ASIA-PACIFIC NETWORK FOR GLOBAL CHANGE RESEARCH

ARCP Final Report


Project Reference Number: ARCP2015-12CMY-Sharp

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

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Project Overview

Project Duration	**:**	2 Years
Funding Awarded	**:**	US$ 45,000 for Year 1; US$ 30,000 for Year 2
Key organisations involved	**:**	Proponent organization: Sirindhorn International Institute of Technology, Thammasat University, Thailand (Dr. Alice Sharp and Dr. Sandhya Babel) Partner organization in Bhutan: 1) Mongar District Office (Mr. Tshering Gyeltshen, Assistant Engineer) and 2) Ministry of Works and Human Settlement, Thimphu, Bhutan (Ms. Sonam Desel) Partner organization in Vietnam: Center for Environmental Technology and Management, Van Lang University, Ho Chi Minh City, Vietnam (Dr. Nguyen Thi Phuong Loan)

Project Summary

This study aims to identify appropriate integrated solid waste management system leading to a zero waste city for Mongar, Bhutan and Ho Chi Minh City (HCMC), Vietnam. Field visits, stakeholder consultations and pilot project were carried out to ensure participation of various sectors. It can be seen that organic waste contributes around 50%. Management gaps were identified as no waste segregation at source due to low awareness and poor waste collection system, and local authority having limited resources. Once the waste is segregated, the management options from the highest to lowest preference are as follows: composting > recyclable > anaerobic digestion > sanitary landfill. HCMC has a total population of more than ten million. Municipal solid waste management is a severe environmental problem as the quantity of solid waste has increased while infrastructure for collection and treatment are not sufficient. Based on the current MSW management system, technologies such as composting, biogas recovery and electricity generation either from anaerobic digestion plant or sanitary landfill are appropriate. Incineration for high calorific value waste can be adopted for energy recovery. Effective recycling technologies to convert waste into valuable product seem to be solutions for approaching zero waste for MSW management.

Keywords: Integrated solid waste management, zero waste initiatives, waste segregation, waste management interventions.

Project outputs and outcomes

Project outputs:

- Relevant literature review
- Training of the trainers workshop was held in Bangkok, Thailand
- Solid waste management baseline report for Mongar, Bhutan and Ho Chi Minh City, Vietnam
- Development of waste management criteria for technology/approach selection
- Implementation of pilot projects in both countries

- Guidelines for solid waste management technology selection for both the countries in both local and English languages
- Awareness raising video clips broadcasted on local television
- Participatory workshop with stakeholders on solid waste management in both the countries
- Strengthening of the network between collaborators and other relevant agencies

Project outcomes:

- Improved awareness of stakeholders in solid waste management
- Guideline as a tools in local language which can be adopted by relevant stakeholders and also at other locations
- Enhance waste utilization and reduce waste entering into the landfill

Key facts/figures

Notable numbers resulted from the project:

- Success factors for sustainable SWM include collaboration of stakeholders, effective leader, transparent management, and adoptable approach.
- Drawback for sustainable SWM in developing countries include lack of long-term management plan and policies, financial constraint, human resources and infrastructures, markets for recyclables, and lack of involvement of stakeholders.
- Integrated solid waste management and separation play essential role in effective waste management.
- Based on the in-depth investigation, criteria selection, and the assessment of technology, proposed management solutions for each country was drawn:
    - For Mongar, Bhutan, the preferred appropriate technologies from high to low ranking include composting > recyclable > anaerobic digestion > sanitary landfill
    - For HCMC, Vietnam, the preferred appropriate technologies from high to low ranking include waste prevention > reuse and recycling > composting > anaerobic digestion with collection of biogas > incinerator with energy collection > RDF as material source for industrial factories > sanitary landfill

Potential for further work

- Expansion of the pilot project implementation in other localities and areas.
- The prepared guidelines should be tested in other localities and amended according to the gaps.
- Develop tools for stakeholders involvement as this is one of the most important success factors

Publications

1. Nguyen, T. P. L., Tran, T. M. D., Le, T. K. O., Sharp, A., & Babel, S. (2019). Possibilities and challenges to approach zero waste for municipal solid waste management in Ho Chi Minh City. In Waste Management and Resource Efficiency: Proceedings of the 6th IconSWM 2016 (p. 980). Kolkata, India: Springer Singapore. *(In the process of publication)*
2. Sharp, A., Babel, S., Gyeltshen, T., Pelden, T., & Dorji, D. (2016). Establishment of integrated Solid Waste Management System in Mongar Town, Bhutan. In

Proceedings of Chemical Biological and Environmental Engineering (Vol. 92, pp. 98–102). Hong Kong.

Awards and honours

Best paper award was awarded for the paper “Possibilities and challenges to approach zero waste for municipal solid waste management in Ho Chi Minh City” at the International Conference in Solid Waste Management in Kolkata, India.

Pull quote

“Waste management is everybody responsibility” - Ms. Tshering Dolker
“Promote 3Rs to be sold from waste materials” - Mr. Ratu Tshering from Clean Bhutan NGO
“Source separation will help getting more waste as well as better quality materials. From the implementation of the pilot project, more recyclable materials could be recovered” – Mr. Tsheltrim Pelden from We Care Waste Management Company
“ Through this project, the Governor of Mongar District get interested in the solid waste management and want to improve the existing conditions” - Mr. Tshering Gyeltshen – Mongar District Engineer
“Technology for separation during waste collection is needed” Mr. Nhân – Official from District 6, HCMC
“The project can create awareness among local people and help in solid waste management. It can also use to identify technology for HCMC, which is needed” Mr. Anh Tuan Ta – researcher from CENTEMA
“This project strengthen the network between CENTEMA and the local government offices” Dr. Nguyen Phuong Loan – Director of CENTEMA

Acknowledgments

Thailand:

- Sirindhorn International Institute of Technology, Thammasat University, Thailand is acknowledged for in-kind support for researchers and administrative staff.
- Prof. Visvanathan C. of Asian Institute of Technology for the experts input on the project report on the criteria selection and technology assessment.

Bhutan:

- Ministry of Works and Human Settlement and Mongar District Office are acknowledged for in-kind support for researchers and administrative staff
- M/S We Care Waste Management Company for the cooperation throughout the project.

Vietnam:

- Center for Environmental Technology and Management, Van Lang University, Vietnam for in-kind support for researchers and administrative staff
- Department of Natural Resources & Environment (DONRE), Ministry of Natural Resource and Environment, Vietnam for the cooperation throughout the project.

1. Introduction

1.1 Background of the study

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 project 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.

2. Methodology

Figure 1 shows the major steps adopted in the implementation this project. These steps are mentioned below:

2.1 Training of the trainers

Initially, the training of the trainers was organized in Bangkok, Thailand for the participants from two collaborator countries. Various experts were invited to give overview of SWM practices in Bangkok. Field visits to different SWM sites including municipalities, private company, and community based were organized to showcase the successful example of best practices. The success and the drawbacks of the visited site were assessed. Lesson learnt can be adapted in collaborator countries.

2.2 Baseline data collection

Collection of baseline data was done between October 2014 and June 2015. Both primary and secondary data are being collected from relevant sources. Data includes characteristics of waste, generation rate, options for waste management, disposal technology including any reuse/recycling adopted, existing policy framework, financial mechanism, and institutional framework.

2.3 Solid waste Management Option Identification

Gaps and management options were identified based on the baseline data collected and comments from stakeholders. In order to select appropriate management option for each locality, criteria for technology selection were developed and each option was assessed using the set of criteria and scoring system.

2.4 Pilot Projects implementation

Pilot projects were implemented in locations where impacts will be easily visible. Communities, schools, and markets were selected as the implementation sites. Methodology adopted for the implementation of the pilot project included involvement of private and public sectors, town representatives, and other relevant stakeholders to improve the current waste management system.

2.5 Guideline development

In order to prepare guidelines for technology selection, country workshops were organized at each study site (Appendix 3 for Bhutan's workshop and Appendix 4 for Vietnam's workshop). Criteria for selection were presented to the stakeholders by the proponent. These criteria were discussed during the workshop. Based on the baseline data the options for sustainable solid waste management were identified. These options were further assessed for their suitability using scoring system for each criterion selected. Criteria description can be found in Chapter 3 of Appendix 1.

The guidelines were prepared for each country based on two scenarios (commingle waste and segregated waste) that can be adopted in similar conditions. Steps for decision making process is also developed.

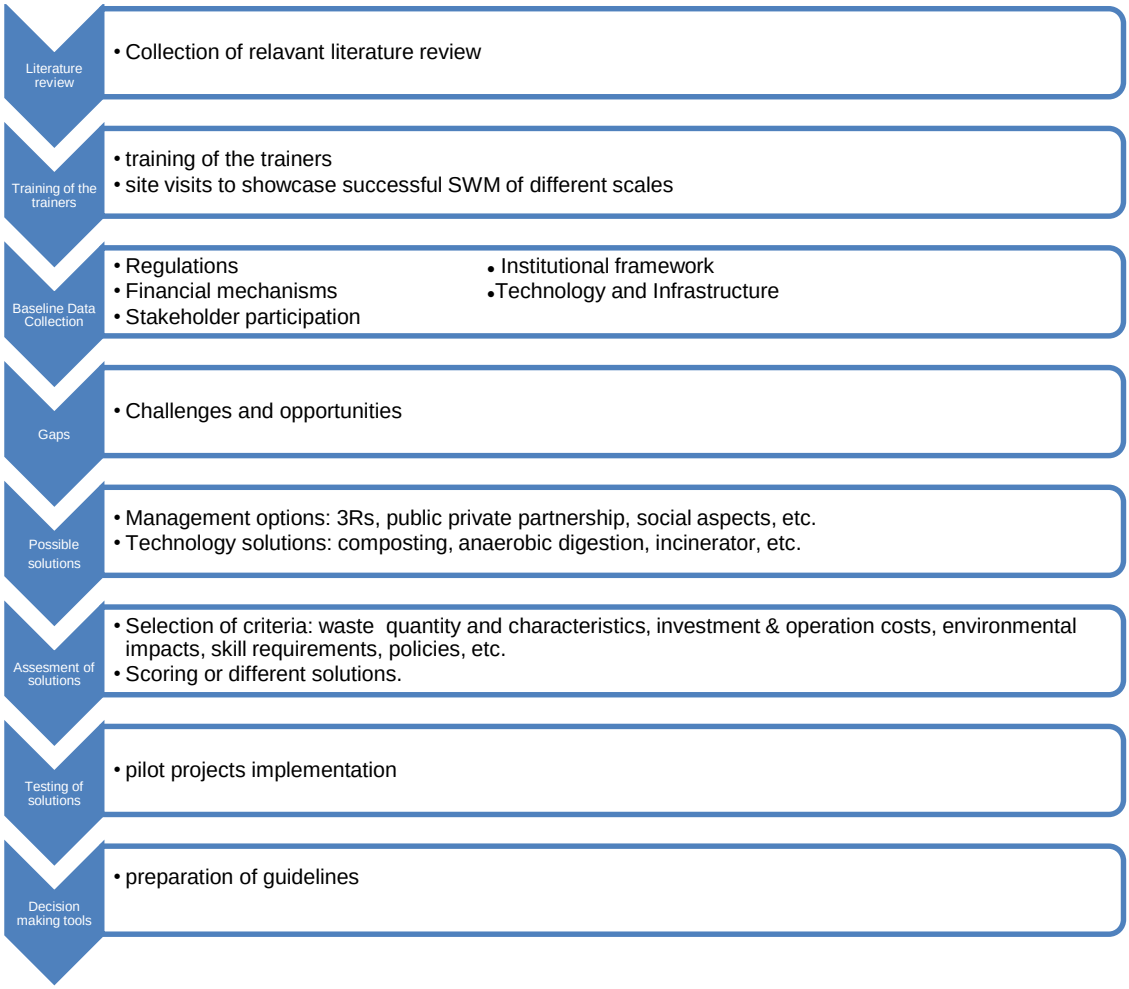

Figure 1 Major steps adopted in project implementation

3. Results & Discussion

3.1 Training of the trainers

Training of the trainers was carried out from March 30 to April 3, 2015. From Bhutan there were three participants coming from the Ministry of Works and Human Settlement, Mongar District Office and the private sector. From Vietnam, five participants joined the training of the trainers. They are from CENTEMA, Department of Natural Resource and Environment-Ho Chi Minh City, and Van Lang University.

Sites visit in Thailand included small, medium, and large size municipalities where integrated solid waste management are being implemented. Various waste management technologies were shown as show case examples, i.e. waste separation at source, community-based solid waste management, centralized and decentralized composting facilities, anaerobic digestion, and preparation of refuse derived fuel (RDF). Knowledge gained from site visits in Thailand, collected data, and literature review would help partners in identifying the gaps in existing solid waste management practices. Additionally, it will help partners to identify suitable management options based on the local conditions.

Details of the sites can be found in Chapter 2 of Appendix I. List of participants and summary of Training of the trainers' workshop in Thailand can be found in Appendix 2.

3.2 Baseline data

3.2.1 Bhutan

A. Waste Generation & Composition

Mongar town generates a total of 0.95 tonnes of MSW per day with a waste generation rate of 0.23 kg/person/day. The results of waste composition undertaken in May 2015 are shown in Figure 2. It can be seen from the results that organic waste contributes at least 50% of the total waste generated. The medical waste generated in Mongar town accounted for 17.66 % as it is the only referral hospital for six districts. The recyclable components including paper, plastic, metals and glass is 24.8 %. The remaining waste, categorized, as 'others' comprises of rubber, wood and textiles is 7.54 %.

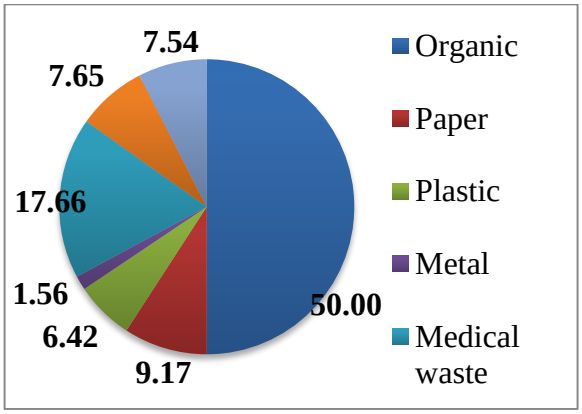

Figure 2 Waste composition in Mongar town

B. Existing Waste Management System

The waste collection system in Mongar town consists of 2 refuse collector trucks, which moves around the town collecting MSW from different areas. A private firm "M/S We Care" is hired by the municipality to collect a part of MSW and transport to the landfill. This firm also collects recyclable materials from the city and the landfill. The efficiency and effectiveness of the collection of MSW 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:

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

Most of the MSW 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. Open dumping is practiced at the landfill, thus increasing the risk of natural resource contamination. A new landfill is currently at the design stage, and will be located at about 7km from Mongar town. This is expected to decrease the cost of transporting the MSW from

Mongar town.

The current practices of waste management are summarized in Figure 3. There are five pathways adopted for each waste stream as shown in the Figure. It can be seen that majority of waste generated end up in the landfill.

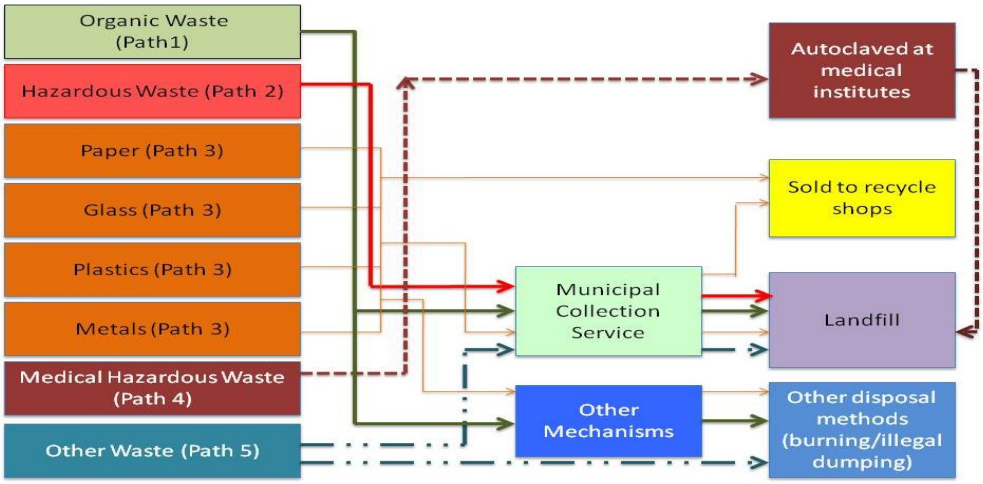

Figure 3 Current waste management streams in Mongar Town

3.2.2 Vietnam

The quantity of solid waste generated has been increasing significantly from 1992 to 2016 (Fig. 4). In 2014, total waste generated was about 9,000 tons/day in which the amount of solid waste disposed was 7,400 - 7,600 tons/day and the rest was sorted, traded, reused and recycled (Viet, 2015). From 2009 to 2015, the solid waste growth rate is about 6 – 8% per year with average solid waste generation is about 1.0 kg/capita/day (DONRE, 2014). Therefore, municipal solid waste management has been considered as one the most severe environmental problem as the quantity of solid waste has increased while infrastructure for collection and treatment are not sufficient. The Government of HCMC has given priority to the problem and is interested in promoting effective and appropriate technology in solid waste management.

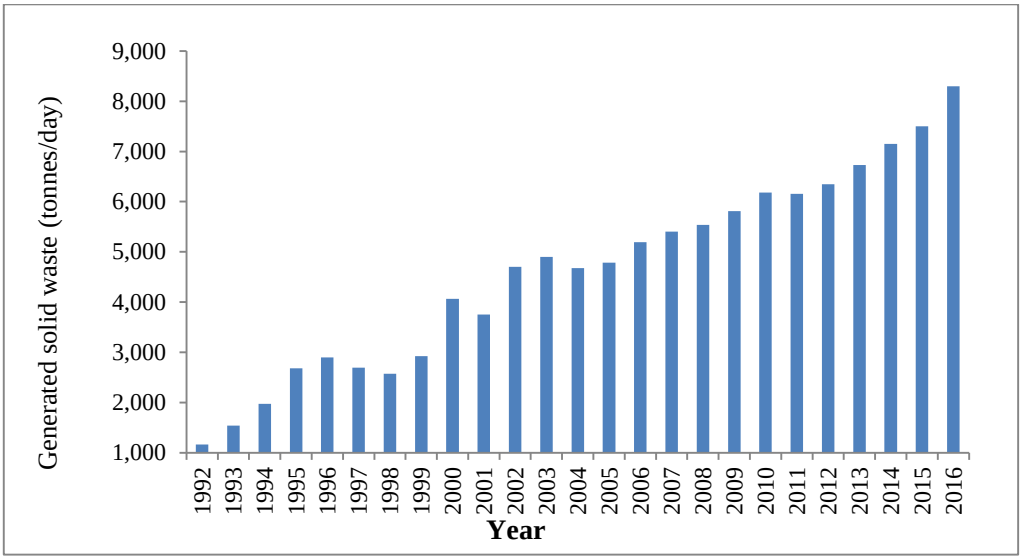

Figure 4 Solid waste generation in HCMC from 1992 to 2016.

A. Waste *Generation and storage*

Generation sources of MSW are residential areas with 2 million households, 346 business units, 354,661 units of hotels/motels, 12,502 medical units, 4,730 offices, education and training organizations and about 12 thousand industrial factories and enterprises. Households generates 57.9% of MSW (DONRE, 2011; Truong *et al*., 2015).

Households do not have standard containers for solid waste storage. Currently solid waste is stored in plastic bags, tins, bamboo containers, etc. Most households, especially those with confined living areas, use plastic bags to store their commingled waste. Offices, schools, etc. have their own type of containers. Markets store their solid waste directly on the floor or in containers. Many restaurants have special storage containers of food waste to be utilized a part as animal feed. No separation of MSW takes place at the source. However, most households separate the valuable wastes such as cans, plastic, paper, etc., from their waste and sell this to waste buyers. In general, the critical points related to the waste generation at sources are high amount of commingled solid waste generated, no standard containers for solid waste storage, and limited place at households for placing containers, high amount of leachate and malodour generation and lack of public awareness.

B. *Solid waste collection and transportation*

Collection, transfer and transportation of solid waste in HCMC are carried out by two systems: public and private system. The public system consists of HCMC City Urban Environment Company Limited (CITENCO) and 22 District Public Work Service Company Limited (DPWSCLs). The private system consists of informal collectors and cooperatives. The private collector collects 60 % of solid waste and public collectors 40 %.
MSW is transferred from generation sources to meeting points by informal collectors or DPWSCLs using pushcarts (660 litters) and from there the trucks transport the waste to transfer stations by DPWSCLs and cooperatives. From transfer station, the waste is transported by CITENCO, DPWSCLs and Cong Nong Cooperatives to landfills or composting plants. Depending on the length and quality of the transport routes, the capacity of the trucks can be selected. In addition, waste from alleys and along minor streets is

transferred directly to transfer stations by informal collectors using small trucks (capacity of 500 kg).

The collection equipment is not standardized. This is especially true for informal collectors. Other problems include narrow transport pathways in the dense areas; non-standardized collection facilities and lack of safety facilities; lack of collection skills and the activity of separating recyclable wastes causing delay in collection time and pollution; lack of monitoring and control; non-integrated management.

HCMC has 33 transfer stations with total design capacity of 5,477 tons/day. According to annual report of HCMC DONRE (2014), 100% of wastes generated were collected, transferred and transported. However, waste transfer and transportation is complex and inadequate for the following reasons: (1) there are many companies involved in this activity, including CITENCO, 22 public service companies, Cong Nong cooperatives and some private companies, which are working independently from each other making it difficult to organize and integrate the transport activities and transport routes; (2) inadequate infrastructures, such as narrow and poorly paved transport routes, non-standardized collection cars/trucks, lack of meeting points and transfer stations; (3) lack of tools, guidelines, regulations to support the transport system; (4) poor management capacity and (5) insufficient funding.

C. Waste Characteristics

The choice of effective recycling technologies is based on composition of solid waste. The survey results from 2009 and 2015 shows that different sources have different waste characteristics (CENTEMA 2009 and 2015). Most of the fraction is biodegradable organic fraction. Recyclable fraction varies depending on the sources as shown in Table 1. In addition, household hazardous wastes (HHW) are also present in the MSW.

Table 1 Composition of municipal solid waste generated in HCMC from 2009 – 2015

Composition	**Results (%ww)**								
	Households		Schools		Market		Sanitary landfill		Composting plant
	2009	2015	2009	2015	2009	2015	2012	2014	2015
Biodegradable fraction	74.3	64.8	28.7	25.5	86.8	87.8	68.9	67.9	53.2
Wood, straw	2.8	0.9	6.9	-	3.6	1.4	0.73.0	0,3	1.0
Paper	6.2	5.1	17.6	35.0	2.5	1.9		2,5	5.7
Plastic	5.2	10.5	25.9	34.9	4.3	7.5	16.0	16.4	12.9
Textile	1.0	3.2	1.1	1.0	0.4	-	5.0	7.2	10.7
Leather	0.2	-	0.1	-	-	-	-	-	-
Rubber	0.9	0.9	1.4	-	0.4	-	0.7	0.7	0.7
Glass	1.3	1.4	0.5	1.2	0.2	-	1.2	0.2	1.7
Nonferrous metal	0.7	0.6	2.1	-	-	-	1.6	3.6	0.3
Ferrous metal	0.3	0.2	0.7	-	0.3	0.1	-	-	-

Composition	Results (%ww)								
	Households		Schools		Market		Sanitary landfill		Composting plant
	2009	2015	2009	2015	2009	2015	2012	2014	2015
Porcelain	0.8	0.5	0.6	-	0.1	-	-	-	2.4
Soil, sand	3.2	2.8	4.0	-	1.0	1.2	-	-	-
Ash	0.4	-	-	-	-	-	-	-	-
Styrofoam	0.3	1.0	9.8	1.5	0.4	0.2	-	-	0.8
Diaper	1.8	8.1	-	-	-	-	2.3	0.6	10.7
Clamshell	0.8	-	-	-	0.2	-	0.8	0.6	-
Hazardous waste	0.002	-	0.1	-	0.1	-	-	-	0.1

Note: "-": no data

Sources: Nguyen Trung Viet el al., (2014), CENTEMA (2009-2015) and DONRE (2009).

D. Solid waste reuse and recycling

Based on the characteristics, composting and recycling of valuable materials are adopted in HCMC.

- ***Composting***

At present, there are three composting plants: (1) Vietstar with capacity of 1,200 tons MSW/day; (2) Tam Sinh Nghia for 1,000 tons MSW/day; and (3)Vietnam Waste Solution (VWS) Company with capacity of 1,000 tons MSW/day. If three composting plants would run at full capacity, 100% of the biodegradable organic fraction of generated MSW would be treated to produce compost. However, VWS Company is not operating because solid waste is not separated. The input of two composting plants is commingled waste and therefore the separation process has to take place after transport, which is complex, costly and requires a lot of labour. An abundant component in the MSW is plastics, which needs to be removed before the waste is composted. At Vietstar and Tam Sinh Nghia plants, the plastics are separated, cleaned and processed into plastic pellets, which contribute to the income of the plant.

The technology at Vietstar plant and Tam Sinh Nghia is aerated static pile composting (windrow composting). At present, capacity of Vietstar plant is 1,200 tons/day, in which 773 tons of solid waste are composted, 7 tons of solid waste are recyclable plastics, and 420 tons of remain solid waste is buried at Phuoc Hiep No.3 sanitary landfill. The capacity of Tam Sinh Nghia plant is 1,000 tons/day, in which 350 tons/day are for composting, 50 tons/day for recycling plastic and 600 tons/day of remain solid waste is burned by incinerator (DONRE, 2015). As mentioned above, the input of all composting plants is commingled waste, thus the compost product contains certain amount of hazardous household waste, glass and plastic, leading to decrease in the quality of compost and it is very difficult to be sold in the market.

- ***Recycling***

The amount of recyclable wastes collected is about 1,400 to 1,800 tons per day (Viet, 2015). The recyclable wastes such as plastics, papers, glasses, metals are collected at several stages of the collection chain at households, at meeting points, during transport process and at composting plants. The recyclable wastes after separation of households are sold to waste buyers, after that to junk shops and then sold to large junk shops or recycling facilities. Most of these recyclable wastes are processed by local recycling facilities. A part of the recyclable waste, like plastic and metal, is exported to China. Depending on the market price, some types of recyclable waste are collected more than others. Additionally, recyclable waste comes from other cities and provinces in the vicinity and is processed in HCMC. The recycling system in HCMC has about 1,100 – 1,200 junk shops and 740 recycling facilities to recycle about 2,000 tons of recyclable wastes per day. Besides, this system creates jobs for 16,000 – 18,000 unskilled labours and labours in recycling facilities.

E. Solid waste disposal

The ratio of MSW disposed at sanitary landfills accounts for about 68 % of total solid wastes collected. This is higher than the target ratio of HCMC 5 years plan of 2010-2015 (only 40% are buried). At present, two sanitary landfills are operating. First, Da Phuoc solid waste treatment complex (VWS) is invested by California Waste Solution Company and this landfill is operating with capacity 5000 tons/day (increasing from 3,000 to 5,000 tons/day in 2015). Most of solid waste generated in HCMC has been transported to Da Phuoc sanitary landfill for disposal. Second, Tay Bac Cu Chi solid waste treatment complex is invested and managed by CITENCO with capacity of Phuoc Hiep No.3 sanitary landfill of 2,000tons/day. This landfill receives the remaining solid waste from Vietstar plant. Both landfill sites are designed as sanitary landfill. However, the current leachate treatment plants in the sanitary landfills are not efficient or they are very expensive and most of them do not reach regulation of Vietnamese discharge standards. Details of the sites can be found in Chapter 4 of Appendix I.

3.3 Solid waste Management Option Identification

3.3.1 Bhutan

- **Challenges**

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 color coded waste bins for sale to the public, people are reluctant to purchase and use these bins due to the high cost (about Nu.2500 or 40 USD). Another factor for limited segregation is the municipal trucks. When collecting the waste, both the recyclable wastes and organic waste are dumped together, which discourages people to segregate the waste.

Inadequate financial resources, technical skills and lack of appropriate equipment also presents a major challenge in implementing solid waste management. 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.
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.

- **Management Opportunities**

The options for sustainable solid waste management are presented in Figure 5. These option includes:

1. *Reduce:* Educational campaigns, seminars, and academic involvement can be used for raising awareness and knowledge in SWM for the residents of Mongar District. The campaign can be implemented in various schools, institutions and the nearby community. Solid waste awareness campaign may include performing dances, short plays, VDO clips, posters or any other entertainment activities to attract a large number of people.

2. *Up cycle:* The waste stream in Mongar town contains approximately 50% organic waste. Thus, the conversion of organic waste to fertilizers through composting appears to be feasible. Organic waste in this context refers solely to the food and vegetable waste and do not constitute any agricultural wastes. Although, the composting technology is simple to be adopted by local people but it is done by few residents only at present.

3. *Material recovery:* There is a private firm “M/S We Care” operating since 2009, which collects recyclable from Mongar town, thus the dry waste can be separated and sold to the firm with some economic incentives to residents. At present, the company employs a small team of unskilled people, who manually segregate the waste into plastics, metals, papers, bottles and other recyclables from the Gyelposhing landfill.

As compared to Figure 3, it can be clearly seen from Figure 5 that majority of the waste can be intercepted after source separation and utilize instead of ending up into the landfill. It clearly indicated that for sustainable solid waste management, source segregation is key to success. The government should invest on the infrastructures to support the segregation and appropriate timely collection.

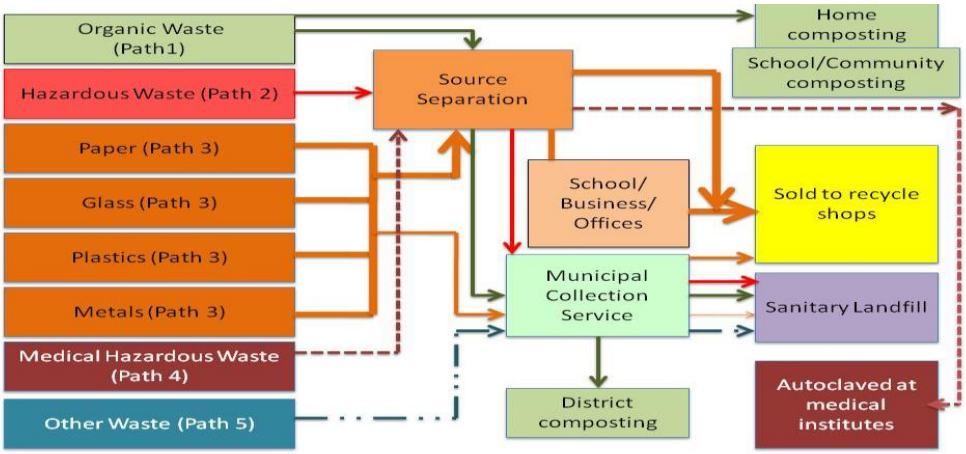

Figure 5 Proposed waste management options and the waste streams after implementation

3.3.2 Vietnam

- **Challenges**

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. When the informal sector collects the waste, both the recyclable wastes and organic waste are dumped together in the containers, which may have discouraged people from segregating the waste.

Financial constraints, lack of human resources and limited availability of technology also presents a major challenge in implementing solid waste management. 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.

- ***Management Opportunities***

The investigation results on situation of solid waste management in HCMC from 2009 to 2016 show that many opportunities for sustainable solid waste management exist as listed below;

- ❖ The potential agricultural demand for organic fertilizers and soil conditioners in the surroundings of HCMC is very high and exceeds the actual production capacity. With high biodegradable organic fraction (64.8-74.3%), composting technology and anaerobic digestion technology with collection of biogas is the most sustainable technology for utilization of solid waste. Non-recyclable waste with high calorific values is suitable for incineration or RDF technologies with energy recovery system.
- ❖ The network for recycling activities in HCMC is very large including 740 private recycling facilities to recycle about 15-20 % of MSW collected. Recyclable components including paper, plastics, and metals can be recycled to create new products. It is an important sector in the solid waste management system of HCMC.

- In order to obtain pure biodegradable organic and remain fractions, solid waste separation at source (SWSAS) plays an important role in the integrated SWM in HCMC. Separating MSW at source can be applied at various levels through media campaign and educational programs. In Vietnam, there are many social organizations such as Women's Union, Young Communist League, Veterans' Union, HCM young pioneer organization; these social organizations can play the leading role in the implementation of the SWSAS program.
- Vietnam has a policy to increase the use of green energy. The unit price for electricity produced from biogas is 7USD/kW and from incineration is 12 USD/kW. This policy can encourage the use of waste treatment technologies such as anaerobic digestion technology with biogas collection and incineration technology with energy collection.

HCMC has established policies to support the SWSAS program and encouraging the investment on technologies for recycling solid waste with energy recovery.

3.4 Pilot Projects Implementation

3.4.1 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. There are four pilot projects implemented in Mongar, Bhutan. Two examples of the successful implementation are presented below. Details of all pilot project implemented can be found in Chapter 6, Appendix I.

A. Pilot Project 1: Waste segregation at source.

The focus of this 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.

The data from the implementation of pilot project really indicate the success of waste separation. From Table 2, 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.

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 2 The outcome of implementation of pilot project in commercial area.

Number of Commercial (A)	216 enterprises
Average waste generation per day Pilot Area (commercial) (B)	1.75 Kg
Total weight (kg) per day(C) =AxB	378 kg
Dry waste average (kg)	110 kg (recyclables) 50 kg (Medical) 20 kg (landfill)
Wet waste average (kg) per day	198 kg (organic materials)
Frequency collection	2 times each a week
Days	Mon and Wed=Wet Tue and Fri=Dry

B. Pilot Project 2: Waste (recyclables) Recover Center at Mongar lower secondary school

The recyclable storage facility 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.

The facility is coordinated by the Nature club teacher and by the student's member in collaboration with "M/S We Care". When the facility is full, the company comes, collects and buy the recyclables. Income from the selling of recyclables are used for 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.

3.4.2 Vietnam

A. Pilot Project 1: Implementation of solid waste separation at source program

In this program, Centema organized the awareness campaign and training of SWSAS for pupils of Lam Son primary school (Figure 6 and 7) 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 campaign of the SWSAS in their family resulting in increasing efficiency of the program.

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

- Trainers guide pupils to sort solid waste with the actual items (food waste, shell, waste cans, and waste plastic bottles).
- Poster to explain each component of solid waste and hazardous solid 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 Training on SWSAS for pupils by backdrop and poster

Figure 7 Training activity for pupils to sort solid waste with the actual items.

The awareness campaign program was held on Monday in May, 2017. The forms of awareness campaign used are 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.

B. Pilot Project 2: Waste exchange for gifts at Lam Son Primary School, ward 12

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 (Figure 8 and 9). 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.

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 3.

Figure 8 Items for waste exchange

Figure 9: Pupils exchanging wastes

Table 3: 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

3.5 Guideline development

Guideline for technology selection were developed both in local language and English. The aim of this guideline was to aid the local authorities in selection of appropriate technology for sustainable solid waste management based on the local situation. This guideline was prepared with the objective to be user friendly and the challenges and opportunities that may influence the successful implementation were pinpointed. This can be adopted in similar situation at other locations. Detail guidelines can be found in Appendix 5 for Bhutan and Appendix 6 for Vietnam.

4. Conclusions

This study was aimed to identify sustainable integrated solid waste management (ISWM) system that will minimize the waste going to landfill. For this, baseline data were collected to identify challenges and opportunities. Some of the gaps of the current SWM practices were the lack of public participation on waste separation, lack of infrastructures and human resources, lack of law enforcement, and appropriate policy.

Bhutan is enriched with natural resources and ecosystems, and thus proper waste management is very important for preservation of these pristine ecosystems. 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. The commingle waste collected was disposed in the open dumping site. The waste characteristics in Mongar indicated that nearly 50 per cent of the waste is organic and almost 40 per cent are recyclables. Therefore, suitable technologies include composting or anaerobic digestion for organic waste and recovery of recyclable materials. As the separation seemed to be necessary for proper waste management, the pilot projects implemented were targeted at waste separation. After the implementation of the pilot project, the segregation of the waste in the implementation area was successful. 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.

Ho Chi Minh City (HCMC) is a mega city with the total population of more than 10 million. The quantity of solid waste generated was about 9,000 tons/day. After source segregation, 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. Since the majority of the waste is biodegradable fraction, thus the composting and anaerobic digestion technologies are suitable. Incineration technology with energy collection is essential for solid waste with high calorific values or RDF technology is as material source for industries, and residual waste requires to be landfilled.

It can be seen that the integrated solid waste management system leading to zero waste for sustainable resource utilization 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, and both governments should promulgate such policies encouraging recycling activities and support funding to improve existing recycling facilities or invest in recycling facilities with appropriate technologies. Technology for each country should be selected based on local conditions. Additional interventions are required for sustainable solid waste management, such as waste segregation at source system development, public-private partnership, capacity building, environmental awareness, and political will of local leaders.

5. Future Directions

- Provide appropriate infrastructures for waste segregation.
- The distribution of guidelines to the relevant stakeholders including policy makers and local organizations responsible for solid waste management.

- Expansion of the pilot project implementation to raise awareness and increase public participation

6. References

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7. Appendices

Appendix 1 Full Project Report
Appendix 2 Thailand Workshop 2015
Appendix 3 Bhutan Workshop 2017
Appendix 4 Vietnam Workshop 2017
Appendix 5 Guidelines for Technology Selection for Sustainable Solid Waste Management in Mongar, Bhutan
Appendix 6 Guidelines for Technology Selection for Sustainable Solid Waste Management in Ho Chi Minh City, Vietnam