Integrated solid waste management system leading to zero waste for sustainable resource utilization in rapid urbanized areas in developing countries

Authors

Dr. Alice Sharp
Sirindhorn International Institute of Technology, Thailand
Dr. Sandhya Babel
Sirindhorn International Institute of Technology, Thailand
Dr. Nguyen Thi Phuong Loan
Center for Environmental Technology and Management, Vietnam
Mr. Tshering Gyeltshen
Mongar Dzongkhag, Bhutan

Supporting Organization

Asia Pacific Network for Global Change Research (APN)

Table of Content

Chapter **Page**

Chapter **Page**

List of Table

List of Figure

CHAPTER 1: INTRODUCTION

1.1. Background of the Report

Problems related with inefficient management of solid waste have been considered as one of the most urgent socio-economic and environmental concerns for governments at all levels. With the rapid growth of population, urbanization, as well as life style changes, anthropogenic impact is the main reason that degrades livelihoods of the ecosystem and all associated creatures. Despite the fact that solid waste is the globally major issue that needs development, developing countries, particularly communities, have encountered many a problem related to insufficient capacity and knowledge to prevent waste generation, properly manage waste, and handle with impacts of waste.

Accordingly, to have effective solid waste management (SWM) system, it is necessary to provide management and governance strategies to engage all stakeholders for collaborating and enhancing the overall sustainable development of societies. Currently, there are many SWM initiatives involving with an array of technologies that have been established for monitoring and mitigating SWM performance. Regardless of the setting, any initiative cannot fit with the circumstances of all communities or cities; however, SWM processes will vary according to the context of waste and resources of each community.

Resource utilization is one of the most effective and ecological ways to manage the waste and extract the best use of it. Instead of discarded all of waste into landfills, a large amount of organic and recyclable waste is considered a valuable source of alternative energy, raw materials, and byproducts. As such, it is essential to manage waste with appropriate technologies for greater management outcomes and more rigorous in monitoring and evaluating SWM system.

Among SWM initiatives, an integrated solid waste management (ISWM) approach is important for sustainable development and appropriate resource utilization. In developing countries, landfill (including sanitary and unsanitary methods) is the most preferable SWM option to manage collected waste in its final process. As a result, the societies are posed to adverse impacts caused by improperly landfilled waste. Thus, to prevent and lessen threats from such impacts, it is important that the governments or responsible authorities understand the overall situation of SWM system, context of waste, related stakeholders, capacity of community, and importance of collaboration for having sustainable SWM in long-term.

The main objective of this report is to identify suitable ISWM system with the potential to contribute to sustainable development and climate change mitigation. In order to identify suitable ISWM system for Mongar, Bhutan and Ho Chi Minh City (HCMC), Vietnam it is important to understand the existing SWM system through baseline data collection, so the gaps of the current SWM practices can be pinpointed. During the project, related stakeholders are engaged for successful implementation of waste management practices towards sustainable development.

Thailand has some small, medium and large scale examples of best SWM practices. The lessons learnt from these good practices were shared with the collaborators through the field visits so that appropriate system can be adopted by the partner countries based on the local situation. This will also help in preparing the guidelines for integrated solid waste management based on the nature of waste and learning from the showcase examples in Thailand. Capacity building of local authorities was promoted through the project's activities.

1.2. Study Sites

Solid waste mismanagement caused from lacks of skills, knowledge, financial resources, or collaboration among stakeholders, can bring irreversible damage to all livings and the environment. Governments, institutions, and advisory bodies have given priority to the problems and have aimed to promote effective and appropriate technologies to be used in the solid waste management system.

In this report, Mongar, Bhutan and HCMC, Vietnam are the two selected cities which have been facing numerous problems in SWM. Mongar, although small as compared to HCMC is growing rapidly. On the other hand, HCMC is a megacity urbanizing rapidly with an increasing amount of solid waste.

Mongar is one of the 20 districts in Bhutan where landfill is currently the preferred solution for waste disposal by local municipal authorities. Presently, about 50 tons of waste is delivered per day to the landfill, which is beyond the capacity of the existing landfill. The segregation at source is very minimal. Financial constraints, manpower and equipment deficiencies can be noticed. Municipalities are unable to deliver services effectively due to illegal dumping on roads and water bodies. Recycling activities are mostly carried out by private company.

HCMC is a center of economic, cultural, education and training in Vietnam. In 2016 the population of HCMC was 8.3 million people (HCM Statistical Office, 2016). According to Department of Natural Resource and Environment (DONRE) of HCMC, the amount of municipal solid waste (MSW) generated was 8,300 tonnes/day in 2016, in which 68.6% of amount of solid waste is buried at sanitary landfill, 24.6% goes for composting, 5.7% is incinerated, and only 1.1 % is recycled. At present, solid waste management does not meet current needs due to lack of finance, infrastructure, human resource, and public awareness as well as policies and legal system are insufficient or overlapping.

1.3 Objectives of the Study

The overall objective of the project is to increase the capacity of local stakeholders in order to improve the existing SWM system for sustainable development. The two sites selected were Mongar (small scale) and HCMC (large scale).

- To compile baseline data for technical, institutional, and financial situation in solid waste management of selected cities.
- Identify appropriate integrated solid waste management system for various waste streams to help local authority.
- Build scientific capacity of local authorities in terms of integrated solid waste management via national workshops and guidelines.
- Develop collaborative network in solid waste management in the region.

CHAPTER 2: WASTE MANAGEMENT AND UTILIZATION TECHNIQUES

2.1. Introduction

Asia consists of over 40 countries and hosts 60% of the world's population [1]. With the technological and economic development, together with the increasing number of population, Asia has encountered a wide range of problems that affect the quality of people's lives and the society. One of the most important concerns that grasped attention from both public and private sectors is waste management [2]. Since the world has turned its development regime by emphasizing more on wellness of the environment, governments have focus on finding solutions for sustainable waste management; however, giving higher priority to waste does not guarantee higher performance of waste management system.

Asia generates over 760,000 tons of waste a day [2]. In terms of management, solid waste streams should be characterized by their sources, types, generation rates, and composition. Generally, organic and compostable waste takes a major proportion in solid waste composition at 40% - 85%, whereas the remaining is recyclable and non-recyclable materials [2, 3]. Government authorities and private sector have successfully adopted and implemented a number of management methods in developed countries to deal with increasing amount of waste.

Major constraints that Asian countries encounter include financial, institutional, technology and market which may be due to lack of resources or knowledge. Therefore, this chapter encapsulates waste management approach and techniques that can possibly be adopted for solid waste management in developing Asian countries.

2.2 Waste Management Process

There are complex and interrelated components in waste management operations ranging from sources of generation to the point where waste is treated. It is vital to understand the various factors required for each operation. This section consists of the first three waste management processes namely waste disposal, waste collection, and waste transportation.

2.2.1 Household disposal

Solid waste is disposed of differently among countries in Asia. Either sorted or unsorted, waste is generally put into a container and left in front of the house for collection. Putting waste in public waste bins is also widely used in urban areas or public places. To increase the possibility of more effective management and to make the system sustainable, a number of motivating activities and strategies should be applied. Basic waste management infrastructure and tools should be sufficient and available in all areas. Generally, suitable waste containers should be provided in every household level (Figure2.1*a*). At community level, larger containers and different types should be available according to the separation of the waste the community is asked to separate (Figure2.1*b and c*). Above all, knowledge on waste separation and disposal should be provided.

(a) (b) (c)

Figure 2.1 Local container deposit system in Thailand; Trang province (a), Community waste container in Nonthaburi province, Thailand (b, c)

In terms of activities or strategies that should be applied to motivate residents to correctly manage generated waste at source or minimize waste separation, the following activities can help waste management system more sustainable.

- *Waste separation at source*: appropriate knowledge on waste separation such as types of waste or impacts of not separating waste should be provided to the residents/community. Apart from this, the residents should be informed of the benefits they would get from separating waste such as having additional source of income from selling separated recyclables or making household compost to be used as soil conditioner. At the community level, separated organic waste can be turned into compost for commercial purpose, or for producing alternative energy through generating biogas to be used in the society.
- *Incentives*: adopting incentive technique to encourage residents' attention or motivate them with focus on public benefits is also an achievable approach for sustainable waste management. Municipal authorities can provide incentives to their residents in numerous ways, such as launching recycling bank campaigns, which can be in both individual and collective forms. Incentives come in the forms of eggs, rice, cooking oil, money, coupon, tax reduction ranging to waste collection service fee exemption.
- *Regulations*: in some cases, when the rewarding strategy does not work, using punishment to make the residents dispose waste correctly can be effective. For e.g., not providing waste collection service to house/s that does not separate waste. Moreover, issuing fine or other punishments can also be applied.

2.2.2 Collection

There are different types of waste collection systems [4]. Each type of collection depends on different factors including settlement geography, types and quantity of waste, availability of management resources, and waste management policies. The frequency of collection is ultimately dependent on local needs and performance of existing services. The collection system should be based on objectives, capacity, and conditions of each municipality.

- *Communal collection*: this method uses large communal storage sites as locations to collect and pickup waste. Despite its inexpensive and simple solution, this method always fails because the demand placed on the generator goes beyond capacity to cooperate. For example, waste has to be manually removed by rake, shovel, and basket, which is a relatively slow process causing non-productive collection as there is excessive waiting time for trucks to load the waste.
- *Curbside collection*: the collection requires a regular frequency and a precise schedule, for optimal efficiency and convenience. Residents are responsible for placing and returning empty containers. The method is one of the least expensive methods of house-to-house collection.
- *Block collection*: collection trucks stop at intersections and the residents take their waste to the staff to empty. The residents are responsible for returning the container. The full containers are brought or set at the collection site by collection staff.
- *Door-to-door collection*: waste collection staff enters household premises, carry waste containers to collection trucks, empty them, and return to the place. It is the method that residents do not get involved. The method is costly in terms of labor cost, due to time spent on collecting waste for each household.

The frequency of collection depends on the quantity of solid waste, time of year, socioeconomic status of serviced area, and performance of responsible parties, namely municipality or waste management contracted companies. In urban or public areas, waste from markets, hotels and restaurants should be collected more often; whereas in residential or rural areas, frequency of waste collection should be the maximum permitted interval.

During the collection process, waste bins or receptacles should be either emptied directly into the garbage truck or replaced with a clean container. Bin-to-bin waste transfer causes spilling, resulting in ground pollution and attraction of flies. Collection trucks directly load waste with lifting and carrying of container; roll of loaded containers on their rims; use small lifts for rolling the containers; or use of large containers into which wastes from small containers are emptied. The collection trucks should be covered and able to compact the collected waste. The storage areas in collection truck should be relatively kept clean and watertight. Apart from collection trucks, collection equipment includes special waste containers, waste pick-up equipment, replacement containers, and sweeps.

Labor requirements depend on the type of service provided and the collection system used. For stationary container system and hauled container system, two to three staffs are needed as one or two staff is responsible for loading and unloading waste bins, and a driver to drive the truck. Occasionally, a driver and two helpers are used. For manually loaded systems the number of collectors varies from one to three, depending on types of service and types of collection equipment (Figure 2.2).

Figure 2.2 Manually loaded waste truck

Practically, curbside collection is widely employed throughout cities in Asia. Still, this waste management process is ineffective in many areas due to countless reasons. As mentioned before, the effectiveness of this process depends on availability of waste collection and equipment, frequency of collection, and appropriateness of allocated waste collection staff. Accordingly, authorities have to ensure that waste collection management process is well planned and fully equipped with required resources.

2.2.3 Transportation

Waste transportation efficiency depends on how effective waste has been collected. Haul distance to the disposal facility is a major concern and must be taken into consideration. If the disposal sites are located at significant distance from points of collection, establishing transfer stations is desirable. These transfer stations will be employed as central sites where collection trucks dump collected waste and reload the waste into large trailers. In urbanized areas, it is more economical to reduce the haul distance by providing large, specially designed trailers at transfer stations. In rural areas, container stations are considered as central locations. Having transfer stations in transportation process helps in reducing the cost of transporting waste by reducing number of required staff and total hauling kilometers. The stations should be located at the center of the collection service areas. Facilities and machines that should be available at the stations are weighing scales, stationary compactors, recycling bins, material recovery facility, forklift trucks, transfer containers and trailers, transfer packer trailers, or mobile equipment [4].

Cities in Asia manage waste transportation by employing so called transfer station. However, in real situation, the station may not be suitably designed. In some cities, waste is dumped with improper management, which makes the station look like open dumping site. This is either because the hauling distance to disposal site is located far away from the station or the poor management system.

2.3. Waste Management Approach

In terms of technologies for municipal solid waste management (SWM), they can be categorized into two broad management viewpoints. The first viewpoint is operational process; considering from cradle to grave, which the processes are waste generation at source, collection, transportation, treatment, and final disposal. The other viewpoint is relating to waste utilization. The processes includes, for example, source separation, composting, recycling, or landfilling. Thus, for a better understanding, essential factors required for effective waste management system are discussed below.

2.3.1 Waste Utilization Techniques

Comparing people's perception on waste in past decades to the current situation, solid waste has increasingly gained more attention on its values rather than being discarded substances. Waste utilization has widely been implemented in numerous ways ranging from a small scale at household level to a very large scale as a power plant. In Asia, waste utilization methods include, for example, composting, recycling, refuse derived fuel (RDF) or solid recovered fuel (SRF), incineration, pyrolysis, and gasification. Important factors of the success in waste utilization are appropriateness of technologies, readiness of facilities and skilled staff together with quality and quantity of waste. Factors that affect performance of resource recovery process are heterogeneity of waste, uncertainty of supply, unproven technology, administrative and industrial constraints, legal restriction, and uncertain market. Techniques that are involved in waste volume reduction and utilization are generally done by compaction (mechanically reduces volume of waste), chemical volume reduction (combustion or digestion); and mechanical size reduction (shredding, grinding, and milling), and component separation (hand-sorting, air separation, magnetic separation, and screening), Figure 2.3.

Figure 2.3 Material recovery facility

2.3.1.1 Composting

Composting is an effective method to utilize waste. In composting, biodegradable materials break down through natural processes and produce humus. Materials that are non-biodegradable must be separated from the degradable materials and disposed of with other treatment techniques.

Aerobic digestion or composting is a biological treatment process using long-term aeration to stabilize and reduce the total mass of organic waste by biologically destroying volatile waste. In an aerobic system, the microorganisms access free gaseous oxygen directly from the surrounding atmosphere. During the decomposition process, there is produced heat, which is enough to kill harmful bacteria and pathogens within the pile. The heat also facilitates the growth of beneficial bacteria species.

Small scale composting (Figure 2.4) can be done in the backyard of a residential household, or in a farm or community activities using the source separated organic fraction of domestic waste. Feedstock can be compostable materials like food waste, garden waste, animal or human manures. It can be carried out using various methods and materials, including compost bins, worm bins, and composting toilets. There are three main types of composting techniques: windrow, static pile, and in-vessel (large scale composting).

For windrow, mixed waste is configured in long rows (windrows) that are aerated by convection air movement and diffusion, or by turning periodically through mechanical means to expose the organic matter to ambient oxygen. For static pile, a stationary waste mixture is aerated by a forced aeration system installed under the pile. For in-vessel composting, composting takes place in closed containers and the environmental conditions are controlled. Factors that can influence the composition and amount of waste stream are season and climate, regional differences, demography, state of the economy, and local source reduction and recycling programs. The end products of an aerobic process are primarily used as a soil amendment or mulch by farmers [3–4, 7].

Good points of aerobic digestion include:

- Availability of resources or feedstocks from domestic or solid waste;
- Lower initial investment for starting up a new facility;
- Useful final product which is an easy technique to produce compost;
- Lower level of skill or expertise which is practical for small, community scale, or large scale composting facilities;
- Easy to use as soil amendments; and
- Less likely to cause environmental burdens comparing to untreated organic waste.

Nonetheless, there are also a number of concerns for implementing this method of waste utilization. The concerns are:

- Possibilities of contamination from infectious waste;
- Large amount of energy and time needed to aerate and turn the compost piles;
- In business perspective, there is no reduction in carbon footprint;
- Dependence on seasonal temperature variations;
- Limited market if there is high level of contaminants; and
- High potential of bad smell and nuisance.

(a) (b) (c)

Figure 2.4 Composting; Small scale composting (a), community scale composting (b), large scale composting (c)

2.3.1.2 Anaerobic digestion (AD)

AD is a controlled microbiological process (Figure 2.5), in which digestible materials decomposes in the absence of free oxygen. The best practice for AD process is separation of waste at source, as feedstocks need to be of high quality to ensure stable operation of the digestion process. Chemical and biological impurities should be strictly monitored for safe and beneficial utilization of final digestate.

The process usually takes places in a specially designed digester tank. The output of the AD process is biogas and compost like product or digestate. Biogas is a 45-60% methane content gas, which can be used as renewable fuel through electricity or heat generation. Digestate is the byproduct of AD process; it is a sludge-like or liquid product, rich in plant nutrients. A variety of AD technologies is available for the treatment of the organic fraction of waste based on the digestion method and the dry matter content of the substrate. Comparing to composting, AD is a time consuming and required appropriate skill, and consistent large quantities of feedstock. Success factors of AD includes: sorted organic waste, size of feedstock, moisture content and temperature control, destruction of pathogenic organisms, time required for composting, reclamation of gas, and testing contamination condition of final compost [3–4, 7].

AD is widely applied as waste utilization technique for the following reasons:

- Useful final products including fibrous and liquid fertilizers and biogas;
- Reduction of odor comparing to untreated organic waste or composting technique;
- Less environmental and health concerns;
- Scalable plants from small to very large;
- Availability of developed technologies;
- Economic benefits from using generated energy or selling excess amount of energy; and
- A great source of alternative energy.

Despite the listed advantages, there are some constraints that need to be for considered. The constraints are:

- High investment cost for commercial scale AD facility;
- Limited market if there is high level of contaminants;
- A great monitoring system is required to prevent contamination and odor; and
- Temperature and time sensitivity.

(a) Bioreactor

(b) Gas collectiontank

Figure 2.5 Anaerobic digestion facility at Rayong City Municipality

2.3.1.3 Mechanical Biological Treatment (MBT)

MBT is a treatment method using a combination of mechanical and biological processes to separate and transform the solid waste residual into several outputs. The method does not give a final disposal solution for treated waste. It is designed to further treat mixed collected waste by extracting value from waste and recover energy contained in it. The mechanical processes are designed to separate out dry recyclables such as glass and metals, whereas the biological processes are to reduce water content and to handle organic-rich fraction of feedstock. Together with non-organic waste, the MBT technique processes compostable waste fraction, which will be further composted or treated by anaerobic digestion. Composting and AD can integrally be part of the same MBT facility. The quality of the digestate produced by MBT can possibly be problematic due to its safe hazard and contamination concerns when applying on soil [8–9].

Advantages of this technique include:

- Reduction of organic waste amount treated by biological process;
- Separation of recyclables from mixed commingled waste;
- A source of alternative energy with required further treatment process;
- Lower level of initial investment comparing to other techniques but composting;
- Reduction of environmental pollution from reduction of methane and leachate production of biodegradable waste;
- Modular facility consisting of small units which is easy to be expanded or taken away; and

- Less potential of hazardous contaminants of waste stream from hazardous waste such as batteries, paints, or light bulbs; reduction of odor and dust.

In terms of disadvantages, points of concerns are:

- Further waste treatment is needed;
- Possibility of contamination;
- Limited market for final products;
- High operating costs for residue treatment; and
- Poor quality of sorted recyclables.

2.3.1.4 Recycling

Recycling has become one of the economically feasible and environmentally sound technologies of waste treatment. In this process, waste is sorted out and then is recycled into new useful materials. Major types of recyclable waste are plastic, paper, ferrous and non-ferrous scrap. The process of waste recycling starts when waste pickers, waste collection staff, or residents take their collected recyclables to sell to junk shops. The shops either sell a large amount of waste to larger shops or to manufacturing companies. Then the companies turn this recyclable waste into raw materials by using various technologies. Small and medium size junk shops usually collect recyclable waste to some amount before bailing and transporting to larger shops or manufacturers (Figure 2.6). This process applies to all types of recyclables. For large size junk shops and manufacturers, several processes are added up to increase value to the recyclables or turn the recyclables into raw materials for manufacturing process. However, the processes and technologies are different depending on types of recyclables and final products.

As recycling technique has gained attention from industries in terms of raw material manufacturing and alternative energy generation, there are a number of advantages of recycling. Advantages includes:

- Environment protection and natural resource conservation by minimizing use of natural resources;
- Reduction in energy consumption comparing raw material processing;
- Reduction in pollution comparing to discarding recyclable waste to other waste treatment methods such as landfilling or open dumping;
- Maximization of resource utilization;
- Expansion of landfill life due to recyclables going for recycling instead of landfilling; and
- A great source of income or saving comparing to buying or processing virgin materials.

Recycling also has some disadvantages including:

- High initial investment due to required state of the arts technologies and facilities, skillful and qualified staff are needed to operate the facilities;
- A pollution control system is required to prevent contaminant and pollutant;

Therefore, responsible authorities or companies need to ensure that the selected recycling techniques are practically and economically feasible with the recyclable resources they are going to reprocess.

Figure 2.6 Bailing of packaging materials

A. *Recyclable plastic*

Waste plastics are one of the most promising resources for fuel production because of its high heat of combustion and its increasing availability in communities. Recycling has become the most effective method for utilization; however it is not a complete solution for plastic treatment, as it can be recycled up to three to four times before it ultimately ends up the lifecycle and disposed of in landfill. Recycling method cannot be applied to some types of plastics. The method is only suitable for processing specific types of segregated plastic materials and is not suitable for assorted waste.

There are two main types of plastics, thermoplastics and thermosetting polymers. Thermoplastics can repeatedly soften and melt if enough heat is applied and hardened on cooling. In this case, they can be made into new plastics products. Thermosets or thermosetting can melt and take shape only once, which are not suitable for repeated heat treatments. The conversion methods of waste plastics into fuel are depended on types of plastics and properties of other materials used in the process. The effective system requires appropriate technologies to be selected based on a number of factors, including environmental, social and technical characteristics. In general, the process of conversion of waste plastic into fuel requires feedstocks which are non-hazardous and combustible. Therefore the major quality concerns when converting waste plastics into fuel resources are well-controlled with non-hazardous and undesirable additives, smooth feeding to conversion equipment, proper combustion and clean flue gas [10].

B. Paper

Recovered paper is suitable for producing a wide variety of final paper products, including newsprint, printing paper, tissue paper, corrugated containers, and paper containers (Figure 2.7). Paper for recycling has to be separately collected from other materials. It is very important that they be separated from other waste, as contaminated paper are not acceptable or very difficult to be recycled. The requirement of papermakers is also a major concern, as they set the specification of acceptable type of waste to be used as raw materials. The recycling process is the same as the one used for paper made from virgin fibers but the recovered ones have to be sorted and cleaned. For example, ink has to be removed from the recovered paper. It is then slushed into pulp and large non-fibrous contaminants are removed. The fibers are progressively cleaned to eliminate non-fiber impurities and resulting as pulp [11].

Figure 2.7 Waste paper

C. Glass

Because of its density and weight, glass makes up a large component of all waste. The process of turning waste glass into usable products is advantageous. Glass is easily recycled and, therefore, is one of the most popular items of recyclable waste. The ingredients of glass are very pure and only a few recycling processes are required. In the process, glass is separated if necessary depending on the end use, recycling glass commonly includes separating it into different colors. Once glass is colored with a coloring agent, the color cannot be removed. Therefore, colored glass can only be recycled into glass of the original color. First, colored glass is separated into colors and metal or other contaminants are removed. Then, the glass is crushed into cullet and melted down. The melted glass is poured into molds and shaped for the end product [12].

D. Ferrous and non-ferrous metals

The pattern of ferrous and non-ferrous metals in containers and packaging is much like that of glass (Figure 2.8). Metals are useful materials by quality of their fracture toughness, thermal and electrical conductivity, and performance at high temperatures. The most common recyclable metals are steel and aluminum. The other metals, for example, silver, copper, brass and gold are very high valued and rarely collected in waste collection process for recycling. This is the first step in metal recycling to sort the metals into types based on their quality. The materials are squeezed and squashed by machines to make them take less space in the conveyor belts. Then, they are crushed and shredded into tiny pieces or sheets for further processing. Each metal is taken to a specifically designed furnace to melt based on its specific properties. After the melting process is complete, purification process is applied to ensure the quality. After the process, the molten metal is cooled and solidified. Other chemicals are then added into the molten metal to make them meet required properties [13].

Figure 2.8 Baled ferrous and aluminum scrap

2.3.1.5 Waste to energy technologies

Waste to energy (WTE) technologies have gained much attention from cities around the world as there is an ever increasing energy demand with depleting fossil fuels. Many technologies offer possible strategies to turn waste into different stages of energy, namely solid, liquid, and gaseous. Accordingly, advantages of WTE are:

- It prevents a vast amount of waste going to the landfill;
- It reduces substantial amount of possible emitted pollution; and
- It provides economically and environmentally alternative fuel or energy.

Although WTE conversion is rapidly increasing, there are concerns in employing this technique. In general, the concerns include:

- High initial investment for WTE facilities;
- WTE systems are very complex, staff with expertise and specific skills are required; and
- A pollution control system is highly important to monitor and prevent adverse impact from contaminants.

In the same way as recycling, responsible parties need to give thorough consideration to WTE techniques whether they are practically and economically feasible with the characteristics of waste and situation of the city.

A. Solid fuel production technologies

Solid fuel includes refuse derived fuel (RDF), solid recovered fuel (SRF) and refuse derived paper (RPF) or plastic densified fuel (PDF). Solid fuel is mainly produced from kitchen waste, paper, wood, and plastics. Due to the presence of moisture in the combustible materials, prior to the conversion to a fuel, a drying process is required to remove the moisture and to allow the solidification of the waste in suitable shapes and densities. The solid fuel production process involves two steps, pretreatment and pellet production. The pretreatment process includes coarse shredding and removal of non-combustible materials, whereas the pellet production includes secondary shredding and palletization. Shapes of the fuel vary depending on the production equipment and required specification. In the production of solid fuel, there is risk of plastic contamination, which may cause air and soil pollution by flue gas emission and incineration ash disposal. Heating values of solid waste may vary depending on the composition of the original feedstock [4–5].

B. Liquid fuel production technologies

Liquid fuel through pyrolysis technique is defined as plastic derived liquid hydrocarbons at a normal temperature and pressure. Only some types of thermoplastics go through thermal decomposition process to yield liquid hydrocarbons used as liquid fuel. Polyethylene (PE), Poly propylene (PP), and Polystyrene (PS), are preferred for the feedstock of the production of liquid hydrocarbons. Depending on the components of the feedstock for fuel production, final liquid fuel may contain other contaminants which may cause flue gas pollution. In these fuels, various additives are usually mixed with liquid hydrocarbons to improve the product quality. Skillful staff and well-equipped facilities are highly required due to the formation of highly flammable liquids and gases [4–5].

C. Gaseous fuel production technologies

The gaseous fuel refers to flammable gas obtained from thermal treatment of waste plastics. Through gasification process, there are two types of gaseous fuel, including gaseous hydrocarbon that are in a gaseous state under normal temperature and pressure; and synthesis gas or syngas that is a mixture of hydrogen and carbon monoxide. In the conversion process of turning plastics into gaseous fuel, waste plastics undergo thermal decomposition in a reactor, resulting in the formation of liquid fuel and gaseous fuel. In a specifically designed reactor, gaseous hydrocarbons become the main product after residing in the reactor for an extended time under controlled conditions. Under these specific conditions, carbon and carbohydrates can be used as feedstocks for the production of gaseous fuel, namely methane and hydrogen. Heating values of gaseous products vary depending mainly on types of feedstock used and levels of contamination. As gasification process needs advanced technologies, skilled staff and proper design facilities are very important factors that the performance of the system relies on [4–5].

2.3.1.6 Other technologies

Instead of installing a new facility to utilize waste, there are alternative SWM techniques for recovering recyclable waste. For example, in steel industry, plastic waste is treated in blast furnace and coke ovens as feedstocks that give high calorific values. However, waste plastics are needed to be at a constant quality while feeding into a blast furnace. Contamination caused by plastics and other materials is highly prohibited to prevent any adverse effects to the steel quality. In cement production, shredded waste plastics are used as feedstocks to put into a cement kiln for use as fuel. In the same way, contamination from waste plastics should be removed prior to the injection to maintain cement quality [10].

2.3.4 Final Waste Treatment and Disposal Techniques

There are varieties of waste treatment options used in SWM. Disposal of solid waste has to be accomplished without (or at the minimum) creation of nuisance, health hazards, and adverse socio-economic problems in order to fulfill the objectives of SWM system. Depending on available management resources and quantity of waste, waste treatment methods that have widely been adopted in the management processes are: landfill, incineration, and open dumping.

2.3.4.1 Incineration

Incineration is a process of burning combustible components materials (Figure 2.9). Generally, this method is operated under two systems namely open or closed systems. In the open system, waste is incinerated in a chamber open to the air, whereas the closed system contains a special chamber designed with various parts to facilitate incineration. Incinerators in both systems require a chimney of appropriate height to provide a good flow of air through the combustion chamber. Sizes of incinerators can be varied depending on waste volume to be incinerated. Getting a proper site as a location for incineration can be burdensome. To have a proper management, skilled staff are highly important for operation and maintenance the system.

Benefits of incineration technology are:

- It requires less land for operating process;
- After treated residue is free of organic materials and nuisance; and
- It provides opportunities of energy generation.

In terms of disadvantages, there are several points of concern [2–3]:

- Incineration needs high initial cost for investment;
- Only combustible materials are incinerated, therefore, a need for separation of the waste into combustible and non-combustible is required; and
- The noncombustible waste needs separate disposal.

Figure 2.9 Incineration plant in Bangkok

2.3.4.2 Sanitary landfill

Sanitary landfill is one of the most widely used methods of waste disposal (Figure 2.10). A properly operated sanitary landfill eliminates insects, rodents, hazards, fire, and other problems existing in open dumping. The method can be used in any community where sufficient suitable land is available. The method consists of four steps: to deposit of waste in a planned and controlled manner; to compact waste in thin layers to reduce volume; to cover waste with a layer of soil; and to compact the top surface with soil. In most cases, the method has proved to be the answer for safe and economical solid waste disposal. Site selection for sanitary landfills is based on hauling distance from waste collection points or transfer stations; availability of suitable access roads; type of soil for covering; groundwater level; traffic situation; drainage channels; available land areas; geologic and hydrologic condition; surface water hydrology; local climatic condition, and local environmental condition. In addition, decomposition and stabilization of landfill depend on compaction of waste, degree of compaction, amount of moisture, inhibiting materials, rate of water movement, and temperature. Normally, type, size and required facilities or equipment will be governed based on size of community served, size of the landfill, and methods of operation. General required facilities include crawler, scrapers, compactors, and water trucks.

Advantages of sanitary landfill over other treatment methods are [2–3, 6]:

- It is a more economical;
- It requires less initial investment compared to other proven methods;
- The operating system is flexible;
- It enables reclaiming of depression and sub-marginal lands;
- With proper management, the completed areas can be used for recreation purposes;

- It prevents unsightliness, hazards and nuisance of open dumping; and
- It can be quickly established.

Some concerns related to sanitary landfill are:

- Lack of suitable land to be landfill sites;
- Risks of seepage of leachate into natural waterbody;
- Good management system and skilled staff are required; and
- Special facilities and equipment are required, especially for landfill gas generation.

Figure 2.10 Sanitary landfill under construction

2.4 Factors Influencing Sustainable Waste Management

Waste management requires policy instruments, institutional arrangements, capacities and stakeholder interactions. It is very important to ensure that strategic goals be reflected in choices, which are made throughout SWM system, not only those related to policies and institutions but also, technology selection, financing, and management structure [3].

Local government authorities play an integral role in delivery of SWM services. Intersectoral interaction among related stakeholders is an approach towards more effective SWM system. Absence of proper system of waste management has created an unsolvable problematic situation with increasing environmental and health related problems. Studies have shown that successful management systems occur where there is involvement of related parties. In many cases, recognition and legitimatization of informal and local community sectors provide significant potential of enhancing service performance.

Along with involvement of private sector and local community sectors, the organization of waste management system should ensure policy setting, awareness raising, capacity building, and resource recovery.

2.4.1 Policy Setting

A. Legislation and regulation

Normally, legislation and regulation that are set up for some particular purposes are difficult to apply to dynamic circumstances in SWM because waste management is dispersed, fragmented, and interrelated with many factors. Governments or municipal authorities should consider the policies that are suitable with local circumstances and fit with community norms, socially suitable, and financially affordable. Strategies that have a higher chance of being accepted and implemented by the community are the ones that relate to public participatory approach. In this manner, stakeholders can get involved, contribute their knowledge and ideas, express their concerns, explain their needs and expectations, and raise issues that are important to their communities. Developing a set of effective strategies for SWM system is a continuous and intensive learning process that involves various activities along the management chain [15–16].

B. Institution

Strong political will to make waste a priority is a vital factor that attracts talented personnel, adequate facilities, and commitment of management levels. Confusing and fragmented divisions of waste management organization are burdensome to the effectiveness of management system. Therefore, mutually set plans, shared responsibility, and jurisdictional disputes among responsible parties can make clear articulation of policy and lead to definite management solutions [15–16].

C. Waste management personnel

Lack of competence and skills of waste management staff is a major problem leading to ineffective and low performance of the management system. Providing appropriate skills and knowledge is a potential way to solve the problem. In addition, providing attractive benefits can be an option to increase the willingness to work in waste management system of staff [16].

2.4.2 Financial Mechanisms

The availability of financial and technical support has been critical to the implementation of waste management. Financial sources of waste management usually come from the central government or local authorities. However, rapid increase in waste generation rates and awareness for effective SWM to protect public health and environment boost up demands for huge investments that brings improvements in SWM chain [17–18]. Consequently, this causes the governments to adopt various financing approaches:

- *National subsidies*: a major source for many local governments to finance environmental infrastructure and services.
- *Annual budget*: an allocated portion of development budget to finance waste management process. It is usually cross-subsidized from the revenue earning sources of governments.
- *User charges*: charges that motivate waste generators to reduce waste. Volume based charges for waste is commonly applied in many countries.

- *Penalty, fine and levy*: an important financing tool for governments to finance waste management. The fine will be charged on those who illegally or incorrectly dispose of waste.
- *Environmental bonds*: bonds that are floated by local governments as a major source to arrange funds for environmental infrastructure and services, including waste management.
- *Environmental fund*: fund that is financed through various modes including national bonds, annual budget, loans from international financing institutions and international cooperation.
- *Direct loans*: local governments take direct loans either from domestic or international financing institutions.
- *International cooperation*: direct multilateral and bilateral cooperation between local governments and international agencies. The agencies provide support to local governments to improve the local environment.

2.4.3 Infrastructure, Facility, and Technology Planning

Once strategic goals are established, a broad range of technological options should be considered to be properly applied in the system with needed infrastructure and facilities. In other words, there should be a policy that entails consideration of technical, financial, and operational aspects.

Concerns about the selection of technologies are very different depending on types and methods of waste management process. As such, affordability and institutional capacities for adequate operation, maintenance, and monitoring are what of concerns. Municipal authorities need to have well-planned policies for infrastructure and facility development, which should be in accordance to methods and technologies used in waste management system. Essential facilities can be invested by either the governments or private sector. Advantages of well-planned policies would increase the overall performance of operational and control processes [19].

2.4.4 Involvement of Stakeholders

The best implementation plan is unlikely to work unless the public is active in helping to reach the final optimal goal. Public involvement or participation must be involved in two-way interactions. There must be a give and take on the final solution. This public involvement is best done with multiple opportunities for both formal and informal inputs. Throughout SWM process, it involves a multitude of stakeholders both directly and indirectly. The stakeholders play different roles in the system as they are beneficial in waste from different perspectives for different reasons. To include stakeholders in waste management system, different approaches can be used to draw their participation [15, 19]. Accordingly, groups of stakeholders are ranked on the basis of their potential to be involved in the SWM system.

- *High influence and high interest (key players)*: it is worthwhile to ensure close involvement throughout the decision-making process and subsequent implementation. These potential stakeholders are large cities, central governments, and large industries.
- *High influence but low interest*: it may be sufficient to keep these stakeholders informed and acknowledge their views in order to avoid disruption. These stakeholders are those that have waste as their low priority. The stakeholders are politicians, governmental agencies, and financing agencies that have waste low on their agenda.
- *High interest but low influence*: this requires special attention, to make sure that their needs and interests are adequately addressed. These stakeholders are citizens, informal service providers, and CBOs.
- *Low influence and low interest*: these stakeholders are unlikely to be involved and require no particular participation strategies.

A. Awareness raising and education

Social instruments are applicable to situations that governments aim to raise people's awareness or change people's attitudes towards public concerns. Social instruments are based on interaction and communication among stakeholders. However, it is very difficult to ensure that the chosen instruments will be effective in achieving behavioral change as there are a number of complex factors and circumstances that people differently depend on. In SWM point of view, a concrete design of activities from the basket of social instruments that includes specialist knowledge of social marketing is needed. This is an area where local authority officials working in the field of waste management gain benefit from contributions. For example, governments often work with NGOs and CBOs to carry out campaigns incorporating a variety of tools, such as informal meetings with the community and its leaders, informative posters, or public hearings [15, 19–20].

B. Capacity building

Occurring in both national and international levels, it has been realized that awareness is the key to motivate people and make efforts for more participation in waste management. One of the other main objectives towards sustainable waste management system is increasing efficiency and capacity of the administration, NGO staff, and the community (Figure 2.11). It can be done through the development and strengthening skills, competencies and abilities of different stakeholders. Through trainings, meetings, or organizing workshops, capacity building requires different actors to orient towards the concept of waste management and objectives. Municipal authorities should play a major role to ensure that capacity building is planned in such a manner that receives adequate participation from all the stakeholders [19–20]. Capacity building can be done in several levels, including:

- *Individual level*: this requires development of conditions that allow individual participants to build and enhance knowledge and skills. The process allows individuals to engage in learning and adapting to change.

- *Institutional level*: this involves aiding institutions in modernizing existing institutions and supporting in formation of practical policies, organizational structures, effective methods of management, and revenue control.
- *Societal level*: this supports the establishment of a more interactive public administration that learns equally from its actions and received feedback from the population at large.

Figure 2.11 Capacity building activity

2.4.5 Markets

Developing new or keeping existing markets for selling recovered materials can create an economically sustainable system that does not require subsidies or government intervention. Markets can be improved by utilizing strategies that enhance the supply or increase the demand. Factors that improve the supply are known as supply-side tools, and factors that increase the demand are known as demand-side tools. The supply and demand are inherently linked. It is important to consider both aspects when considering markets. When the supply or demand is insufficient, an unbalanced market affects feasibility of recovering materials. Thus, the primary goal of market development is to create a system of material flow that is stable and economically sustainable [5, 20].

A. Demand side

Measures that stimulate a stable demand for final products made from recovered materials are called demand-side tools. Creating a demand is attractive because good markets help to cover the cost of operation, avoid disposal cost, conserve resources, and provide economic development opportunities. Tools that can be used to stimulate or maintain demand are as follows:

- *Government procurement programs*: the governments have enormous purchasing power that can be used to promote markets for recovered materials. Therefore, the governments should exercise their power in managing or take active actions in creating demands for recovered material products.
- *Education*: consumer education about recycling is a vital step for the success of any integrated waste management system. Knowledgeable consumers tend to support or acquire the produced products.

- *Recycled content and utilization programs*: utilization rate programs require manufacturers to ensure that a certain percentage of their products meet a minimum recycled content requiring recycled content is a way of directly increasing the use of recycled material in products.
- *Product standards and specifications*: standards and specifications for recycled products or compost give consumer confidence and often allow those products to be used in more applications. Standards and specifications for a product can guarantee a certain level of performance or ensure that a product is safe for its intended use.
- *Financial tools*: financial tools can be used to give products made from recovered materials a cost advantage over products made with virgin materials. The tools can be used to generate market competition with virgin materials. Financial incentives can also be used to encourage the use of processes that conserve resources.

B. Supply side

In many communities, the most common effect of having large-scale composting (Figure 2.12) or recycling plants is generally an oversupply of the recovered material. Thus, the challenge is to provide appropriate quality and quantity of material to various end users at a minimum cost. Measures that improve the supply of recovered materials to operations are known as supply-side tools. Improving quantity and quality of the supply can surely increase the stability of markets and increase investment in the industries. Therefore, those tools are, for example:

- *Disposal bans and disincentives*: the most possibly effective way to increase supply of a material is to prohibit its disposal. It is important that sufficient capacity exist to utilize the supply. Making it less economical to dispose of materials will encourage people to consider more on recycling.
- *Technology*: new technologies to improve or modify supply of materials can be developed to meet needs of end users. The technologies can focus on areas such as methods of separating materials, cleaning techniques, or processing techniques.
- *Logistics*: reliable supply of both quality and quantity of recovered material is critical to build the relationship between product providers and end users.
- *Material quality*: the quality of the recovered materials can be modified at the source (source separation), during collection process, or during sorting process.
- *Producer responsibility*: producer responsibility laws require manufacturers to create an infrastructure for collection and management of their products. This type of system has been successfully implemented in Europe for waste packaging management. Internalizing the costs of waste management makes manufacturers more aware of the problems associated with their products.

Figure 2.12 Bagged compost

2.5 Good Practices of Solid Waste Management in Thailand

The training of the trainers was provided to collaborators in the first year of the project to showcase good examples of solid waste management in Thailand. Field visits to these sites were conducted and the detail overview was provided by the authorities. The selection of the sites was done by the proponents and can be categorized into municipality of different sizes, private sector, and community based operation and management. The lessons learnt for these visits can be adopted by the partners and success and drawbacks of each system were also highlighted.

2.5.1 Klang Municipality, Rayong

Type of organization: Sub-district

Management level: Local government (SMALL)

Location: Klang Sub-district, Klang District, Rayong Province

Area: 14.5 sq.km, 13 communities

Households: ~ 6,500

Population: ~ 20,000

SWM capacity: 35 tons/day

Klang municipality represents small size district administration with the current waste management capacity of 35 tons per day. The main goal of Klang municipality is to overcome insufficient budget and diminishing landfill space problems.

With the aim to minimize quantity of waste to be landfilled, the following processes are implemented at the waste management center: (1) hand sorting for recyclables by conveyor belts (sold to junk shops), (2) baling of beverage carton (sold to junk shops), (3) biogas – generate electricity, which amount suffices for using within the center, (4) composting (for sale), (5) earthworm or vermicompost (for sale), and (6) grease management (distribute for household use) (Fig 2.13).

Figure 2.13 Waste management activities at Klang Municipality

The success factors and drawbacks of Klang Municipality waste management system are as follows;

Success factors

- Effective community leader: have vision for solutions
- Involvement of people: residents, institutions and private sectors
- Collaboration: supports and knowledge are provided from NGOs and SWM experts
- Transparent management: management and operating processes are open to the public
- Societal contribution: the approach has been implemented in other communities

Drawbacks

- Capability: malfunctioned of tools/equipment impacting running operating processes
- Continuity of SWM policy: the policies are different depending on different visions of the mayors
- Limited budget: operating and management cost is high

2.5.2 Nonthaburi City Municipality, Nonthaburi

Type of organization: City

Management level: Local government (Medium to Large)
Location: Nonthaburi City Municipality, Nonthaburi Province
Area: 38.9 sq.km, 6 sub-districts

Households: ~ 143,000

Population: ~ 256,000
SWM capacity: ~ 420 tons/day

Nontaburi city Municipality represents medium size district administration. The field trip allowed the participant to learn the overview of municipal solid waste management, which is administrated in a local government level. Generated municipal solid waste of the municipality is collected and disposed of at a landfill in Ayutthaya province, Thailand. Organic waste is composted and infectious waste is incinerated at the same location in Ayutthaya.

The municipality promotes energy saving, climate change mitigation, low carbon, 3Rs, recycling banks in community projects. The success factors and drawbacks are listed below;

Success factors

- Effective leader: has high commitment
- Clear role and responsibility: having Bureau of Public Health and Environment with financial support that is especially allocated for public health and environmental concerns
- Consistency and commitment: executives and responsible persons, each project has at least 1 responsible person consistently following up the implementation
- Collaboration: NGOs, public and private sectors(Thailand and abroad)
- Adaptability: adopt successful techniques and knowledge to be appropriately used in local circumstances
- Empowerment: authorize power to communities emphasizing on results oriented rather than ways of implementation
- Technology: applying GPS as a monitoring technology to ensure efficiency of collection and transportation process

Drawbacks

- Inconsistent collaboration: some of the projects worked well when they were piloted with central government and private sector. Unfortunately, after the piloting period, municipality had to take responsibility for all costs.
- Limited budget: operating and management cost is high

2.5.3 Bangkok Metropolitan Administration (BMA)

Type of organization: City

Management level: Local government (Large)

Location: Bangkok Metropolitan Administration

Area: 1,568.737 km^2, 50 sub-districts

Populations	Registered	~ 5.7 million persons
	Non-registered	~ 4.0 million persons
Population Density		3,617 persons/ km^2

Households 2,593,827

Solid waste generation: 9,940 tons/day (2014)

Bangkok is a mega city with a total population of about 10 million. The amount of waste generated as of 2014 was 9,940 tonnes/day. Majority of the waste is disposed to sanitary landfill. Infectious and hazardous wastes are treated by incinerator (Table 2.1). BMA adopts different options for waste utilization as presented in Figure 2.14. The composting plant has a capacity of 1,200 tons/day and produce 300 tons/day fertilizer. The process adopted is aerobic composting and the quality of the compost product is good and marketable. BMA also adopt waste to energy technology that can incinerate 300 tons/day and produce 8MW of electricity.

Table 2.1 Waste generation and management in BMA in 2014

Waste Generation	
General waste	9,940 tonnes/day
Waste Management	88% disposed by sanitary landfill 12% treated by composting
Infectious waste	32 tons/day by incinerator
Hazardous waste	2 tons/day by incinerator
Generation rate	1.2 kg/capita/day

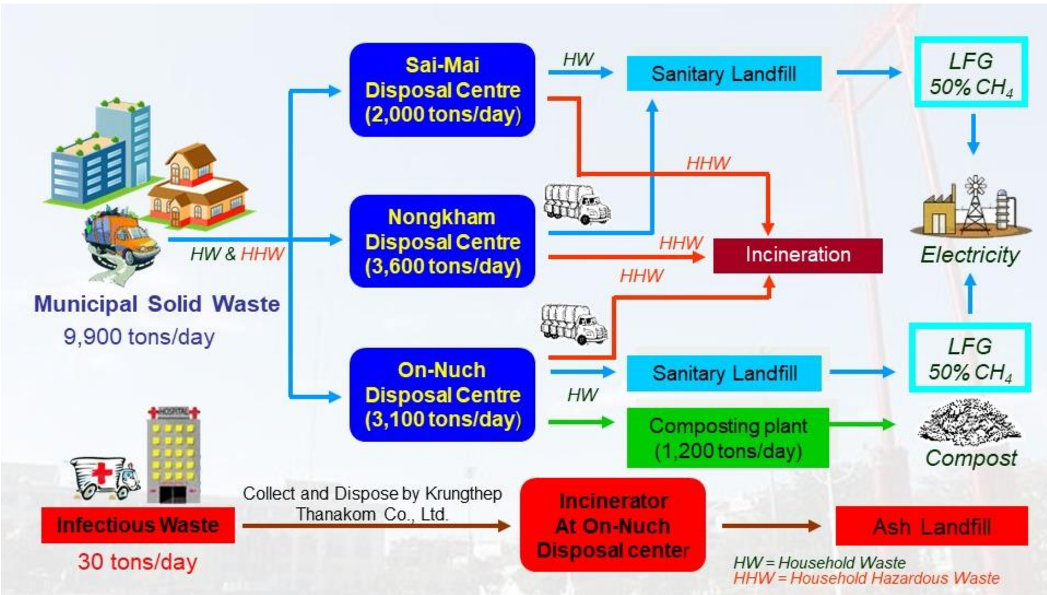

Figure 2.14 Waste treatment and utilization at BMA

Drawbacks

- Inadequate waste separation at source
- Rapid economic growth leading to changes in waste composition and generation rate
- Waste collection and disposal are not consistent with waste composition
- Limitations of area for landfill
- Inadequate budget for solid waste management
- Lack of regulation to support waste reduction at source

2.5.4 Private sector: Wongpanich Recycling Center, Samut Prakarn

Visiting Wongpanich Recycling Center gave a chance to the participants to learn how to manage waste in business point of view. At the center, recyclable waste such as paper, cardboards, metals, plastics, and some e-wastes are collected. This wastes come from two different ways. First, people collect waste and sell to the center. Second, the business has a free pick-up service to buy recyclable waste at source if there is a large amount of recyclables. The center has different types of equipment to process the waste in the form that can be sold to recycling companies.

The business informs the public of what acceptable types of recyclable waste and the price. They also educate public on how to properly sort waste to get higher price. Offering convenience to customers and operating business with standards allow the center to receive more recyclables and gain trust. The business has received increasing amount of recyclable waste selling to the center.

2.5.5 Community Based Management: Zero Baht Shop, Bangkok

Organizing a visit to Zero Baht Shop, a CBM project, has given very useful information and experience to the participants. The concept of the zero baht shop is to exchange waste with commodities. Public can bring the waste such as papers, metals, and plastics to the shop and get the goods of their liking. The prices are displayed in the shop. The group leader then sells the collected recyclables to the larger junkshops to get income to operate the business. The group members, in their free time, use theses recyclable waste to make handicraft products which are sold in the shop. All processes of the project run by residents and project members. Key success factors of the Zero Baht Shop are commitment of community leader, involvement of the people, strong community, and transparent management.

Waste separation at source successfully implemented as people perceive that waste is money. Initiatives and management processes aim to provide benefits to the public (mutually agreed). In addition to financial income, they also provide health insurance scheme which is very beneficial to the poor community.

2.5.6 Conclusion from Case Studies

Table 2.2 summarizes the key success factors and drawbacks of each level of SWM category. It can be seen that collaboration is the most essential factor for all cases. Effective leader, transparent management, and being an adoptable approach are also important factors for the success SWM. Other factors are involvement of community as a whole and use of suitable technology based on the local conditions. In terms of business point of view, influencing factors are offering convenience to customers, reliability, and being the market leader.

As for the drawback, the outstanding barriers include long-term management plan and financial constraint. Other concerns are conflict of interest among involved stakeholders, capability of facilities and inconsistent collaboration. In business viewpoint, recycling business is affected by more number of new comers who get into the same market and the fluctuation of commodity price that influences price of recyclable waste.

Overall it seems that different waste management scale has different issues and thus require different management approach. It can also be clearly seen that integrated waste management is a key to success.

Table 2.2 Summary of success and drawbacks of the different solid waste management system in Thailand

	Cases	Zero Bath Shop	Klang Municipality	Nonthburi Municipality	Wonpanit Recycling Center
	Business types	Community (Informal)	Local government (Small)	Local government (Large)	Private sector (Medium size business)
SUCCESS FACTORS	Effective leader	O	O	O	
	Community as a whole	O	O		
	Collaboration among stakeholders	O	O	O	O
	Transparent management	O	O		O
	Good perception of residents	O			
	Adoptable approach	O	O		O
	Clear role and responsibility				
	Localization technique			O	
	Empowerment			O	
	Suitable technology			O	O
	Offering convenience				O
	Reliability				O
	Market leader				O
DRAWBACKS	Conflict of interest	O			
	Long-term management	O	O		
	Capability of facilities		O		
	Inconsistent collaboration			O	
	Limited budget		O	O	
	Competitor				O
	Price fluctuation				O

REFERENCES:

[1] United Nations, Department of Economic and Social Affairs (DESA), Population Division, 2015. World Population Prospects: The 2015 Revision, Key Findings and Advance Tables. Working Paper No. ESA/P/WP.241.

[2] Hoornweg, Daniel; Thomas, Laura; Hoornweg, Daniel*Thomas, Laura. 1999. *What a waste : solid waste management in Asia (English)*. Urban and local government working paper series ; no. UWP 1. Washington, D.C. : The World Bank.

http://documents.worldbank.org/curated/en/694561468770664233/What-a-waste-solid-waste-management-in-Asia

[3] The World Bank, Urban Development and Local Government Unit, 2012. Urban Development Series knowledge papers, What a Waste: A Global Review of Solid Waste Management. Washington, D.C.

[4] United Nations Environment Programme (UNEP), 2005a. Solid Waste Management (Volume 1), Part I - Principles of Solid Waste Management. ISBN: 92-807-2676-5.

[5] United Nations Environment Programme (UNEP), 2005b. Solid Waste Management (Volume 1), Part II- Processing and Treatment. ISBN: 92-807-2676-5.

[6] United Nations Environment Programme (UNEP), 2005c. Solid Waste Management (Volume 1), Part IV- Key Non-Technical Considerations. ISBN: 92-807-2676-5.

[7] Ethiopia Public Health Training Initiative (EPHTI), 2004. Solid and Hazardous Waste Management. Lecture Notes from Carter Center

https://www.cartercenter.org/health/ephti/index.html

[8] Friends of the Earth, 2008. Mechanical and Biological Treatment (MBT).

https:/ /friendsoftheearth.uk/sites/default/files/downloads/mchnical_biolo_treatmnt.pdf

[9] Maier, A., Neubacher, P., and Ges.m.b.H., P., 2016. Mechanical Biological Treatment of Mixed Municipal Solid Waste: Experience in Austria and Portugal. http://www.iswa.org/uploads/tx_iswaknowledgebase/Maier.pdf, Accessed February 06, 2017.

[10] United Nations Environment Programme – International Environmental Technology Centre (UNEP), and Institute of Environmental Engineering and Management, and Mehran University of Engineering and Technology, 2016. Converting Waste Agricultural Biomass into resource.

http://www.unep.or.jp/Ietc/Publications/spc/WasteAgriculturalBiomassEST_Compendium.pdf

[11] Paper Recycling Promotion Center, 2015. Paper Recycling in Japan.

http://www.prpc.or.jp/linkfile/english-paperrecycling.pdf

[12] Solid and Hazardous Waste Education Center, University of Wisconsin, 2012. Material Manufacturing and Recycling: Glass.

[13] United Nations Environment Programme (UNEP), Reuter, M. A., Hudson, C., Van Schaik, A., Heiskanen, K., Meskers, C. and Hagelüken, C., 2013. Metal Recycling: Opportunities, Limits, Infrastructure, A Report of the Working Group on the Global Metal Flows to the International Resource Panel.

[14] The Environmental Protection Agency (EPA), 2009. Hazardous Waste Characteristics: A User-Friendly Reference Document.

[15] United Nations Environment Programme (UNEP) and International Solid Waste Association (ISWA), 2015. Global Waste Management Outlook. ISBN: 978-92-807-3479-9, DTI /1957/JA.

[16] Van de Klundert, A. and Lardinois, I., 1995. Community and Private (formal and informal) Sector Involvement in Municipal Solid Waste Management in Developing Countries. Inttingen Workshop, The Swiss Development Cooperation and Urban Management Programme.

https://www.gdrc.org/uem/waste/swm-finge1.htm

[17] United Nations Environmental Programme (UNEP), Division of Technology, Industry and Economics, International Environmental Technology Centre, 2009. Converting Waste to Plastics into a Resource: Compendium of Technologies, DTI/1230/JP.

[18] Mahadevia, P. and Parasher, A., 2005. NGO Led Partnership in Solid Waste Management – Ranchi, Working Paper No. 39. School of Planning CEPT University, Kasturbhai Lalbhai Campus, University Road, Navrangpura, Ahmedabad

[19] Hand, C., 2006. A Specially Commissioned Report, Waste Management: The New Legislative Climate, Thorogood Publishing, London, ISBN 1854183672.

[20] Tchobanoglous, G. and Kreith, F., 2002, Handbook of Solid Waste Management (Second Edition), DOI: 10.1036/0071356231.

CHAPTER 3: WASTE MANAGEMENT CRITERIA SELECTION

3.1. Introduction

To decide what SWM operation or utilization technique is appropriate for managing waste in a city is not an easy task; thus, based on the participation of related stakeholders, responsible authorities have to consider a number of criteria to evaluate suitability and capability of a city to manage waste.

Criteria used for SWM are versatile and dynamic according to situations and circumstances of solid waste in each city. Therefore, this report includes 12 fundamental management criteria for eight operations and utilization techniques. However, these criteria can be modified based on the local condition.

The twelve criteria are technology development, types of solid waste, operating scale, regulation compliance, final products, capital investment, operating cost, land requirement, needed operating skills, possible adverse impacts, and contribution to energy and food security.

As discussed in the previous chapter, eight SWM operation and utilization techniques that are applicable for managing waste are composting, anaerobic digestion, mechanical biological treatment, landfill, incineration, refuse derived fuel or solid recovered fuel, pyrolysis, and gasification.

3.2. Waste Management Criteria

Arranging 12 SWM criteria in terms of eight operation and utilization techniques to manage solid waste, Table 3.1 presents how each criterion relates to the operation and utilization technique in general view.

The Table demonstrates an overview of waste utilization methods commonly used in cities worldwide. However, to describe specifically for cities in developing countries, Table 3.2 describes relationship of each criteria and waste operation/utilization technique in details according to the sustainability assessment of technology (SAT) framework. In this table, impact and influence of the criteria on solid waste management are discussed.

Explaining how Table 3.2 can be adopted in a real solid waste management planning, on the quantitative perspective, Table 3.3 demonstrates how the 12 criteria and eight techniques can be selected as a waste utilization technique by applying scoring concept.

To identify potential waste operation or utilization techniques that are possible to be implemented as solid waste management method for each city or community, Table 3.4 demonstrates an example of how Tables 3.1 to 3.3 can be used as a decision making tool that supports responsible authorities to decide which waste utilization techniques should be implemented.

In Table 3.2, there are eight waste operational or utilization techniques mentioned previously in Table 3.1. The eight techniques for waste utilization are named as T1 to T8. These techniques are paired with different criteria that can be used as benchmark for a suitable SWM technique that will increase the effectiveness of SWM process and make it more sustainable. There are 12 criteria in total, including waste characteristics (organic, recyclable, commingled waste), waste quantity (small, medium, large amount), compliance with laws (local, national), land requirement (small, large), multisector involvement (community, private company), public acceptability, possible impacts (environment, society, economy), demand for final products, initial investment, operating cost, time consuming, and complexity and required skills. For each utilization technique, level of impact (low, medium, high) and rank of influence of the impact (positive, neutral, negative) is given for each criteria. The influence of impact is represented by three colors, which green represents positive, yellow is neutral or indifferent, and red refers to negative influence. In addition, details of criteria and technique is provided for each pair.

Table 3.1 Criteria on SWM operation and utilization techniques (Adapted from [1])

Criteria	Waste management operation/ utilization methods							
	Composting (Aerobic)	**Anaerobic digestion (AD)**	**MBT**	**Landfill**	**Incineration**	**RDF or SRF**	**Pyrolysis**	**Gasification**
1. Status of technology development	Widely used	Widely used	Widely used in developed countries	Widely used; especially in developed countries (for gas recovery)	Widely used in developed countries	Widely used	Mostly applied in developed countries	Mostly applied in developed countries
2. Types of solid waste	Sorted organic waste; High lignin material (wood) is acceptable	Sorted organic waste; Animal or human excreta; Sludge; Less suitable for high lignin material	Unsorted waste without hazardous waste	Unsorted waste without hazardous and infectious waste	Unsorted waste	Unsorted waste without hazardous and infectious waste	Specific type of recyclable plastic waste	Waste; Pre-processed RDF or SRF from MBT
3. Appropriate scale	Small scale (Household: yard waste, vermicomposting); Large scale (Community: windrow, aerated, static pile, in-vessel)	Small scale (on-farm composting); Large scale (community organic waste)	Large scale (Community)	Large scale (Community, city)	Large scale (Community, city)	Large scale (Community, city)	Large scale (Community, city)	Large scale (Community, city)
4. Conditions for success	Temperature sensitive; Long residence time; Regular aeration required; Odor control; Clean input material; Contamination sensitive measure	Clean, homogeneous, and consistent input materials; Good process control (easily disruption of microbial)	Clean, homogeneous, and consistent input materials; Good process control	Clean, homogeneous, and consistent input materials; Good process control (leachate, methane, and contamination)	Homogeneous and consistent input materials; Good process control (syngas)	Clean, homogeneous consistent inputs; Good process control	Clean, homogeneous consistent inputs; Good process control	Homogeneous and consistent input materials; Good process control (syngas)
5. Final products	Compost-like product	Compost-like product; Low calorific RDF; Heat	Compost-like product; RDF or SRF product; Heat	Biogas	Heat	RDF	Oil-like product	Heat

Criteria	Waste management operation/ utilization methods							
	Composting (Aerobic)	**Anaerobic digestion (AD)**	**MBT**	**Landfill**	**Incineration**	**RDF or SRF**	**Pyrolysis**	**Gasification**
6. Capital investment	Low for windrow technique; Medium for in-vessel technique	High	Low	Medium	High	Medium	High	High
7. Operational cost	Medium for windrow technique; High for in-vessel technique	Medium for manual system; High for automated system	Medium	Medium	High	Medium	High	High
8. Land requirement	Medium for windrow technique; Low for in-vessel technique	Low	Medium	High	Low	Low	Low	Low
9. Skill requirement	Technical skills required; Training required specially for in-vessel technique	Technical skills required; Training required	Technical skills required; Training required	Technical skills required; Training required	Technical skills required; Training required	Technical skills required; Training required	Technical skills required; Training required	Technical skills required; Training required
10. Potential adverse impacts	Odor and insect problem	Leakage of methane gas problem	Odor and insect problem	Problems form odor, insect, rodent, methane emission, leachate leakage, limited recovery efficiency of recyclable materials, fire	Pollution from syngas and toxic emission	Uncertain heating value	High energy consumption during operation; Noise and air-pollution	High energy consumption during operation; Noise and air-pollution
11. Contribution to energy security	None	Power generation from biogas	Energy from RDF; Power generation from combustion	Power generation from biogas	Power generation from heat	Energy from RDF	Power generation or use as raw materials of oil-like product	Power generation from heat
12. Contribution to food security	Use as compost for cultivation	Use as compost for cultivation	Use as compost for cultivation	None, high contamination	None	None, high contamination	None	None

Table 3.2 Impact and influence of criteria on SWM operation and utilization methods

Utilization techniques / Criteria	T1 (Composting)		T2 (Anaerobic digestion)		T3 (MBT)		T4 (Landfill)		T5 (Incineration)		T6 (RDF or SRF)		T7 (Pyrolysis)		T8 (Gasification)	
	Details		Details		Details		Details		Details		Details		Details		Details	
(1) Solid characteristics - Organic or biodegradable	H	Contamination concern	H	Contamination concern	H	Contamination concern	M	Contamination concern, Should be sorted out	L	Should be sorted out	M	Should be separately sorted, contamination/pollution/moisture concerns	L	Should be sorted out	L	Should be sorted out
- Recyclable	L	Should be sorted out	L	Should be sorted out	M	Contamination concern, should be sorted out	L	Contamination concern, Should be sorted out	M	Should be sorted out	M	Should be separately sorted, suitable for only some types, contamination/pollution/moisture concerns	H	Suitable for only some types, contamination and pollution concerns	H	Suitable for only some types, contamination and pollution concerns
- Commingled waste	L	Further treatment required	L	Further treatment required	L	Further treatment required	M	Contamination concern	M	Pollution concern	L	Further treatment required	L	Should be sorted out	L	Should be sorted out
(2) Waste quantity - Small amount (household or small community levels)	H	Depends on size of facility, consistent feedstock amount	M	Depends on size of facility, consistent feedstock amount	M	Depends on size of facility, consistent feedstock amount	H	Acceptable	L	Not suitable for very small amount of waste	L	Not suitable for very small amount of waste	L	Not suitable for very small amount of waste	L	Not suitable for very small amount of waste

Utilization techniques	T1 (Composting)		T2 (Anaerobic digestion)		T3 (MBT)		T4 (Landfill)		T5 (Incineration)		T6 (RDF or SRF)		T7 (Pyrolysis)		T8 (Gasification)	
- Medium amount (medium to large community levels)	H	Depends on size of facility, consistent feedstock amount	H	Depends on size of facility, consistent feedstock amount	H	Depends on size of facility, consistent feedstock amount	H	Acceptable with limited time	H	Depends on size of facility, consistent feedstock amount	H	Depends on size of facility, consistent feedstock amount	H	Depends on size of facility, consistent feedstock amount	H	Depends on size of facility, consistent feedstock amount
- Large amount (large community to city levels)	H	Depends on size of facility, consistent feedstock amount	H	Depends on size of facility, consistent feedstock amount	H	Depends on size of facility, consistent feedstock amount	H	Acceptable with limited time	H	Depends on size of facility, consistent feedstock amount	H	Depends on size of facility, consistent feedstock amount	H	Depends on size of facility, consistent feedstock amount	H	Depends on size of facility, consistent feedstock amount
(3) Compliance with laws - Local	H	Close monitoring required	H	Close monitoring required	H	Close monitoring required	H	Close monitoring required	H	Close monitoring required	H	Close monitoring required	H	Close monitoring required	H	Close monitoring required
- National	H	Close monitoring required	H	Close monitoring required	H	Close monitoring required	H	Close monitoring required	H	Close monitoring required	H	Close monitoring required	H	Close monitoring required	H	Close monitoring required
(4) Land requirement - Small area	H	Depends on size of facility	M	Depends on size of facility	M	Depends on size of facility	L	Require extensive area	H	Depends on size of facility	M	Depends on size of facility	M	Depends on size of facility	M	Depends on size of facility
- Large area	H		H		H		H		H		H		H		H	
(5) Multisector involvement - Community	H	Source separation	H	Source separation	M	Source separation	M	Source separation	L	Source separation	M	Source separation	L	Source separation	L	Source separation

Utilization techniques	T1 (Composting)		T2 (Anaerobic digestion)		T3 (MBT)		T4 (Landfill)		T5 (Incineration)		T6 (RDF or SRF)		T7 (Pyrolysis)		T8 (Gasification)	
- Private company	H	Partner or sole operator	H	Partner or sole operator	H	Partner or sole operator	H	Partner or sole operator	H	Partner or sole operator	H	Partner or sole operator	H	Partner or sole operator	H	Partner or sole operator
(6) Public acceptability	M	Close monitoring required	M	Close monitoring required	M	Close monitoring required	L	Low acceptability	L	Low acceptability	M	Close monitoring required	M	Close monitoring required	M	Close monitoring required
(7) Possible adverse impacts - Environment	M	Close monitoring required	M	Close monitoring required	M	Close monitoring required	H	Close monitoring required	M	Close monitoring required	M	Close monitoring required	M	Close monitoring required	M	Close monitoring required
- Society	M	Close monitoring required	M	Close monitoring required	M	Close monitoring required	H	Close monitoring required	M	Close monitoring required	M	Close monitoring required	M	Close monitoring required	M	Close monitoring required
- Economy	L		M	Close monitoring required	M	Close monitoring required	H	Close monitoring required	H	Close monitoring required	H	Close monitoring required	H	Close monitoring required	H	Close monitoring required
(8) Demand for final products	H	Close monitoring of product quality required	H	Close monitoring of product quality required	M	Close monitoring of product quality required	L	There is demand if biogas technique is applied but with close monitoring system	M	Demand if energy generation technique is applied but with close monitoring system	M	Close monitoring of product quality required	H	Close monitoring of product quality required	H	Close monitoring of product quality required

Utilization techniques	T1 (Composting)		T2 (Anaerobic digestion)		T3 (MBT)		T4 (Landfill)		T5 (Incineration)		T6 (RDF or SRF)		T7 (Pyrolysis)		T8 (Gasification)	
(9) Initial investment	L 🟢	Depends on size of facility	L 🟢	Depends on size of facility	M 🟡	Depends on size of facility	M 🟡	Depends on size of facility	H 🔴	Depends on size of facility	M 🟡	Depends on size of facility	H 🔴	Depends on size of facility	H 🔴	Depends on size of facility
(10) Operating cost	L 🟢	Depends on size of facility	L 🟢	Depends on size of facility	M 🟡	Depends on size of facility	M 🟡	Depends on size of facility	H 🔴	Depends on size of facility	M 🟡	Depends on size of facility	H 🔴	Depends on size of facility	H 🔴	Depends on size of facility
(11) Time consuming for entire process	M 🟡	Depends on quantity waste	M 🟡	Depends on quantity waste	M 🟡	Depends on quantity waste	H 🔴	Depends on quantity waste	L 🟢	Depends on quantity waste	L 🟢	Depends on quantity waste	L 🟢	Depends on quantity waste	L 🟢	Depends on quantity waste
(12) Complexity and required skills	L 🟢	Depends on quantity of waste and system of facility	M 🟡	Depends on quantity of waste and system of facility	M 🟡	Depends on quantity of waste and system of facility	M 🟡	Depends on quantity of waste and system of facility	H 🔴	Depends on quantity of waste and system of facility	M 🟡	Depends on quantity of waste and system of facility	H 🔴	Depends on quantity of waste and system of facility	H 🔴	Depends on quantity of waste and system of facility

Waste utilization techniques: T1 = composting, T2 = AD, T3 = MBT, T4 = sanitary landfill, T5 = Incineration, T6 = RDF, T7 = Pyrolysis, T8 = Gasification

Level of impact of each criterion: L = Low, M = Medium, H = High

Influence of impact of each criterion: 🟢 *= Positive,* 🟡 *= Neutral,* 🔴 *= Negative*

Level of impact and influence of the impact on each criteria is determined specifically on how each operation or utilization technique impacts on the specified criteria. For example, explaining the relationships of T1 (Composting technique) and organic waste, and between T1 and recyclable waste. It can be seen from the Table that composting technique has high impact with positive influence on organic waste. This is because organic or biodegradable waste is suitable to get treated by composting method. However, comparing to recyclable waste is not suitable with composting method but can be appropriately treated by T7 (Pyrolysis technique) and T8 (Gasification technique).

With the same 12 criteria and eight operation/utilization techniques presented in Table 2, impact and influence of each criteria is transcribed into numbers, which the score of each criteria ranges from '3' (positive influence), '2' (neutral or indifferent influence), to '1' (negative influence).

In other words, changing from qualitative data shown in Table 3.2 (represented as colors and levels of impact), Table 3.3 presents the same information but in quantitative perspective. This helps local authorities or waste management practitioners can easily identify the appropriate waste utilization methods that suit waste management situation in their city.

To practically apply in real situation, Table 3.4 presents an example of how Tables 3.1 to 3.3 work as a basic decision making tool. Giving a scenario that, there is a small community located in a small valley that has waste generation rate per capita of 0.7 kg/day, with a total population of 500 people. The majority of generated waste is 70% organic waste. The community is located in the agricultural area where most of the population are farmers.

By incorporating all information from Tables 3.1 to 3.3, scoring those waste related criteria given in the scenario with regard to the quantified levels of influence (3, 2, and 1) helps responsible waste management authorities learn the potential waste operation/utilization techniques.

Table 3.3 Example of simplified table of impact and influence of criteria on SWM operation and utilization methods

Criteria	**T1**	**T2**	**T3**	**T4**	**T5**	**T6**	**T7**	**T8**
(1) Solid characteristics								
- Organic or biodegradable	3	3	3	2	1	2	1	1
- Recyclable	1	1	2	1	2	2	3	3
- Commingled waste	1	1	1	2	2	1	1	1
(2) Waste quantity								
- Small amount (household or small community levels)	3	2	2	3	1	1	1	1
- Medium amount (medium to large community levels)	3	3	3	3	3	3	3	3
- Large amount (large community to city levels)	3	3	3	3	3	3	3	3
(3) Compliance with laws								
- Local	3	3	3	3	3	3	3	3
- National	3	3	3	3	3	3	3	3
(4) Land requirement								
- Small area	3	2	2	1	3	2	2	2
- Large area	3	3	3	3	3	3	3	3
(5) Multisector involvement								
- Community	3	3	2	2	1	2	1	1
- Private company	3	3	3	3	3	3	3	3
(6) Public acceptability	2	2	2	1	1	2	2	2
(7) Possible adverse impacts								
- Environment	2	2	2	1	2	2	2	2
- Society	2	2	2	1	2	2	2	2
- Economy	3	2	2	1	1	1	1	1
(8) Demand for final products	3	3	2	1	3	2	3	3
(9) Initial investment	3	3	2	2	1	2	1	1
(10) Operating cost	3	3	2	2	1	2	1	1
(11) Time consuming for entire process	2	2	2	1	3	3	3	3
(12) Complexity and required skills	3	2	2	3	1	2	1	1
Total score for each waste utilization technique	**55**	**51**	**48**	**42**	**43**	**46**	**43**	**43**

Waste utilization techniques: T1 = composting, T2 = AD, T3 = MBT, T4 = sanitary landfill, T5 = Incineration, T6 = RDF, T7 = Pyrolysis, T8 = Gasification

Influence of impact of each criterion: 3 = Positive, 2 = Neutral, 1 = Negative

Table 3.4 Example scenario to evaluate SWM operation and utilization methods

Criteria	**T1**	**T2**	**T3**	**T4**	**T5**	**T6**	**T7**	**T8**
(1) Solid waste characteristics								
- Organic or biodegradable	3	3	3					
- Recyclable	1	1	2					
- Commingled waste	1	1	1					
(2) Waste quantity								
- Small amount (household or small community levels)	3	2	2	3	1	1	1	1
- Medium amount (medium to large community levels)								
- Large amount (large community to city levels)								
(3) Compliance with laws								
- Local	3	3	3	3	3	3	3	3
- National	3	3	3	3	3	3	3	3
(4) Land requirement								
- Small area	3	2	2	1	3	2	2	2
- Large area								
(5) Multisector involvement								
- Community	3	3	2	2	1	2	1	1
- Private company	3	3	3	3	3	3	3	3
(6) Public acceptability	2	2	2	1	1	2	2	2
(7) Possible adverse impacts								
- Environment	2	2	2	1	2	2	2	2
- Society	2	2	2	1	2	2	2	2
- Economy	3	2	2	1	1	1	1	1
(8) Demand for final products	3	3	2	1	2	2	3	3
(9) Initial investment	3	3	2	2	1	2	1	1
(10) Operating cost	3	3	2	2	1	2	1	1
(11) Time consuming for entire process	2	2	2	1	3	3	3	3
(12) Complexity and required skills	3	2	2	2	1	2	1	1
Total score for each waste utilization technique	**46**	**42**	**39**	**27**	**28**	**32**	**29**	**29**

Waste utilization techniques: T1 = composting, T2 = AD, T3 = MBT, T4 = sanitary landfill, T5 = Incineration, T6 = RDF, T7 = Pyrolysis, T8 = Gasification

Influence of impact of each criterion: 5 = Positive, 3 = Neutral, 1 = Negative

As presented in Table 3.4, composting (T1) is the most possibly applicable waste utilization method for this community, follow by T2 (Anaerobic digestion) and T3 (MBT), respectively.

However, it is useful to be noted that the levels of impact and influence presented in Tables 3.1 to 3.3 are assigned in the context of waste management situation in developing countries. The effectiveness of SWM system of each community depends on different factors that are dynamic over time.

Therefore, to ensure the effectiveness and efficiency of SWM system, it is substantially imperative for responsible authorities and related stakeholders to collaborate and take all important factors into consideration before deciding which waste management criteria, operation/utilization techniques, and scoring should be used. The example of techniques and assessment methods in the given scenario can only be applied as a basic guideline of selecting appropriate SWM operation/utilization techniques.

REFERENCE

[1] Sharp, A. and Sang-Arun, J., 2012. A Guide for Sustainable Urban Organic Waste Management in Thailand: Combining Food, Energy, and Climate Co-Benefits, IGES Policy Report 2012-02, ISBN: 978-4-88788-088-7.

CHAPTER 4: WASTE MANAGEMENT IN BHUTAN AND VIETNAM

4.1 Baseline Information of Bhutan

4.1.1 General Information of the Country

Bhutan is a small landlocked nation located in eastern Himalayas, bordered by India in the east, south and west and by China in the north. With a total land area of 38,394 km^2. The country is entirely mountainous rising from southern foothills of 160 m above sea level to over 7,500 m high peaks in the north [1]. The country's population in 2014 was 745,153 [2]. A map indicating the location of Bhutan in Southeast Asia is shown in Figure 4.1.

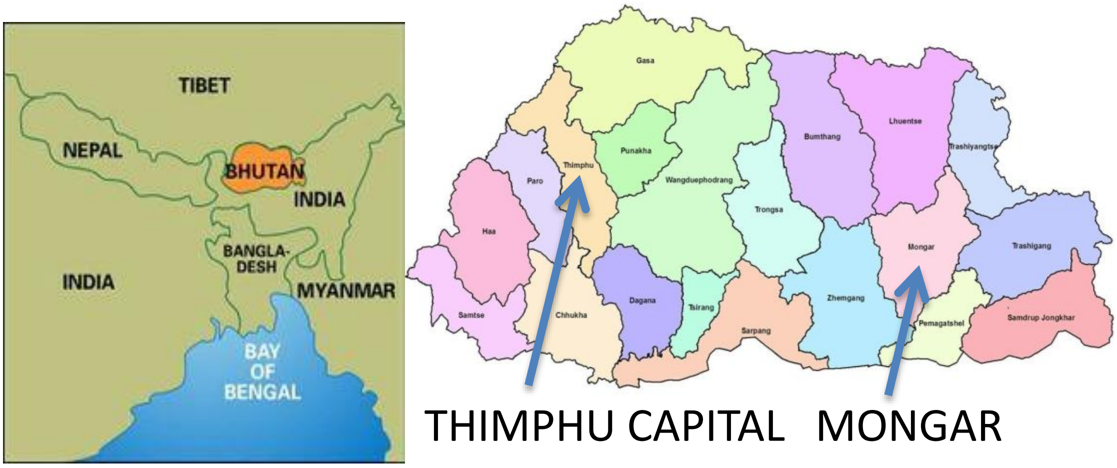

Figure 4.1 Map showing the location of Bhutan in Southeast Asia

Ever since Bhutan emerged out of a self-imposed isolation and initiated the five-year plans for its developmental activities, the national GDP growth rate increased from approximately 5% in 1998 to more than 8% in 2004. The revenue generation from hydropower electricity export and agriculture subsistence farming contributes significantly to the national GDP. The completion and commissioning of the 1,020 MW Tala Hydroelectric Power Station in 2006 also substantially elevated Bhutan's GDP. In 2013, Bhutan's gross domestic product per capita was US$ 2,440 [3]. Unfortunately, this unprecedented socio-economic achievement is accompanied by adverse impacts on natural resources and the environment.

With population concentration in the urban areas and changes in consumption pattern driven by economic gains, various social services management challenges have surfaced lately. Escalation of solid waste generation especially in urban areas has emerged as one of the serious challenges, lately, to the Royal Government of Bhutan (RGoB). The RGoB, over the past years has been researching for options and opportunities to tackle this challenge. However, high demand of resources and management expertise coupled with mere technological capacity limits the chances to improve the deteriorating situation. The fragile mountain ecosystem adds to the limitation of finding and developing landfill sites. To date, public participation in the waste management system has not been strong. The waste quantity generated may not be alarming compared to the waste quantities in other countries, but for the population size and urbanization system in a steep mountain terrain, it has become a serious concern.

The prudent management of SWM is therefore paramount in providing a safe and healthy environment for the people living in these urban areas. To plan and to provide an efficient and effective SWM, the need for reliable baseline data on the current state of affairs is vital.

This baseline information, therefore, reflects the present SWM situation in the Mongar town, Mongar district in the eastern Bhutan. It also examines the institutional and financial arrangements of the waste management agencies. In addition, it leads to the conclusion on gaps, challenges and opportunities of enhancing SWM system.

4.1.2 General Information of the Selected City, Mongar Town

Mongar District (Figure 4.2), which covers both the Mongar and Gyelposhing towns amongst others, is located in the eastern Bhutan at 27°25’ N latitude and 91° 2’E longitude (Mongar Dzongkhag, 2014). The total area covered by this district is 1,940.26 sq.km, with altitudes ranging from 400m to 4000m above mean sea level [4]. Therefore, the lower and southern parts are sub-tropical while northern and higher regions have temperate climatic conditions. Summer can be hot and humid and winter cold. Mongar town lies in between the sub-tropical and temperate climatic zones while Gyelposhing town is located in the sub-tropical part of the district.

The average temperature in 2017 ranged from 15°C to 30°C with a maximum of 26°C and a minimum of 8.2°C recorded for Mongar district [5]. A total of 1000mm of rainfall is common, and 7,800mm per year has been registered at some locations in humid, subtropical south, ensuring the thick tropical forest. (Tourism Council of Bhutan, 2017) with most of the rain falling from June to September.

Mongar district’s population is 35,534 calculated in year 2016[6]. The detailed breakdown of the population of Mongar district is given in Table 4.1.

Figure 4.2 Map of Mongar district showing Mongar town (Mongar Dzongkhag, 2014)

The town of Mongar had a population of 2757. The average population growth rate is estimated at 1.7% for whole of Monger District.

Table 4.1 Detailed breakdown of population of Mongar district in 2016 [7]

MONGAR DISTRICT	Total Population (2016)
Balam	955
Chali	1253
Chaskhar	2382
Dramitshi	2699
Drepong	952
Gongdu	769
Jurmi	1206
Khengkhar	1847
Mongar gewog	2757
Natshang	745
Saling	284
Shermung	1095
Selimbi	464
Thangrong	1759
Tshakaling	1135
Tshamang	530
Dramitshi town	2699
Mongar town	2757
Total	**35534**

Mongar town is divided into six zones for the purpose of administration and management of the municipal area (Figure 4.3). These six zones are:

1. Town area (commercial)
2. Trailling area
3. Hospital area
4. Naling area
5. Kadam area
6. Changshingpeg area

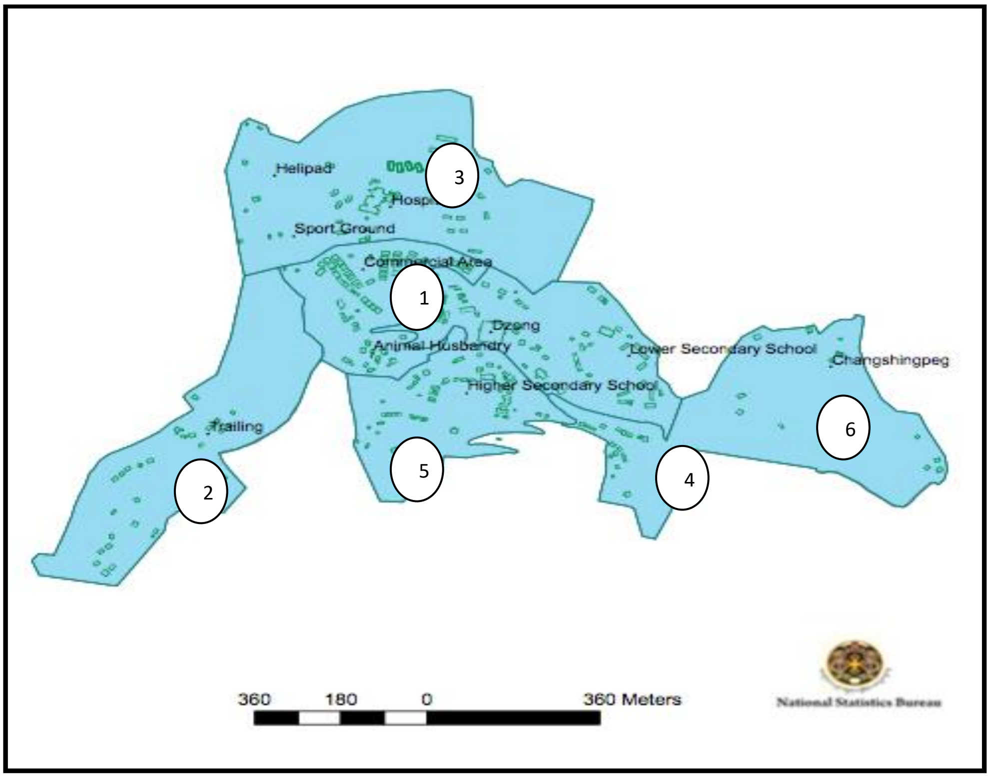

Figure 4.3 Map of Mongar town showing the six different zones

4.1.3 Solid Waste Management Baseline Data of the City

For planning, design and implementation of an effective and efficient solid waste management, reliable, robust long-term data on solid waste generation and composition is essential [8-9]. The Mongar municipality therefore conducted a comprehensive survey on the waste generation and composition in the two towns of Mongar and Gyelposhing in May 2015. The data collection was undertaken for a week.

4.1.3.1 Municipal solid waste generation and composition

A. Municipal solid waste generation

Mongar town generates a total of 0.95 tonnes of solid waste per day with a waste generation rate of 0.23 kg/person/day. A study of ten urban centers in Bhutan found that the per capita waste generation of Mongar town was around 0.28 kg/person/day in 2008 [8]. The present waste generation rate is therefore slightly lower than the one found in 2008.

B. Municipal solid waste composition

The results of waste composition undertaken in May for the two towns are shown in Figure 4.4.

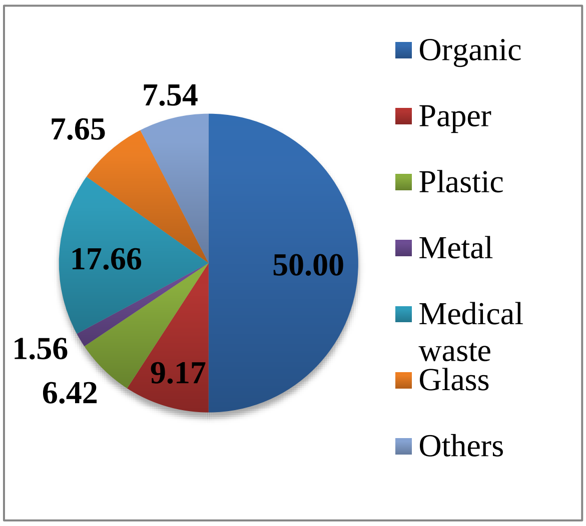

Figure 4.4 Waste composition for Mongar town expressed in %

It can be seen from the results that organic waste contributes at least 50% of the total waste generated in Mongar Town. The percentage of medical waste generated in Mongar is high as the hospital located nearby town is the Mongar Eastern Region Referral Hospital. From six eastern districts, all referral case are referred to Mongar hospital. These contribute to high medical waste generation. Except for the percentage of medical waste generated in Mongar town, the contribution of other components of waste such as paper, plastic, metals and glass are in the range of 6 -9 %. The remaining waste, categorized, as 'others' comprises of rubber, wood and textiles made up 7.54% in Mongar.

4.1.3.2 Municipal solid waste management system

A. Waste collection and transportation

The waste collection system in Mongar town consists of 2 refuse collector trucks, which moves around the municipality area collecting waste from different areas. The two waste collector trucks are solely responsible for waste collection in Mongar town. The efficiency and effectiveness of the collection of waste in Mongar town is therefore to a large extent dependent on the reliability of these two waste collector trucks.

At present, the Mongar municipality employs two types of waste collection methods:

I. **Door to door collection**: Households dump their waste in the municipal truck, which moves from door to door of the residents.

II. **Community waste collection**: Community waste bins are located in certain parts of the town, where local residents can dispose their waste. The municipality later empties these community bins.

The schedule of the collection of solid waste in Mongar town is reflected below in Table 4.2.

Table 4.2 Schedule of solid waste collection in Mongar town

No.	Day of the Week	Area of collection services offered
1	Mondays	Town (commercial area), Two schools
2	Tuesdays	Kadam, Trailing, Changshingpeg (residential areas), hospital areas
3	Wednesdays	Town (commercial area), Naling (residential areas)
4	Thursdays	Trailing, Changshingpeg (residential area), hospital areas
5	Fridays	Town (residential area)

Most of the waste collected from Mongar town is currently in the mixed form as very minimal segregation takes place at the source of waste generation. The waste collected is then transported to a landfill site located in Gyelposhing, 30 km away from Mongar town. The previous landfill site was closed as it attracted a lot of public complaints and criticisms of foul odour in its vicinity. A new landfill is currently at the design stage, identified about 7 km from Mongar town. This is expected to decrease the cost of transporting the solid waste from Mongar town. At the Gyelposhing landfill, a private firm "We-Care" waste management employs 2 workers to segregate the recyclable wastes, from the mixed waste being deposited by the Mongar municipality.

The frequency of the collection services in the town of Mongar is shown in Table 4.3. As seen in the table, 705 residential area is inclusive of commercial area. Collection frequency is thrice a week in commeriacl areas followed by twice a week in residential areas and Hospital areas.

Table 4.3 Frequency of solid waste collection in Mongar town

	Residential areas	Commercial areas	Industrial areas	Schools	Hospital
No of Establishments	705	271	9	3	1
Frequency	2 times/week	3 times/week	None	Once/ week	2 times/ week

In Mongar town, the presence of informal sector or people collecting recyclables from people's door is increasing. The informal sector pay people more than what is paid by the formal sector, thereby providing strong competition to private companies such as "We Care".

B. Waste treatment and disposal

- *Composting by household*

In Mongar town, some of the households compost their organic wastes, which is used in their garden. Among the six zones under the town area, household that carry out such activity mainly resides in the residential area of Trailing and Changshingpeg.

The remaining organic waste generated from the residential and commercial areas in Mongar town, is disposed in the landfill in the absence of a composting plant in Mongar town.

- *Residential sector*

Due to the lack of awareness among the public, few commercial establishments and residents carry out waste segregation at source in Mongar town. The valuable recyclables are either sold to informal waste collectors or to "We Care", who then transport to the neighboring Indian town of Jaigaon in West Bengal, where the recyclables are sold.

- *Commercial sector*

In Mongar town, there are a total of 271 commercial establishments that includes mainly hotels, restaurants and shops. This commercial sector is the major producer of waste in the town. The municipal waste generated by the hotels and restaurants, in particular consists of a large amount of organic waste compared to the waste generated by the residential sector.

Currently, in Mongar town, the organic waste from some of these commercial establishments are given free of cost to farmers who have animal farms. The rest of the organic waste is disposed in landfill. At least one fourth of the commercial establishments in Mongar town separate the recyclables from other wastes, which are sold to the informal waste sector and We Care. Rest of the commercial establishments does not undertake any segregation and therefore both recyclables and non-recyclables are dumped in the municipality waste collector trucks, which finally disposes in the landfill at Gyelposhing.

- *Hospital*

The biggest hospital in eastern Bhutan with a capacity of 150 patients is located in Mongar town. Although there is no incinerator for the treatment and disposal of medical wastes from the hospital, it is autoclaved before being disposed together with waste from Mongar town. Therefore, the medical waste is also currently disposed in the same landfill at Gyelposhing. The hospital also generates other waste which includes food waste, dry waste, and recyclable waste.

- *Industrial sector*

Dzongkhag Administration Mongar have allocated a separate area for industries in lower Trailing that include small scale industries such as furniture production, timber saw mills, motor vehicle workshop, recycling unit, incense production unit and steel fabrication. The land on which these industries are located falls under the municipality, which is leased to the industries who have to pay land tax annually. The waste generated from the industrial area is not treated and the effluent waste from the motor vehicle workshops is released into the environment without treating it. The furniture production unit and timber saw mill waste consists of sawdust and other wood waste, which is used as firewood by people.

- *Schools*

The Mongar lower secondary school under Mongar Municipality carry out segregation of recyclables while the Mongar higher secondary school undertake composting and segregation of recyclable. Both these schools have nature clubs that lead and carry out these activities. The members join together and collect the recyclables from the school premises as well as the students bring the recyclable to schools from their home. The recyclables are sold to "We Care" Waste Management. In the higher school, the organic waste generated by the school kitchen is composted and the compost is used in the school agriculture garden.

At the Gyelposhing landfill, "We Care" employs a small team of unskilled people, who manually segregate the waste into plastics, metals, papers, bottles and other recyclables (Figure 4.5).

Figure 4.5 Waste segregation at landfill site in Gyelposhing undertaken by We Care Waste Management

4.1.4 Regulatory, Institutional and Financial Arrangements

4.1.4.1 Regulatory framework

The National Environment Protection Act of Bhutan 2007 outlines the fundamental duty of every individual to protect the environment. The principles of reduce, reuse and recycle (3Rs) and the principle of polluter pays are discussed although solid waste management is not mentioned specifically in the Act.

The regulatory framework for managing solid waste management in the country received a legal backing with the adoption of the Waste Management and Prevention Act 2009. This act, which repealed the Bhutan Municipal Act 1999, covers all kinds of wastes, both hazardous and non hazardous waste. The act propagates the need to reduce wastes, promote segregation, reuse and recycle waste and dispose the waste through the polluter pays principle and 3Rs. Different agencies have been entrusted with the management of different wastes. The key goals of the Waste Prevention and Management Act 2009 are to protect and sustain human health through protection of the environment by:

- Reducing the generation of waste at source,
- Promoting segregation, reuse and recycling of wastes,
- Disposal of waste in an environmentally sound manner, and
- Effective functioning and coordination among implementing agencies.

The Waste Prevention and Management Regulation (2012) was formulated to enforce the Waste Management and Prevention Act. It came into effect on 18 April 2012. This is a comprehensive regulation for waste minimization and management. It establishes various agencies and monitoring authorities for effective implementation of the regulation. The National Environment Commission (NEC) is the apex monitoring body under this regulation, which shall coordinate and monitor the overall performance of implementing agencies designated to efficiently implement the provisions of this regulation.

The Waste Prevention and Management Regulation (2012) classifies wastes into four categories for the purpose of clearly demarcating the roles of the implementing agencies under respective waste categories for effective waste management. These categories are:

I. Medical Wastes Management

The Ministry of Health and Ministry of Agriculture and Forests shall monitor the implementing agencies, which include health clinics, hospitals, BHUs, Department of Livestock, Bhutan Narcotic Control Agency and Drug Regulatory Authority.

Medical wastes under this regulation are classified into categories of general waste, pathological waste, infectious waste, sharps, pharmaceutical waste, chemical waste, radioactive waste and pressurized containers.

II. Municipal Waste Management

The Ministry of Works & Human Settlement shall be the responsible agency for monitoring and implementation within the jurisdiction of Thromdes (municipalities) with the help of municipal offices of the Thromdes and Dzongkhags (districts) as implementing agencies.

III. Industrial Waste management

The Ministry of Economic Affairs in cooperation with other related agencies shall monitor the implementing agencies.

IV. E-Waste Management

E-waste management shall be implemented by Thromdes (municipalities), Dzongkhags (districts), Gewogs (blocks) and Chiwogs (sub-blocks) with overall directives and guidelines from the Department of Information Technology. This section lays down detailed provisions for very producer, importer, exporter, consumer or bulk consumer for the management and handling of e-waste.

4.1.4.2 Organizational set up

The Engineering Sector under Mongar District Administration is mandated to carry out/ implement various capital works related to provision of rural infrastructures and of urban facilities/ amenities such as water supply, sewerage, roads, drainages, buildings, footpaths, streetlights, other infrastructures apart from operating and maintaining the existing facilities/ systems. The municipal in-charge reports to the District Engineer, who reports directly to the Governor (Figure 4.6).

From a total of 63 staff in the engineering section, there are three municipal engineers, one building inspector, three technicians, three operators and six drivers who look after the various municipal services provided to the residents of Mongar town. These services amongst others include drinking water supply, sewerage and solid waste management, operation and maintenance of street lighting facilities etc.

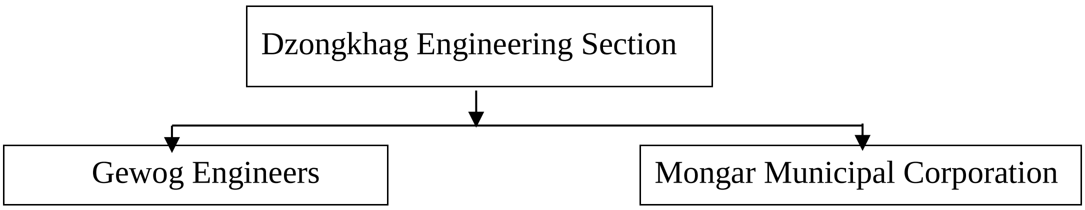

Figure 4.6: Organogram of the Municipality under Mongar District

4.1.4.3 Financial resources

Mongar Municipality is responsible for the management of solid waste in Mongar town. The Sanitation Division under the Engineering Sector of the Mongar District Administration is entrusted with this mandate. This division studies the expenditure for the past one year, after which it then proposes to the Ministry of Work and Human Settlement for next year's fund for the municipal activities. This fund covers expenditure for fuel, drivers' pay and maintenance of solid waste collection vehicles. Casual workers such as town sweepers, drain cleaners and waste collectors are met from a Current & Deposit (CD) account. This CD account receives money from various services provided by the municipality that includes water supply and solid waste management, rental income from public hostel, canteens and the vegetable market. The Table 4.4 shows the monthly source of income for the municipality.

Table 4.7 Monthly income of the Mongar Municipality

No.	Particulars	Monthly charge	Amount
1.	Water meter rent (220)	20	4,400
2.	Solid waste management fees (220)	5	1,100
3.	Rental income from public Hostel (1)	13,333	13,333
4.	Rental income from park canteen (1)	7,999	7,999
5.	Other rental income (3)	3,000	9,000
6.	Vegetable market (23)	500	11,500
Total income			**Nu.47,332**

Source: Mongar Municipality, 2016.

Therefore, the total annual income for the Mongar municipality is Nu 567,984 (1USD ~ 63 Nu). The Mongar municipality however, spends a total of Nu 967,518 on solid waste management annually. The details of the expenditure spent on solid waste management in Mongar town are reflected in Table 4.5.

Table 4.5 Expenditure of solid waste management for Mongar town

No.	Particulars	Amount (Nu)	
1.	Collection of municipal solid waste	708,000	Payment for drivers and labour
2.	Transportation and maintenance	79,518	For the two refuse trucks
3.	Vehicle fuel	180,000	
Total		**967,518**	

Source: Mongar Municipality, 2016.

4.1.5 Challenges and Opportunities

4.1.5.1 Limited waste segregation at source

Due to low level of awareness among the public, waste segregation is a big challenge. As such, most of the municipal waste is currently not separated at source. Further, absence of different bins for residents to store the recyclable waste and organic waste also hinders waste segregation. Although Mongar municipality has different colour coded waste bins for sale to the public, due to the high cost of these bins (about Nu.2500 ~ 40 USD), people have been reluctant to purchase and use these bins.

This limited segregation could also be because when the municipal trucks collect the waste, both the recyclable wastes and organic waste are dumped together in the truck, which may have discouraged people from segregating the waste.

4.1.5.2 Lack of resources

Inadequate financial resources, technical skills and appropriate equipment presents a major challenge in initiation of studies, researches, skill development and up-gradation, and enforcement of rules and regulation [10].

4.1.5.3 Sustainability of the solid waste management services

The amount of revenue collected from the services provided by the municipality is less than the amount it invests in collection, transportation and disposal of solid wastes. Therefore, the current form of waste management is unsustainable in the long run.

4.1.5.4 Collection problems

A major impediment to achieving successful collection of waste is the lack of roads in some areas, while in other areas; poor condition of the roads makes it inaccessible during rainy season. Inadequate numbers of refuse collection vehicles and lack of adequate manpower also hampers collection efficiency. As a result, only about 80-85% of the waste generated within the municipality is collected daily.

4.1.5.5 Opportunities

The study focused on the following aspects of the SWM as solutions for waste minimization in Mongar District:

- Reduce - raise awareness through education.
- Up Cycle – turn organic waste to valuable fertilizer through composting.
- Recycle – recover resource from landfill through recycling.

A. Reduce – raise awareness through education

This study proposes educational campaigns, seminars, researches and academic involvement as a method for raising awareness and knowledge in SWM for the people of Mongar District. It includes students from various schools and institutes and the nearby community. The list of schools chosen for promoting awareness on waste education is shown in Table 4.6.

Table 4.6 Schools chosen for solid waste awareness programs

No.	Name of school	Location of the school
1	Mongar Higher Secondary School	Mongar town
2	Sherub Reldi Higher Secondary School	Mongar town
3	Mongar Lower Secondary School	Mongar town
4	Gyelposhing Higher Secondary School	Gyelposhing

The schools are chosen based on their grade and strategic location in Mongar town, number of students and the roles they already play in the community SWM.

In order to carry out the awareness campaigns, the project proposes to seek voluntary help and support from teachers and students. These volunteers will help the team conduct campaigns and prepare education materials to raise the awareness. Solid waste awareness campaign may include performing dances, short plays or any other entertainment activities to attract a large number of people.

B. Up cycle – turn organic waste to fertilizers through composting

One of the main methods to ensure the "reuse" of the waste materials is to convert the unwanted materials into a useful product and energy. The waste stream in Mongar and Gyelposhing towns contains at least 50% organic waste. Organic waste in this context refers solely to the food and vegetable waste and do not constitute any agricultural wastes. Thus, the conversion of organic waste to fertilizers through composting appears to be feasible. To establish this system, this project seeks to develop a composting plant to convert the organic waste into fertilizers and thereby minimize the amount of waste deposited in the landfill.

4.2 Baseline Information of Vietnam

4.2.1 General Information of the Country

Vietnam is one of the Southeast Asia's fastest growing economies. Vietnam's economic growth rate has been among the highest in the world. With respect to that, Vietnam has set its sights on becoming a developed nation by 2020[1].

The population of Vietnam was 95,145,114 people (accounted until 22nd, 2017) and that made the country to be the World's 14th most populous country and the 8th most populous Asian country (Institute of Statistical Science, 2017).

Shaped like a long 'S', Vietnam is geographically bordered by China to the north, Laos to the northwest, Cambodia to the southwest, and Malaysia and Thailand across the East sea. It extends 1,650 km from north to south. Its capital city has been Hanoi since the reunification of North and South Vietnam in 1975. A map indicating the location of Vietnam is shown below in Figure 4.7.

[1] http://www.bbc.com/news/world-asia-pacific-16567834

Figure 4.7 Map showing the location of Vietnam [2]

With the rapid growth of population and urbanization that leads to increasing waste generation amount, Vietnam is also a country with no exception. Solid waste is a huge problem and is limited by weak institutional capacity and insufficient human and capital resources in addressing the crisis.

The amount of solid waste generated in Vietnam has been increasing over the last decade. Within a mere 8 years (2007 – 2015), amount of generated municipal solid waste increased from about 17.7 million tonnes to 38.0 million tonnes per day (MONRE, 2016). Accordingly, with strong economic growth and uncontrolled urbanization, the problems related to SWM system have pushed waste management to the forefront of environmental challenges. Therefore, it is necessary to find a suitable approach to sustainably alleviate and enhance SWM in Vietnam

This baseline report, therefore, reflects the present SWM situation in a selected city, Ho Chi Minh City (HCMC) and discusses the existing SWM system.

[2] https://www.cia.gov/library/publications/the-world-factbook/geos/vm.html

4.2.2 General Information of the Selected City, Ho Chi Minh City (HCMC)

Ho Chi Minh City (HCMC) is a center of economic, cultural, education and training. This is an important political position of the country; and this also is an international exchange hub, industrial central, and multi-disciplinary services of the region and South East Asia. The total natural area of HCMC is 2,095 km^2, including 24 districts in which 19 urban districts (District 1, District 2, District 3, District 4, District 5, District 6, District 7, District 8, District 9, District 10, District 11, District 12, Phu Nhuan District, Binh Thanh District, Thu Duc District, Tan Binh District, Tan Phu District, Binh Tan District, and Go Vap District) and 5 rural districts (Hoc Mon District, Binh Chanh District, Nha Be District, Cu Chi District and Can Gio District). Administration map of HCMC is presented in Figure 4.8.

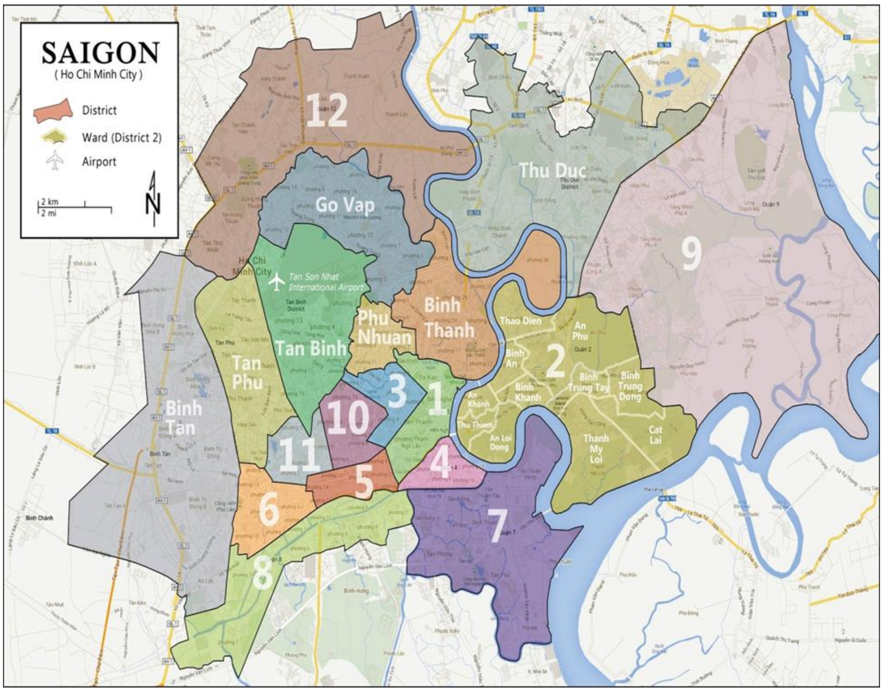

Figure 4.8 Administrative map of HCMC

Population of HCMC increased by 12% from 7.4 million in 2010 to 8.4 million in 2016 (Statistical Office in HCMC, 2010 and 2016). In 2016, the total gross domestic products (GDP) per capita was 5,700 USD, an increase by 73% compared to the value of GDP in 2010 (www. hochiminhcity.gov.vn).

Beside the accelerated economic growth, rapid urbanization and lack of infrastructure, the environmental pollution especially municipal solid waste has become a major concern for HCMC.

4.2.3 Solid Waste Management

4.2.3.1 Central level

The functions, tasks and responsibilities for the ministries and sectors involving the solid waste management are assigned at central level. There are 5 Ministries including Ministry of Construction (MOC), Ministry of Industry and Trade (MOIT), Ministry of Health (MOH), Ministry of Agriculture and Rural Development (MARD) and Ministry of Natural Resources and Environment (MONRE) responsible for direct participation in solid waste management.

4.2.3.2 Local level

Department of Natural Resources and Environment (DONRE) plays an important role in waste management, environmental quality observation, management and implementation of the policies and regulations on waste management issued by MONRE and Provincial People's Committee (PPC) of HCMC. Structure of HCMC Department of Natural Resources & Environment (DONRE) is shown in the Figure 4.9. With the organization structure presented in Figure 4.9, structure of solid waste management is shown in Figure 4.10.

Actually, the coordinating activities between the state management organizations in the environment field are limited. That is why the policy management operations have low efficiency, inspection and supervision operations are overlapped. The coordination between authorized departments and agencies is not strong leading to inefficient human resources.

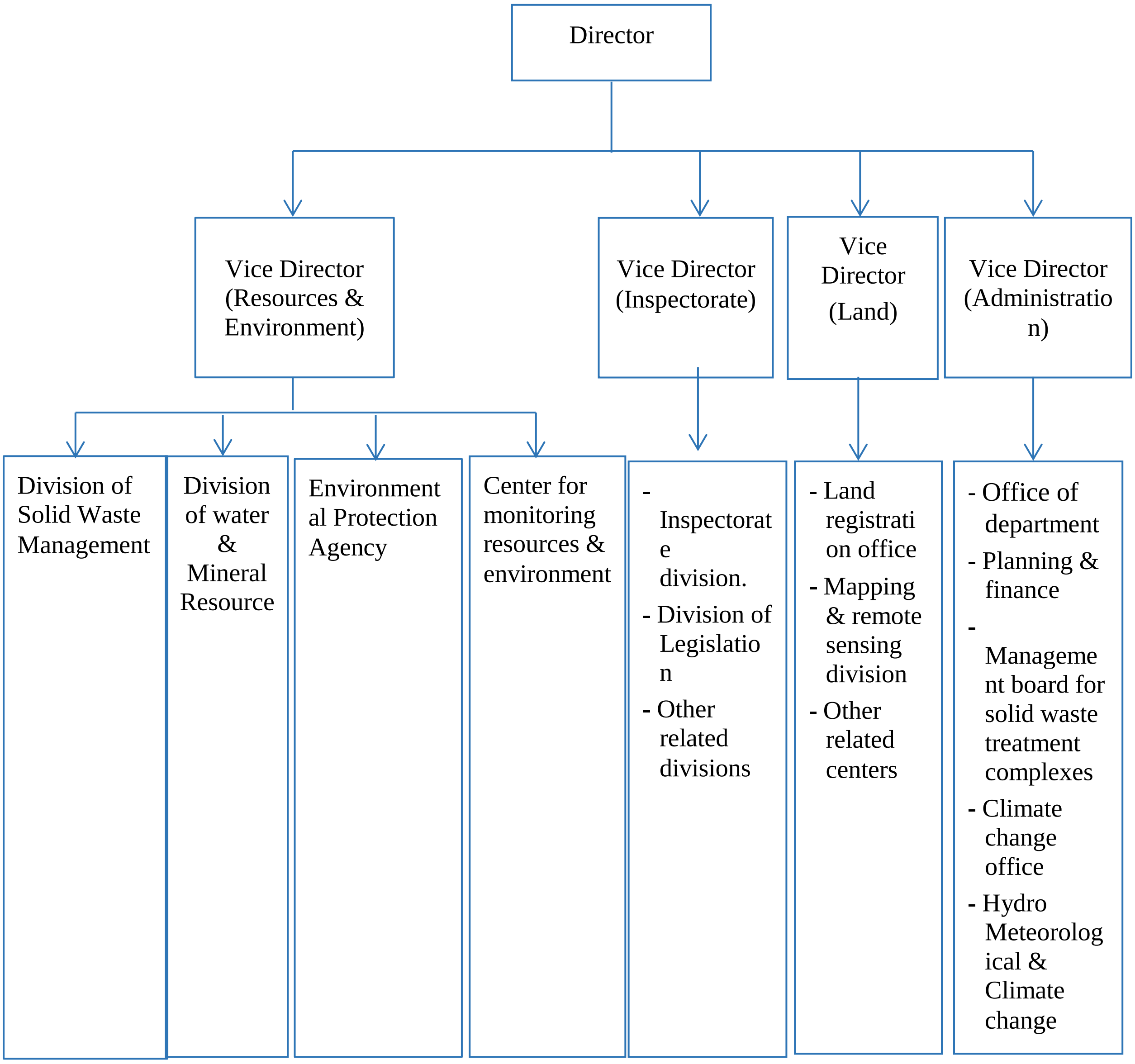

Figure 4.9 Organization chart of HCMC Department of Natural Resources & Environment (DONRE)

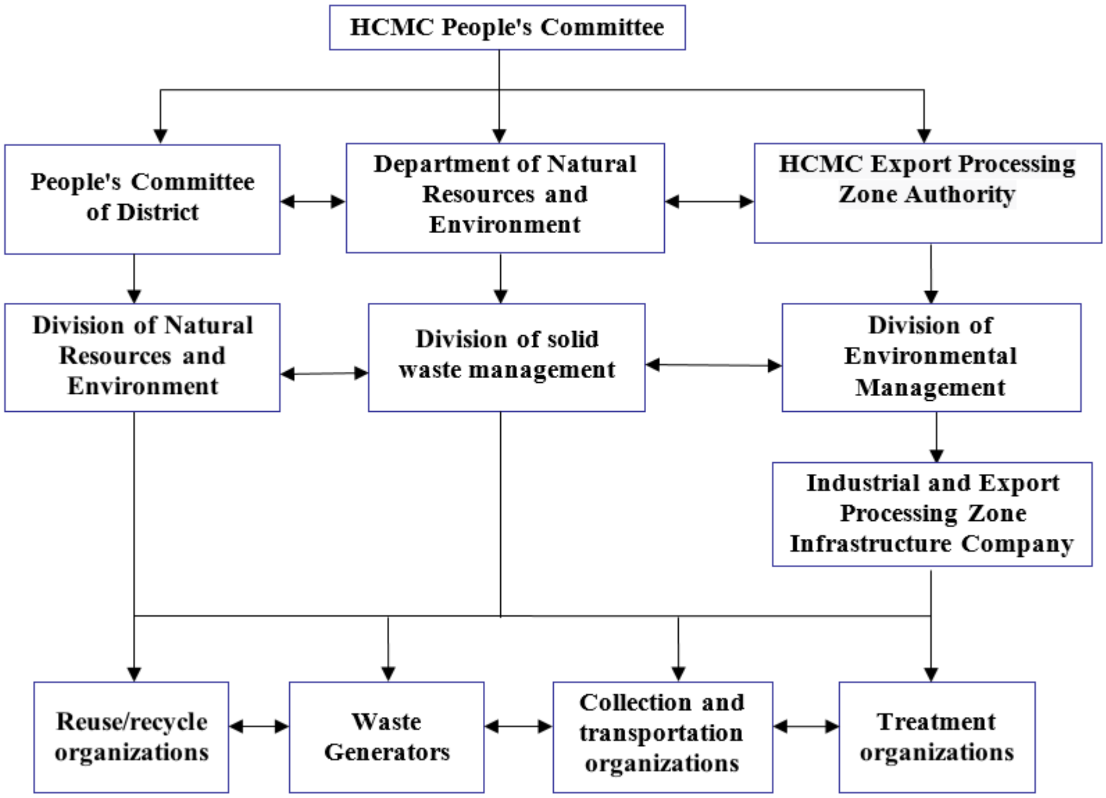

Figure 4.10 Structure of state management system in solid waste management at HCMC

4.2.3.3 State management functions

To perform state management functions in solid waste management at HCM city, division of solid waste management has function in two main fields: (1) policy management and (2) operation management.

A. *Policy management*

Policy management of the division includes: instructing performing legal text of Government; consulting and proposing for HCMC People's Committee in publishing legal text that is under authority of city and department to serve for state management in solid waste management at HCM city.

In detail, works of division of solid waste management includes:

- Strategy of solid waste management
- Arrangement of solid waste management
- Formulate legal texts
- Formulate and perform solid waste management programs

B. *Operation management*

Operation management is monitored, checked and solved breaches relating to environment protection law. To perform the function division of solid waste management is executing the following works:

- Monitor and solve problem relating to solid waste management system at 24 district of HCMC
- License to waste generator and organization of transportation and treatment in hazardous waste field, following ISO process
- Check and monitor system of collection, transportation, treatment and disposal in solid waste field
- Report problem relating to solid waste and suggest measures to leader of DONRE
- Appraise and submit HCMC people's committee policy and plan of solid waste treatment project at HCMC
- Combine with related organization to check and inspect executing waste management regulations

4.2.3.4 Institution and policy on solid waste management

The legal documents on solid waste management issued and became effective include:

- The solid waste management has received the attention of the Communist Party and State through the legal regulations and provisions on solid waste management of Environment Protection Law (2014) (No. 55/2014/QH13 dated June 23, 2014 of The National Assembly on Environmental Protection).
- Decree No.155/2016/ND-CP dated November 18, 2016 of the Government on sanction of administrative violations in the field of environmental protection.
- Decree No. 38/2015/ND-CP dated 24/4/2015 of The Government on wastes and scraps management, in which mentioned regulations and responsibilities of generators, collectors, transporters and treatment companies for domestic solid waste and responsibilities of Ministries (MONRE, MOC, MOST) and People's Committee of province for domestic solid waste management.
- Decision No. 592/QD-BXD dated May 30, 2014 of The Ministry of Construction on "Announced estimated norms of collection, transportation and disposal of urban solid waste.
- Decision No. 798/QD-TTg dated May 25, 2011 of the Prime Minister issued the on approval of the solid waste treatment program in period of 2011-2020 for investment projects of constructing solid waste treatment complex, local waste treatment facilities nationwide implemented by domestic businesses, organizations with specific targets on collecting, treating, recycling and reusing of urban and rural solid waste, industrial and medical solid waste.
- Decision No. 2149/2009/QD-TTg dated 17/12/2009 of Prime Minister on the approval of National Strategy on integrated management of solid waste to 2025 and vision to 2050. In which mentioned the National Strategy on integrated management of solid waste to 2025 and vision to 2050.

- Decree No. 69/2008/NĐ-CP dated 30/5/2008 of Prime Minister on encouraging the socialization of the activities in the fields of education, vocational training, healthcare, culture, sports and environment.
- Decree No. 59/2007/ NĐ-CP dated April 09, 2007 of The Government on Solid waste Management; almost all the targets of environment protection on solid waste defined in this decree.
- Decree No. 174/2007/NĐ-CP dated November 29, 2007 of The Government on Environmental Protection Charges for solid wastes; This decree mentioned the normal solid waste and hazardous solid waste generated from production, commercial activities and services, etc. (excepting for domestic solid waste from households) will be subjected to environmental protection tax. Almost all revenues from the environmental protection fee on solid waste will be spent for solid waste management at localities.
- Directive No. 23/2005/CT-TTg dated June 21st, 2005 of The Prime Minister promulgated on promoting the management of solid waste in urban areas and industrial zones.
- Decision No.256/2003/QD-TTg dated September 3rd, 2003 of The Government on approving the National Strategy on Environmental Protection to 2010 and orientations to 2020.
- Decision No. 88/2008/QĐ-UBND dated December 20, 2008 of HCMC People's Committee on sanitation charges and environmental protection charges for Solid waste in HCMC;
- Decision No. 130/2002/QĐ-UB dated November 18, 2002 of HCMC People's Committee on promulgate regulations on solid waste management in HCMC.

4.2.4 Solid Waste Management Baseline Data of the City

4.2.4.1 Municipal solid waste generation and composition

A. Municipal solid waste generation

Sources of solid waste generation in HCMC are very diverse with many different scales and divide into 7 sources as follows:

1. Household: about 2 million of households (villas, town houses and apartment buildings).
2. Hotel, motel and restaurant: 354,661 units
3. Industry: 54.053 units (factories and enterprises)
4. Healthcare: 12.502 units (185 hospitals, 317 dispensaries and 12,000 private clinics)
5. Office: 4,730 units (offices and education and training organizations: primary, junior, senior high school, colleges, universities, institutes and research centers)
6. Public place: 734 units (squares, parks, zoos, monuments, sport centers, cinemas, theaters, bus stations, train stations, airports, streets and sidewalks, etc.)

7. Commerce and service: 346 (218 traditional markets and 218 shopping centers and supermarkets).

The total amount of solid waste generated has been significantly increasing from 1992-2016. In recent years (2010 to 2016), the average solid waste growth rate is about 5.2 % per year and amount of solid waste in 2016 increased 38% in comparison with the year 2006 (DONRE, 2016). The increasing amount of waste is due to the rapid economic growth and rapid urbanization process with higher living standards and significantly changing life styles. The amount of generated solid waste from 1992-2016 is presented in Figure 4.11.

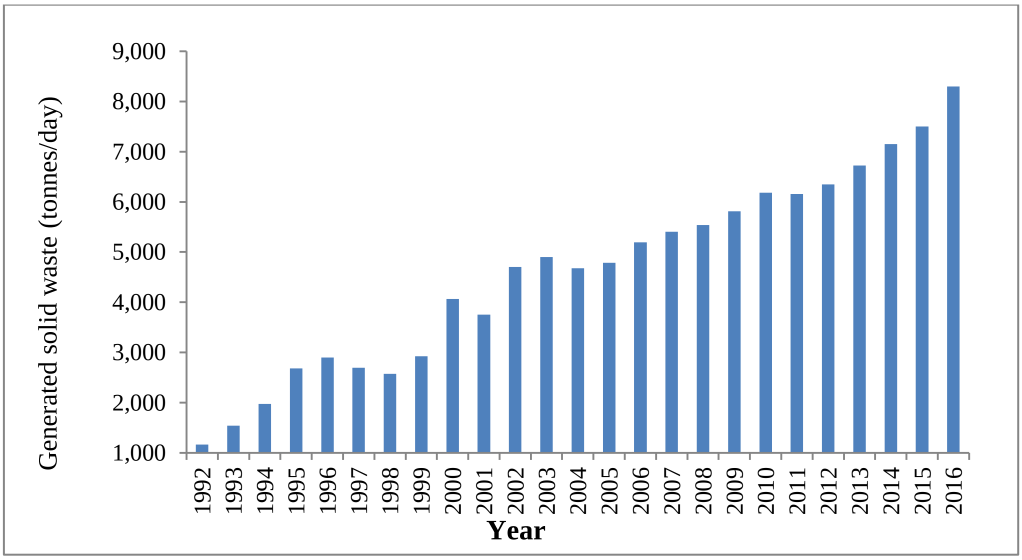

Figure 4.11 Amount of generated solid waste in HCMC from 1992 – 2016

According to DONRE (2012), the proportion of different sources of solid waste in HCMC was as follows:

- Household: 58 %;
- Public places: 14.2%;
- Markets and service: 25% (traditional markets taking 13% and services taking 12%);
- Office: 2.8%.

B. Municipal solid waste composition

Composition of solid waste differs for different generation sources. Identification of composition of waste is crucial for selection of the appropriate technologies for reuse, recycling, treatment and disposal. Composition of generation sources is below:

- *Households*

The analysis results of solid waste composition show that characteristics of solid waste from households have a higher biodegradable organic fraction (64.8-74.3%) and high moisture content (55-65%). The bulk density of waste is in the range of 375 – 400 kg/m^3 (Centema, 2015). Composition of generated waste of households in 2009 and 2015 is presented in Table 4.7.

Table 4.7 Composition of generated solid waste from households

No.	Composition	Results (%ww)	
		Year 2009 (*)	Year 2015 (**)
1	Biodegradable fraction	74.3 (±15.9)	64.8 (±7.2)
2	Wood	2.8 (±6.0)	0.9 (±0.9)
3	Paper	6.2 (±6.1)	5.1 (±0.8)
4	Plastic	5.2 (±4.8)	10.5 (±1.3)
5	Textile	1.0 (±3.3)	3.2 (±1.2)
6	Leather	0.2 (±1.0)	-
7	Rubber	0.9 (±3.7)	0.9 (±0.6)
8	Glass	1.3 (±3.4)	1.4 (±0.9)
9	Nonferrous metal	0.7 (±1.7)	0.6 (±0.3)
10	Ferrous metal	0.3 (±1.1)	0.2 (±0.2)
11	Porcelain	0.8 (±3.2)	0.5 (±0.5)
12	Soil, sand	3.2 (±9.2)	2.8 (±0.4)
13	Ash	0.4 (±1.6)	-
14	Styrofoam	0.3 (±0.5)	1.0 (±0.6)
15	Diaper	1.8 (±4.0)	10.4 (±5.5)
16	Clamshell	0.8 (±1.8)	-
17	Hazardous waste	0.002 (±0.03)	-

Source: (*) DONRE, 2009 with n = 299 and (**) CENTEMA, 2015 with n =20

Remark: "-" – data not available ; "ww" – wet weight.

Table 4.7 shows that the biodegradable organic component has changed in 2009 and in 2015. The highest component of solid waste was biodegradable organic with 74.3% in 2009 and 64.8% in 2015, a decrease of about 9.5%. Other components of solid waste such as plastic, diaper have changed significantly. Amount of plastic component increases from 5.2% in 2009 to 10.5 % in 2015 and tend to increase with the use of plastic bags and plastic products because they are cheap and convenient. The amount of diaper has increased significantly from 1.8 % in 2009 to 10.4 % in 2015 with change in consuming patterns due to rapid urbanization. The diapers are used not only for children but also for elderly people. The increase of plastic waste is one of problems in treatment of solid waste of HCMC. The remaining components of solid waste are more or less the same in 2009 and in 2015.

- *Schools*

The composition of solid waste generated from schools normally contain high paper and plastics in comparison to other fractions and increasing year by year. Amount of paper increased from 17.6% in 2009 to 35% in 2015 and the plastic increased from 25.9 % to 34.9

%, respectively. The biodegradable organic fraction is the same with 28.7% in 2009 and 25.5% in 2015. The remaining fractions of solid waste composition are non-recyclable waste such as leather, textile, and styrofoam are low. Composition of waste generated from schools is presented in Table 4.8.

- *Markets*

Solid waste composition generated from traditional markets in 2015 varies a little in 2009. The composition of solid waste generated from markets is presented in Table 4.9.

Table 4.8 Composition of solid waste generated from schools

No.	Composition	Results (%ww)	
		Year 2009 (*)	Year 2015 (**)
1	Biodegradable organic	28.7 (±26.9)	25.5 (±0.5)
2	Wood	6.9 (±10.3)	-
3	Paper	17.6 (±13.8)	35.0 (±0.2)
4	Plastic	25.9 (±17.4)	34.9 (±1.1)
5	Textile	1.1 (±3.2)	1.9 (±0.6)
6	Leather	0.1 (±0.7)	-
7	Rubber	1.4 (±4.7)	-
8	Glass	0.5 (±2.1)	1.2 (±0.1)
9	Nonferrous metal	2.1 (±4.4)	-
10	Ferrous metal	0.7 (±2.6)	-
11	Porcelain	0.6 (±2.0)	-
12	Soil, sand	4.0 (±9.0)	-
13	Ash	-	-
14	Styrofoam	9.8 (±9.9)	1.5 (±0.2)
15	Diaper	-	-
16	Clamshell	-	-
17	Hazardous waste	0.1 (±0.7)	-

Source: (*) DONRE, 2009 n =81 and (**) CENTEMA, 2015 n = 4

Remark: "-" – data not available ; "ww" – wet weight.

Table 4.9 Composition of solid waste generated from markets

No.	Composition	Results (%ww)	
		Year 2009 (*)	Year 2015 (**)
1	Biodegradable organic	86.8 (±6.8)	87.8 (±1.0)
2	Wood	3.6 (±6.2)	1.4 (±0.2)
3	Paper	2.5 (±3.4)	1.9 (±0.2)
4	Plastic	4.3 (±3.0)	7.5 (±0.7)
5	Textile	0.4 (±1.4)	-
6	Leather	-	-
7	Rubber	0.4 (±1.5)	-
8	Glass	0.2 (±0.7)	-
9	Nonferrous metal	-	-
10	Ferrous metal	0.3 (±1.1)	0.1 (±0.1)
11	Porcelain	0.1 (±0.5)	-
12	Soil, sand	1.0 (±2.3)	1.2 (±0.2)
13	Ash	-	-
14	Styrofoam	0.4 (±0.5)	0.2 (±0.1)
15	Diaper	-	-
16	Clamshell	0.2 (±1.2)	-
17	Hazardous waste	0.1 (±0.6)	-

Source: (*) DONRE, 2009 n = 55 and (**) CENTEMA, 2015 n = 6

Remark: "-" – data not available ; "ww" – wet weight.

The composition of solid waste generated from market is mainly biodegradable organic component; this component has changed insignificantly from 2009 to 2015. However, the plastic waste component rises from 4.3 % in 2009 to 7.5% in 2015 with increase in using plastic bags because they are cheap.

- *Offices, hotels- restaurants, and shopping centers*

Composition of solid waste generated from offices, hotels - restaurants, and shopping centers are presented in Table 4.10 and Table 4.11.

Table 4.10 Composition of solid waste generated from hotels, restaurants and shopping centers

No.	Composition	Results (%ww), Year 2009	
		Shopping centers	Hotels - Restaurants
1	Biodegradable organic	55.1 (±24.6)	66.2 (±18.7)
2	Wood	1.0 (±2.6)	1.3 (±4.9)
3	Paper	13.6 (±13.7)	8.8 (±14.2)
4	Plastic	14.7 (±11.9)	8.1 (±9.5)
5	Textile	0.2 (±1.2)	0.7 (±3.2)
6	Leather	0.1 (±0.5)	0.1 (±0.5)
7	Rubber	1.2 (±3.3)	0.5 (±2.5)
8	Glass	1.7 (±6.7)	2.8 (±6.7)
9	Nonferrous metal	1.3 (±2.5)	3.8 (±8.5)
10	Ferrous metal	-	-
11	Porcelain	0.4 (±1.7)	0.7 (±2.9)
12	Soil, sand	4.2 (±14.8)	0.3 (±1.8)
13	Ash	-	1.3 (±5.3)
14	Styrofoam	4.8 (±5.8)	2.8 (±9.7)
15	Diaper	0.6 (±2.0)	1.0 (±3.)
16	Clamshell	0.9 (±3.3)	2.5 (±7.0)
17	Hazardous waste	0.1 (±0.3)	0.4 (±1.7)

Source: DONRE, 2009; offices: n = 27 and hotels –restaurants: n = 98

Remark: “-“ – data not available ; “ww” – wet weight.

Table 4.11 Composition of solid waste generated from offices

No.	Composition	Results (%ww),Year 2009
1	Biodegradable organic	43.7 (±29.7)
2	Wood	5.0 (±11.4)
3	Paper	19.4 (±17.1)
4	Plastic	12.6 (±9.9)
5	Textile	3.5 (±8.7)
6	Leather	0.3 (±1.8)
7	Rubber	0.4 (±1.7)
8	Glass	1.7 (±4.6)
9	Nonferrous metal	2.0 (±4.4)
10	Ferrous metal	0.9 (±3.6)
11	Porcelain	1.1 (±4.9)
12	Soil, sand	6.0 (±11.8)
13	Ash	-
14	Styrofoam	2.3 (±4.1)
15	Diaper/napkin	0.6 (±1.6)
16	Clamshell	-
17	Hazardous waste	0.6 (±2.3)

Source: DONRE, 2009 n=71

Remark: "-" – data not available ; "ww" – wet weight.

The Table 4.10 and 4.11 indicate the general characteristic of shopping centers, hotels-restaurants and offices. Hotels have higher biodegradable organic compared to offices. Paper and plastic components in shopping centers and offices is higher than hotels - restaurants.

- *Landfills*

There are 2 sanitary landfills (Phuoc Hiep and Da Phuoc) in HCM, in which Phuoc Hiep does not receive the domestic solid waste from 2014 (it is used as reserve sanitary landfill). At present, Da Phuoc is still in operation with capacity of 5,000 tonnes/day. The solid waste composition at two sanitary landfills (Phuoc Hiep and Da Phuoc) in 2010, 2012, 2013, and 2015 are presented in Table 4.12.

Table 4.12 Composition of solid waste at Phuoc Hiep and Da Phuoc sanitary landfill

No.	Composition	Results (% ww)				
		Phuoc Hiep			Da Phuoc	
		Year 2010 (*)	Year 2012 (**)	Year 2013 (**)	Year 2010 (*)	Year 2015 (***)
1	Biodegradable organic	83.0 – 86.8	68,9	67,9	83.1 – 88.9	59.5
2	Wood	0.5 - 1.7	0,7	0,3	1.5 - 2.2	0.6
3	Paper	4.1 - 5.5	3,0	2,5	2.5 - 4.8	4.8
4	Plastic	2.2 – 3.1	16,0	16,4	1.5 – 2.4	20.2
5	Textile	0.2 – 1.8	5,0	7,2	0.9 – 1.8	3.6
6	Leather	0.0 – 0,02	-	-	0.0	1.2
7	Rubber	0.1 – 0.4	0,7	0,7	0.1 – 0.2	
8	Glass	0.4 – 0.5	1,2	0,2	0.4 – 0.5	-
9	Nonferrous metal	0.1 – 0.2	1,6	3,6	0.1 – 0.2	0.41
10	Ferrous metal	-	-	-	0.2 – 0.3	-
11	Porcelain	0.1 – 0.3	-	-	0.1 – 0.2	-
12	Soil, sand	1.2 – 4.5	-	-	1.0 – 4.5	-
13	Ash	0.0 – 1.2	-	-	0.0	-
14	Styrofoam	0.0	-	-	0.2 – 0.3	-
15	Diaper	0.9 – 1.1	2,3	0,6	0.5 – 0.9	4.8
16	Clamshell	0.0 – 0.2	0,8	0,6	1.1 – 1.2	1.4
17	Hazardous waste	0.1 – 0.2	-	-	0.1 – 0.2	-
18	Non -organic	-	-	-	-	3.1
19	Other	-	-	-	-	0.4

Source: (*) DONRE, 2010 and (**) HCM Climate Change Bureau, 2014

Remark: "-" – data not available ; "ww" – wet weight.

The data on solid waste composition from Phuoc Hiep and Da Phuoc sanitary landfills in 2010 shows that biodegradable organic component was very high in the range of 83.6-88.9% and this component decreased through 2012, 2013, and 2015. The decrease of biodegradable organic component is due to the operation of two composting plants in 2010 and 2012, and as the biodegradable organic from markets is transported to the two composting plants.

The recyclable components have low percentage because the valuable materials are collected by collectors or pickers at sources. For Phuoc Hiep sanitary landfill, component of plastic has increased 5.2 -7.3 times from 2010 to 2013. For Da Phuoc sanitary landfill, plastic component increased 10.2 times from 2010 to 2015. The increasing amount of plastic waste in the composition of domestic solid waste is due to increase in consumption of plastic bags and products. In addition, textile component also increase from 2010 to 2015 because in HCMC textile waste is not separated and it is collected together with domestic solid waste and dumped in landfill. The increase of textile and plastic components are an important factor for selection of suitable technology for recycling and treatment of domestic solid waste in future.

- *Composting plant (Vietstar composting plant)*

  The analysis results of waste composition of solid waste from Vietstar – composting plant in 2015 is presented in Table 4.13.

Table 4.13 The solid waste composition from composting plant

No.	Composition	Results (%ww)
1	Biodegradable organic	53.2 (±3.4)
2	Wood	1.0 (±0.6)
3	Paper	5.7 (±2.3)
4	Plastic	12.9 (±1.2)
5	Textile	10.7 (±4.6)
6	Rubber & Leather	0.7 (±0.7)
7	Glass	1.7 (±0.5)
8	Nonferrous metal	0.3 (±0.3)
9	Ferrous metal	-
10	Porcelain	2.4 (±2.4)
11	Soil, sand	-
12	Ash	-
13	Styrofoam	0.8 (±0.3)
14	Diaper	10.7 (±4.6)
15	Clamshell	-
16	Hazardous waste	0.1 (±0.1)
17	Non-organic	-
18	Other	-

Source: CENTEMA, 2015, n=3

Remark: "-" – data not available ; "ww" – wet weight.

Table 4.13 indicates that percentage of biodegradable organic fraction had an average value of 53.2% and the remaining fractions were 46.8 %. Plastic, diaper, and textile contributed to 12.9%, 10.7% and 10.7%, respectively. The two composting plants in HCMC takes approximately 35-64% and remaining non-compostable materials are buried at sanitary landfill or burned by incinerator. The quality of compost product is low because product is mixed by scrap glass, plastics and other components resulting in difficult consumption of the product.

4.2.4.2 Municipal solid waste management system

A. Waste collection

The rate of solid waste collected from households in urban areas is 95%, and the remaining waste is about 5% that are not collected directly. These 5 % solid wastes are put along the streets or put waste into common bins or thrown into the canals. Every day, District's Public Services Companies sweeps and collects waste on the streets, common bins and dumping sites. In rural areas, the rate of waste collected from households is about 70% - 80 %, the remaining waste is dumped into garden or empty land of some households.

- *Storage at sources*

At the present, separation of waste from household is not practiced at sources. Households equipped themselves with plastic trash cans, some households use metal trash cans or bamboo baskets. Most of the residents use plastic bags to contain waste and put them in trash cans. When the waste collection time comes, households carry garbage trash cans or plastic bags outside so that collectors can easily collect them.

At markets, due to limited business area, the majority of small traders use empty space to store goods, only few places have solid waste bins. Most of the waste generated are disposed at markets' allies. After market is closed, entire waste is collected.

The trading activities (fixed and roving), traffic on the roads are a complex problem and cause difficulties in storing waste. The mess of illegal disposal of solid waste generated from these activities on streets happens frequently and has become a bad habit that is not easy to change.

In schools, offices, restaurants, hotels, waste is stored in small bins. Then, most of the wastes were transferred into 240L bins. In public areas on streets and sidewalks, waste bins are not placed, or not enough, or not functioning well.

- *Sweeping and collection on streets*

Sweeping and collection on the street are conducted by District's Public Services Companies in the public areas; roads, sidewalks, islets, manholes, and etc. (Figure 4.12).

Figure 4.12 Sweeping and collecting activities on streets

To maintain the sanitation quality of streets, Districts' Public Services Companies has organized a force of 2,414 workers to carry out this task. In addition, Districts' Public Services Companies has equipped 5 sweepers to clean the central streets.

- *Collection at sources*

The waste collection has carried out by two systems including public and private systems. The public system includes HCMC Environment Company (CITENCO) and 22 of District's Public Services Companies. The private system includes individual collectors, collecting unions and cooperatives.

(1) The public system is composed of Urban Environmental One-Member Limited Company (CITENCO) and 22 of District's Public Services Companies (two new districts including Tan Phu District and Binh Tan District are have not established their own Public Services Company). The public system has responsibility for sweeping all streets and roads, collecting solid waste generated from markets, offices, shopping centers, public areas, and 30% of solid waste generated from households which located along main streets in the city and then transporting solid waste collected to transfer stations, treatment complex or sanitary landfills.

(2) The private system includes informal (individual) collectors, collecting unions and cooperatives (District 2, District 4, District 6, Go Vap District, and Thu Duc District) which has responsibility for collecting 70% of solid waste generated from households (alleyway) and domestic solid waste generated from enterprises (by contracting with the People's Committee of Wards).

The data of HCMC DONRE in 2014 shows that:

- More than 200 of small loading capacity trucks (550 kg); approximately 1,000 of homemade vehicles (3 or 4 wheels) and more than 2,500 of 660 liters pushcarts are used for collection activity (Figure 4.13).
- Approximately 4,000 of private collectors and 1,500 of collectors in the District's Public Services Companies and cooperatives are employed currently. Amount of collected solid waste of the public system and the private system is presented in Figure 4.14.

Small loading capacity
trucks (550 kg)

660 liters pushcart

Homemade vehicles
(3 or 4 wheels)

Homemade vehicles
(3 or 4 wheels)

Figure 4.13 Solid waste collection vehicles

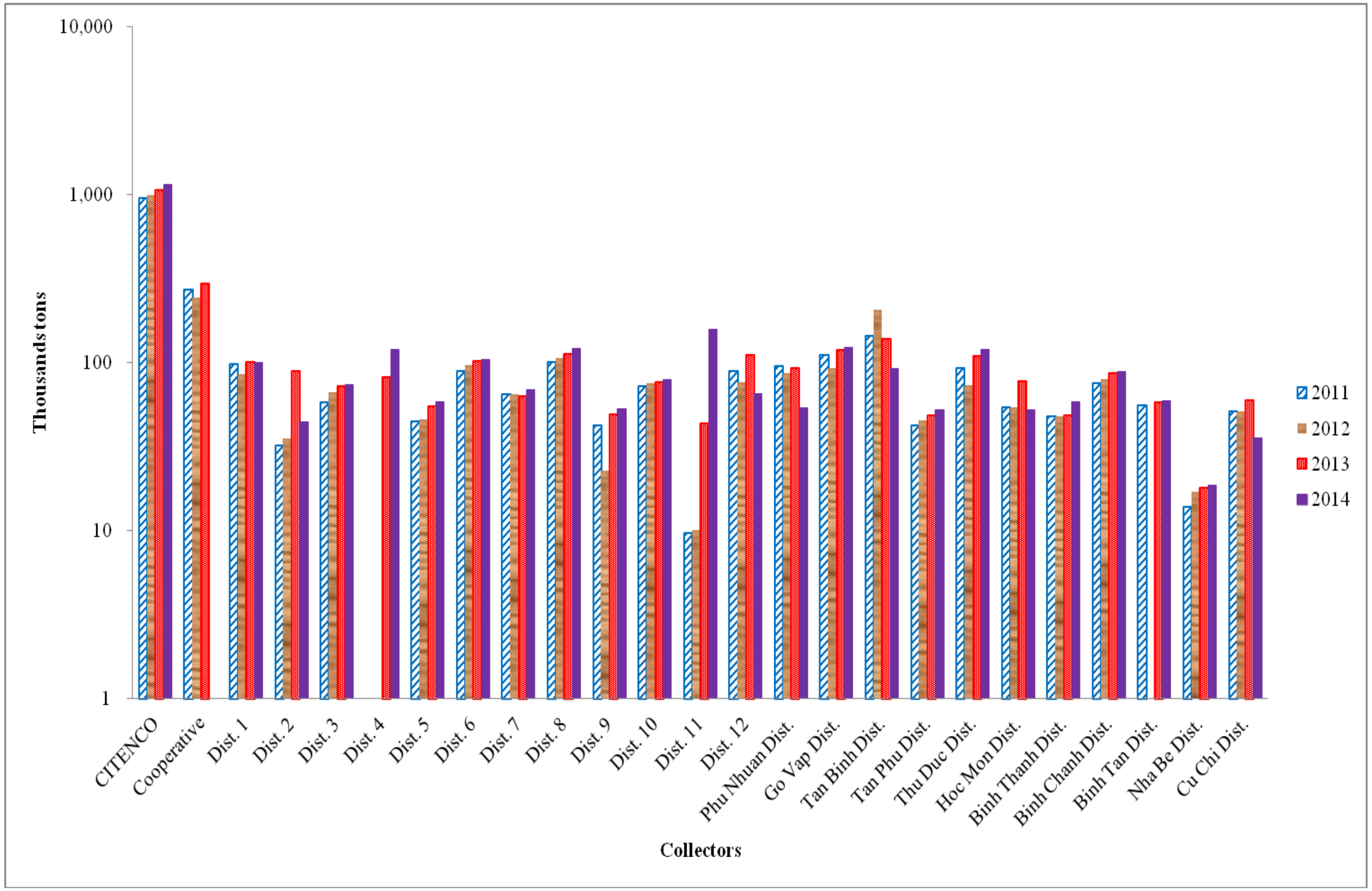

Figure 4.14 Amount of collected solid waste of the public and the private system in HCMC

B. Waste transfer and transportation

CITENCO as the general contractor share the contract with Districts' Public Service Companies, organizations receiving and collecting waste at rendezvous points, public containers or spontaneous rendezvous points after that:

- Using small compact garbage trucks with loading capacity less than 4 tonnes to move waste to the transfer stations.

- Using compression garbage truck with loading capacity more than 4 tonnes to directly carry waste to waste treatment complex or composting plant.

In addition, District 1, Tan Binh District, Tan Phu District, Binh Tan District, Binh Chanh District and Cu Chi District have decentralized transportation of solid waste through contracts with the District People's Committee.

- *Transfer*

The composition of the waste transfer system in HCMC is composed of meeting points and transfer stations (including transfer sites, opened and closed transfer stations).

Meeting point

- Meeting point is a location that gathering push-carts to move waste to transportation means.
- Now, there are 891meeting points in HCMC, almost exiting meeting points are located in 22 districts such as District 3 (191meeting points), District 10 (85 meeting points) and Can Gio District (75 meeting points), Binh Thanh District (63 meeting points), Tan Binh District (61 meeting points), and other districts have about 10-18 meeting points/ district (DONRE, 2015).
- Management units of the rendezvous points are mainly the Public service limited companies of the districts, Urban Environmental One-Member Limited Company – CITENCO has managed the rendezvous in Tan Phu District, Binh Tan District Binh Thanh District, District 6, and District 12.
- Locations of meeting points are often changed due to bad sanitation conditions.
- In the future, urban rendezvous points need to be gradually reduced and replaced by transfer station with proper technology.

Transfer station

Transfer station is the place that has received solid waste from small loading capacity vehicles and then loads them to larger vehicles before transporting to waste treatment complex or composting plant. According to report of DONRE (2015), there are 22 transfer stations (21 transfer stations of type 3 and 01 transfer stations of type 2) and these ones haven't ensured sanitary conditions and caused serious environmental pollution pollution in surrounding residential areas. Location of transfer stations and rendezvous points in HCMC are presented in Table 4.14.

Transfer station is divided into 4 types as follows:

Type 1: closed transfer station (Figure 4.15a)

Receiving capacity: over 800 tonnes/day

Technology: using hook-lift trucks

Operating area: meeting design standards and having large area, strong structure including hard concrete floor and roof

Controlling environmental issues: having leachate collection and dust & odour control closely system

Type 2: opened transfer station

Receiving capacity: 200 - 270 tonnes/ day

Technology: using hook-lift trucks

Operating area: having surrounding walls, roof, cement floor, a guard house, and leachate collection system.

Type 3: opened transfer station

Receiving capacity: over 100 tonnes/day

Technology: using compact garbage trucks or dumper trucks

Operating area: having surrounding walls, a guard house, with/without roof, cement floor, with/without leachate collection system.

Type 4: opened transfer station (Figure 4.15b)

Receiving capacity: less than 100 tonnes/day

Technology: using compact trucks or dumper trucks

Operating area: having surrounding walls, without guard house, without roof, cement floor, and without leachate collection system.

(a)

(b)

Figure 4.15 (a) Transfer station No.1 at Tong Van Tran Street, District 11 (type 1); (b) A opened transfer station (type 4) at Tien Lan Hamlet, Ba Diem Commune, Hoc Mon District.

Table 4.14 Location of transfer stations in HCMC

Districts	Name of transfer station	Address	Capacity (tonnes)	Area (m^2)	Management unit
Type 1: 3 transfer stations					
Go Vap	12A Quang Trung	No.12A, Quang Trung street, ward 11	1,000 – 1,500	5,000 – 6,000	CITENCO
Tan Binh	Tan Binh	Pham Van Bach street, ward 12	300	600	PWSCL of Tan Binh District
11	No.1 Tong Van Tran	No.1, Tong Van Tran, ward 5	800 – 1,000	6,500	CITENCO
Type 2: 9 transfer stations					
2	Binh Trung Tay	Road No.10, Binh Trung Tay ward	20	670	PWSCL of District 2
4	Ton That Thuyet	No.1, Ton That Thuyet Street	250 - 300	980.19	Cong Nong Cooperative
6	Ba Lai	No.16, Ba Lai street, ward 7	70 - 80	812	PWSCL of District 6
9	Long Hoa	Thuy Loi street, quarter 2, Long Thanh My ward	100	2,000	PWSCL of District 9
	Phuoc Long A	Thuy Loi street, quarter 2, Phuoc Long A ward	60	363.4	
	Vinh Thuan	Vinh Thuan Quarter, Long Binh Ward	25	192	PWSCL of District 9
10	Distrct 10 PWSCL	No.250B, Tran Binh Trong street, ward 1	40	700	PWSCL of District 10
11	Tan Hoa	No.70A, Tan Hoa street, ward 3	270	1,990.03	Cong Nong Cooperative
Binh Thanh	Phan Van Tri	No. 348/26, Phan Van Tri street, ward 11, Binh Thanh District	270	981	CITENCO
Type 3 & 4: 21 transfer station					
7	Dao Tri	Dao Tri street, Phu Thuan ward	100	9,481.8	PWSCL of District 7

Districts	**Name of transfer station**	**Address**	**Capacity (tonnes)**	**Area (m^2)**	**Management unit**
7	Tu So	Group18, quater 3, Tan Kieng ward	60	572	
8	Electricity cabin	Ward 3	40	665.8	PWSCL of District 8
9	Vinh Thuan	Vinh Thuan Quarter, Long Binh Ward	25	192	PWSCL of District 9
12	Tan Thoi hiep	Quater 6, Hiep Thanh ward	50	150	PWSCL of District 12
12	Phuoc Hiep Thanh	Tan Thoi Hiep ward	40	420	
Tan Phu	Pham Van Xao	-	70	1.357.3	
Thu Duc	Go Dua	Linh Dong ward	13	35.75	PWSCL of Thu Duc District
	So Ga	Tam Binh street, Tam Phu ward	30	68.73	
	Tam Than	Tam Phu ward	48 – 55	56.25	
	Linh Xuan	Linh Xuan ward	35 – 42	84.86	
	Thu Duc general hospital	Le Van Chi street, Linh Trung ward	56 – 60	36	
	Truong Tho	Truong Tho ward	68 – 72	49	
	Hiep Binh Chanh	Song Hanh street, quater 7, Hiep Binh Chanh ward	100 - 115	67.15	
Phu Nhuan	Nguyen Kiem	No. 553/73, Nguyen Kiem street, ward 9	350	600	PWSCL of Phu Nhuan District
Binh Chanh	Le Minh Xuan	Hamlet 6, Le Minh Xuan ward	95	2.040	PWSCL of Binh Chanh District
	Binh Chanh	Hoang Phan Thai street, hamlet 1, Binh Chanh commune, Binh Chanh district	150	2.254	
Hoc Mon	Ba Diem	No.1/5R, Bui Van Ngu street, Tien Lan commune, Hoc Mon district	80	300	PWSCL of Hoc Mon District
	Xuan Thoi Thuong	Hamlet 6, Xuan Thoi Thuong commune	40	250	

Districts	**Name of transfer station**	**Address**	**Capacity (tonnes)**	**Area (m^2)**	**Management unit**
	Tan Thoi Nhi	Hamlet Dan Thang 1, Xuan Thoi Nhi commune	30	400	
	Hoc Mon	Hoc Mon town	20	200	
Cu Chi	Tan An Hoi	Tam Tan hamlet, Tan An Hoi commune	100	2.000	PWSCL of Cu Chi District
Total	**33 transfer stations**				

Source: DONRE, 2015

- *Transportation*

There are 3 ways of transportation: (1) from meeting point, solid waste is loaded into small trucks with capacity of 2 - 4 tons and solid waste is transported to the transfer station, and from there, big trucks (7 - 12 ton capacity) transport the solid waste to sanitary landfills or composting plants; (2) from meeting point, big trucks (7-12 ton capacity) or compress trucks transport the solid waste directly to sanitary landfills or composting plants; (3) solid waste is gathered and discharged in public containers/bins with a volume of 240 - 660 L alongside roads, or the solid waste is coming from concentrated sources (supermarkets, commercial canters, etc.), which is transported to transfer stations or loaded into compress trucks and transported to sanitary landfills or composting plants. This form is particularly used for street-sweeping wastes but also for a considerable quantity of household wastes.

Currently, in HCMC there are 3 companies which are responsible for transportation, including CITENCO (53%), Districts' Public Service Companies (30%) and Cong Nong Cooperative (17%).

Whole collection and transportation system has more than 570 vehicles (compact garbage trucks, dumper trucks, forklift trucks). The number of vehicles used to transport waste from the meeting points and transfer stations and from transfer stations to waste treatment complexes are 261 vehicles. Total amount of collected solid waste in HCMC are showed in Table 4.15.

Table 4.15 The quantity of solid waste collection and transportation vehicles in HCMC

Loading capacity Vehicle (tonnes)	**Before 1990**	**From 1991 to 2000**	**From 2001 to 2005**	**From 2006 to 2009**	**After 2011**	**Total**	**Capacity of vehicles**	**The total amount of collected waste (tons/day)**
(1)						**(2)**	**(3)=(2)*90%**	**(4)=1*3*k**
5	6	24	6	7		43	38.7	**387**
7	12	16	12	10		50	45	**945**
10	3	55	9	4		71	63.9	**1917**
12	1	40	39	5	1	86	77.4	**2786.4**
15	1	8	2			11	9.9	**445.5**
Total	**23**	**143**	**68**	**26**	**1**	**261**		**6480.9**

Source: DONRE, 2009

Note: k - number of turns of trucks (about 2 or 3 times).

Transportation distances from the districts to solid waste treatment complex are presented in Table 4.16.

Table 4.16 Transportation distance from the districts to the solid waste treatment complex in kilometer.

Company	**Transfer stations**	**Da Phuoc Lanfill**	**Phuoc Hiep Landfill**	**Vietstar Joint Stock Company**	**Can Gio Landfill**
Transportation Division No.1 (City Environmental Company - CITENCO)	17.35	40.30	45.81	40.38	
Transportation Division No.2 (City Environmental Company - CITENCO)	6.19	29.70		37.74	
District 1	17.32	23.29	50.35	37.95	
District 2	35.00		70.27		
District 3	20.17	23.81			
District 4 - Cong Nong cooperative	7.50	20.50			
District5	10.49	21.37		60.20	
District 6		25.38		53.92	
District 7		27.44			
District8	11.68	22.46			
District 9		70.89	68.55	69.04	
District 10		21.71	53.43	54.18	
District 11 - Cong Nong cooperative		24.50	43.55	44.15	
District11 - Public service Company District 11	3.41				
District 12			53.46	56.01	
Tan Binh District	4.47		42.55	43.40	
Tan Phu District	9.65			44.01	
Binh Tan District		28.85			
Binh Chanh District	12.80	25.98			
Phu Nhuan District	4.03	26.10	43.85		

Company	Transfer stations	Da Phuoc Lanfill	Phuoc Hiep Landfill	Vietstar Joint Stock Company	Can Gio Landfill
Go Vap District	9.96	51.34	48.33	49.49	
Thu Duc District	30.00	62.16	57.88	60.31	
Hoc Mon District			38.52		
Binh Thanh District	9.81		51.58		
Nha Be District	61.30	55.66			
Cu Chi District			24.02		
Can Gio District					13.05

Source: DONRE, 2011.

Data in Table 4.16 shows that most of vehicles transport the waste about 2 to 3 round trips per day. Due to continuous operation during day and most of vehicles are old, thus not fully efficient. Many vehicles were invested in 1984 or 1985 (more than 55% of collection vehicles were invested before 2005). Transportation units must provide 1 or 2 other vehicles in order to replace existing ones when they have to be maintained.

According to DONRE (2011), about 55% of waste collection and transportation vehicles are equipped with leachate collection system. The leachate collection system helps to avoid discharging leachate during the transportation on the routes. However, there are about 45% of vehicles without leachate collection system. It means that a large number of vehicles operation do not meet the environmental regulations.

The average distances of waste transportation in HCMC to Phuoc Hiep and Da Phuoc sanitary landfill are 47.66 km and 29.08 km, to Vietstar composting plant is 50.17 km (DONRE, 2011).

C. Recycling and reuse

Nowadays, recyclable components (scraps) of waste generated is collected by a free collection network around the city. Mixture of recyclable waste (scraps) and non- recyclable waste generated from daily activities of households, offices, commercial centers in HCMC, are collected.

Most of junk shops and recycling enterprises are small scale and located in the residential areas. Recyclable waste such as paper, plastic and metal is mostly recycled in small scale private enterprises. Because applied recycling technology is backward, quality of the recycling products are not high enough.

Approximately 90% of recyclable waste collected includes paper, plastic, metal that are reused to produce other recycling products, and only 10% of recyclable waste collected is not recycled and disposed on the sanitary landfill (Figure 4.16). Recycling activities has brought economic benefits for the residents. Most of workers who work in recycling enterprises have low education and poor. Hence, it is very difficult to apply new technologies for recycling industries.

Figure 4.16 Recycling activities in HCMC

HCMC has about 740 private recycling enterprises to recycle about 2,000 tonnes/day (DONRE, 2012). These recycling enterprises are mainly located in the District 11 with 67 for plastic, 15 for glass recycling, 9 for metal, 7 for paper and 2 for rubber recycling. [3]

Manpower working in recycling activities in the city includes:

- Manpower for waste collection at sources: 4,000 - 6,000 persons;
- Waste pickers and waste buyers: 2,500 - 3,500 persons;
- Manpower of junk shops and recycling enterprises (about 800 – 1,000 of shops and enterprises): 6,000 - 10,000 persons

The data is presented in Table 4.17 is the composition and quantity of scrap purchased at 202 junk shops and 100 recycling shops surveyed. Majority of the junk shops (178 of 202 junk shops, about 78%) have to rent shops and area of these shops are small. There are only a few junk shops that have large area (about several hundreds square meters) and many workers (more than 6 persons). The percentage of large size shops is about 4.5%.

[3] Environment national report on solid waste, 2011.

Table 4.17 The composition and quantity of scrap purchased at junk shops and recycling shops

<table>
<tr><th>No.</th><th>Type of scrap</th><th>Amount of purchased scrap at 202 of junk shops (tons/month)</th><th>Amount of purchased scrap at 100 of recycling enterprises (tons/month)</th></tr>
<tr><td>1</td><td>Paper</td><td>1,696.8</td><td>1,667</td></tr>
<tr><td>2</td><td>Plastic</td><td>179.4</td><td>3,654</td></tr>
<tr><td>3</td><td>Copper</td><td>15.2</td><td rowspan="4">78.5</td></tr>
<tr><td>4</td><td>Aluminum</td><td>25.7</td></tr>
<tr><td>5</td><td>Scrap-iron</td><td>1,005</td></tr>
<tr><td>6</td><td>Zinc</td><td>0.1</td></tr>
<tr><td>7</td><td>Lead</td><td>0.01</td><td>-</td></tr>
<tr><td>8</td><td>Glass</td><td>48.3</td><td>336</td></tr>
<tr><td>9</td><td>Scrap of fabric</td><td>36.7</td><td>-</td></tr>
<tr><td>10</td><td>Bottles</td><td>36.6</td><td>-</td></tr>
<tr><td>11</td><td>Rubber</td><td>-</td><td>34.6</td></tr>
</table>

Source: DONRE, 2011

D. Treatment and disposal

Since 2008, the disposal of waste has been completely operated by local and foreign companies. According to DONRE (2016), the solid waste treatment technologies currently used are sanitary landfill (68.6%), composting (24.6%), recycling (1.1%) and incinerator (5.7%) as can be seen in Table 4.18.

Table 4.18 The waste treatment and recycling plants capacity

No.	Items	Investors	Area (ha)	Operation time	Designed capacity (tons/day)	Receiving capacity (tonnes/day)	Note
1	Da Phuoc solid waste treatment complex	Vietnam waste solutions (United States)	128	Nov, 2007	Sanitary landfill: 3,000	5,000	Increasing from 3,000 to 5000tons/day from 2014
					Composting: 1,000	-	Not yet
2	Composting and recycling plastics	Vietstar Environmental Joint Stock Company (United States)	35	Dec, 2009	1,200	1,200	Full capacity
3	Composting , recycling and incineration of solid waste	Tam Sinh Nghia Investment-Development Joint-Stock Company	20	Nov, 2012	1,000	1,000	Full capacity
4	Phuoc Hiep No.3 sanitary landfill	HCMC Urban Environment Company Limited CITENCO	20	Sep, 2013	2,500 - 3,000	400-500	- Reservation - Landfilling remain waste of Vietstar plant

Sources: DONRE, 2015

4.2.4.3 Cost of municipal solid waste management

A. Treatment fee

From 2006 to 2016, HCMC paid about 307- 2,148 million VND approximate 14.3 - 99.8 billion USD from budget for MSW activities such as sweeping streets, collection, transfer and transportation, recycle and treatment of solid waste (not including cost of collection from waste generators and management supervision). The cost of solid waste collection at solid waste sources is paid by generators. Management cost of waste through years in HCMC is presented in Table 4.19.

Table 4.19. Solid waste management cost in HCMC

Year	Quantity	Cost (VND)		
		Cost of collection and transportation	Cost of treatment	Total
	Tons/day	*Million/year*	*Million/year*	*Million/year*
2006	5.194	205	102	307
2007	5.401	278	92	370
2008	5.538	378	396	774
2009	5.813	426	463	889
2010	6.184	500	532	1,032
2011	6.156	663	599	1,262
2012	6.345	772	616	1,388
2013	6.727	794	710	1,504
2014	7.153	783	1,011	1,794
2015	7.500	793	1,199	1,992

Source: DONRE, 2016,

Remarks: 1 USD = 21,515 VND

B. *Collection fee*

Collection fee at sources is paid by generators. Based on Decision No. 88/2008/QĐ-UBND dated December 20, 2008 of HCMC People's Committee on sanitation charges and environmental protection charges of solid waste in HCMC, collection fee per household is 10,000 – 20,000 VND/month. Collection fee in detail is presented in Table 4.20 and Table 4.21.

Table 4.20 Collection fee of household

Household		**Collection fee (VND/month)**	**Collection fee (USD/month)**
Urban districts	Frontage of street	20,000	0.9
	Alleyway	15,000	0.7
Rural districts	Frontage of street	15,000	0.7
	Alleyway	10,000	0.5

Source: Decision No. 88/2008/QĐ-UBND of HCMC People's Committee

Remarks: 1 USD = 21,515 VND

Table 4.21 Collection fee for other sources

Other sources	**Collection fee** (VND/month)	**Collection fee (USD/month)**
Group 1: - Family restaurants - Small commerce - Schools, libraries. - Administrative, careers offices Amount of generated solid waste < 250kg/month	60,000	2.8
Group 2: - Indoor and sidewalk restaurant - Small commerce - Schools, libraries. - Administrative, careers offices Amount of generated solid waste >250kg/month and ≤ 420 kg/month	110,000	5.1
Group 3: - Another sources: - Large restaurants, hotels - Market, supermarkets, commercial center; - Solid waste from production facilities, healthcare, entertainment areas construction, etc.	176,800 VND/m^3/month (1m^3 solid waste ~ 420 kg)	8.2

Source: Decision No. 88/2008/QD-UBND of HCMC People's Committee

4.2.5 Challenges and Opportunities

4.2.5.1 Constraints on solid waste management

With the experience of Ho Chi Minh City, compared with studies in other countries, some of the following lessons are drawn (DONRE, 2011):

Separation of solid waste at source:

- The separation of solid waste at source program is made with individual at local scale (only perform at ward/district scale in Hanoi and Ho Chi Minh City), lack of synchronization direction from Central Government (Ministry of Natural Resources and Environment). Therefore, there are no legal documents, policies and financial support.
- No experience to implement on a large scale (compared to Vietnam) due to lack of facilities, financial support, and human resources.
- Lack of examples to replicate.
- Lack of staff (technical, economic, social) have enough ability to build the program and implementation plan.
- The system of social organization is not enough ability to propagandize and campaign an extensive and long term classification of solid waste at source program. Viet Nam hasn't got a NGO in the true sense of the word but only has SBO (Social Based Organizations); such as Ho Chi Minh Communist Youth Union, Women's Union, Veteran's Union, etc.).

Solid waste management:

- Lack of infrastructure for collection, transportation, recycling and treatment.
- Lack of legal documents, policies and finance.
- Lack of staff (technical, economic, social) having enough ability to build the program and implementation plan.
- Standard of knowledge must be improved and more comprehensive to meet actual needs. Particularly, this matter should be evaluated more carefully and more scientifically.
- Underestimate the role and influence (good and bad) of informal collection force and "picker" collection force yet.

In conclusion, it can be said that separation at the sources program is not adopted by all citizens. It may take long time to change the mindset of the people for successful solid waste management.

4.2.5.2 Future plan for solid waste management in HCMC (2030)

The People's Committee of HCMC has issued future plan for solid waste management. Several activities are planned, some are ongoing some are planned for future.

A. *Solid waste separation at source*

- Solid waste separation at source program has been done at many supermarkets.

- Solid waste separation at source program has being developed in 6 districts such as District 1, District 3, District 5, District 6, Binh Thanh District and District 12: solid waste separation at source pilot of 100 – 200 households in each district. Particularly District 6, the program is implemented on the whole Ward 12 (with more than 6,000 households).
- Solid waste separation at source program has being expected to apply at:
  - Industrial zones and export processing zones;
  - New Phu My Hung resident (District 7).

B. Sanitation fee

- Sanitation fees paid by household are progressive in nature. Fee collected is used for waste management activities.
- DONRE has being implemented the project on revising the Decision No. 88/2008/QĐ-UBND dated December 20, 2008 of HCMC People's Committee on sanitation charges and environmental protection charges for solid waste in HCMC.
- Proposed sanitation and environmental protection fees will be transferred to the service fee (the rate will be promulgated by the People's Committee of the city).

C. Transfer station improvement

- Improving 13 transfer stations in most of districts.
- Expectedly, some closed - transfer stations have being constructed in District 2 and District 9.

D. Other bidding projects

- Zoning for sweeping, collection and transportation of waste, expected to develop in 2016 -2018.

E. Solid waste management master plan

- Temporarily still abiding by the previous plan in 2011: “Master plan on the waste management system in HCMC by 2020. Vision 2030”. However, the plan is not yet approved by the People’s Committee.
- Heading to the green management system focus on solid waste separation, increasing activities for sanitation fee collection, zoning bidding, etc.

REFERENCES OF BHUTAN'S INFORMATION

[1] National Statistical Bureau. (2012). Statistical Yearbook of Bhutan 2012. 30. Retrieved 27 April, 2013, from http://www.nsb.gov.bt/publication/files/pub10pp3748yo.pdf

[2] National statistical Bureau. (2014). *Bhutan at a glance 2014*. Retrieved from http://www.nsb.gov.bt/publication/files/pub2lq3514or.pdf.

[3] National Statistical Bureau. (2013b). Key Indicators. Retrieved 19 June, 2015, from http://www.nsb.gov.bt/publication/publications.php?id=9

[4] Mongar Dzongkhag. (2014). Dzongkhag at a glance. Retrieved 18 June, 2015, from http://www.mongar.gov.bt/index.php/dzongkhag-at-a-glance

[5] National Statistical Bureau. (2013a). Annual Dzongkhag Statistics 2013. Retrieved 18 June, 2015, from http://www.nsb.gov.bt/ADS2013/

[6] National Statistical Bureau. (2008). Dzongkhag Population Projections: 2006-2015. Retrieved 27 April, 2013, from http://www.nsb.gov.bt/publication/files/pub3uu3600pb.pdf

[7] PHCB. (2005). Results of Population & Housing Census of Bhutan 2005 (pp. 492). Thimphu: Royal Government of Bhutan.

[8] Phuntsho, Sherub, Herat, Sunil, Yangden, Dechen, Vigneswaran, Saravanamuthu, Shon, Hokyong, Tenzin, Ugyen M., & Dulal, Ichharam. (2010). Studying municipal solid waste generation and composition in the urban areas of Bhutan. *Waste Management & Research, 28*(6), 545-551. doi: 10.1177/0734242X09343118

[9] UNEP. (2005). UNEP Annual Report: Chapter 3 Waste Quantities and characteritics (pp. 19).

[10] National Environment Commission. (2014). Country Report:Voluntary reporting on progress/achievements/initiatives towards implementation of the Ha Noi 3R Declaration - Sustainable 3R Goals for Asia and the Pacific (2013-2023).

REFERENCES OF VIETNAM'S INFORMATION

[1] CENTEMA (2015). Analysis of composition of municipant solid waste and amount generated solid waste from generators. Integrated solid waste management system leading to zero for sustainable resource utilization in rapid urbannized in developing country project, HCMC.

[2] Do Ngat (2017). World Population Statistics in 2017, Institute of Statistical Science. Ha Noi.

[3] HCM People's Committee. (2016). Announced 10 outstanding events of Ho Chi Minh City in 2016. Retrieved 29 December, 2016, from http:// www. hochiminhcity.gov.vn/ thongtinthanhpho/tintuc/Lists/Posrs

[4] HCMC DONRE (2009). Analysis of composition of municipal solid waste and amount generated solid waste from generators, the database of solid waste management monitoring program in Ho Chi Minh City in 2009.

[5] HCMC DONRE (2010). Program on updated database of monitoring solid waste management in Ho Chi Minh City in 2010.

[6] HCMC DONRE (2011). Amount of municipant solid waste generated from 1992-2010, Master plan (orientation) the waste management system in HCMC to 2020 and Vision 2030 - Heading to the green management system.

[7] HCMC DONRE (2011). Master plan (orientation) of the waste management system in HCMC to 2020 and Vision 2030 - Heading to the green management system.

[8] HCMC DONRE (2014). The statistical data of HCMC DONRE in 2014 about amount of collected solid waste of the public and the private system in HCMC through 2011, 2012, 2013 and 2014.

[9] HCM Climate Change Bureau (2014). Composition of solid waste at Phuoc Hiep sanitary landfill.

[10] HCMC DONRE (2015). The database on monitoring solid waste management in Ho Chi Minh City.

[11] HCMC DONRE (2016). Report on results of work in 2016 and work planning in 2017, Division of Solid Waste Management.

[12] HCMC DONRE (2017). Data on solid waste management in period 2006-2017, forecast to 2025.

[13] Ministry of Natural Resources and Environment (2011). National State of Environment: Urban Environment, Ha Noi.

[14] Ministry of Natural Resources and Environment (2016). National State of Environment: Urban Environment, Ha Noi.

[15] Statistics Yearbook (2010, 2016). Population and labour, Statistical Office in Ho Chi Minh City.

[16] http://www.bbc.com/news/world-asia-pacific-16567834

CHAPTER 5: SELECTION OF WASTE MANAGEMENT CRITERIA AND TECHNOLOGY FOR EACH COUNTRY

A sustainable technology is compatible with or readily adaptable to the natural, economic, technical, and social environment and that offers a possibility for further development (Annelies et al, 1998). The sustainable technology can either be high-tech or low-tech as long as it is appropriate for the particular circumstances. In addition, a sustainable technology is appropriate for sustainable development circumstance as it has the lowest costs (investment and operation costs), feasibility of technical and legal aspects, ensuring pollution treatment efficiency and community acceptability (Mara, 1996; Sarmento, 2001; Ujang & Buckley, 2002).

In the Chapter 3, the eight possible solid waste management operations and utilization technologies are listed (composting, anaerobic digestion, mechanical biological treatment, sanitary landfill, incineration, refuse derived fuel or solid recovered fuel, pyrolysis and gasification techniques) and 12 criteria (characteristics of solid waste, waste quantity, compliance with law, land requirement, multisector involvement, public acceptability, possible adverse impacts, demand for final products, initial investment, operating cost, time consuming for entire process, and complexity & required skills) for selection of sustainable techniques for solid waste management are recommended. This chapter describe selection of criteria and sustainable technology for solid waste management for each country based on the current situation and national strategies on solid waste management.

5.1 Selected Solid Waste Management Criteria for Mongar, Bhutan

In Mongar district, almost 50% of waste is organic (Figure 5.1). Therefore, it is possible to segregate the waste into biodegradable (wet) and recyclable (dry) waste at household in core town area. At present, only some households do the separation at source. The municipality has different days of collection for wet and dry wastes. In commercial area the waste is collected twice a week. The total amount of organic waste collected per week from commercial area can be as high as 400 – 450 kg.

If the separation can be done effectively, the municipality plans to construct a small aerobic composting facility with fencing to keep the wild animal away near the Mongar landfill (7 km from town). The facility would contain six concrete chambers.

The dry waste consists of 90% recyclables and 10 % non-recyclables. Unsegregated waste after disposal to the landfill was further sorted on a landfill site by M/s We Care Waste Management. Some of the recyclables were collected directly from the households, school, and business by the We Care Company. Land and the facility is leased by municipality to We Care for the operation of the facility. This provide employment opportunity to the youth, increase the life span of the landfill as recyclables were diverted. Market for the recyclables are good enough to cover the operation cost.

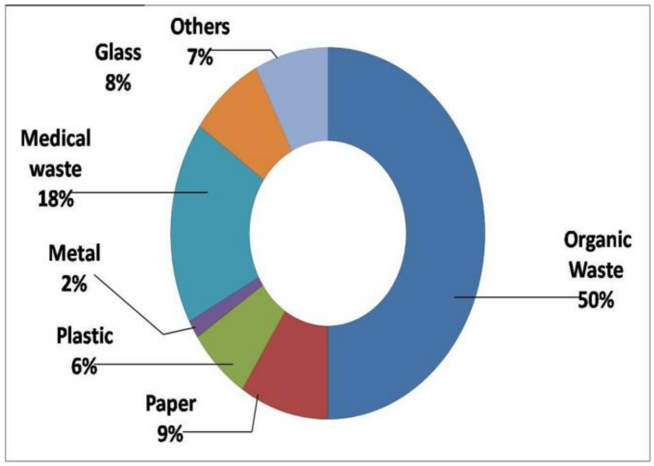

Figure 5.1 Composition of waste in Mongar town

Based on the above mentioned waste characteristics and local infrastructure and facilities available the technology that is applicable for case of Mongar are composting, anaerobic digestion, recycle and sanitary landfill. Regarding the criteria, 10 criteria were selected from the list in Chapter 3. The selected technology and criteria are shown in Table 5.1 for commingled waste and Table 5.2 for the segregated waste.

If the waste is not segregated it is difficult to justify a single technology as the solution for solid waste management in Mongar since the scores seem to be in the similar range. Composting and materials recovery seems to be preferred options based on the composition of the waste and the existing private sector, We Care Company. At present, there is no sanitary landfill in Mongar, however, if the sanitary landfill will be constructed in the future, for the commingle waste it is the least preferred option as shown in Table 5.1. This is due to the mountainous terrain and the pristine forest ecosystem that make it difficult to obtain the available land for sanitary landfill construction and also would lead to higher transportation cost.

When the waste is segregated, the appropriate technology can be clearly distinguished. Composting and anaerobic digestion score higher due to the nature of the waste generation and also because of segregation. Since the waste is separated, good quality of recyclable materials can be collected and sold at better price. Sanitary landfill is still the last preferred choice for the same reasons as mentioned. The biogas for such small amount of the waste generated is not economical and viable for both the cases.

The government policy also are trying to force the residence, government offices, schools, hospitals, and business enterprises to segregate the waste as they have the motto to have clean Bhutan and to preserve the natural resources.

Table 5.1 Assessment of solid waste management options and treatment technologies for commingle waste

Criteria	**Composting (windrow aerobic)**	**Anaerobic Digestion (AD)**	**Sanitary Landfill**	**Material recovery for reuse and recycle**	**Landfill (Baseline)**
(1) Solid waste characteristics					
- Separated solid waste at source	-	-	-	-	
- Commingled waste	1	1	5	1	1
(2) Waste quantity:	3	1	4	3	1
(3) Time consuming for entire process	2	2	5	3	5
(4) Ease of use	5	3	3	3	5
(5)Amount of valuable final products	4	4	1	3	1
(6) Initial investment	4	3	3	3	4
(7) Operating cost	4	4	2	4	5
(8) Land requirement:	4	3	1	3	1
(9) Possible adverse impacts					
- Odor	2	2	2	2	1
- Wastewater	2	2	1	4	1
- Dust and air pollution	2	4	1	4	1
(10) Public acceptability	4	4	1	2	1
Total score for each waste utilization technique	**37**	**33**	**29**	**35**	**26**

Note: Influence of impact of each criterion: 5 = most favorable, 4 = favorable, 3 = Neutral, 2= less favorable 1 = not favorable

Table 5.2 Assessment of solid waste management options and treatment technologies for segregated waste

Criteria	**Composting (window compost)**	**Anaerobic Digestion (AD)**	**Sanitary landfill**	**Material recovery for reuse and recycle**	**Landfill (Baseline)**
(1) Solid waste characteristics					
- Separated solid waste at source	5	5	4	5	1
- Commingled waste	-	-	-	-	
(2) Waste quantity:	5	5	4	4	1
(3) Time consuming for entire process	2	3	5	5	5
(4) Ease of use	5	3	3	5	5
(5)Amount of valuable final products	5	5	1	5	1
(6) Initial investment	4	2	3	3	4
(7) Operating cost	3	3	2	3	5
(8) Land requirement:	4	3	1	3	1
(9) Possible adverse impacts					
- Odor	2	2	2	2	1
- Wastewater	2	2	1	4	1
- Dust and air pollution	2	4	1	4	1
(10) Public acceptability	4	4	1	2	1
Total score for each waste utilization technique	**43**	**41**	**28**	**45**	**26**

Note: Influence of impact of each criterion: 5 = most favorable, 4 = favorable, 3 = Neutral, 2= less favorable 1 = not favorable

5.2 Assessment of Solid Waste Management Options and Treatment Technologies for Commingle and Separated Wastes.

From the above assessment (Table 5.1 and 5.2), we concluded that separation of wastes at source into two categories; dry and wet waste is very important. Dry wastes can be further separated for material recovery. The wet (biodegradable) waste will be sent for composting. After segregation, volume of biodegradable waste will reduce and the compost can be used in public areas. Anaerobic Digestion (AD) is another option for managing biodegradable waste. However, the operation of AD required skilled operators and training but it is recommended to do on small scale for the purposes of bio gas for cooking and heating. Lastly only small portion of non-recyclable waste will go to sanitary landfill as it cannot be separated completely into wet and dry waste.

Medical waste is a big issues as it mostly consist of non-recyclable wastes. Although medical wastes are autoclaved, the landfill has higher risk for labors with syringe needles, medicine, and glasses. It is recommended to have separate landfill for medical wastes. Another option is to use incinerator for medical wastes, which is not harmful to the environment as that of in Bangkok.

To improve the enforcement of waste separation, the authority should look in to willingness of people to segregate. Those who do not separate waste, their waste will not be collected by municipal authority. The government policy also are trying to force the residence, government offices, schools, hospitals, and business enterprises to segregate the waste as they have the motto to have clean Bhutan and to preserve the natural resources.

5.3 Selection of Sustainable Technology for Solid Waste Treatment in Vietnam

The goal of assessing the sustainability of solid waste treatment technology is to choose technologies that can be promptly applied in HCMC's condition. The assessment of sustainability of solid waste treatment technology is based on criteria system which will help responsible solid waste management authorities to decide which sustainable technology should be adopted.

Selection of criteria will depend on many factors such as natural, economic, technical, and social environment. In Vietnam, the selection of technology also considers the National strategy on integrated management of solid waste.

According to the National strategy on integrated management of solid waste to 2025 and vision to 2050 of the Prime Minister in 2009, DONRE has developed the program on minimize environmental pollution for HCMC every 5 years in which targets of solid waste management in period 2010-2015 including the sanitary landfill took 40%, composting technology took 40%, recycling waste took 10%, and incineration technology took 10 %. However, these targets have not been achieved because set targets are too high to compared infrastructure condition, technology level, and human resource of HCMC. In June 2017, HCM City People's Committee promulgated Resolution on "Urban environmental protection and waste management in the HCMC" in which targets of solid waste management to 2020, the sanitary landfill technology will take 60% and other technologies take 40%; to 2025 the sanitary landfill technology will remain 25% and other technologies will increase 75%. National strategy on integrated management of solid waste to 2025 and vision to 2050 of the Prime Minister in 2009 and set targets for management of solid waste in HCMC are presented in Table 5.3.

Table 5.3 National strategies on integrated management of solid waste to 2025 and vision to 2050 of the Prime Minister in 2009 and set targets for management of solid waste in HCMC

Item	2011 – 2015			2016 - 2020		2021- 2025		2025- 2050	
	Targets is given by		Achieved HCMC (*)	Targets is given by		Target is given by		Target is given by	
	Central Gov.	HCMC*		Central Gov.	HCMC Gov. *	Central Gov.	HCMC Gov. *	Central Gov.	HCMC Gov. *
Collection rate of solid waste	85%	100%	95%	100%	100%	100%	100%	100%	Not yet
Landfilling under the national technical regulation	40%	40%	68.6%	15%	60%	10%	25%	10%	Not yet
Other technologies: - Recyclable waste (paper, plastic, metal, glass, construction waste)	60%	10%	1.1%	85%	40%	90%	75%	90%	Not yet
- Incineration		10%	5.7%						
- Biodegradable waste to product composting, biogas		40%	24.6%						

*Source: Decision No.2149/2009/QD-TTg of the Government dated 17/12/2009 on approving the National Strategy on integrated management of solid waste to 2025 and vision to 2050, * the program on minimize environmental pollution of HCMC every 5 years and resolution on "Urban environmental protection and waste management in the HCMC"*

In case of HCMC, five of the eight solid waste treatment technologies (as mentioned in chapter 4) selected, these technologies are (1) composting; (2) anaerobic digestion; (3) sanitary landfill (with collection of biogas) or bioreactor landfill; (4) incinerator; (5) refuse derived fuel (RDF) or solid recovered fuel (SRF). The selection of these technologies is based on their wide application in many countries in the world as well as in HCMC (composting, sanitary landfill, and incinerator). Three remaining technologies are not compatible with economic, technical, and human resources condition of HCMC. The pyrolysis and gasification are advanced technologies, difficult to operate, and costly, while the MBT technology does not give a final disposal solution for treated waste.

Five technologies were compared according 11 of 12 criteria as mentioned above in which the multisector involvement criterion was rejected because it was considered the least important one in the HCMC's condition. The calculation was performed by scoring with regard to the quantified levels of influence of impact of each criterion in arrange of 1 to 5 scores (5 = most favorable, 4 = favorable, 3 = Neutral, 2= less favourable, 1 = not favorable).

The assignment of score to each criterion is based on expert methodology (the basis of experience and knowledge of experts), the system profile, on-site survey, and results of monitoring quality of environment. The sum of all scores for each technology is the "Sustainability Index" (SI) of technology. If the technology has the highest score, the sustainability is the highest and technology's sustainability level is reduced by decreasing score as compared to the highest score.

According to situation of solid waste management, the natural, economic, technical condition, social environment, and set targets for management of solid waste in HCMC, two scenarios are given, the first scenario is that solid waste is commingled waste (unsorted solid waste), and the second scenario is that solid waste is separated at source. Results of assessment of sustainability of solid waste treatment technologies in HCMC are presented in Table 5.4 and 5.5.

As results shown in Table 5.4, total scores of five technologies are not much different. For commingled waste, the technology's sustainability level ranks that the sanitary landfill with collection of biogas (37 points) is the most possibly applicable sustainable technology, followed by incinerator with energy collection (36 points), composting with windrow aerobic (35 points), RDF or SRF (34 points), and anaerobic digestion (32 points). Components of non-recycling solid waste (plastic, diaper, textile, leather, etc) with high calorific value are increased significantly and the food fraction of solid waste is decreased from 2009 to 2015 so that incinerator technology is ranked the second suitable technology for solid waste management.

As mentioned in chapter 2 the composition of solid waste in HCMC is commingled waste, complicated by containing household hazardous wastes (HHW) and many non-recyclable components. In addition, the characteristic of solid waste in HCMC has high biodegradable organic fraction (60.8-74.3% of wet weight) and high moisture (55-65%) so that sanitary landfill (with collection of biogas) is a sustainable technology for solid waste management for next few years. Amount of non-recyclable fraction (taking about 25% including plastic, diaper, textile, rubber & leather, styrofoam, wood) with high calorific value have increased significantly and the biodegradable organic fraction has decreased from 2009 to 2015. Due to lack of available land in HCMC, incineration technology is ranked the second from five treatment technologies with possible energy recovery from solid waste. However, energy yield is very low due to the high moisture content of the solid waste, high investment and operation costs compared to the other technologies. The composting technology is ranked the third because input for composting plant is commingled waste therefore the separation step has to be carried out before the waste is composted and this step requires a lot of labor and thus increasing the cost of production. In addition, quality of compost using commingled waste is low because product is mixed by scrap glass and plastics resulting in difficult consumption. The RDF technology ranked the fourth as this technology is possible for recovering resources from solid wastes. However, RDF system does not exist in HCMC and demand of the product is not known as well as the lack of regulation on these recycling products. The anaerobic digestion technology has the lowest score due to uncertainties regarding investment and operation costs of anaerobic digestion plants, low energy prices, damaged reputation due to unsuccessful plants as well as this technology need the source sorted organic. These results are in consistent with the set targets for management of solid waste in HCMC according to National strategies on integrated management of solid waste.

In the case of Bangkok Metropolitan Administration (BMA), solid waste is also not separated at source. The amount of solid waste generated in BMA was 9,940 tons/day with biodegradable organic fraction (42%) as major component. Other components such as recyclable component contribute 13%, non-recyclable with high calorific value accounted for 42% and non-organic fraction 3%. The applied technologies for treatment of solid waste in the BMA include sanitary landfill with collection of biogas taking 88%, composting technology taking 12% (BMA, 2014).

Since 2005, the BMA has operated a composting and material recovery facility with capacity of 1200 tonnes/day using unsorted solid waste. This facility can recover approximately 80 tonnes/day of recyclable waste and can produce about 300 tonnes/day of compost product. The composting process consists of 3 main units such as pre-treatment; aerobic composting (static pile technology) including two activities: intensive aerobic and slow aerobic; and fine compost separation. In composting process, fine compost separation step is an important step as it can remove most scrap glass, plastics, and hard particles from compost. The compost product has been used widely by households and farms due to the quality of product.

Future plans for waste management in BMA (2015 – 2019) is to increase the amount of waste disposed by appropriate technology up to 30% including a new composting plant with capacity of 600 tons/day, a new incinerator with capacity of 2,000 tons/day, and mechanical biological treatment (MBT) plant with capacity of 800 tonnes/day.

In the case of HCMC, solid waste is also not separated at source and composition of solid waste is similar to that of BMA. However, compost product from HCMC is very difficult to consume because it has scrap glass and plastics contamination. Experience learned from compost processing in BMA is that the compost plants in HCMC should install the fine compost separation step to better control the quality of the product by removing glass and plastic debris. In addition, aerated pile composting technology will better control than windrow composting. According to case of BMA, incinerator (with energy collection) is considered as the appropriate technology for solid waste treatment, based on the results in Table 5.4, incinerator technology is ranked the second for sustainable solid waste treatment technology in HCMC.

The scenario 1 shows sanitary landfill with collection of biogas is feasible technology for next few years. At present it plays an important role in the SWM in HCMC taking 68.6% of total generated solid waste. However, this technology is not yet ensuring pollution treatment efficiency, community acceptability is low and it is also requirement of large land so that the scenario 2 of separated solid waste for SWM in HCMC is assessed. Result for separated waste is shown in Table 5.5.

Table 5.4 Assessment of sustainability of treatment technologies for commingled waste (Scenario 1)

Criteria	Composting (windrow aerobic)	Anaerobic digestion (AD)	Sanitary landfill with collection of biogas	Incineration with energy collection	RDF or SRF
(1) Solid waste characteristics					
- Non-separated solid waste at source	-	-	-	-	-
- Commingled waste	2	2	5	3	3
(2) Waste quantity:					
Large amount (large community to city levels)	3	1	3	3	1
(3) Compliance with standard/regulation of National technology of Vietnam	5	5	5	5	5
(4) Time consuming for entire process	2	3	5	5	3
(5) Complexity and required skills	5	3	4	2	3
(6) Demand for final products	2	2	2	2	2
(7) Initial investment	4	2	3	1	2
(8) Operating cost	2	2	5	1	2
9) Land requirement: - Large scale	2	3	1	4	3
(10) Possible adverse impacts					
- Odor	2	2	1	2	2
- Wastewater	2	2	1	4	3
- Dust and air pollution	2	3	1	2	3
(11) Public acceptability	2	2	1	2	2
Total scores for each treatment technology	**35**	**32**	**37**	**36**	**34**

Note: Influence of impact of each criterion: 5 = most favorable, 4 = favorable, 3 = Neutral, 2= less favorable 1 = not favorable

Table 5.5 Assessment of sustainability of treatment technologies for segregated solid waste (Scenario 2)

Criteria	Composting (windrow compost)	Anaerobic digestion (AD)	Bioreactor landfill (Sanitary with recovery biogas)	Incineration with energy collection	RDF or SRF
(1) Solid waste characteristics					
- Separated solid waste at source	5	5	5	5	5
- Commingled waste	-	-	-	-	-
(2) Waste quantity					
Large amount (large community to city levels)	5	5	5	4	4
(3) Compliance with standard/regulation of National technology of Vietnam	5	5	5	5	4
(4) Time consuming for entire process	2	3	1	5	4
(5) Complexity and required skills	5	3	4	2	3
(6) Demand for final products	4	4	1	4	3
(7) Initial investment	5	3	4	2	3
(8) Operating cost	5	3	4	2	3
(9) Land requirement - Large scale	2	3	1	4	3
(10) Possible adverse impacts					
- Odor	2	2	1	2	2
- Wastewater	2	2	1	4	3
- Dust and air pollution	2	4	1	2	3
(11) Public acceptability	2	3	1	3	3
Total scores	**46**	**45**	**34**	**44**	**43**

Note: Influence of impact of each criterion: 5 = most favorable, 4 = favorable, 3 = Neutral, 2= less favorable 1 = not favorable

Table 5.5 shows that total scores of all technologies in scenario 2 is higher than scenario 1 because solid waste is separated at source to form clean food fraction, recyclable fraction, and remain fraction. Assessing sustainable treatment technologies for using separated solid waste, the composting technology (46 points) is the most possibly applicable for the SWM in HCMC, follow by anaerobic digestion and RDF with 45 points, incinerator with collect energy (44 points), and the last is bioreactor landfill (34 points) respectively.

Table 5.5 shows that total scores of all technologies in scenario 2 is higher than scenario 1 because solid waste is separated at source to form clean biodegradable organic, recyclable, and remaining fraction. Assessing sustainable treatment technologies for separated solid waste, the composting technology (46 points) is the most possibly applicable, followed by anaerobic digestion (45 points), incineration with energy collection (44 points), RDF or SRF (43 points), and the last is bioreactor landfill or sanitary landfill (34 points), respectively.

The potential demand for organic fertilizers and soil conditioners in the surroundings of HCMC is very high and exceeds the actual supply. With source clean biodegradable organic fraction from separated solid waste and thus composting technology is the most sustainable one because of its simplicity, low cost, and high demand of composting products. At present quality of compost product is not controlled so that it is very difficult to consume. The anaerobic digestion can be used to produce green electrical energy and soil conditioner from biodegradable organic fraction and it is ranked the second after composting technology because of its higher complexity and cost compared to the composting technology. The bioreactor landfill or sanitary landfill with collection of biogas requires large amount of land, generate huge volume of leachate and odor emissions therefore it has the lowest score. Components of remaining solid waste after separation (plastic, diaper, textile, rubber, leather, etc) with high calorific value, the incineration technology with energy collection obtains high score when compared to RDF technology. The reason that that RDF technology‘s acceptability is considered lower than incinerator because of lack of regulation on these recycling products and market.

The results of the assessment of the sustainability of solid waste treatment technologies from two scenarios show that scenario 2 have specific advantages such as low operation, high quality of composting product, more efficient land use, lower environmental impacts and higher production of biogas, energy collection in comparison with the scenario 1 so that the scenario 2 will be selected for integrated solid waste management in HCMC. These results are consistent with situation of solid waste and the set targets for management of solid waste in HCMC. In addition, it is clear that one technology would hardly achieve efficiency of solid waste management in HCMC. The need for combination of multiple technologies yields integrated solid waste management system leading to zero waste for sustainable resource utilization in HCMC. Ideally, the composting technology followed anaerobic digestion technologies is found to be the most sustainable for solid waste in the HCMC, incineration with energy collection is essential only for non-recyclable solid waste (with high calorific value) and residual solid waste will always be a need for landfilling.

With regard to solid waste management system leading to zero waste for future application, the main aspect to be considered is solid waste separation at source. According to quantity and composition of generated solid waste in HCMC, by separating solid waste at sources (application of scenario 2), the City will be able to: (1) recycle 70 to 80% of city's solid waste, among which about 60% is used for producing compost and organic fertilizer and anaerobic digestion for generating energy, and 10-20% is used for recycling; (2) incinerator of non-recycling solid waste (about 15 %) for energy collection; (3) sanitary landfill is used for of 10 % of generated solid waste; (4) decrease pollution caused by odour and leachate from landfills; and (5) raise people's awareness for environmental protection. For future plans for solid waste management, the central government should issue policies for waste recycling and the policies to encourage the use recyclable materials from solid waste. The results above show that SWSAS plays an important role in the integrated SWM in HCMC so that pilot project of solid waste separation at source program at Ward 12, District 6 is implemented and reported in Chapter 6.

5.4 Conclusion

The method to assess the sustainability of technologies is based on criterion (with 11 criteria) and scoring with expert opinion. This method is considered simple, understandable, and applicable especially in developing countries. The criteria have been designed in the flexible manner, overtime new criteria can be added and others, proving less effective can be removed to adapt each local condition. In addition, the scoring of each criterion can be changed according to the importance of criterion for local condition. The assessment of sustainability of solid waste treatment technology is based on criteria system which will help responsible solid waste management authorities to decide which sustainable technology should be adopted in local's condition.

REFERENCES

[1] Annelie, J. B., R, W, Stefan., and J. D. L Fred. (1998), On methodologies for comparison of wastewater treatment systems with respect to sustainability. WIMEK conference "Options for closed water system" March 11-13, 1998, Wageningen, the Netherlands, 130p.

[2] Mara, D. D. (1996). Low-cost urban sanitation. John Wiley & Sons, West Sussex, UK.

[3] Sarmeto, V. (2001), Low-cost sanitation improvement in poor communities: conditions for physical sustainability. PhD Thesis. University of Leeds, Leeds, UK.

[4] Ujang, A. and C. Buckley (2002), Water and wastewater in developing countries: present reality and strategy for the future. Water Science Technology. Vol.46 No.9 P1-9.

CHAPTER 6: PILOT PROJECTS IMPLEMENTATION

6.1 Pilot project implementation in Bhutan

There are four pilot projects implemented in Mongar, Bhutan. Based on waste composition, and waste management criteria selected, the most appropriate technology to be implemented in Bhutan is waste separation at source for composting and recyclable materials recovery.

6.1.1 Pilot Project 1: Waste segregation at source.

Mongar town can be divided into six zones. In total the town generates 0.95 tons of solid waste per day with a waste generation rate of 0.23 kg/person/day. The waste consist of 50 percent wet waste and the rest are dry waste (Figure 6.1). If wastes are separated at source, the treatment process employed can also be done effectively.

However, segregation cannot happen in all six zones, therefore the initial focus of the pilot project was on the high waste generation area which is a commercial area (core town) consisting of 216 business enterprises with the total population of 2090 people.

People staying in this area has to separate the waste into two categories; wet waste and dry waste. A constant household-wise monitoring and education were done to make people understand how to segregate different waste materials. It took about two months to make people fully understand the segregation process. The wet waste was taken for aerobic composting and the dry waste were further separated into recyclables and non-recyclable, the latter were dumped into landfill.

Comparing to past years the waste entering into landfill decreased from this zone thus increasing the employment opportunity, helping economically disadvantage people and lastly helping our pristine mother environment.

Methodology adopted for the implementation of the pilot project is as follows:

- Involvement of private sector: at first municipality cooperates with M/S We Care Waste Management Company for overall operation of composting of organic waste. The transportation of organic waste to the composting site is taken care by Mongar Municipality.
- Involvement with public: Mongar Town public accepted the Project and were willing to cooperate with municipality regarding waste segregation from the source.
- With discussion with the town representative, Mongar municipal, and other relevant stakeholders decided and elected a committee from the Town comprising of six members volunteer to monitor the function of the pilot project.
- Penalty is reinforced to the person or the household who do not segregate the waste and was charged a minimum fine of Nu 1000 and 2500 for littering and dumping the waste in inappropriate places and the money was transferred to the separate account of this project and will be used for the project.
- Employment opportunity in the initial phase was the hiring of 2 workers on a daily wage basis.
- The final compost product will be sieved and packed according to the sizes.

- To increase the awareness and promote the compost to the public and the farmers, the first batch of compost product will be sold at the minimum price to get the feedback from the users.
- The segregated dry waste was collected by We Care waste management company. On average, 110 kg of recyclable materials were diverted from landfill on a daily basis.
- The remaining 70 kg of dry waste consisted of medical waste and non-recyclables were dumped into landfill.

The data from the implementation of pilot project really indicate the success of waste separation. From Table 6.1, it can be clearly seen that waste going to landfill is approximately 19 %. The remaining could be recovered for composting and recycling. Thus, the waste going to the landfill can be drastically reduced by appropriate segregation and interception.

For other zones, the practice commonly followed is shown in Figure 6.2. Figure 6.2 (a) shows the disposal of commingle waste disposal from other zones of Mongar town on the landfill. As a results, the We Care Company have to hire the labors to segregate the recyclables from the dump site, shown in Figure 6.2 (b) and (c). The current practice increases the cost of recovering the recyclables and reduces the lifespan of landfill. Moreover, not all recyclable can be recovered as they are mixed with organic wastes.

The success of the pilot project from the core town or commercial area suggested that similar activities can be done in different zones to have proper waste management leading to minimization of the waste going to the landfill.

Table 6.1 Outcome of implementation of pilot project in commercial area

SL No	**Particulars**	
1	Number of Commercial (A)	216 enterprises
2	Average waste generation per day Pilot Area (commercial) (B)	1.75 Kg
3	Total weight (kg) per day(C)=AxB	378 kg
4	Dry waste average (kg)	110 kg (recyclables) 50 kg (Medical) 20 kg (landfill)
5	Wet waste average (kg) per day	198 kg (organic materials)
6	Frequency collection	2 times each a week
7	Days	Mon and Wed=Wet Tue and Fri=Dry

Figure 6.1 Segregation of waste into dry and wet waste

(a)

(b) **(c)**

Figure 6.2 Prevalent practice followed at the landfill sites. (a) disposal of commingle waste on the landfill, (b) and (c) recovery of recyclable materials at the landfill site

6.1.2 Pilot Project 2: Waste (recyclables) Recovery Center at Mongar Lower Secondary School

The recyclable storage facility (Figure 6.3) was constructed in the school premises for storing recyclable generated within the school and also collected by teachers and students from their home and on the way to school. Therefore, this activity helped in reducing the waste going in the municipal waste truck and consequently to the landfill (Figure 6.4).

The facility is coordinated by the Nature club teacher and by the student's member in collaboration with We Care Waste Management. When the facility is full, the company will come, collect and buy the recyclables. Income from the selling of recyclables will be transferred to school development fund.

The two major recyclables materials recovered from school are pet bottles and cardboards. On average, the school recovers 70 kg of these materials per week, which is more than 3,.000 kg per year.

Figure 6.3 Recyclable storage facility

Figure 6.4 Recyclable waste collection at Mongar lower secondary school

6.1.3 Pilot Project 3: Rigde Mahaguru Chhoetshok (RMGC) Recyclables Waste Recovery Center

Rigde Mahaguru Chhoetshok is a Non-profit organization with a modern approach to teach the Buddhist philosophy to all walks of life. In order to maintain Green Monastery, RMGC has come up with the concept of 4-Rs, which is: Renewable, Reuse, Recycle, and Reduce. RMGC has initiated collection of recyclables diverting the waste going to landfill (Figure 6.5). There are around 200 members collecting recyclables and sell to We Care waste management firm. The income from selling the recyclables is used as the Green Monastery fund.

RMGC aims to mobilize funds and strengthen its resources base as well as organizational structure to carry out lawful and prudent investment of its capital and resources and govern the judicious use and management of all its assets and resources to ensure the long-term sustainability of the monastic activities.

In order to sustain the activities, it is planned to construct the big facility for the group to store the recyclables that they collect.

Figure 6.5 Recyclables segregation at the Monastery

6.1.4. Pilot Project 4: Communal wire mesh bins

The weir mesh bins shaped in rectangle, made up of metal frame with roofing and hole at the top in order to drop the solid waste where there is no road accessibility for municipal vehicle to reach door to door. Weekly collection is done by the municipal waste workers.

In order to protect the littering in natural environment and also from wild animals, the total 12 wire mesh bins (Figure 6.6) were placed in area where public can dump the waste instead of open area.

Table 6.2 shows the summary of recyclables collected by We Care Waste Management Company from 2014 to 2016 for Mongar Town. It can be clearly seen that the amount of recyclables collected increased in 2016 after the implementation of the pilot projects as discussed above. The other reasons contribute to increase recyclables are;

- Increase in population
- Improved waste management
- Awareness program among the public, regarding waste separation and disposal
- Private public partnership programs

On the other hand, there are also some drawbacks in the solid waste management system as listed below:

- Low public awareness and community participation
- Frequent break down of municipal vehicle during collection time
- Labour intensive process
- Financial problem for deploying workers
- Lack of human resources in municipal solid waste department
- Public not willing to buy waste bins for different waste

Figure 6.6 Construction of communal wire mesh bin

Table 6.2 Summary of recyclables collected by We Care Waste Management Company from 2014 to 2016.

Year	Plastic (kg)			Tin (kg)	Papers (kg)		Iron(kg)	e-waste (kg)	Copper * (kg)	Low grade Aluminum (kg)	High grade Aluminum * (kg)	Total (kg)
	PET	HDPE	Plastic Syringe		Cardboard	Papers						
2014	3408	1697	81	629	1683	4630	256	57	6.5	48	5	12499.7
2015	4385	758.5	241	450	4401	477	273	428	89	72	49	11623.5
2016	6664	1316	424	1576	5366	2389	1159	139	19	90	7	19148

Note: * collected from e-Waste

Conclusion

Based on the result of pilot projects, waste segregation at source seems to be must for sustainable waste management. Based on waste composition and waste management criteria selection, the composting and recovery of recyclable materials seems to be feasible. In addition, awareness program among the public, regarding waste separation and disposal are also required.

6.2 Pilot Project Implementation in Vietnam: Solid Waste Separation at Source Program at Ward 12, District 6, Vietnam

6.2.1 Introduction

District 6 is a suburban district in the southwest of Ho Chi Minh City with a total natural area of 7.19 sq.km taking 0.34% of the natural area of the city (Figure 6.7). The strength of District 6 is the trade and services, in which are mainly small traders. People of District 6 are mostly labourers. District 6 is divided into 14 wards (from Ward 1 to Ward14), Ward 12 is one of the major wards of District 6 with an area of 0.73 sq.km taking 10.15% of the natural area of District 6.

Total population of ward 12 is 27,743 people from 4,839 households and 1,372 small traders. The ward 12 consists of 8 quarters with 156 population groups, and an average population density of 9,078 people/sq.km. This ward has a high population density in District 6, Kinh people account for 73.31%, Chinese people account for 26.10% and remaining groups include Cham, Khmer, Tay, Nung, etc.

There are 7 schools in ward including 3 kindergartens, 2 primary schools, 1 junior high and 1 high school, and 1 college. This ward has 53 healthcare units including 1 medical station of ward, clinics, and pharmacies. In addition, the ward 12 has 1 Phu Dinh market and 15 religious units.

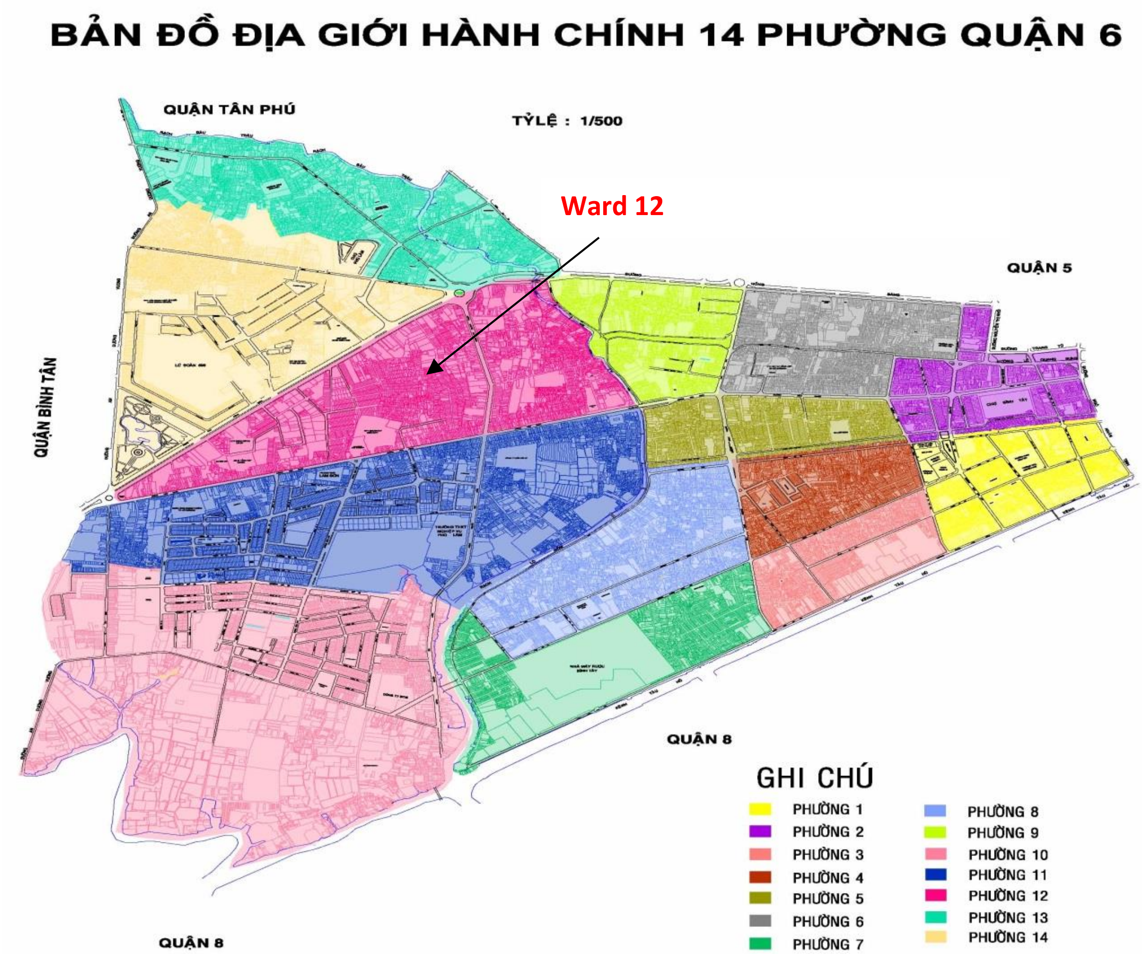

Figure 6.7 Administration map of District 6 and location of ward 12

6.2.2 Solid Waste Separation at Source Program at Ward 12, District 6

In Ho Chi Minh City, separating biodegradable waste without any hazardous component in order to create “clean” sources of organic substance that can be used to make high quality compost and microorganism fertilizer. The recyclable materials can be also recovered by source separation.

According to the resolutions of the Ho Chi Minh city People's Committee, in 2015 DONRE has implemented SWSAS program in districts 1, 3, 5, 6, 12 and Binh Thanh District, in which SWSAS program at Ward 12, District 6 is in large scale and it can become a good example to be replicated to the whole city. This program was divided into 2 phases for 2 years (2015 and 2016).

Phase 1: Starting on February 24, 2015, the SWSAS program had been carried out for 131 households including 40 households (from No. 716A to 762 Hau Giang street and 788 to 814 Hau Giang street) and 90 households in the Phu Lam A residential area and 1 religious unit.

Phase 2: Starting on September 6, 2015, it was expanded to the whole Ward 12 with about 6,062 waste generators including 4,683 households and 896 small traders, 7 schools, 53 healthcare units, Phu Dinh market and 15 religious units.

6.2.2.1 Implementation of solid waste separation at source program

Implementation of solid waste separation at source program of Ward 12 includes training, propaganda, monitoring and assessment of efficiency of the program. In the implementation of the program, 4,839 households, 7 schools, 1 market, and 53 religious units were provided free of charge two 15 L garbage bins. One garbage bin for storing food waste and another one for storing the remaining waste. In addition, Doan Ket cooperative (informal sector for collection of solid waste) was also provided free of charge 15 pushcarts with volume of 660 L.

A. Training

People's Committee of ward 12, district 6 in coordination with DONRE and Institution for Environment and Resources (IER) had organized training for participants which are presented in Table 6.3.

Table 6.3 Number of participants trained on solid waste separation at source

No.	Participants	Training time (one training: half day, 4 hrs)
1	Head and deputy head of quarter (164 people)	2
2	Members of Youth Union and Women Union (669 people)	7
3	The waste collector (50 people)	1
4	Households (4839 people)	48
5	Minor traders (960 people)	10
6	Schools (301 people)	3
7	Market (including a management board and 355 minor traders)	1
8	Healthcare units (80 people)	3
9	Religious units (45 people)	1
Total		76

B. Awareness Campaign

In 2015, awareness campaign of SWSAS program is implemented with banners and loudspeaker (everyday from office of People's Committee of ward). The awareness campaign is also carried out on media such as television with contents as follows:

- Broadcast trailer and awareness campaign on how to separate solid waste at sources (provided by DONRE).
- Broadcasting 3 video clips (about 3 minutes) on the implementation of the solid waste separation at sources program in the districts where the programs are implemented.

In 2016, ward 12 has launched many forms of awareness campaign as organization of solid waste separation at sources contest for women's groups in the quarter to improve the role of the Women's Union in the awareness campaign of SWSAS.

The awareness campaign is concentrated in the core force including the quarters and population groups (8 head of quarters and 156 head of population groups), the Women's Union (2 people) and Ho Chi Minh Communist Youth Union (2 people), which is an important nucleus in the implementation of SWSAS program.

At Zero Baht Shop in Bangkok, which is a community based solid waste management (CBM) project, waste separation at source was successfully implemented as people perceive that waste is money and initiatives and management processes aim to provide benefits to the public (mutually agreed). Based on the experience of visiting Zero Baht Shop, Centema has implemented waste exchange for gift program in primary school. In this program, Centema organized the awareness campaign and training of SWSAS for pupils of Lam Son primary school (Fig. 6.8 and 6.9) in 2017. The purpose of this awareness campaign and training is to create a conscious behavior towards waste separation and recycling at an early age. The pupils in Lam Son primary school mostly reside in the locality (Ward 12, District 6) and are thus important nucleus in the awareness

Four forms of awareness campaign were selected at Lam Son primary school:

- Trainers teach pupils to sort solid waste with the real waste items (food waste, shell, waste cans, and waste plastic bottles).
- Poster to explain each component of solid waste and hazardous waste, guiding the classification of solid waste at source.
- Backdrop introduces the ongoing solid waste separation program at Lam Son primary school to attract the attention of pupils and parents.
- To increase the efficiency of the solid waste separation at school, one of the main points of this propaganda is the exchange of valuable waste for gifts to create more practical exercises for children for understanding solid waste separation.

Figure 6.8 Training on SWSAS for pupils by backdrop and poster

Figure 6.9 Training activity for pupils to sort solid waste with the actual items

The program consists of two parts as follows:

The awareness campaign program was held on Monday in May, 2017. The forms of awareness campaign used were interactive questions and the visual method by showing actual pictures of the types of waste generated in daily life and guiding pupils to put waste into different bins. In addition, the other forms of propagation such as banners and posters were also used. A banner was hanged outside the school gate and 4 (A2-sized) posters were posted along the main pathway of classrooms (Fig. 6.10 a).

The waste exchange program was carried out for two weeks (from 15 to 28 May 2017) and it was operated with exchange of recyclable waste for gifts such as pen, pencil, bookmark, sticker, note book, etc. Recyclable waste was converted into points which were recorded on the voucher and it was used to swop any gift that the pupil enjoys when they have earned enough points (Fig. 6.10 b). The rule of calculating point is as follows:

- 1kg of paper, newspaper, cardboard can be counted as 3 points;
- 1 plastic bottle (PET) or metal cans (soft drink) can be counted as 1 point;
- 1kg of washed milk bottle and washed can be counted as 5 points.

(a) **(b)**

Figure 6.10 Waste exchange program in Lam Son primary school (a) How to calculate points for recyclable waste; (b) Voucher for swop gifts

C. Quantity of solid waste generated

Solid waste in ward 12 is generated from households, small restaurants, small traders, government offices and small enterprises, school, market, etc. The quantity of generated solid waste within ward 12 is 22.3 tons/day (DONRE HCM, 2015) in which the Phu Dinh market generates about 0.5-0.7 tonnes/day.

D. The solid waste collection fee in 2012

The solid waste collection fee from households at ward 12 was 577.5millionVND per year. The informal collectors received 563 million VND (97.5%), the People's Committee of District 6 received 5.7 million VND (1%), and the People's Committee of ward 12 8.7 million VND (1.5%).

The solid waste collection fee from non-household locations was 187.3 million VND per year. The informal sector received 76.5 million VND, the People's Committee of the District 6 1.9 (1%) million VND, and the People's Committee of Ward 12 2.8 million VND (1.5%). The contribution from the state budget was 106.1 million VND.

E. The socio-political organizations in ward 12

There are 4 socio-political organizations in ward 12 concerning the SWSAS program including:

- Vietnam Women's Union: 2250 members;
- Communist youth union: 40-120 members;
- Vietnamese Fatherland Front: 31 members;
- Veteran union: 10 members.

F. Assessment of solid waste separation program at source at ward 12

After the first year of implementation of SWSAS program, Natural Resources and Environment of Ho Chi Minh City together with People’s Committee of District 6 and ward 12 carried out evaluation the effectiveness of the program in order to draw the lessons learnt for application in the whole City.

Generation sources

According to the survey results of DONRE in 2015 and 2016 for SWSAS program at Ward 12 (consist of 8 quarters), in the first stage (from 14 to 20 October, 2015) out of 6,211 waste generators, 60% implemented SWSAS, but only 22.8% could separate waste correctly. In the second stage (from 25 to 31 May, 2016), the results of checking and evaluating SWSAS of 1,878 waste generators showed that the number of participant in the SWSAS program was 70%.

In addition, the survey results for waste generators participating in the SWSAS program shows that only 30.4% of waste generators separated waste into two categories; 47.2% waste generators did not properly separate the waste as the biodegradable organic fraction were mixed the remaining fraction and vice versa; and 22.4% waste generators did not carry out SWSAS. In the program, small traders were the main participants (54%). The proportion of waste generators implementing solid waste separation in 8 quarters of ward 12 is presented in Figure 6.11.

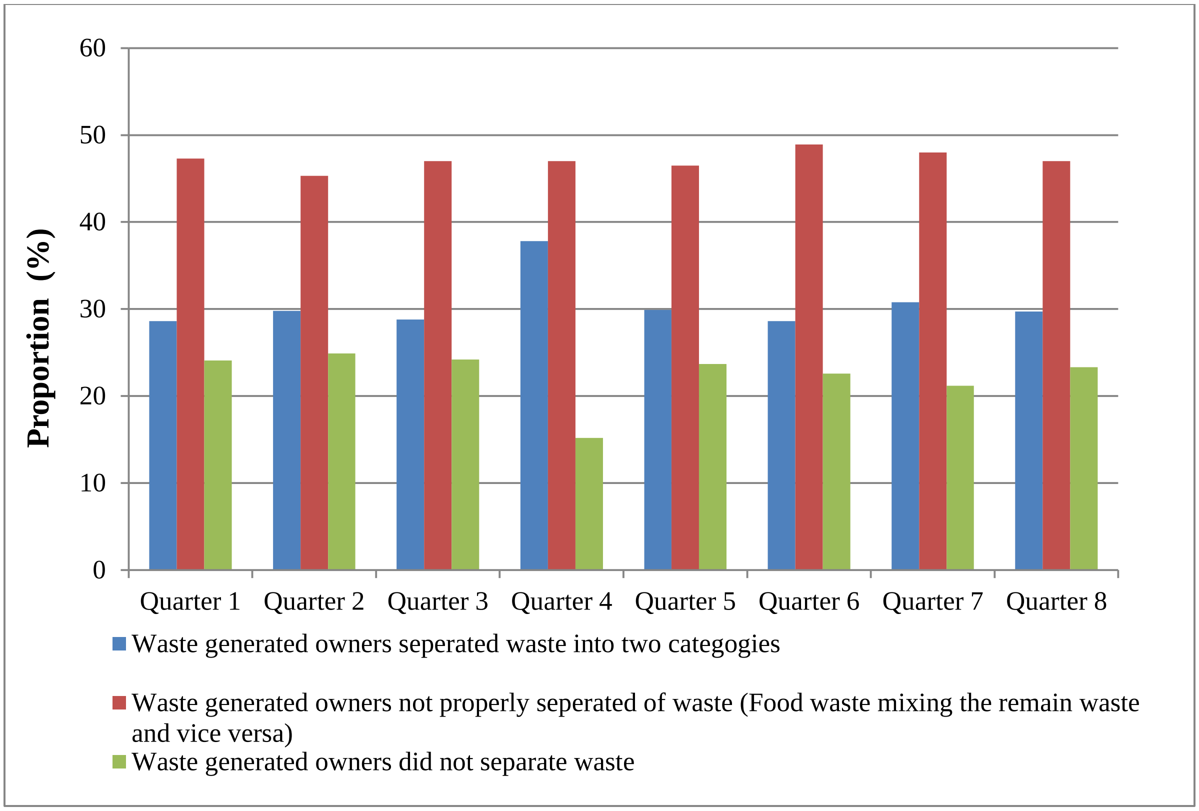

Figure 6.11 Situation of implementing solid waste separation at source program

In order to assess efficiency of the training for SWSAS in ward 12, DONRE in coordination with Center for Environmental Technology and Management (ETM) took 141 waste samples (separated solid waste at source including food waste fraction and remaining waste fraction) for measure composition of each fraction. Results showed that waste generators did not properly separate waste as the food waste fraction was mixed with other waste and vice versa. Detail of composition of separated food waste and remaining waste fraction are presented in Figure 6.12 and 6.13.

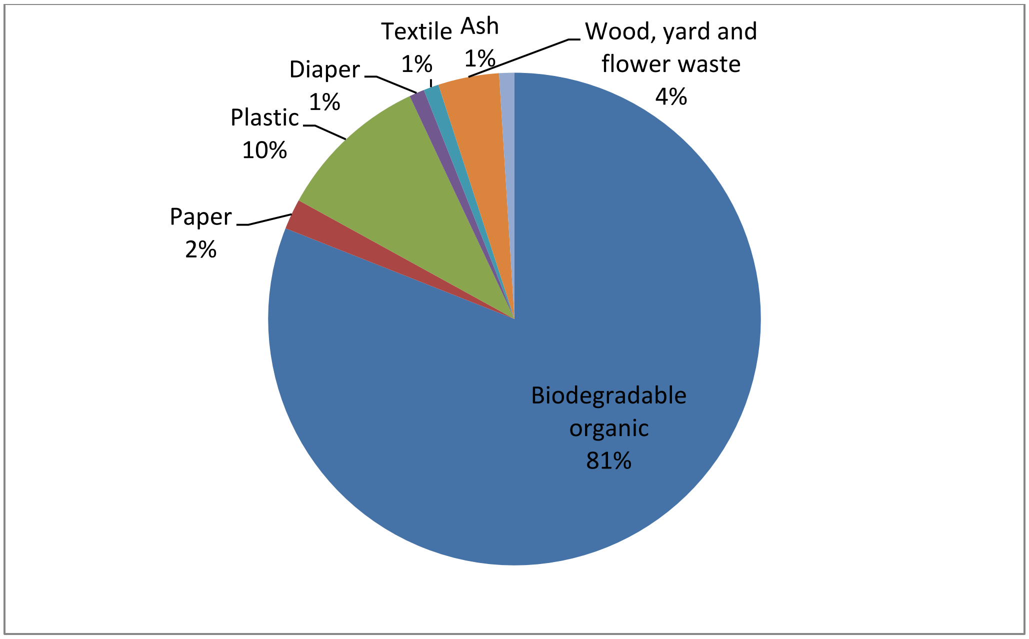

Figure 6.12 Composition of biodegradable organic fraction (DONRE, 2015 and 2016)

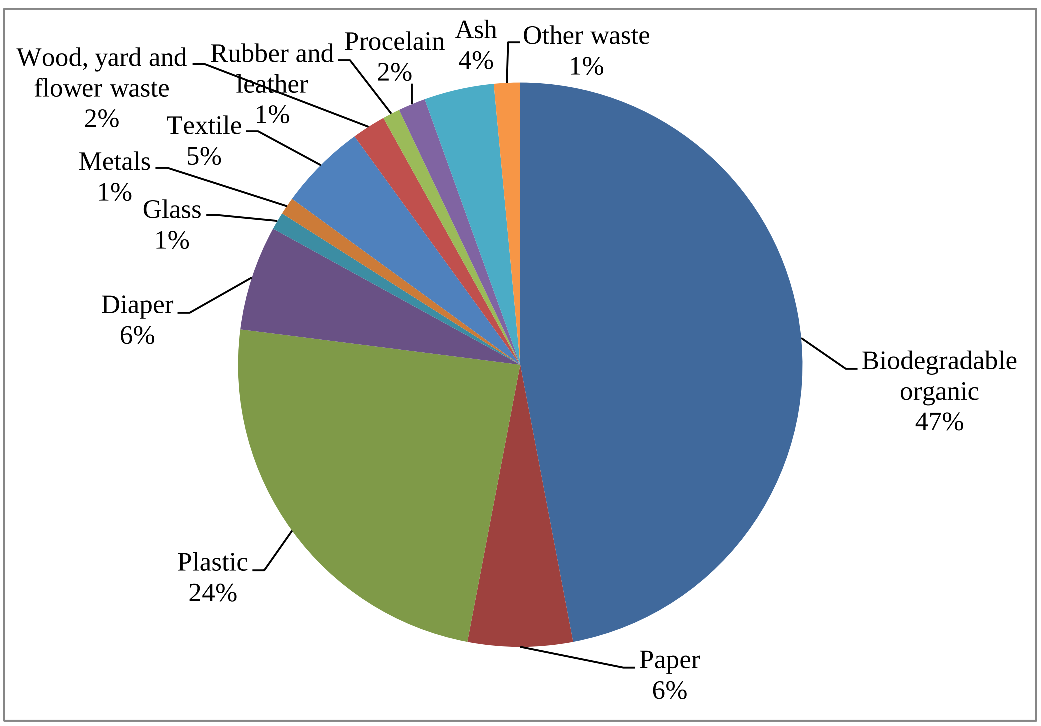

Figure 6.13 Composition of remaining fraction (DONRE, 2015 and 2016)

In 2016, Centema coordinated with DONRE and People's Committee of ward 12 to survey the implementation of SWSAS program in Ward 12 and in 2017 Centema had carried out an evaluation of the SWSAS program as an independent unit. The evaluation was conducted through survey and sampling on three solid waste collection lines of Doan Ket cooperative (informal sector). Three lines are proposed by DONRE and People's Committee of ward 12 as based on assessment results of DONRE in 2015 and 2016 for SWSAS program. The first line includes households who implemented good solid waste separation, the second line represented incorrect separated households and the last line represented households that did not separate waste.

The survey and sampling time was on Thursday and Saturday and was conducted in two stages, the first of stage from 11 to 13 May, 2017 and the second stage from 20 to 25 May, 2017 (Figure 6.14).

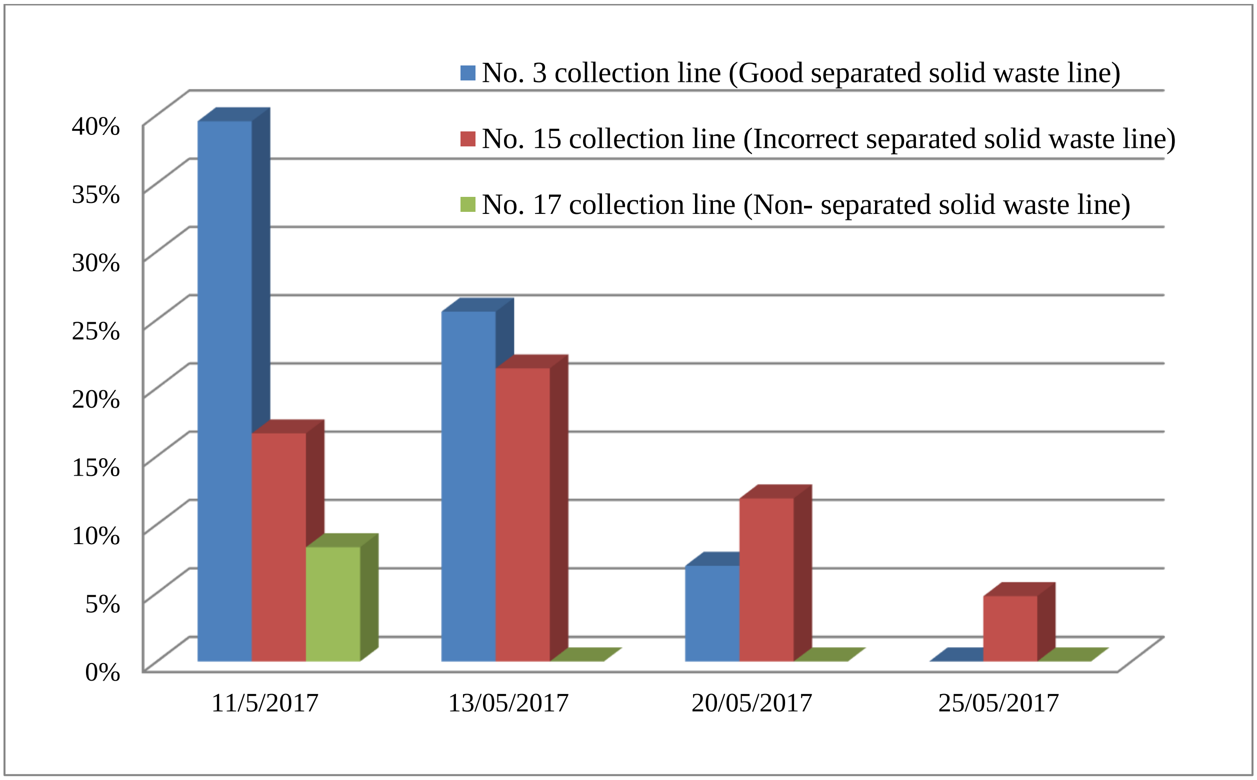

Figure 6.14 Percentage of waste generators implementing solid waste separation at source

The results show that percentage of waste generators separating waste into two categories is low and most of them do not separate solid waste regularly and also incorrect, even though they have been trained on solid waste sorting methods. Some figures for situation of waste storage at source in three collection lines are presented in Figure 6.15 (a), (b), and (c).

(a) Storing solid waste at No. 3 collection line (good separation waste line)

(b) Storing solid waste at No. 15 collection line (incorrect separation waste line)

(c) Storing solid waste at No. 17 collection line (non- separation waste line)

Figure 6.15: Situation of waste storage at source at three waste collection lines

According to the amount of solid waste generated by 20 households surveyed randomly in ward 12, waste generation per capita was in the range of 0.4 to 1.3 kg/capita/day (Centema, 2017). The variation of waste generation rate was due to some households rented the house but do not cook at home (less amount of solid waste) and some households were small restaurants, catering businesses, entertainment services, and thus created high amount of solid waste). The amount of solid waste generated by 20 households at ward 12 is summarized in Table 6.4.

Table 6.4 Amount of solid waste generated by households

Address	Number of person in a household	Amount of generated waste per household (kg/household)	Amount of waste per capita(kg/capita)
995/52	5	5.7	1.1
995/54/12	4	2.3	0.6
995/54/14	3	3.4	1.1
995/54/16	5	3.6	0.7
995/54/22	5	3.8	0.8
995/54/22A	3	2.0	0.7
995/31A	5	6.7	1.3
995/50A	6	6.5	1.1
995/25	4	1.9	0.5
995/50	4	1.6	0.4
995/25/8	4	5.2	1.3
995/38/4	7	7.3	1.0
995/38/6	5	4.9	1.0
995/52A	4	2.2	0.6
995/26	4	1.8	0.5
995/36	4	1.6	0.4
995/15	4	1.5	0.4
61 Kinh Duong Vuong Street	5	3.3	0.7
217 Kinh Duong Vuong Street	5	2.5	0.5
39 Kinh Duong Vuong Street	4	2.8	0.7

Centema took samples from 75 households (on three solid waste collection lines of Doan Ket cooperative) to measure composition of separated solid waste to assess efficiency of SWSAS program at ward 12, District 6.

The composition of solid waste at No. 3 and No. 15 collection lines are presented in Figure 6.16 and 6.17. Although No. 3 collection solid waste line is said to be good separation solid waste line (DONRE, 2016), solid waste at households is almost not separated, the biodegradable organic fraction is mixed with the remaining fraction. Some households sorts the valuable component from solid waste and sell them to waste buyers. Collection line No. 15 was categorized as incorrect separation line (households have implemented separation at source but they it was incorrect).

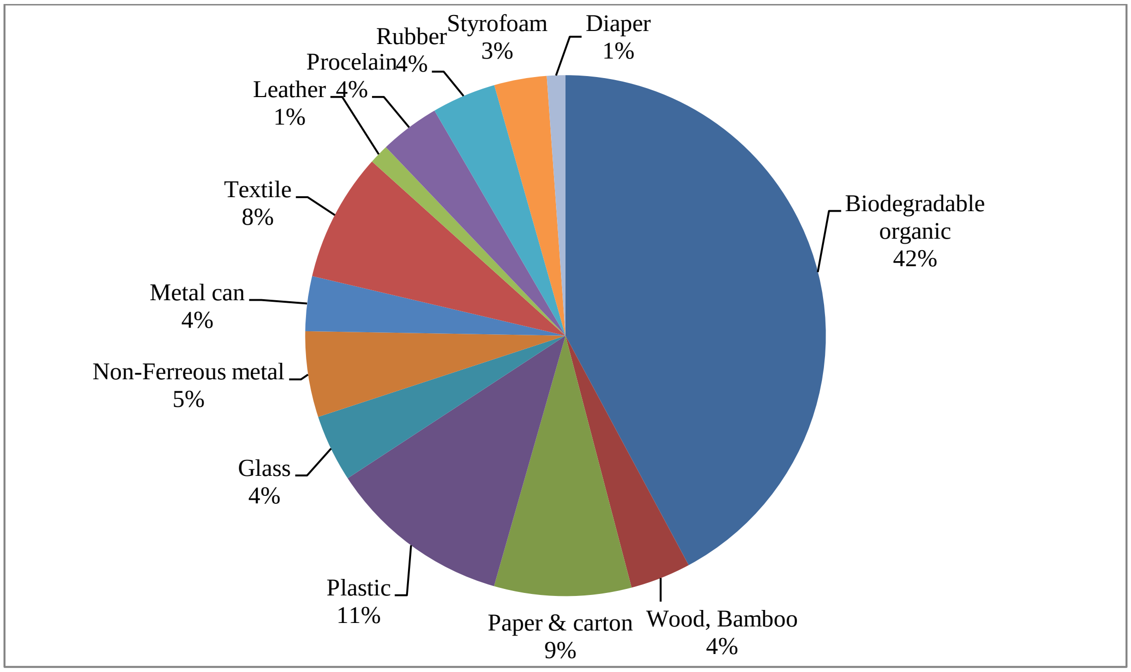

Figure 6.16 Composition of solid waste from No. 3 collection line (good separation solid waste line)

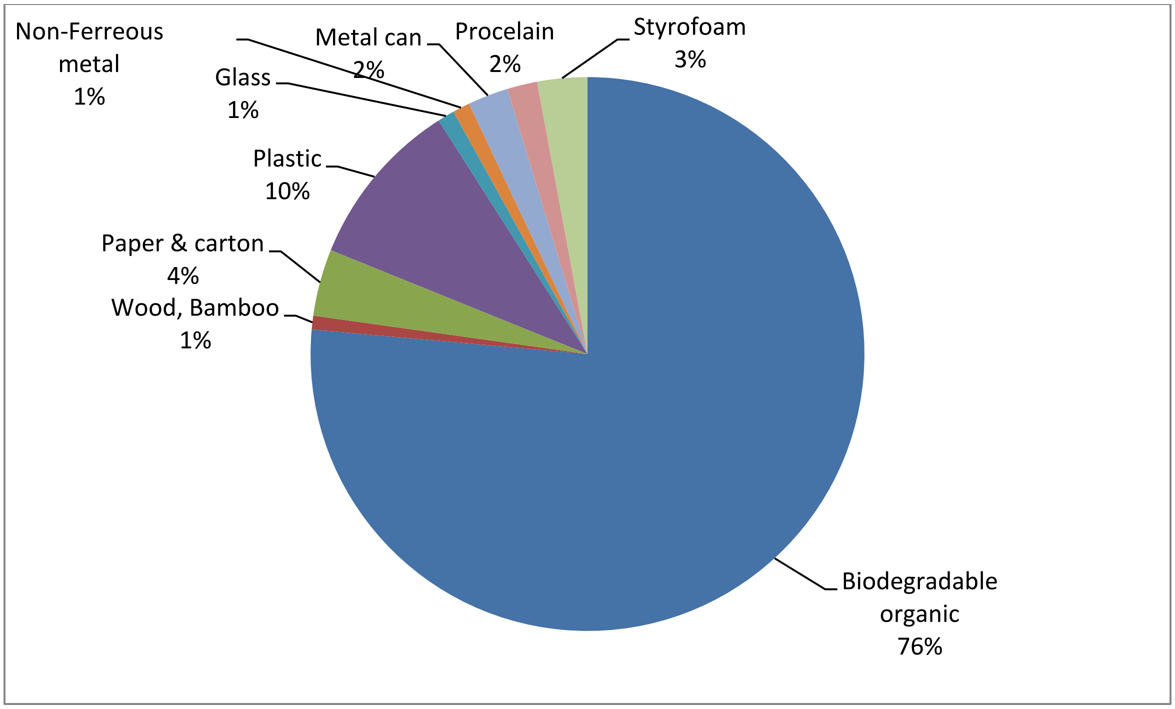

Figure 6.17 Composition of solid waste at No. 15 collection line (non- separation solid waste line)

In general, the SWSAS program at Ward 12 has not achieved the desired effect. People only separate solid waste when they feel convenient, rather than conscious behaviour in classifying and sense of regular separation. For example, in the good separated solid waste line, only 40% of households classified solid waste into two categories on the first day survey, but on the second day, no household implemented waste separation, this shows that these lines have been assessed as good waste separation implemented (based on data of DONRE, 2016), however, the activity was not maintained after the end of the program.

The implementing ineffective SWSAS program has many different causes. The main reasons are as follows:

- People do not really understand the meaning of the program; they do not see the benefit of doing, and are less interested in SWSAS program.
- Due to old habit which has formed long ago and hard to be changed in a short time.
- People of ward 12 are mostly labourers and small businesses with low level of education, so it is very difficult for the people to distinguish different components of waste to correct solid separation.

G. Assessment of the outcome of awareness raising campaign for solid waste separation program at ward 12

The awareness campaign has a great impact on the solid waste separation at the source. The awareness campaign for waste generators was implemented by Ward 12 People's Committee in collaboration with Institution of Resources and Environment. At the beginning of the program, the awareness campaign was carried out within 5 weeks with 76 spells for all participants of ward 12. Although awareness campaign has affected waste generators, it did not meet the desired results. The reason is that the awareness campaign was not carried out continuously and regularly as well as lack of materials such as banners and posters at common areas of population group to remind people about the SWSAS program, and lack of financial resource.

H. Collectors

Worker of three collection solid waste lines belonging to Doan Ket cooperative and each collector collects in range of 60 to 100 households. It takes about 2 hours to complete the collection on their entire line. Each collector is responsible for collecting 4 - 6 lines for a day and collects each line once a day. The main vehicles of collector are tricycles machine (Figure 6.18). In the small alley or small road collector will use handmade trolley with capacity of 100 L to collect at source. After collecting full of hand made trolley, the waste will be poured into handmade vehicles with capacity of 1 m^3 and transported to Tan Hoa transfer station.

Figure 6.18 Tricycles machine and handmade trolley

Through the survey and interview of collectors, most of them assumed that the implementation of the solid waste separation at source program was not feasible for several reasons:

- Ward 12 has many small roads, therefore it is very difficult to use two collection vehicles (push-cart with capacity of 660L) to collect solid waste separated (food waste and remain waste) or a large collection vehicle (with two parts) to collect solid waste separated. Besides push-cart which is heavy and do not have engine, so the worker find it difficult to push on small and rugged road with long distances.

- The collectors blame waste generators for their behavior of putting all waste into a collection vehicle. The collectors said that households do not separate waste at source why they need two vehicles to collect and this is pointless.
- The collectors will spend more time to collect separated solid waste.

As mentioned above, informal sector (Doan Ket cooperative) is the main force for waste collection (accounting for 95%) and District 6 Public Service Company Limited collected the remaining 5%. This informal sector is one of key factors contributing to the successful implementation of the SWSAS program, but this force has not reached a consensus with the program due to increasing time and funding for collecting separated solid waste. In addition, almost collectors have a low level of education, not professional, operating according to habits (each line owner has a way of operating separately) as well as they are not local people. These are very large barrier in implementation of SWSAS.

6.2.3 Waste Exchange for Gifts at Lam Son Primary School, Ward 12

Lam Son primary school has 1,300 pupils studying both morning and afternoon. The exchange waste takes place from 8 :00 AM to 4:20 PM during two weeks, but the waste is mostly exchanged in the morning. After two weeks of exchange, the quantity of waste exchanged was about 510 kg and total cost saved during the period was 2.1 million VND (approximate 92 US$). The detail of quantity and kinds exchanged waste is present in Table 6.5 and Figure 6.19 – 6.21.

Figure 6.19 Items for waste exchange

Figure 6.20 Pupils exchanging wastes

Table 6.5 Quantity and kinds of exchanged waste

Day	Paper (kg)	Pet bottle (kg)	Metal can (kg)
15/05	90	7,6	0
16/05	213	17	3.1
17/05	79	12	1.75
22/05	18,7	7	0.6
23/05	29	5,5	0
24/05	19	3,5	0
Total	448,7	52,6	5,5

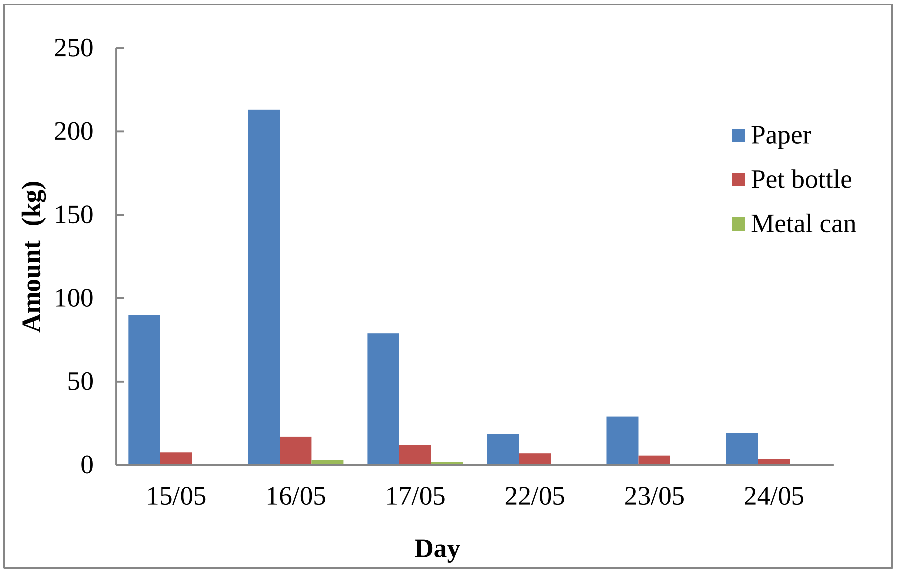

Figure 6.21 Quantity and kinds of exchanged waste

Figure 6.21 indicated that the largest amount of exchanged waste is paper; the reason is that the program was implemented at the end of school year so pupils bring out most of the old books and textbooks to swop. Besides, pupils also bring recyclable wastes from household to school in order to swop, and ask the members of family to recyclable waste separation. The estimated number of pupils participating in waste exchange was 50% of pupils of school and these pupils are under grade 2, 3, and 4. At elementary level, the children begin to focus attention and have good sense of learning. Therefore, the pupils are an appropriate age to educate a conscious behavior towards waste by the idea of separation and recycling waste

From amount of exchanged waste, it can be seen that the program is attracting the attention of the pupils. The school can earn additional income from saleable waste to maintain the program as well as practice for the pupils a conscious behavior towards waste separation and recycling. Lam Sơn primary school agreed to continue the implementation in new school year. In addition, the program can become an example to replicate at primary schools in city to increase conscious behavior towards waste with aim of waste reduction.

6.2.4 Conclusion

6.2.4.1The SWSAS program

The SWSAS program at Ward 12 has not achieved the desired effect. The ineffectiveness of SWSAS program has many causes. The main reasons are as follows:

- People only separate solid waste when they feel convenient, rather than conscious behavior in classifying and sense of regular separation.
- People do not really understand the meaning of the program; they do not see the benefit of doing, so they only made a perfunctory way and are less interested in SWSAS program.

- Due to old habit which has formed long ago and hard to change in a short time.
- People are mostly laborers and small businesses with low level of education, so it is very difficult for the people to distinguish different components of waste to correct solid separation.
- Lack of finance.
- Lack of infrastructure and vehicle.
- Lack of human resource in implementation of program.
- The awareness campaign does not carry out continuously and regularly as well as lack of materials such as banners and posters at common areas of population groups to remind people about the SWSAS program.

In addition, informal collector sector is one of key factors contributing to the successful implementation of the SWSAS program, but this force has not reached a consensus with the program due to increasing time and funding for collecting separated solid waste. This sector also has a low level of education, not professional, operating according to habits (each line owner has a way of operating separately) as well as they are not local people.

6.2.4.2The waste exchange program

The waste exchange program was very successful at Lam Son primary school. The program was only implemented for a short time (2 weeks) but the number of pupils participating in the program was high and a large amount of waste was exchanged. This shows that the program is attracting the attention of the pupils. At elementary level, the children have good sense of learning program so they are at an appropriate age to educate a conscious behavior towards waste by the idea of separation and recycling waste.

The pupils in Lam Son primary school mostly reside in the locality (Ward 12, District 6) and thus are important nucleus in the awareness campaign of the SWSAS in their family resulting in increasing efficiency of SWSAS program. With this program, school can earn additional income from saleable waste to maintain program as well as practice for the pupils' conscious behavior towards waste separation. In addition, the program can become an example to replicate at primary schools in the City to increase awareness towards waste with aim of waste reduction.

REFERENCES

[1] HCMC DONRE (2015). Report on assessment of efficiency of solid waste separation at source at ward 12, District 6.

[2] HCMC DONRE (2016). Report on assessment of efficiency of solid waste separation at source at ward 12, District 6.

CHAPTER 7: CONCLUSIONS

In principle, the solid waste management activities in an order of decreasing preference is as follows: waste prevention (highest preference) > reuse and recycling > composting> anaerobic digestion with biogas recovery and electricity production/or RDF as material source for industrial factories (a high heating value using boiler) > incinerator with electricity production > landfill (least preferred). This project aims to intercept the waste as a resource and minimize the waste entering to the landfill. The goal is achieved through this project in the two cities in partner countries. The major conclusions are presented below. The concept can be followed for other places in two countries.

7.1. Bhutan

Bhutan is enriched with natural resources and ecosystems, proper waste management is very important for preservation of these pristine ecosystems. Although the government has issued waste management policies and trying its best to implement them, but these are not fully enacted due to lack of human resources, financial constraints, and lack of awareness.

The total waste generation in Mongar town is 0.95 ton per day. Waste generation per capita in 2015 was 0.23 kg/day. However, in the core town area, the generation was 0.93 kg/capita/day. Based on the baseline data there was no waste separation at source except by some schools and hotels. The recyclables are collected by a private company; M/S We Care Waste Management. The commingle waste collected was disposed in the open dumping site located 30 kilometers away from Mongar town. The dumping site is close to a freshwater stream. In addition, the topography is mountainous, it takes long time and efforts for transferring of the waste.

The waste characteristics in Mongar indicated that nearly 50 per cent of the waste is organic and about 25 per cent are recyclables. Therefore, suitable technologies include composting or anaerobic digestion for organic waste and recovery of recyclable materials. From the ten criteria selected for the commingle waste, the technology that scored the highest to lowest are as follows: composting > recyclable > anaerobic digestion > sanitary landfill. For the segregated waste, the pattern is the same but the scores are much higher compared to the commingle waste. This indicates that separation is desirable for solid waste management at Mongar city. It should be noted that, the scoring is based on the local conditions such as infrastructure, waste collection facility, and man power.

As the separation seemed to be necessary for proper waste management, the four pilot projects implemented were targeting at waste separation. After the implementation of the pilot project the segregation of the waste in the implementation area was successful. This can be clearly seen from the amount of recyclables that were collected by We Care Waste Management increased in 2016 as compared to 2014. Although at present the composting is not carried out but after the segregation, it can be easily adopted and the final product can be useful for the farmers since most of the rural people income is through farming. Moreover, the technology is simple to be adopted.

As the local conditions are similar in many of the towns in Bhutan, this success story can be adopted at other places. The result showed that composting is the most possibly applicable waste utilization technology, followed by anaerobic digestion and sanitary landfill. Each of utilization techniques cannot treat all components of solid waste and thus some amount has to be dumped to the landfill. Ideally, the composting and anaerobic digestion technologies are sustainable technology for clean biodegradable fraction and small portion of non-recyclable will go to landfill as tabulated below:

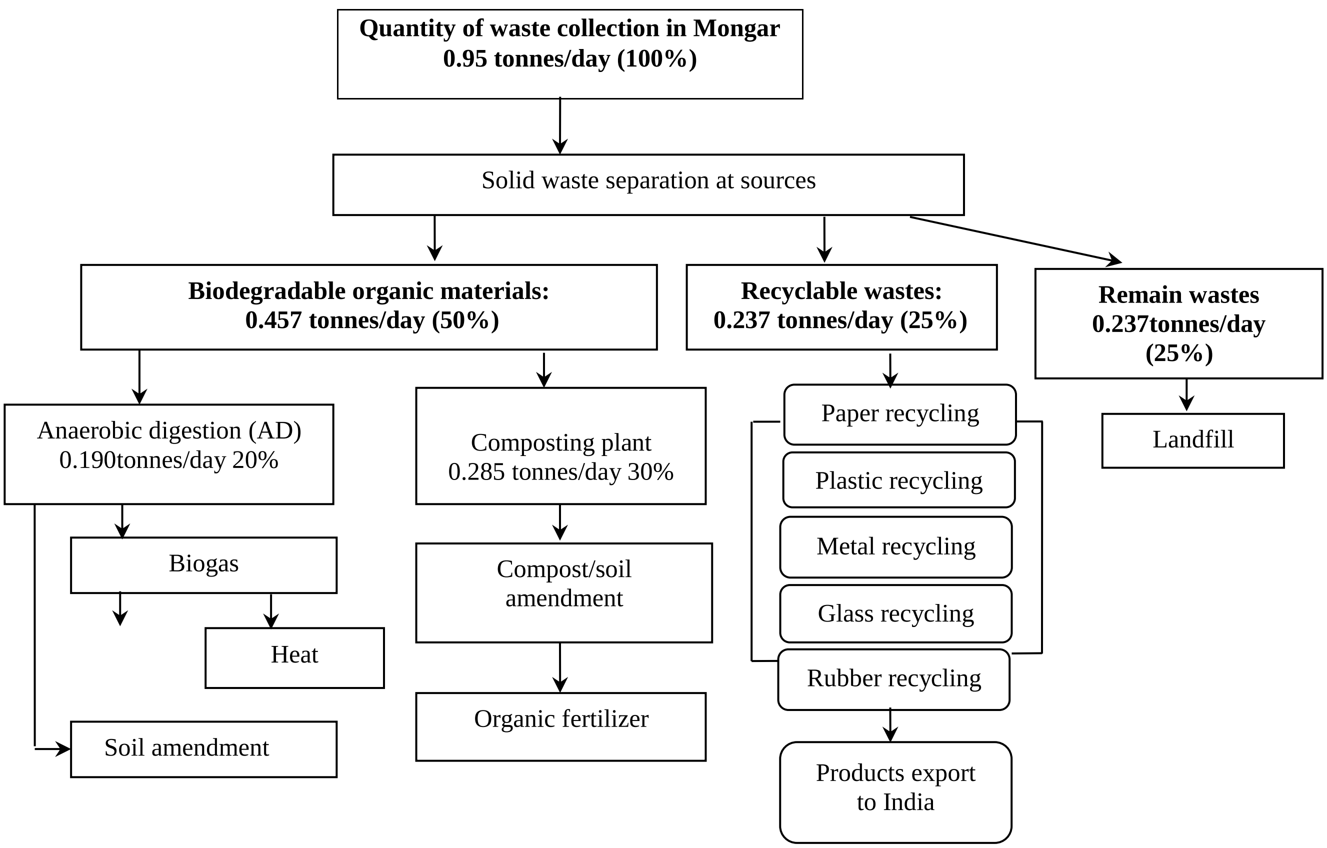

Figure 7.1 Combination of technologies towards zero solid waste management in Mongar

7.2. Vietnam

The solid waste generation in HCMC has increased during 1992-2016 and in recent years the average solid waste growth rate is about 5.2 % per year. The main component of waste in HCM is biodegradable organic, however this component has decreased, while non-recyclable components (such as plastic, diaper, textile, rubber, and leather) with high calorific value have increased significantly from 2009 to 2015. HCMC has not achieved set-targets for solid waste management in the period 2010-2015. In order to achieve the targets in the period of 2016-2025, solid waste treatment technologies should be improved or changed. In case of HCMC, five of the eight solid waste treatment technologies were selected. These technologies are (1) composting; (2) anaerobic digestion; (3) sanitary landfill (with collection of biogas) or bioreactor landfill; (4) incinerator; (5) refuse derived fuel (RDF) or solid recovered fuel (SRF). Selection of sustainable technology for solid waste management in HCMC is based on criteria system. This criteria system will help responsible solid waste management authorities to decide which sustainable technology should be adopted in local condition. In case of HCMC, 11 criteria were used for assessment of sustainability of five waste treatment technologies selected.

According to situation of solid waste management, the natural, economic, technical, social environment, and set targets for management of solid waste in HCMC in period 2016-2025, two scenarios were assessed. The first scenario was for commingled waste and the second scenario was for solid waste separated at source.

For the first scenario, sanitary landfill with collection of biogas was the most possibly applicable sustainable technology, followed by incinerator with energy collection, composting, RDF or SRF, and anaerobic digestion. However, sanitary landfill is not assuring pollution treatment efficiency, community acceptability is low and it is also require large amount of land.

The results obtained from the second scenario plays a strong emphasis on activities that avoid the generation of wastes, stimulation of reuse, recycle, and recovery of valuable materials from solid waste. From this principle, the solid waste management activities in an order of decreasing preference is as follows: waste prevention (highest preference)> reuse and recycling > composting> anaerobic digestion with collection of biogas > incinerator with energy collection > RDF as material source for industrial factories > sanitary landfill. However, each of five solid waste treatment technologies cannot treat all components of generated solid waste. Ideally, the composting and anaerobic digestion technologies are sustainable technologies for pure biodegradable organic fraction, incineration technology with energy collection is essential for solid waste with high calorific values or RDF technology is as material source for industrial factories, and residual waste will always need landfilling.

The second scenario is selected for integrated solid waste management system leading to zero waste for sustainable resource utilization in HCMC. The system is proposed in Figure 7.1.

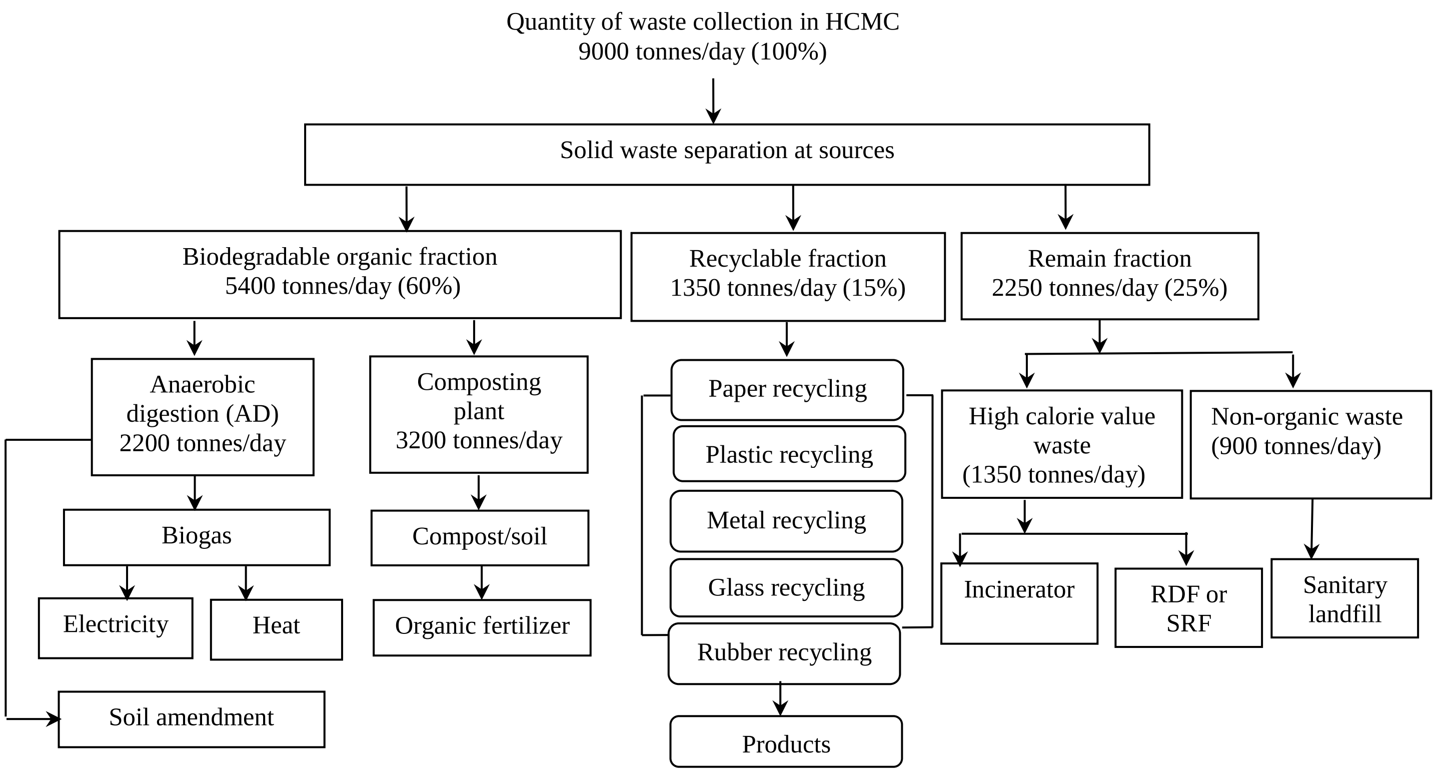

Figure 7.2 The integrated solid waste management system leading to zero waste for sustainable resource utilization in HCMC

The integrated solid waste management system leading to zero waste for sustainable resource utilization in HCMC can undergo successfully into practice when having the combination of two aspects: policy and technology. Policies in relation to support recycling sector are currently insufficient, the government of HCMC should promulgate such policies encouraging recycling activities and support funding to improve existing recycling facilities or invest in recycling facilities with advanced technologies. The incineration, anaerobic digestion, RDF technologies are the new technologies; therefore, the encouraging policies are strongly required to put the technology into practices. Besides, based on the experiences from others countries and based on the specific condition of HCMC, it is important to set up the policy to encourage the use of green energy based on the decision No. 2014, in which, the unit price for electricity produced from biogas is 7 USD/kW and from incineration is 12 USD/kW. This is the good support for these new treatment technologies. However, it needs more policies relation to: (1) clear and simple in investment regime; (2) support infrastructure to put the green electricity into the government network.

With regard to solid waste management system leading to zero waste for future application, the main aspect to be considered is solid waste separation at source. For HCMC, SWSAS program is proposed as follows:

- Increase the participation of authorities at all levels (City, district and ward) as well as social organizations such as Women's Union, Veterans' Union, Ho Chi Minh Communist Youth Union, and HCM young pioneer organization for SWSAS.
- The good implementation of SWSAS depends on good leadership and good urban management.
- Establish the legal documents to serves the SWSAS program: (1) regulation on classification and storage at source, (2) collected from the source and picked up on the street, (3) transit and transport, (3) reuse and recycling, (4) treatment and recycling; (5) favoured policies, (6) the participation of the economic and social organization, and (7) other issues.
- Regulation on administrative handling and violations in SWM (with the prescribed specific behaviours, not yet included in the Decree on sanctioning of administrative violations and apply coercive measures and strictly handling and violation).
- Establish the regulation on management of informal collector and handling and environmental violation. If the informal collector force is managed effectively, it will contribute significantly to success of socialization on collection of SWSAS.
- Human resources related to solid waste management can be improved through many activities in capacity building and international cooperation. Strengthening capacity of staff for all environmental management levels of HCMC, especially at Commune levels is needed. These improvements can be of great value.

In addition, the public play an important role in increasing effectiveness of SWM, thus the public participation and increase the community role in solid waste separation at source, waste reduction, and recycle is very essential. The activities of increasing people awareness on the negative impacts caused from inappropriate waste management should be carried out at various levels by awareness campaign programs which should be carried out continuously and regularly in various forms (song, fashion models, dance, etc) to attract the public participation. The awareness raising campaign for SWM should be included at school level through the "Waste Exchange Model" or "School Sanitary Program".