86%	67.16%
Organic carbon	38.34%	38.46%	38.55%	38.63%
C/N ratio	24.40	23.98	23.66	23.40
Aeration rate (lit/minute)	2.24	2.22	2.20	2.18

Figure 3.17 Experimental study 2 (6 February – 6 March, 2016)

(3) Experiment 3

In the experiment 3 (See Figure 3.18), four reactors with different mixing materials obtained from food leftover, vegetable scraps, rice husk and leaf composted are composted. The raw material properties are described in table 3.6 and the proportion of initial compost for experiment 2 is shown in table 3.7.

Table 3.6 Proportion of initial compost for experiment 3

Parameter	Food leftover: **Vegetable scraps**: Rice Husk: Leaf composted			
	Reactor 1 1:**0**:0.5:0.5	Reactor 2 1:**0.25**:0.25:0.5	Reactor 3 1:**0.5**:0.5:0.5	Reactor 4 1:**0.75**:0.5:0.5
Moisture (%)	64.81%	64.34%	63.95%	63.62%
Organic carbon	38.34%	38.46%	38.55%	38.63%
C/N ratio	24.40	23.98	23.66	23.40
Aeration rate (lit/minute)	2.16	2.15	2.14	2.14

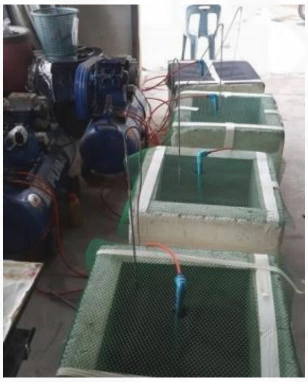


Figure 3.18 Experimental study 3 (6 February – 6 March, 2016)

(4) Experiment 4 (See Figure 3.19)

The waste combination and raw materials properties used in this experiment are shown in table 3.7. Cow manure was used as a nitrogen source, food leftover mixed with vegetable scraps were used as a source of microorganisms. Agricultural waste consisted of oil palm EFB, yard wastes which have high carbon content. Therefore, this raw material can maintain the appropriate composting condition; proportion of initial compost for experiment 4 is shown in table 3.8.

Table 3.7 Raw material properties of experiment 4

Parameter	Food+ Vegetable scraps	Cow manure	Agricultural waste
pH	6.725	8.585	6.665
Total organic carbon (%)	46.93	45.60	9.92
Total Nitrogen (%)	2.1	2.4	0.72
C/N ratio	22.35	19.00	13.7
Moisture content (%)	81.67	41.07	20.12

Table 3.8 Proportion of initial compost for experiment 4

Parameter	Food +Veg scraps : Cow manure : **Agricultural waste**			
	Reactor 1 0.25 : 1 : **0**	Reactor 2 0.25 : 1 : **0.25**	Reactor 3 0.25 : 1 : **0.5**	Reactor 4 0.25 : 1 : **0.75**
Moisture (%)	59.16%	55.54%	52.53%	50.00%
Organic carbon	37.88%	33.22%	29.89%	27.40%
C/N ratio	19.11	18.74	18.42	18.13
Aeration rate (lit/minute)	0.90	0.86	0.82	0.80

Figure 3.19 Experimental study 4 (9, March – 9 April, 2016)

(5) **Experiment 5** (see Figure 3-20)

The raw material used in this experiment is organic commingled waste collected from the waste stream which excludes food waste. Cow manure was added to improve the nitrogen content and oil palm EFB was used as a carbon source. The raw materials properties and proportion of initial compost for experiment 5 are shown in Table 3.9 and 3.10 respectively.

Table 3.9 Raw material properties of experiment 5

Parameter	Organic commingled waste except food waste	Cow manure	EFB
pH	6.725	8.585	6.665
Total organic carbon (%)	7	45.60	9.92
Total Nitrogen (%)	0.313	2.4	0.72
C/N ratio	22.35	19.00	13.7
Moisture content (%)	81.67	41.07	20.12

Table 3.10 Proportion of initial compost for experiment 5

Parameter	**Organic commingled waste except food waste : Cow manure :** EFB			
	Reactor 1 **0**: 1**:** 0.25	Reactor 2 **0.25:**1**:** 0.25	Reactor 3 **0.5**: 1 **:** 0.25	Reactor 4 **0.75**: 1**:** 0.25
Moisture (%)	61.87%	59.72%	64.05%	56.89%
Organic carbon	43.07%	43.99%	46.70%	39.45%
C/N ratio	16.96	18.40	17.21	17.83
Aeration rate (lit/minute)	3.53	3.81	3.61	3.66

Figure 3.20 Experimental study 5 (30 April – 20 May, 2016)

The different mixed of materials in each experimental study was calculated to obtain the initial carbon: nitrogen (C/N) ratio 20-30:1 furthermore, four experimentals set-up of the composting.

3.7 Composting plant establishment

The plant has been belonging to Thachi municipality (see Figure 3.21). There is 15 m × 25 m and was built in 2011 for rubber manufacturing. Figure 3.22 shows the engineering design of the composting facility for setting up the Serial-self turning reactor system.

Figure 3.21 Plant modification and setting up the equipment

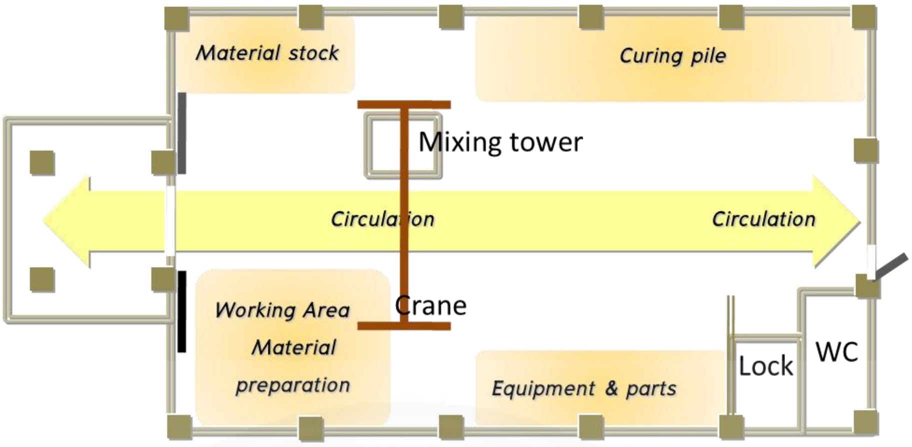


Figure 3.22 Plant layout

Engineering design of the composting facility for setting up the Serial-self Turning Reactor system was conducted (see plant layout in Figure 3.22). Then, cost estimation and operation commissioning was undertaken, the mixing tower and crane were installed as well as additional equipment were applied for a large-scale operation, such as the shredder machine for material preparation and conveyor system (see Figure 3.23). Table 3.11 showed the cost estimation of the composting facility while the equipment for primary testing the qualities of material and final product such as pH meter, EC meter, moisture and carbon content analyzer are moved to composting plant.

Table 3.11 Cost estimation of composting facility

STRs (Reactor)	Equipment and Machine	
	Item	Cost
Size 1.3×1.3×1.0 m.	Mixing tower	387,390 THB
Capacity 2.0 m^3	Operational Equipment	538,288 THB
Unloaded reactor 310 kg	Testing Equipment	523,961 THB
Loaded reactor 2000 kg	Total	= 1,449,639 THB

Table 3.12 The handle capacity of STR composted material

Description	Unit
Total waste generation	1.569 ton/day
Waste generation	1.12 kg/cap/day
Organic waste	48.3 %
Waste collection	95 %
Waste separation efficiency	50 %
Bulk density	225.56 kg/m^3
Organic load STR	385.43 kg/day
Mixing ratio 1:1 for 2m^3/day	**770.86 kg/day**

Table 3.12 showed the designed of handle capacity of MSW used for supply to STRs composting plant by analyzing from the MSW generation rate. Mixing ratio of material 1:1 for two different of co-composting was supplied to the composting process.

Conveyor machine   Pallet compressing machine   Shredder machine   Sieving machine

Figure 3.23 Operational equipment and machines

3.8 Large scale composting

Large scale experiment was performed by using best mixed proportion of the small scale experiment and the final product properties can achieve the conventional standard properties of organic fertilizer. The waste combinations consist of food and vegetable waste. Cow manure and EFB were used as bulking agent. However to maintain the composting condition in the large scale composting, EFB will use as a carbon source of composting because the cow manure and food with vegetable waste consist of high nitrogen content.

3.8.1 Material preparation

Cow manure was taken from a local farming of Thachi sub-district municipality. Vegetable scraps and food leftover was collected from the local restaurant and local market of a neighboring district. Oil palm empty fruit bunch (EFB) was obtained from oil palm mill near the community. Table 3.13 shows the raw material properties of large-scale experiment.

Table 3.13 Raw material properties of large-scale experiment

Parameter	Food and Vegetable scrap	Cow manure	Oil palm empty fruit bunch
pH	5.97	8.58	8.08
Total organic carbon (%)	49.37	42.65	50.47
Total Nitrogen (%)	1.967	3.708	1.352
C/N ratio	25.1	11.5	37.329
Moisture content (%)	35.95	53.76	33.33

However, the mixing proportion of the large scale was adjusted from the small-scale experiment by add EFB to balance the C/N ratio and also the amount of food and vegetable scraps is not enough to use in the full scale composting. The mixing proportion is 1 : 1 : 0.5 with the waste combination is food and vegetable scraps while cow manure and EFB were used as a bulking agent (F+V: CM: EFB). Table 3.14 demonstrated the initial composted material of co-composting which depend on C: N ratios and moisture content of material. Bulking agents were added for maintaining the composting condition [8]

Table 3.14 Proportion of initial compost for large-scale experiment

Materials	Description		
	Food and vegetable scraps	Cow manure	EFB
proportion	1	1	0.5
Weight (kg)	326.21	189.87	83.91
C/N ratio	18.46		
Aeration rate (lit/minute)	0.62 liter/minute		

3.8.2 Experimental set-up

The experimental study used large reactors with the dimension 1.3 m×1.3 m ×1 m. The aeration was supplied by air compressors through the perforated polyvinyl chloride (PVC) pipes (see Figure 3.24), design to supply the air covering all positions in the reactor. Air flow rate recommended from the previous study was used is 0.5 lit/minute/kg organic matter to increase biodegradation rate [9]

Figure 3.24 Setting up of aeration system

In addition, Composting factors were controlled by measurement of the parameter can effect to the compost condition. The temperature was measured by thermocouples and recorded by the data logger (see Figure 3.25). Thermocouples were installed at 3 positions in large scale reactor including in the middle of the reactor, at the bottom which the sensor was installed far away from the bottom of reactor 20 cm., and the temperature was measured at the corner of the reactor where the heat easy release to the ambient.

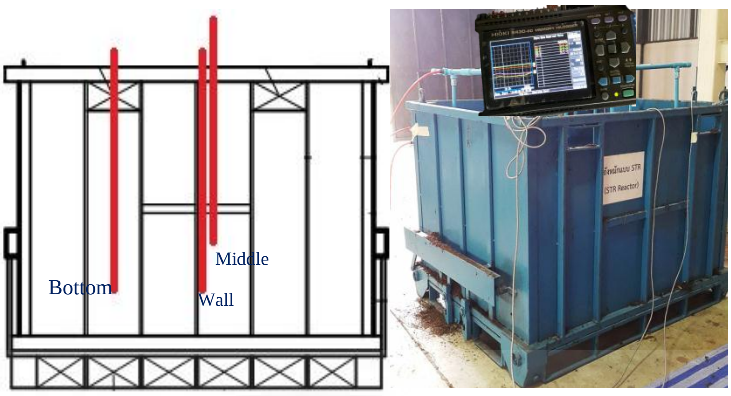
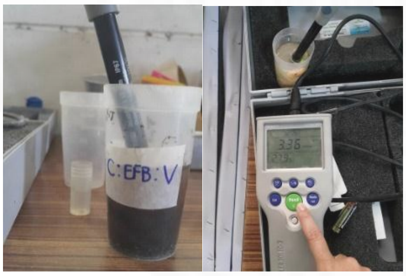


Figure 3.25 Thermocouple set up for temperature measurement

Composting parameters were measured followed by the Figure 3.26, which the moisture content was analyzed by moisture analyzer AND MX-50, pH meter MettlerToledor, electrical conductivity (EC) meter MettlerToledor, total organic carbon was analyzed by furnace CARBOLITE, aeration was supplied by air compressors through the perforated PVC pipe, the temperature will be recorded by data logger Hioki8430 with 10 channels through the thermocouple and the hand lift move the reactor to compost and wait to meet the maturity of composting process.



pH and EC measurement

Moisture content analysis

Figure 3.26 Composting parameters were measured

The composting process of STRs system shown in the figure 3.27, start from material preparation which materials were loaded using conveyor, crane with the capacity lift the reactor up to the top of the mixing tower and release the materials into mixing box, preparing reactor at the bottom for receiving the material from the self-turning unit.

Figure 3.27 STRs composting process

The pile was turned on day 7, 14 of the composting period by loading the compost mixed through the self-turning units and curing for 2 weeks. After 28 days, biochemical properties of the final product were sent to the Central Laboratory for testing.

Figure 3.28: Demonstration of STRs system to Thachi sub-district municipality

3.8.3 Primary testing of STRs systems

For ensure the STRs system properly operated, the primary testing to check the material flow through the mixing-box should be undertaken by demonstrates the STRs technology to Thachi sub-district municipality (see Figure 3.28) for the primary checks of reactors, the mechanism of the bottom doors of reactor was checked with the recycled compost from previous study. The experiment was followed by the operational systems of serial self-turning composting process are described in Figure 3.29 and described step by step below;

Step 1: Material preparation and the net weight

Step 2: Input raw material into the bucket (20 litters), weight and deduct the self-weight bucket

Step 3: Transfer compost material by conveyer machine

Repeat from step 1 to step 3 until the last of material is inputted

Step 4: Lift up to the tower and mixing through bio-mybox

Step 5: Install the aeration pipe to supply the air for the cases under aeration condition

Step 6: Install the thermocouple to measure the temperature at 3 positions

Middle: The middle of the reactors

Bottom: 20 cm to the bottom of reactors

Wall: 20 cm to the bottom near dead wall zone

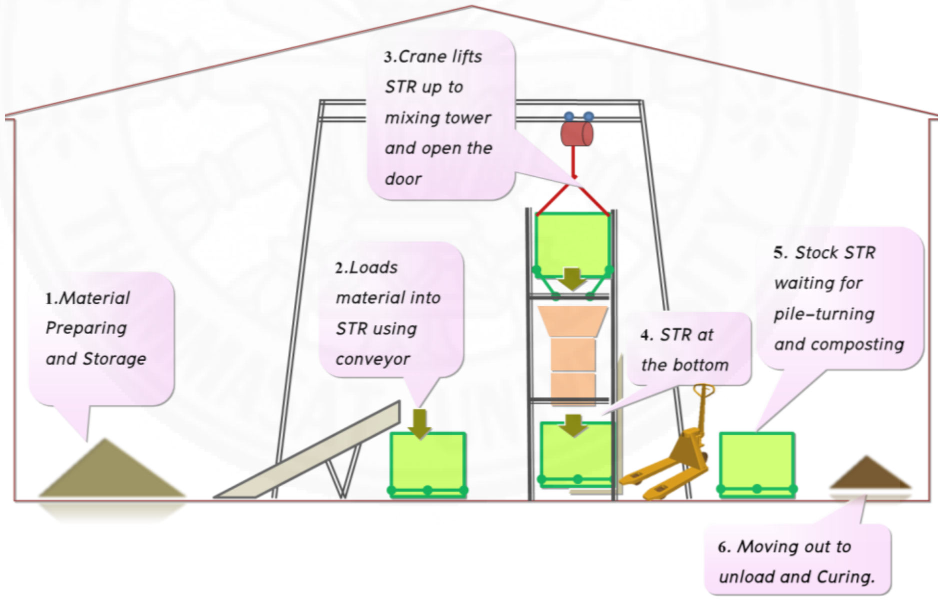


Figure 3.29 Plant operation of serial-self turning reactors

Chapter 4

Results and Discussions

4.1 Current situation of solid waste management in study area

4.1.1 Municipal solid waste management problems

Thachi sub-district municipality, lacks of the data of MSW quantity and composition. They did not have appropriate technology-based waste management, and have no specific basis of strategies on MSW management system. There are some problem of MSW management system; improper disposal, open dumping and open burning and high cost for waste disposal (450 baht/ton). Household source storage and separation of organic, inorganic, and hazardous wastes are neglected. Generally, all types of waste are mixed together as commingled solid wastes which are collected at the household bin.

Result from community observation of Municipal solid waste management problems in study area are shown as below:

4.1.1.1 Source separation at household is not commonly practiced; a collection of mixed waste leads to presence of salable recyclable waste in mixed waste stream. Hence, the collection system becomes inefficient.

4.1.1.2 People did not place waste bags at collection points, and this problem causes the difficulty in to collection of waste.

4.1.1.3 The problem on illegal solid waste disposals such as open dumping, open burning and unsanitary landfill can contaminated in the environment.

4.1.1.4 The problem on solid waste recycle that the local government did not have appropriate waste recycle project.

Figure 4.1 shows the appropriate waste management practices

As a result of this observation in MSW management problem, the local authorities can use this result as fundamental information to setting the policies and improve MSW management systems.

Figure 4.1 Illegal dumping and open burning

4.1.2 Waste generation rate

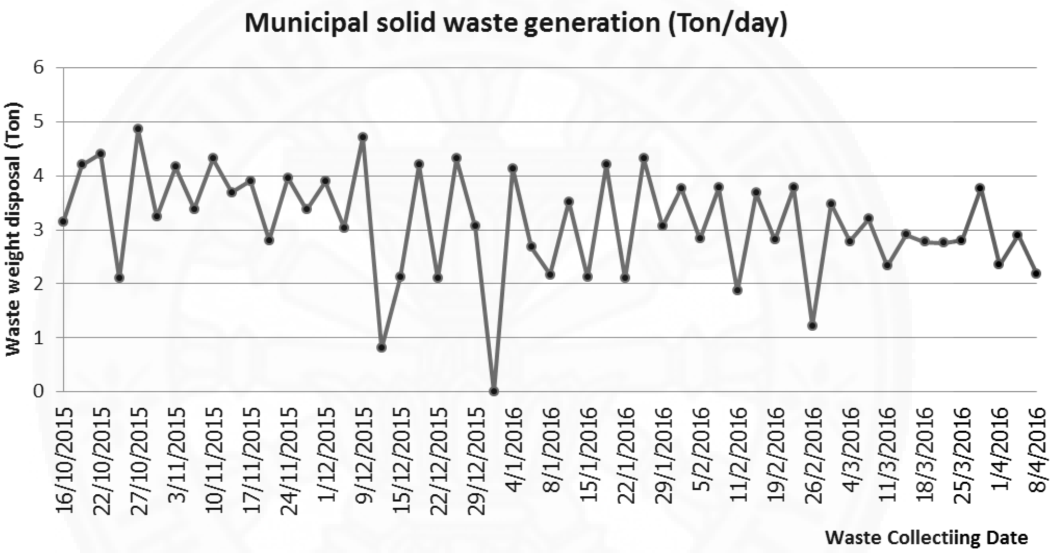


Figure 4.2 Municipal solid waste generation rate

The primary data of the waste generation rate was taken from the weight balance scale reading at the disposal site. The quantities of waste generated in Thachi sub-district municipality during October 2015 to April 2016 (7 months) were collected in this study. Figure 4.2 shows the waste generation rate. From the result, the average waste generation rate is 1.596 ton/day or 0.32 kg /capita/day. Average bulk density of MSW is 225.56 kg/m^3. The high densities of the waste are attributable to high moisture containing waste such as food leftovers and fruit peelings. From the previous study, bulk density data from Thailand and Indonesia, 300-500 kg/m^3 for some developing countries [58]

4.1.3 Municipal solid waste characterization

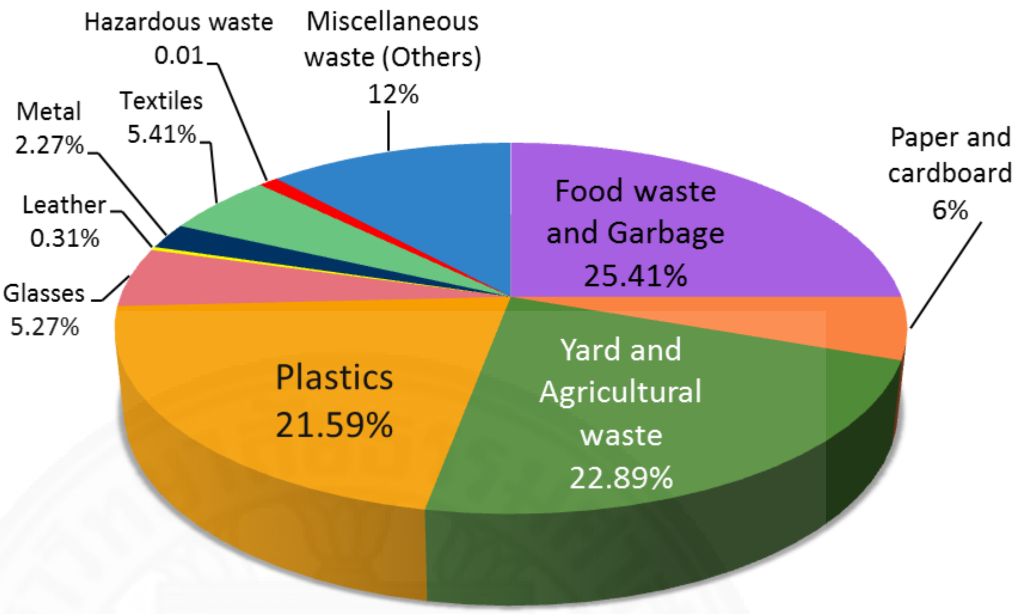


Figure 4.3 Municipal solid waste compositions

In this study, MSW characterization in rural community and agricultural sector was analyzed in term of material types. From the Figure 4.3 it was found that the average composition of MSW which was sampled monthly during Nov, 2015 to April, 2016 is as follow; a large number of biodegradable waste (53.78%) and 46.22% of non-degradable waste but this could be recycled. The municipal solid waste contains food waste garbage include vegetable market waste (25.41%), yard waste and agricultural waste (22.89%), plastic (21%), miscellaneous waste (12%), paper and cardboard (6%), textile (5.41%), glass (5.27%) and metal (2.27%) respectively.

Table 4.1: Result of chemical analysis of MSW

Parameter	***Average Result***
Moisture (%)	50.28
Total Solid (%)	59.76
Volatile Solid (%)	87.06
% Carbon	48.37
% Ash	12.94
Total Nitrogen	0.135

For proximate analysis of MSW compositions were shown in Table 4.1. The waste composition in Tachi mostly consist of organic wastes (vegetable/fruit waste and food leftover) with a high percentage of moisture content (50.28%) and hence this waste composition making it very suitable for composting.

4.1.4 Solid waste management practices

4.1.4.1 Waste reduction and separation

Municipal solid waste was collected by waste collection crews including one truck driver and three waste collectors who load manually MSW from recycle bin to the waste collecting truck. During waste collection, they separate the recyclable waste such as plastic bottle, glass bottle, can, metal and cardboard etc. Source separation at household is not commonly practiced in this community.

4.1.4.2 Waste collection

Municipal solid waste collection, transportation, and disposal system in Thachi sub-district municipality is the responsibility of sub-district municipality based on the municipal regulation which was promulgated to deal with the MSW management. Local authorities provide one waste collecting truck and 500 cylindrical plastic bins (200 liters) for household (see Figure 4.4), and waste discarded in the municipal bins is collected by the municipal waste collection crews.

Figure 4.4 Cylindrical bin and compact waste collecting truck

4.1.4.3 Waste transfer (See Figure 4.5)

Waste collection services in Thachi Sub-district Municipality, there are 6 villages. Waste was collected from door to door of household by rear loaded compact collection truck which collects waste with the different collecting routes; waste were collected on Monday and Tuesday for 1,3,4 village and collects waste on Thursday and Friday for 2, 5, 6 village. MSW collecting time, start from 09.00 a.m. to 12.00 p.m. and from 13.00 to 15.30 p.m., two trips per day. Collected MSWs were transported to neighboring disposal facilities.

Figure 4.5 Waste collection and transportation

4.1.4.4 Waste treatment and disposal

Waste was transported directly to a disposal site in the neighboring area, Wiangsa district. Transporting and unloading distance is 50.6 Kilometers. Under the contracting of LUCKY CLEAN ENERGY COMPANY LIMITED (see Figure 4.6), production and transmission of electricity from solid waste management and disposal of general waste by incineration technology will be executed in the future.

Figure 4.6 Waste disposal site (Wiangsa district, Bansong sub-district)

4.2 Community-based initiative

Thachi sub-district municipality has no appropriated technologies for with MSW management system. However, sub-district authorities and household have the willingness to solve the MSW management problem. The examples of community-based MSW management project by public participation are as follow;

4.2.1 Noticeboard has been placed on the illegally dumped site, for all 6 villages of sub-district municipality. It can make the people more realize with MSW management problems in case of the public spaces in the community are not proper dumped site (see Figure 4.7)

Figure 4.7 Noticeboard

4.2.2 Recycling project has been done with primary schools to set up recycling waste banks to create environmental awareness among the children toward their future and can help their hometown reduce waste generated. Lesson learnt from this project is that the primary school did not have enough manpower and time to deal with waste recycling project, the recycle waste bank has not been done yet because of less incentive in student and lack of long terms monitoring (see Figure 4.8).

Figure 4.8 Waste bank project in primary school

4.2.3 Community-based MSW management project joined forced with the local stakeholders as the social innovator, to encourage household waste separation and recycling. Based on community-based waste management, the participants separated waste at household in order to add the value to the recyclable waste by selling to informal sector at the central recyclable material stations in the municipal office (see Figure 4.9). From this project performed by the amount of recyclable wastes is about 360 kg consisting of glass and plastic materials and beverage cans. They organized training courses on MSW separation at source and household composting technology for Thachi sub-district municipality. This activities were performed by the people realize the potential of MSW management problem and value of the recyclable waste by sell to the recycled junk shop and use biodegradable waste as materials for composting. The efficiency of public participation with source separation practice has more effective at the beginning but not sustainable.

Figure 4.9 Community-based waste recycling projects

4.2.4 Training from neighborhood "Bannasan's Model" has been applied for the appropriate waste management project in their community. Training about the MSW management process which leads community realizes the potential of problem and value of some kind of waste that can be used for waste utilization, recyclable waste separated at the source for sell to waste recycling informal sector, use the biodegradable waste as a feedstock for composting. The community members noted that MSW management problem as an important issue to be emphasized.

As a result, many households stopped operating the waste recycling activity because no continuous monitoring. Some household kept separate waste and sale as recyclable waste to the junk shop. The households that concerned with the MSW management use the alternative waste bins for segregate recyclable waste before disposal which performed by the household that have been applied source-separated practice before the project started as their habit (see Figure 4.10). As well as partial community members do not cooperate with Thachi sub-district municipality because there is no good reason for doing so and no economic incentive from the waste recycling project (got a little money from selling recyclable waste).

Figure 4.10 Source separated practice at household

On the contrary, waste collectors have more potential for selling recyclable waste since they can segregate from mixed waste while collecting and bring to storage site nearby their office, if they not enough container to fill up the recyclable waste, they will contact the junk shop for sale their recyclable waste, however they did not have the an appropriate waste recovery practice for example they directly separated copper from electric wire without any protection equipment (See Figure 4.11 to. 4.12).

Figure 4.11 Recyclable waste separating practice of waste collectors for sale

Waste recycling practice by waste collector

Recyclable waste

Hazardous waste

Figure 4.12 Waste recycling practiced by waste collectors

4.3 Result from the data collecting of questionnaire survey of MSW

General information of participants

From the questionnaire interview, total 45 participants in waste recycling project as shown in table 4-2, the average MSW generation rate is 0.5 kg/capita/day. Half of participants well known about household waste separation and waste recycling. However, open burning and/or dumping of waste were practiced at their household dumpsite. Each household generated waste between 0.5 to 1 kg/capita/day. According to the household have to paid the MSW collection and disposal fee per mount to the municipality which only provides the recycle bin for the household requirement.

Table 4.2 Result from the questionnaire survey

General information of participants	Amount
Average household size	4 people
Average MSW generation	0.5 kg/capita/day
Participation who sort MSW at household	22 people
Open burning and/ dumping in their dumpsite	15 people
Composting and/or waste utilization practice	5 people

As a result of community-based waste management by public participation performed by waste recycling project

In terms of waste separation, about half of participant (48.89 %) had the recyclable waste separation for sell as the recyclable material to the informal junk shop. However, the percentage of participants who generally conduct source separation practice in their everyday life is around 22.22 %.

When asking the 10 interviewers about the MSW management system from the community and municipality stakeholders provide the 65 % realize that the MSW was the one of urgent environmental problem and agree with the MSW problems need to be manage properly, include community members should be response. Moreover, they suggest that MSW management should be the MSW problem and the government should allocate the budget to the local government.

Most of the 27 participants in this study (60%) have the willingness to manage their MSW in terms of waste recycling and source separating through the 3Rs strategies. Knowledge on using organic waste as a resource for waste utilization in communities is not commonly practice and community members have low awareness in campaign of organic waste utilization. Community members have willingness to use waste which gets the financial benefits from sell a recyclable waste to local informal sectors however, some peoples of participant mention that the MSW problem should be the responsible of municipal authorities.

4.4 Result of experimental study

Five small-scale experiments were conducted during 28 days, including two phases: 14 days for composting and 14 days for curing. During the composting process, composting mixtures were turned once on day 7 of composting periods to provide oxygen to the microbial activity. Experiments 1, 2 and 3 were performed to study the effects of food waste and vegetable scraps on co-composting while EFB, rice husk and leaf compost were used as a bulking agent performed in the different mixing ratio of F : V : EFB : A by supply the same aeration rate of 0.5 l/min/kg dry organic matter. On the contrary, experiment 4 was conducted to examine the effect of different mixing proportions of food waste mixed with vegetable scraps while EFB, agricultural waste and cow manure were used as a bulking agent, the proportion of mixing materials; F+V : CM : **A** (0.25:1.0:**0.25**, 0.25:1.0:**0.5**, and 0.25:1.0:**0.75**) at the same aeration rate of 0. 5 l/min/kg dry organic matter.

To determine the completion of composting maturity, the temperature inside the composting pile should be equal or near the ambient air temperature. The colour of finished compost should be dark brown to black with little or no impurity particle sizes present in the matured compost. Include lack of the attraction of insects and/or development of insect larvae in the final product and absence of displeasing odour.

Waste decomposition rate are affected by the composting factors that optimize the microbial growth which are; moisture content, pH, temperature profile, organic carbon and C/N ratio. Therefore, the physiochemical properties of final product can determined by the measurement of parameters were shorn in Table 4.3 and Table 4.4.

4.4.1 Final product properties of experiment 1 (Food waste: Vegetable waste: Oil palm EFB)

Incomplete composting condition occurred after 21 days of composting periods, resulting in particle size of oil palm EFB scraps quite big (bigger than 5 cm.) that made difficult to degrade. As for the proper material, particle size should between 1 to 5 centimeters. More appropriate volumes of mixing materials in the composting pile are obtained for sufficient cumulated temperature, can increase the degradation rate of composting include for pathogen destruction.

Figure 4.13 Final product of small-scale composting (Experiment 1)

4.4.2 Final product properties of experiment 2 (Food waste: Vegetable scraps : Oil palm EFB : Leaf compost)

Four experiment 2 carried by the different of bulking agent, composting was completed of 4 different mixing materials were obtained from the waste combination of food leftover, vegetable scraps oil palm EFB, and leaf composted. Three final products (reactor 1, 2 and 4) of composting were sent to physiochemical analysis.

Figure 4.14 Final product of small-scale composting (Experiment 2)

According to maturity of the composting process was determined by examining of physical, chemical and biological characterization of the final product. The temperatures profile of reactor 1 presented in the thermophilic phase within 5 days of composting period, showed rapid initiation of the composting process. Final product of composting in reactor 1 was completed, by using the waste combination of F : V : EFB : LC with the mixing ratio is 1 : 0 : 0.5 : 0.5 formed in brownish black and soil-liked. Maximum temperatures were achieved within 2 to 5 days of starting the ranged between 45-55°C, can reach the thermophilic stage, then temperature decreased in each case. (See Figure. 4.15)

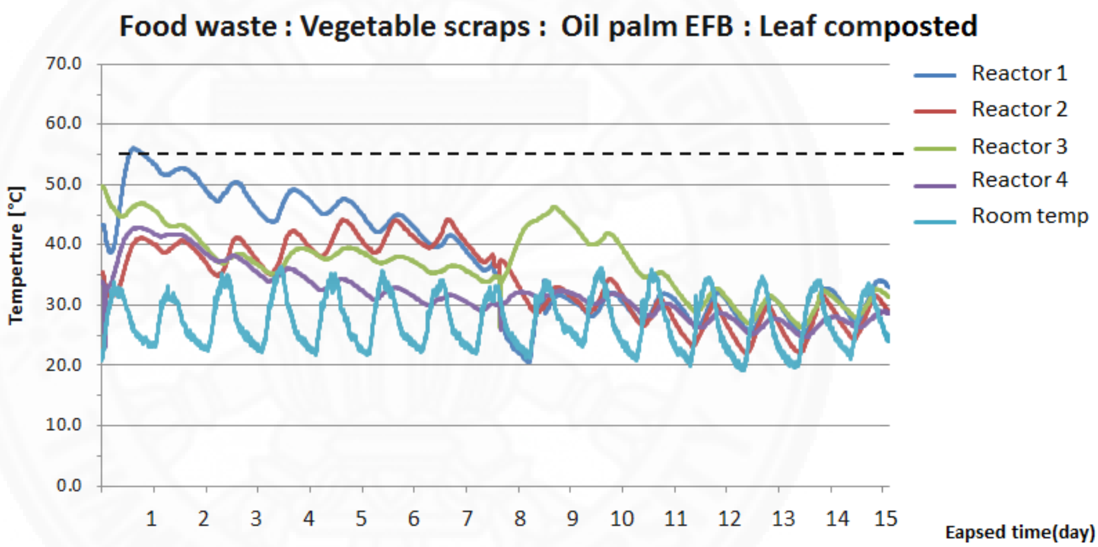


Figure 4.15 Temperature profile of small-scale composting (experiment 2)

However, the physiochemical parameters were only analyzed at the beginning and the end of composting periods as shown in table 4.3.

From the result of physiochemical properties obtained from the mixing material proportion with 1 : 0 : 0.5 : 0.5 of waste combination of food leftover mixed with vegetable waste which EFB and leaf compost was used as a carbon source and bulking agent (F : V : EFB : LC). Resulting in the finished composts of reactor 1 contained 1.71 and 1.92 % (N) nitrogen, 0.7% (P) phosphorus and 1.5% (K) potassium.

Table 4.3 Physiochemical properties of final product of the experiment 2 (Food leftover: **Vegetable scraps**: EFB: Leaf compost)

Mixing material proportion	Food leftover **:Vegetable scraps** : EFB : Leaf compost						DOA Standard
	1 : **0** : 0.5 : 0.5 *(Reactor 1)*		1 : **0.25** : 0.5 : 0.5 *(Reactor 2)*		1 : **0.75** : 0.5 : 0.5 *(Reactor 4)*		
Parameter	**Initial compost**	**Final product**	**Initial compost**	**Final product**	**Initial compost**	**Final product**	
pH	6.45	8.72	6.53	7.655	6.73	8.785	**5.5-8.5**
Electrical Conductivity dS/m	1.660	7.950	1.713	5.955	1.964	3.000	**≤ 10**
Moisture content (%)	58.12%	27.441%	58.40%	28.671%	58.77%	20.991%	**≤ 30**
Total organic carbon (%)	38.15%	13.8%	38.34%	12.5%	38.58%	18%	**N/A**
Total Nitrogen (%)	1.92	1.7777	1.91	1.6165	1.89	0.8797	**≥ 1**
C/N ratio	19.85	7.76284	20.06	7.73276	20.32	20.4615	**< 20:1**
Organic matter (%)	42.51%	23.8%	37.08%	21.6%	30.29%	31.1%	≥ 20
Total Phosphorus (%)	-	0.7	-	0.5	-	< 0.5	**≥ 0.5**
Potassium (%)	-	1.5	-	1.5	-	1.7	**≥ 0.5**

4.4.3 Final product properties of experiment 3 (Food waste: Vegetable scraps: Rice husk: Leaf compost)

Four experiment 3 carried by 4 different mixing materials were obtained from waste combinations of food leftover and vegetable scraps while rice husk and leaf composted were used as a bulking agent (F: V: RH: LC). Experiment 3 failed because the mixing ratios of composting mixtures were not reasonable in practice. The initial moisture content of compost mixed exceeded 65% that may effect to the microbial activity which respiration of microorganism were limited. Resulting in the maturity of composting was not completed because rice husk contains more lignin. In addition, rice husk consists of high in carbon content and have the limited porosity for air transfer in composting pile and is not suitable to compost with high moisture content material. According to the effective bulking agent for good composting condition, particle size should not smaller than 1 cm, limited porosity of composting pile that caused the anaerobic condition especially the food leftover which have more moisture content and less porosity can promote low oxygen transfer in mixing materials and released the toxic gases.

Figure 4.16 Final product of small-scale composting (Experiment 3)

4.4.4 Final product properties of experiment 4

(Food waste+Vegetable scraps: Cow manure: Agricultural waste)

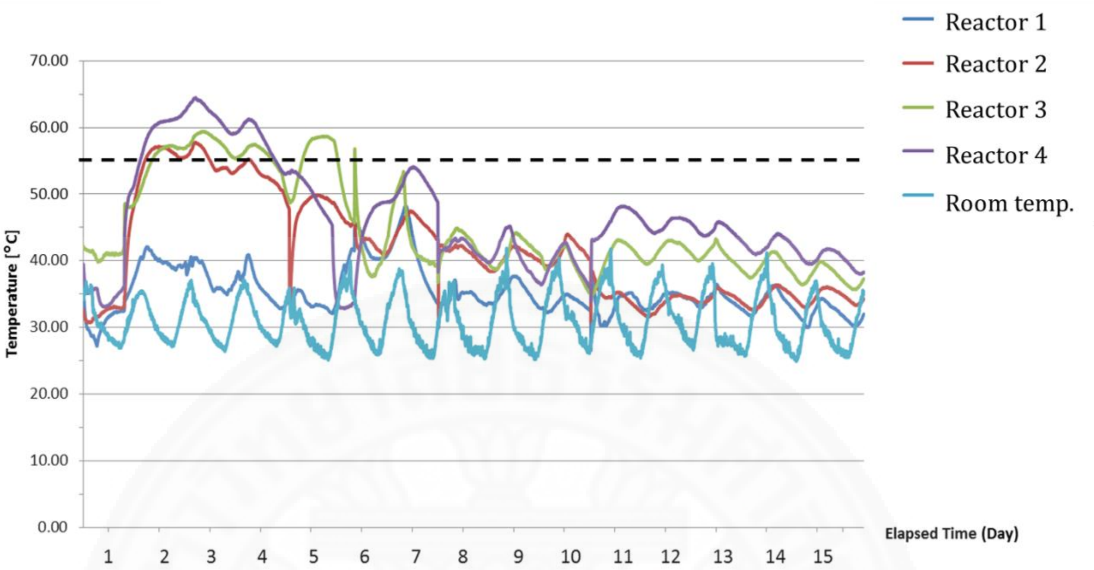


Figure 4.17 Temperature profile of small-scale composting (experiment 4)

Maximum temperatures were achieved within 2-5 days of starting the ranged between 50-65°C, can reach the thermophilic stage, then temperature decreased in each case. (See Fig. 4.17)

Figure 4.18 Final product of small-scale composting (Experiment 4)

Four cases of mixed different material, food +vegetable scraps: cow manure and yard waste + agricultural waste were used. The color of all compost mixing ratio was brownish black. (see Figure 4.18)

According to the standards for the conventional organic fertilizers determined by Department of Agricultural (DOA) of Thailand provided on Table 4.3 and 4.4, the final product should contain nitrogen not less than 1%, phosphorus not less than 0.5%, and potassium not less than 0.5% [46]. Three cases of well compost mixed from this experiment obtained from cow manure, kitchen waste (Food +vegetable) mixed with agricultural and yard waste, contained 1.2-1.9 % N, 0.9-1.6% P, 3.4-4.1% K. All parameters of final products in the three cases of compost mixed have clearly met the corresponding standards described on Table 4.4. Therefore, these final products can be used as soil nourishment and/or for plant nutrient source.

Table 4.4 Physiochemical properties of final product of the experiment 4 (Food + Veg scraps: Cow manure: Agricultural waste)

Mixing material proportion	Food + Vegetable scraps: Cow manure: **Agricultural waste**						DOA Standard
	0.25 : 1 : **0.25** *(Reactor 2)*		0.25 :1 : **0.5** *(Reactor 3)*		0.25 : 1 : **0.75** *(Reactor 4)*		
Parameter	**Initial compost**	**Final product**	**Initial compost**	**Final product**	**Initial compost**	**Final product**	
pH	6.905	7.56	6.880	7.58	5.850	8.183	**5.5-8.5**
Electrical Conductivity dS/m	1.660	2.463	1.713	3.073	1.964	3.160	**≤ 10**
Moisture content (%)	55.54%	27.20%	52.53%	27.61%	50.00%	25.92%	**≤ 30**
Total organic carbon (%)	33.22%	18.25%	29.89%	19.7%	27.40%	14.07%	**N/A**
Total Nitrogen (%)	1.77%	1.9%	1.62%	1.2%	1.51%	1.4%	**≥ 1**
C/N ratio	18.74	9.605	18.42	16.417	18.13	10.05	**< 20:1**
Organic matter	33.22%	31.46%	37.88%	33.96%	27.40%	24.26%	≥ 20
Total Phosphorus (%)	-	1.3	-	1.6	-	0.9	**≥ 0.5**
Potassium (%)	-	3.9	-	3.4	-	4.1	**≥ 0.5**

4.4.5 Final product properties of experiment 5

(**Organic commingled waste except food waste**: cow manure: EFB)

The composting was not completed according to the waste combination in this experiment compose of organic commingled waste collected from the MSW stream which not include food waste, cow manure was added for improve the nitrogen content, however the EFB which have more carbon content and high in C/N ratio but low moisture content. The potential for microbial degradation from use only cow manure produces inadequate nitrogen for composting.

4.5 Primary checks of reactors

The mechanism of the bottom doors of reactor was checked with the recycled compost material from the small scale experiment and mixed with vegetable waste. The result in the trial test showed that the door opened easily and most of the materials can pass through Bio-mybox without any clogging problem; less than 5% of mass lost after passing. The mixing tower and a crane system were easy to lift 1 tons reactor up.

Figure 4.19 Primary checks of reactor and STR equipment

4.6 Final product properties of large scale composting

According to the large scale, the composting process had been completed, physical, chemical and biological properties of the final product were determined. Final compost of large scale experiment formed in the brownish black and soil-like (see figure 4.20)

Figure 4.20 Final product of large scale composting

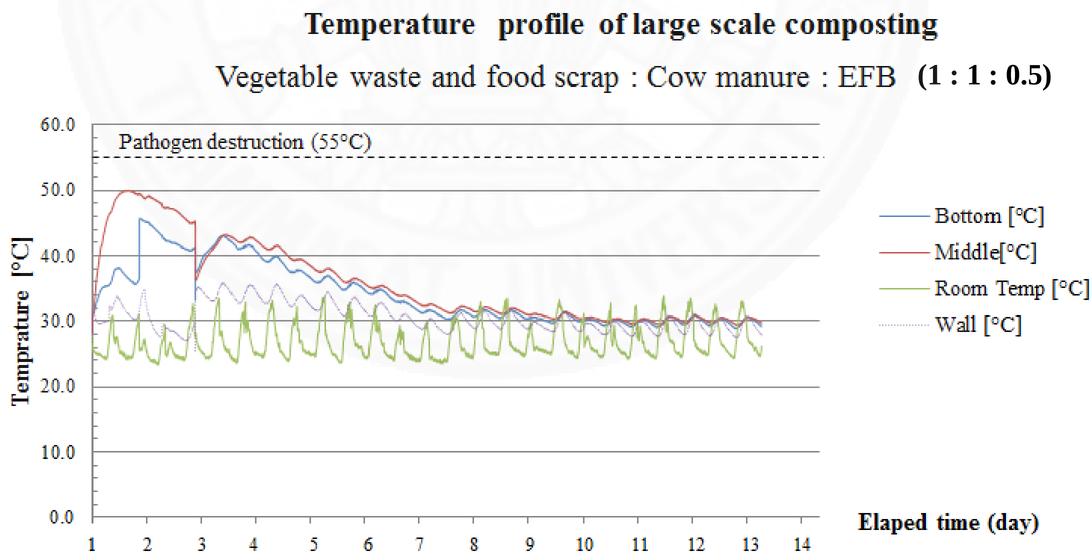


Figure 4.21 Temperature profiles of large scale composting

Maximum temperatures of composting were achieved within 2 to 5 days, can reach the thermophilic phases ranged from 45 to 50°C performed by the temperature measured at the middle of the reactor.

However, the temperature did not meet the requirement of pathogen destruction level, specific required that the composting process attains a temperature of 55°C [59]. Then the temperature decreases slowly during the first 7 days of composting. (See Figure. 4.21)

Table 4.5 Final product properties

Parameter	Initial compost	Final product	DOA Standard
Aeration rate 0.5 lit/minute			
F+V : CM : EFB	1: 1: 0.5	1: 1 : 0.5	-
pH	6.12	8.18	5.5-8.5
Electrical Conductivity dS/m	2.37	2.109	≤ 10
Moisture content (%)	57.72	43.76	≤ 30
Total organic carbon (%)	45.43	23.45	N/A
Total Nitrogen (%)	-	**< 0.5**	**≥ 1**
Total Phosphorus (%)	-	**< 0.5**	**≥ 0.5**
Potassium (%)	-	0.58	≥ 0.5
C/N ratio	18.46	16.6 : 1	< 20:1

F+V = Food and vegetable scraps , CM = Cow manure

EFB = Oil palm empty fruit bunch, DOA = Department of Agriculture, Thailand

After maturity of the composting process had been completed, the final products of composting were analyzed by examining of physical, chemical and biological properties. Primary result of final products from large scale composting have clearly met the corresponding standards for the conventional organic fertilizers determined by Department of Agriculture (DOA) of Thailand provided on table 4.5, the final product should have pH in range 5.5 to 8.5, EC less than 10 dS/m, and moisture content not less than 30% [46].

Chapter 5
Conclusion and Recommendation

5.1 Conclusion

Composting of municipal organic waste are feasible in this study, thus the final products of small scale composting can approach the standard properties of organic fertilizer determined by Land Development Department (LDD) of Thailand. Composting technology can be used as a proper management for utilized the organic waste generated in the community. However, the successful of MSW management project will not possible, if the lack of community cooperation and participation. Waste recycling campaign followed by community-based waste management projects can reduce waste generation rate at the beginning of recycling project was provided, but the lack of long term activities, some household had been stopped separating recyclable waste to sell for junk shop, because economic incentives are not significant. The leadership and community members of Thachi sub-district municipality should encourage public cooperation in the separation of recyclables waste by promoting source separation and use organic waste for composting facilities that specified in community policy to strengthening and promoting the environmental conservation for sustainable MSW management. There are many factors having a potential to community participation in solid waste management. Especially, they have low concerning in waste separation at source, low willingness to participate in source separation practices, waste collection, composting or recycling projects.

The principal components on a weight basis are compostable organics (garden and food waste; 48.3 %), paper and cardboard (6%) and plastic (21.59%). On a volume basis, the principal components are compostable organics (36.2%), plastic (22.6%) and paper and cardboard (19.2%). This is primary results from the first ever practical survey of the waste composition from the MSW stream carried out in the Thachi sub-district municipality. In conclusion, MSW in Thachi has an average recyclable and compostable content of 77.43 %, which recyclable waste include food and vegetable waste, yard and agricultural waste , plastic, paper and cardboard, metal and glass. This provides a significant potential to use the waste utilization. Food waste and vegetable waste already feed as animal in some village in this community.

Three types of differentiated waste combination in accordance with utilization options; food leftover and vegetable waste used in a material for composting, agricultural waste consists of yard waste and palm plantation residues used for bulking agents in the composting process, and salable recyclable waste for reuse and recycling. The composting plant was modified from rubber processing plant, mixing tower and machines were setting up and operate. Alternative technologies include STR composting facility was implement and waste recyclable project activities that would reduce landfill waste and possibly collection and transportation costs.

As a result of small-scale experiments 1,3 and 5 provide the composting was not completed and the compost mixed cannot use as a soil conditioner because the co-composting material are not suitable for composting and . On the other hand, the final product properties in reactor 1 of experiment 2 can meet the conventional standard of organic fertilizer. Performed by waste combinations are food waste mixed with vegetable scraps, oil palm EFB and leaf compost were used as a bulking agent with the mixing proportion is 1 : 0 : 0.25 : 0.25 with the waste combination is F:V:EFB:A, also the temperature profile performed by reactor 1 can reach the thermophilic phase at 55 °C which can kill the pathogen. Thus, these final composted can be used as a soil conditioners.

From the best mixing proportion of co-composting materials (F+V : CM : A) used in experiment 4 which the, food leftover mixed with vegetable scraps were used as a source of microorganism, cow manure are used as a nitrogen source, and agricultural waste includes oil palm empty fruit bunch and yard waste was feasible to use as a materials for composting by the waste proportion is 0.25 : 1: 0.5 obtained from reactor 2. The completion of the composting was determined by examined the physical properties of final product e.g. temperature of composting pile was equal to the ambient temperature, the composted material turn to soil-liked and perform brownish black. Then, physiochemical and final product was sent to the Central Laboratory of Thailand can fulfill the criteria of conventional fertilizer defined by Land Development Department of Thailand, the finish composted should contain percent of nitrogen not less than 1, phosphorus not less than 1% and potassium not less than 0.5% was obtained from the cow manure combined with food and vegetable scraps mix with agricultural waste composting provide the finished composts contained 1.9% (N) nitrogen, 1.3% (P) phosphorus and 3.9% (K) potassium.

However, for the large scale experiment should follow the best mixing material and proportion in the small-scale experiment obtained from reactor 2 of the experiment 4, performed by F+V: CM: A, but proportion of the large scale was adjusted by add EFB to balance the C/N ratio and also the amount of food and vegetable scraps is not enough to use in the full scale composting. Thus, the waste combination is F+V: CM: EFB with the proportion is 1 : 1 : 0.5. Resulting in the final product properties of composting cannot meet the corresponding standard of trade nutrients values identified by N:P:K values for guarantee that this final product are the good fertilizer and have the potentials to nourish the soil and plant. As a result of the physiochemical properties of large scale composting contained the nutrient value lower than the criteria can be estimated that the compost condition was not appropriate because the oil palm EFB have low moisture content and high in carbon content can promote the dry condition which not suitable for microorganism activities, the caw manure used as a source of nitrogen are inadequate for composting which providing the low N% includes the volume of raw material that is not enough to supply to composting facility. But changing in during composting period cannot reach the temperature of the composting pile at 55^{o}C which can destroy pathogens Therefore, the final product of composting cannot use as a soil conditioner because it is not safe to use for the plant and agricultural parts.

Eventually, when the composting plant was operating fully, they had soil nourishment for supply to the agricultural sectors which they used to grow in community and sell some as organic fertilizer to the vicinity. The community will have well-nourished and recognizes the waste was a valuable resource for community. The experiences show that community initiative on solid waste management work better when they are embedded in economic activities in which people realizes waste as a resource for waste recycling and composting.

5.2 Recommendations

For strengthening up public responsibility of community-based municipal solid waste management for improving the MSW management system, local government, communities and private sector should

5.2.1 Provide refused bins for organic waste to the household

5.2.2 Reduce the amount of MSW generation rate by using leftover food through use as a feedstock for composting facility. Include agricultural waste such as fruit peel, dried leave and oil palm residue

5.2.3 Provide site central refuse collection point within communities

5.2.4 Provide resource (material) and technology for waste collection and segregation such as the collection facility for recyclable waste and organic waste

5.2.5 Support fund for MSW management campaigns

5.2.6 Provide a resource for environmental and public health education including the technicians for inspects the communities to carry out their MSW

5.2.7 Promote local market and groceries and agricultural sector in community separate biodegradable waste such as food waste, fruit peel, and agricultural waste

5.2.8 Give information and education to households and communities by involved in clean-up campaigns

5.2.9 Household could be proactive in the MSW management project through segregate waste at source.

5.2.10 Provide continuous mitigation and monitoring on the projects

Accordingly, the information from this study will benefit to related organizations. They will use as fundamental information for setting policies and plan on the solid waste management system.

For improve the source separation system more finely from household waste, the greater its contribution to recycling. Local authorities should prepare specific waste container in different types of materials as following examples;

Container 1 which receives organic or putrescible waste includes food leftover and postconsumer waste excluding toxic substances, glass, and plastic materials. The materials from this container can be taken to a composting plant that also used as a material for composting mixed with bulking agents collected from agricultural parts such as yard waste, oil palm empty fruit bunch or fruit and vegetable waste for produces soil nourishment.

Container 2 would receive all types of recyclable paper include clean paper, newspapers, cardboard, and cartons which separated from a central recyclable waste collection point in the community and sold to a junk shop.

Container 3 receives all of glass materials include glass bottles and aluminum and metals

Container 4 would prepare for all of the recyclable plastics materials

Later on for a fifth container could be added other waste which receives ceramic, textile, and rubber. This container considered as non-recyclable can be sent to landfill facility or for further separation.

5.3 Limitation

According to in the study on waste characterization which samples were drawn from compacted trucks might not be accurately sorted in the field because wastes were mixed and compressed together in the truck. Wet wastes like drinks and food waste got absorbed into paper, plastic and film. For this problem, further sorting, drying and reweighing were recommended.

Even the community-based MSW management project was not expected to be easy to follow up, needs more collaborate from many sectors including community, local authorities and private sector especially household, local shop, restaurants and agricultural sector. Including the amount of organic waste materials; food and vegetable scraps is not enough for use to supply to the large-scale composting. In addition, difficult to maintain the composting condition because organic waste material quantity and quality is not stable.

Reference

1. PCD, *Thailand State of Pollution Report 2013*, in *State of Waste and Hazardous Substance*. 2014. p. 2-1 to 2-9.
2. PCD. *Thai Environmental Regulations*. 2015 [cited 2015 December, 8]; Available from: www.pcd.go.th/info_serv/en_reg_polwaste.html.
3. Sang-Arun, J.a.B., M. , *Improved organic waste management : Climate benefits through the 1St in developing Asian countries.* IGES-WMR Working Paper 2009-001, 2009. **1**: p. 52.
4. Regional Environmental Office 14, *Waste and hazardous waste management Planning, Surat thani province (4 year,2015-2020)*. December, 2014.
5. AIT, *Municipal Solid Waste Management in Asia*. Asian Regional Research Program on Environmental Technology (ARRPET). 2004, Pathum Thani, Thailand: Asian Institute of Technology.
6. Ngoc, U.N. and H. Schnitzer, *Sustainable solutions for solid waste management in Southeast Asian countries.* Waste Management, 2009. **29**(6): p. 1982-1995.
7. Wolkowski, R.P., *Nitrogen management considerations for landspreading municipal solid waste compost.* Journal of Environmental Quality, 2003. **32**(5): p. 1844-1850.
8. Sungsomboon, P.Y., et al., *Pilot-scale tests of an innovative 'serial self-turning reactor' composting technology in Thailand.* Waste Manag Res, 2013. **31**(2): p. 212-22.
9. EPA, *Wastes - Non-Hazardous Waste - Municipal Solid Waste* in *Municipal Solid Waste*. 2016, U.S. Environmental Protection Agency.
10. Janya Sang-Arun, N.M., Agamuthu, P, *Co-benefits of the 3Rs (reduce, reuse and recycle) of municipal solid waste on climate change mitigation*, in *Factsheets Series on 3R Policy Indicators*, M.o. environment, Editor. 2014, Institute for Global Environmental Strategies. p. 19-24.
11. EPA, U.S.E.P.A.U.S., *MSW CHARACTERIZATION METHODOLOGY*. 2015.
12. EPA., U.S., *"Characterization of municipal solid waste in the United States : 1998 update"* 1999, U.S. Environmental Protection Agency Office of Solid Waste: Washington, D.C.
13. V Gawaikar, D.V.P.D., *Source Specific Quantification and Characterization of Municipal Solid Waste -- a Review.* IE(I) Journal-EN, 2006. **86**: p. 33-38.
14. Pichtel, J., *Waste Management Practices*. Second ed. Municipal, Hazardous, and Industrial. 2014: CRC Press,Taylor & Francis Group.
15. Shekdar, A.V., *Sustainable solid waste management: An integrated approach for Asian countries.* Waste Management, 2009. **29**(4): p. 1438-1448.
16. PCD, *Final Report of Surveying and Analysis of Municipal Solid Waste Composition Across the Country Project*. 2004, Pollution Control Department: Thailand.
17. Bolaane, B. and M. Ali, *Sampling household waste at source: lessons learnt in Gaborone.* Waste Management & Research, 2004. **22**(3): p. 142-148.
18. J. H. Martin, A.R.C.a.R.G.D., *A sampling protocol for composting, recycling, and re-use of municipal solid waste.* Air & Waste Management Association, 1995. **45**: p. 864-870.

19. R.Chandrappa, D.B.D., *Solid Waste Management Principal and Practice*. 2012, Environmental Science and Engineering.
20. Chiemchaisri, C., J.P. Juanga, and C. Visvanathan, *Municipal solid waste management in Thailand and disposal emission inventory.* Environmental Monitoring and Assessment, 2007. **135**(1): p. 13-20.
21. Kaosol, T., *Sustainable solutions for municipal solid waste management in Thailand.* World academy of science, engineering and technology, 2009.
22. PCD, *"Thailand State of Solid Waste" Reports in year 2013*. 2014, Pollution Control Department,Thailand: Thailand.
23. Vanapruk, P., *Improvement of Municipal Solid Waste Management Policy in Thailand*, in *Environmental Management*. 2012, Prince of Song University: Song, Thailand. p. 257.
24. PCD, *Measures and solutions to manage solid waste and hazardous waste*. 2014, Pollution Control Department (PCD): Thailand.
25. PCD, *Roadmap of MSW and hazardous wastes management*. 2014.
26. PCD, *Guidelines and technical documents related to solid waste management and hazardous waste*. 2014, Pollution Control Department: Thailand.
27. PCD, *"The Enhancement and Conservation of National Environmental Quality Act, B.E. 2535"*, M.o.N.R.a. Environment, Editor. 1992, Pollution Control Department, Thailand: Bangkok, Thailand.
28. Office, T.P.M.s., *Executive Summary One-Year Performance Reportof the Government of General Prayut Chan-o-cha (12 September 2014 - 12 September 2015)* 2015, The Prime Minister's Office: Thailand.
29. Thomas- Hope , E., *Solid Waste Management* 1998, West Indies: Canoe Press University of the West Indies.
30. Tchobanoglous, G., H. Theissen, and S. Vigil, *Integrated solid waste management*. 1993, New York: McGraw-Hill.
31. Amin, A.T.M.N. *Changes in Waste Recycling and Composting Practice Associated with the Stages of Economic Development* in *International Conference on Integrated Solid Waste Management in Southeast Asia Cities*. 2005. Siem Reap, Cambodia: Asian Instituted of Technology.
32. Ramasamy, A.a., *Biotechnological methods of pollution control*. 1999, Hyderabad, India: Orient Longman (Univesities Press India Ltd.).
33. Ahmad, R., Jilani, G., Arshad, M., Zahir, Z. A., & Khalid, A. , *Bio-conversion of organic wastes for their recycling in agriculture: An overview of perspectives and prospects.* Annals of Microbiology, 2007. **57**(4): p. 471-479.
34. Tang, J.-C., Shibata, A., Zhou, Q., & Katayama, A. , *Effect of temperature on reaction rate and microbial community in composting of cattle manure with rice straw. Journal of Bioscience and Bioengineering*, 2007. **104**(4): p. 321-328.
35. Purnomo, A.S., Koyama, F., Mori, T., & Kondo, R., *DDT degradation potential of cattle manure compost.* Chemosphere, 2010. **80**(6): p. 619-624.
36. Diaz, L.F., Savage, G.M., Eggerth, L.L. and Golueke, C. G. , *Composting and Recycling Municipal Solid Waste*. 1993, Tokyo: Lewis publishers.
37. UNEP, *Biogas Fertilizer System*, in *Technical Report on a Training Seminar in China*. 1981, United Nations Environmental Program (UNEP) Nairobi, Kenya.

38. B. Hellmann, L.Z., A. Palojarvi, and Q Bai, *Emission of climate-relevant trace gases and succession of microbial communities during open-windrow composting.* Applied and Environmental Microbiology, 1997. **63**: p. 1011-1018.
39. Singh, R.P., et al., *Composting of waste from palm oil mill: a sustainable waste management practice.* Reviews in Environmental Science and Bio/Technology, 2010. **9**(4): p. 331-344.
40. Yusoff, S., *Renewable energy from palm oil – innovation on effective utilization of waste.* Journal of Cleaner Production, 2006. **14**(1): p. 87-93.
41. Ma AN, C.S., Chow MC . , *Current status of palm oil processing waste management*, in *Waste management in Malaysia: current status and prospects for bioremediation*, Y.B.e. al, Editor. 1993, B.G. p. 111–136.
42. Yusri A, M.R.A., Mohammed O, Azizah H, Kume T, Hashimoto S, *Biodegradation of oil palm empty fruit bunch into compost by composite microorganisms.* EU-ASEAN conference on combustion of solids and treated product, 1995.
43. MA, D., *Hands-on experience in the production of empty fruit bunches (EFB) compost*, in *CETDEM malaysian organic farming seminar*. 1998. p. 50–61.
44. Haug, R.T., *The Practical Handbook of Compost Engineering*. 1993: Lewis Publishers.
45. Standards, M.o.A.a.C.N.B.o.A.C.a.F., *THAI AGRICULTURAL STANDARD TAS 9000-2003* in *ORGANIC AGRICULTURE*. 2003, Ministry of Agriculture and Cooperatives Thailand.
46. DOAE, *Biofertilizer Standard*. 2009, Department of Agriculture Extension: Thailand.
47. Shapkota, P., Coowanitwong, N., Visvanathan, C., Traenkler, J., *Potenitals of Recycling MSW in Asia vis-a-vis Recycling in Thailand*. 2006.
48. Singhirunnusorn, W., Donlakorn, K., Kaewhanin, W., *Contextual factors influencing household recycling behaviours*. a case of waste bank project in Mahasarakham municipality. 2011, Bandung 36: AcE-Bs.
49. Suttibak, S. and V. Nitivattananon, *Assessment of factors influencing the performance of solid waste recycling programs.* Resources, Conservation and Recycling, 2008. **53**(1–2): p. 45-56.
50. GOERGE TCHOBANOGLOUS, F.K., *Handbook of Solid Waste Management*, ed. second. 2002: McGraw-Hill
51. DOPA, D.o.P.A., *Statistic Information Services: Population rate* 2015.
52. Maps, G. 2016.
53. (ASTM), A.S.f.T.M., *ASTM D5231-92 (2003)*, in *Standard Test Method for Determination of the Composition of Unprocessed Municipal Solid Waste*. 2008, American Society for Testing Material: United States.
54. ASTM, *Standard test method for determination of the composition of unprocessed municipal solid waste*, in *ASTM standard D5231-5292* 1998, American Society for Testing and Materials: U.S. .
55. Barrena, R., et al., *Co-composting of hair waste from the tanning industry with de-inking and municipal wastewater sludges.* Biodegradation, 2007. **18**(3): p. 257-68.

56. Standard, E., *Determination of Kjeldahl Nitrogen in soil, biowaste and sewage sludge*. 2005. p. 10.
57. USDA, U.S.D.o.A., *Environmental Engineering National Engineering Handbook. Part 637,* in *Chapter 2 composting Design of compost mixed*. 2000. p. 2-11.
58. Egypt, A.R.o., *National Environmental Action Plan*. 1992, Arab Republic of Egypt: Cairo, Egypt.
59. R.Chandrappa, *Solid Waste Management Principal and Practice*. 2012: Environmental Science and Engineering.

Appendix 1

Questionnaire survey of municipal solid waste in community

Questionnaire **Municipal solid waste management in community**	Date _________ No _________

1. General information of household

1.1 Address………… Moo……………..Soi…………Road…………..

Sub-district………………. District……………… Province……………

1.2 Family members ………………..persons

2. MSW management practice

2.1 MSW generation rate …………………..kg/capita/day

2.2 Do you separate waste before dispose?

☐ Yes ☐ No

2.3 What type of waste that you separated? How did you do after separation?

☐ Organic waste (food leftover, vegetable waste, agricultural waste)

…………………..…………………..…………………..…………………..……

☐ Recyclable waste (paper, plastic, glass, metal)

…………………..…………………..…………………..…………………..……

☐ Hazardous waste (battery, electronic device, chemical container)

…………………..…………………..…………………..…………………..……

☐ General waste and/or others (miscellaneous waste)

…………………..…………………..…………………..…………………..……

2.4 What is the waste utilization method or MSW management practice?

☐ Open dumping ☐ open burning ☐ landfill facility

☐ 3Rs (reduce, reuse and recycle) ☐ others (Specific)……………………..

3. Knowledge on waste utilization technology

3.1 Do you know waste utilization?

☐ Yes ☐ No

3.2 What is the waste utilization; please select your familiar technology and/or which technology was undertaken in your community

☐ Composting

☐ Landfill

☐ RDF (Refused derived fuel)

☐ Incineration

☐ Waste to energy (Produce electricity from waste)

3.3 Do you agree with the waste utilization as organic waste composting

☐ Agree ☐ Disagree

3.4 Have you willingness to use organic waste fertilizer with your agricultural sector? And do you interest in waste utilization by organic waste composting?

☐ Use (interest)

☐ Use (not interest)

☐ Non-user (interest)

☐ Non-user (not interest)

Suggestion and Comment

……………………..……………………..……………………..……………………..……

……………………..……………………..……………………..……………………..……

……………………..……………………..……………………..……………………..……

……………………..……………………..……………………..……………………..……

……………………..……………………..……………………..……………………..……