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A guide for improving municipal solid waste management and promoting urban organic waste utilization in Lao PDR

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Authors

Janya Sang-Arun, Institute for Global Environmental Strategies (IGES)

Korakanh Pasomsouk, National University of Laos (NUOL)

Reviewers

Magnus Bengtsson, Institute for Global Environmental Strategies (IGES)
Nirmala Menikpura, Institute for Global Environmental Strategies (IGES)

Institute for Global Environmental Strategies (IGES)
2108-11 Kamiyamaguchi, Hayama, Kanagawa, 240-0115, Japan
Tel: +81-46-855-3720 Fax: +81-46-855-3709
E-mail: iges@iges.or.jp URL: http://www.iges.or.jp

A guide for improving municipal solid waste management and promoting urban organic waste utilization in Lao PDR

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

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

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Preface

The objective of this report is to facilitate local governments in improving municipal solid waste management as a whole and promoting utilization of urban organic waste which can contribute to sustainable solid waste management as well as national agendas on food and energy security and climate change mitigation.

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

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

Lao PDR is a developing Asian country that has very limit experience on urban organic waste utilization. There is no pilot project on the 3R (reduce, reuse, recycle) and urban organic waste utilization project implemented systematically during our study. Major tasks of municipal solid waste management is limited to waste collection and transport to the designated disposal sites which can be basically classified as open dumping.

The Lao's version of this report was distributed to local governments and other stakeholders participating in the workshop "Capacity Building on Accounting and Utilizing GHG Emission Reduction Measures for Local Waste Management Actor in Lao PDR" held on 4-6 October 2011 in Vientiane Capital, Lao PDR. The workshop was co-organized by Institute for Global Environmental Strategies (IGES) and the University of Laos (NUOL) with financial support from Ministry of Environment of Japan (MOEJ) and Asia-Pacific Network for Global Change Research (APN). The organizers are impressed with positive response from participants and their willingness to implement urban organic waste utilization projects in Lao PDR.

This English version is a revised version of the distributed one that was in Laos. The authors believe that this guide would be also useful for other local governments in Lao PDR and other countries that could not attend the workshop. Nevertheless, this guide will be also useful for national governments and academia that involved in municipal solid waste management in Lao PDR. Therefore, the authors are currently revising the document, rearranging the story-line and

brushing-up the language, and then it will be published under an IGES Policy Report in 2012. *Therefore, the authors recommend that the readers should follow-up the progress of the revising version of this guide which will be available on the IGES website or send a request to Dr. Janya Sang-Arun for the revised verison.*

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

The authors welcome feedback and comments on this guide, which can be sent to Dr. Janya Sang-Arun *(sang-arun@iges.or.jp or janyasan@gmail.com)* and Associate Professor Korakanh Pasomsouk *(*kanhpss@yahoo.com*)*. In addition, we are looking forward to sharing experience with all readers, which would be useful for further improvement of this guide.

Janya Sang-Arun

Policy Researcher
Institute for Global Environmental Strategies

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I would also like to thank to all staff members of Urban Development Administrative Agencies of Vientiane Capital, Luangprabang, Savannakhet, and Champasak for their valuable contribution during this study.

Janya Sang-Arun, Ph.D.
Policy researcher, Sustainable Consumption and Production Group (SCP),
Institute for Global Environmental Strategies (IGES),
2108-11 Kamiyamaguchi, Hayama-machi, Kanagawa-ken
240-0115, JAPAN
Telephone:+81-46-826-95(Direct)
Fax:+81-46-855-3809
E-mail: sang-arun@iges.or.jp; janyasan@gmail.com
URL: http://www.iges.or.jp

Assoc. Prof. Korakanh Pasomsouk
Department of Mechanical Engineering Faculty of Engineering
National University of Lao PDR
Sokpauang Campus
Mobile Ph. 856 -20- 55517025
Email : kanhpss@yahoo.com

Executive Summary

Lao PDR, a developing country, faces increasing municipal solid waste, while government capacities remain low, both in terms of budget and personnel skills. Many wastes are discarded in empty spaces scattered around the city which, is a leading cause for environmental pollution and health risk of residents. A fraction of generated waste is collected by local governments and disposed of in designated dumpsites which are classified as open dumping. Burning is practiced from time to time to reclaim landfill space. Sometimes, waste pickers burn the waste to search for recyclables such as metals. The level of awareness on health risks associated with these improper practices is very low.

The Institute for Global Environmental Strategies (IGES) realised that Lao PDR needs international support to overcome its solid waste management problems. Together with the National University of Laos (NUOL), IGES is proposing that the use of urban organic waste be explored within the context of sustainable development. We argue that sustainable organic waste management can contribute to the national agenda for food and energy security, framed within sustainable consumption and production systems and a 'low carbon society'.

Under the scope of this project, we aim to improve the capacity of local governments to: understand their solid waste management problems and links with their national agenda on food, energy and climate change; and provide guidance on how they can improve the situation of municipal solid waste as a whole and increase utilization of urban organic waste as a resource.

To make this report useful and pragmatic for local governments and policy makers, we conducted detailed analysis of waste management in four major cities in Lao PDR (Vientiane Capital, Savannakhet, Champasak and Luangprabang) through field observations, stakeholder interviews, and review of secondary data sources. In addition, we conducted a preliminary analysis of waste composition in the studied cities to estimate the significance of organic waste management on issues related to climate change and food and energy security.

According to our field studies, waste generation rates in selected four major cities are 212 tonnes/day in Vientiane Capital, 42 tonnes/day in both Luangprabang and Savannakhet, and 51 tonnes/day in Champasak. The major fraction of waste consists of food waste which amounts to 30-62% of waste generated.

Waste collection was limited to areas where residents could pay for the service as there is no subsidy for this activity. Therefore, waste collection coverage is limited to approximately 60% in Vientiane Capital, 60% in Luangprabang, 70% in Savannakhet, and 42% in Champasak. In addition, the capacity of local governments on collection of waste is restricted due to lack of budget to purchase new collecton trucks. Most of the functioning collection trucks are very old.

Most of the collected waste is disposed of at the designated dumpsites which are classified as open dump sites with no lining, no leachate collection, or treatment systems. Most of the dumpsites are located in upland areas which are relatively small. Waste separation at source is not practiced, except for the separation of some recyclable materials that can be sold by households and food waste collection for animal feed that is practiced by farmers. There is no systematic urban organic waste utilization practices such as composting within the period of this study.

Lao PDR faces fundamental problems of resident's behaviours traditional practices of consumption and disposal. Knowledge of the residents on environmental pollution and sanitation is relatively low. Therefore, the local governments need to improve the conditions of municipal solid waste as a whole. Awareness raising to educate people not to litter on public space, and to discard waste in the waste bins, should be prioritised. At the same time, waste collection efficiency should be improved in an economically viable approach such as the redesign of waste collection routes.

Rapid degradation of urban organic waste such as food waste in Lao PDR can be treated at the household level or at the waste utilization facility which can be located at a disposal site. According to our study, a family with 2-3 members generates about 2-4 kilograms of food waste per day. Reduction of food waste can be achieved to avoid over demand for consumption at each meal. Use of organic waste as animal feed is being practiced by farmers and should be encouraged as it could significantly reduce the workload of local governments on waste collection and disposal.

A majority of households in Lao PDR is single houses with a small space for gardening. In this case, composting or anaerobic digestion should be promoted at the household level. In addition, use of charcoal is still common, therefore, fuel briquettes made from paper and plant residues would be applicable. Monetary benefits for these practices may not be high but they can significantly contribute to improving sanitary conditions of the city and minimise workload of the local governments.

At the disposal site, the local governments may allocate a space for composting, anaerobic digestion, or fuel briquette making. This activity may increase the workload of local governments, but it can significantly save landfill space. Investment in this activity may be offset by the revenue generated by selling compost and fuel briquettes and replacement use of chemical fertilizer with compost, replacement liquid petroleum gas, charcoal and firewood with biogas and fuel briquette.

According to the training workshop organized in Vientiane Capital in October 2011, most of the participating local governments were interested in composting at the disposal sites. The authors also agreed that composting is a promising technology for the current situation in Lao PDR. It can significantly reduce waste disposed of at the dumpsites, avoid methane emission during waste degradation in the dumpsites, recirculate nutrients for food production, improve soil quality, and increase carbon sequestration in the soil. In addition, it can contribute to income generation, which is a mandate of the country, or poverty reduction and associated cost savings in purchasing chemical fertilizer

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I. Introduction

1.1 General information of Lao PDR

Lao People's Democratic Republic (Lao PDR) is a developing country in Southeast Asia. The total area of the country is 236,800 km^2. The total population as of 2012 was 6.6 millions. The population growth rate (except in Vientiane Capital City) is approximately 1.7% per year. Average life expectancy at birth is 63 years. Approximately, 67% of the total population lives in rural areas and suffers from poverty. Only 33% of the total population lives in urban areas (CIA, 2012).

In 2011, the economic growth rate was 8.3% per annum and the GDP was USD 2,700 through services (37%), industry (35%) and agriculture (28%). However, agriculture contributes 75% to employment (CIA, 2012).

Population and economic growth are concentrated in four main cities: Vientiane Capital (330,798), Savannakhet (65,724), Champasak (Pakse) (72,955) and Luangprabang (70,481). However, other cities are also experiencing economic growth especially from tourism.

Consequently, waste generation increases, but local government capacity on waste management remains low. Lao PDR has a very low industrial development, so that industrial pollution issues are at an early stage. Improper waste management is a serious environmental issue.

1.2 Background of the study

Proper management of municipal solid waste directly contributed to cleanliness, sanitation and aesthetic value of the city. Additionally, solid waste management is directly related to public health and environmental issues at the local level including heavy metals and dioxin contamination and in soil, water and air. In addition, disposal of organic waste at the dumpsites can emit a significant amount of methane, and the burning of plastic waste can emit fossil based carbon dioxide. These are greenhouse gases that absorb and emit radiation within the thermal infrared range in the atmosphere. Therefore, they contribute to global warming and climate change issues.

In Lao PDR, environmental impacts from municipal solid waste are increasing seriously due to a rapid increase of waste generation, and proper disposal sites for sanitary landfilling are limited. For instance, the disposal site in Vientiane Capital in 2011 was almost full as the waste is being dumped on the surface. Landfilling can not be practiced due to a high water table and no equipment. Furthermore, waste was being discarded elsewhere as Laotians have low awareness on waste associated health and environmental problems.

Municipal solid waste in Lao PDR comprises a large percentage of organic waste such as food, wood and plant residues and paper. Food waste can create foul odor and induce health risk to residents as it becomes a food source of disease carrying vectors such as rodents, cockroaches, houseflies, and so on. On the other hand, if managed properly, this waste can be used as a resource for food production and an alternative energy source. In addition, avoidance of organic waste landfilling can significantly contribute to climate change mitigation.

Therefore, this guide aims to facilitate local governments on improvement of municipal solid waste management in Lao PDR as a whole and, in particular, promoting utilization of urban organic waste. The current situation of municipal solid waste management in Lao PDR was investigated through field surveys and interviews with relevant national and local governments. Waste composition analysis was conducted in studied cities as there is no country specific data available. Waste composition is the key information which is required to identify appropriate technology for waste treatment.

1.3 Outline of the report

This report consists of three main sections. The first part presents the current situation of solid waste managmenet in Lao PDR, including national policy and regulation, information on waste generation, collection, and disposal in four major cities (Vientiane Capital, Luangprabang, Savannakhet, and Champasak).

Secondly, the report provides guides for improving municipal solid waste management in Lao PDR which includes raising awareness of residents, introducing waste separation at source, increasing waste collection efficiency, establishment of front-end waste separation facility, and improving organic waste management under the 3Rs (reduce, reuse, recycle) concept.

Finally, the report introduces technologies that are appropriate for organic waste utilization in Lao PDR. Three technologies were found applicable under the local conditions in Lao PDR: composting, anaerobic digestion, and fuel briquettes. Small scale implementation of these technologies at households, communities, and disposal sites is recommended. However, further experiments to improve efficiency of anaerobic digestion are required.

A large scale waste management project such as mechanical biological treatment prior to landfill and sanitary landfill with gas recovery were not included in this guide as it requires high technical skills and capital investment. Introduction of advanced and large scale technologies in Lao PDR can be only in the form of international aid or international investment.

II.
Current Situation of the Solid waste Management in Lao PDR

II. Current Situation of Solid Waste Management in Lao PDR

2.1 Laws and policies related to solid waste management in Lao PDR

In Lao PDR the regulations and the framework for waste management is in progress. The Department of Housing and Urban Planning (DHUP) of the Ministry of Public Work and Transport (MPWT) and the Ministry of Natural Resources and Environment (MOE) are responsible for municipal solid waste management. While as the DHUP is responsible for urban planning and urban development, the MOE is responsible for environmental issues related to solid waste management. Recently, these authorities drafted relevant laws and national policies for improvement of municipal solid waste management. The Urban Development and Administrative Agency of each city is directly responsible for collection and disposal of urban solid waste.

Relevant regulations to solid waste management are the National Constitution, the Environmental Protection Law, and the Decree on Implementation of the Environmental Protection Law.

- The National Constitution (1991, Article 17)
  All Lao citizens must protect the environment and natural resources: land, subterranean, forests, fauna, water resources, and atmosphere.

- The Environmental Protection Law (1991, Chapter 3 Article 23 Prevention Measures and Pollution Control)
  All kinds of littering are forbidden. Waste disposal sites must be allocated and waste should be separated before disposal. The governments must support implementation of technologies for the waste treatments, reuse, and recycling. It is forbidden to import, transport and carry any kind of hazardous waste over land, water, and sky borders of Lao PDR.

- Decree on Implementation of the Environmental Protection Law (2002, Chapter 4 Article 14: Environmental Quality Standard and Article 15: pollution control).

The National Environmental Action Plan (NEAP) envisages gradual expansion of waste management program from large to smaller towns. However, there is no quantitative target. The general direction of the NEAP includes:

- Increasing coverage of waste collection service in urban areas
- Cost recovery including payments by households, depending on the level of service
- Investment on equipment
- An emphasis on organization and community mobilization helps reducing the capital and operation costs of waste management systems

2.2 Current situation of solid waste management in Lao PDR

In Lao PDR, solid waste management is a new concept for residents. Historically, most Lao people have lived a subsistence lifestyle. Waste generation is very little, and is mostly organic that is naturally degraded.

Over the past few decades, a process of urbanization has resulted in growing urban population, changing lifestyle and consumption patterns. The residents gradually depend on monetary value as well as consuming more imported, processed, and manufactured products. Income is increasing through commercial and tourist activities. Meanwhile, residents are still practicing the traditional practices for waste management, e.g., *burning and burying* it in their backyard, *dumping* it outside their property, such as on the roadside or surrounding areas, and *throwing* it in a nearby swamp or river (Figure 2.1).

Figure 2.1 Self-disposal of waste by open dumping and open burning by some residents in Lao PDR

2.2.1 Sources of waste generation

Sources of waste generation are households, markets, offices, shops, construction sites, streets, school, hospitals, restaurants, and so on. Moreover, there is a large portion of waste that is generated by tourists and visitors. The amounts of waste in Vientiane Capital in 2000 are generated by different sources. Households are the largest waste generators (**Table 2.1** and **Fig. 2.2**).

Table 2.1 Waste generations by different sources in Vientiane Capital in 2000

Sources	Quantity (Tonnes/day)	Percentage (%)
Households	178	75
Shops	36	16
Markets	9	4
Construction places	6	**2**
Hospitals	2	1
Schools and offices	2	1
Litter on streets	2	1
Total	235	100

Source: SEA, 2000

Figure 2.2 Waste discarded by households

2.2.2 Waste generation rate

Historically, Laos was in poor economic condition. The quantity of food for household consumption is relatively small. Leftover food and residues are fed to animals that are raised at home. Therefore, there is almost no waste for systematic treatment.

The lifestyle of people has changed over the past few decades due to economic and urban development. People prepare a large quantity of food for household consumption and ceremonies. Most Laotians believe that if there is a lot of food leftover, the family will have a good fortune.

In addition, numbers of restaurants and food shops have gradually increased to serve tourists and local people who prefer eating out. Consequently, the quantity of leftover food is increasing. Figure 2.3 presents leftover food at restaurants and noodle shops.

Figure 2.3 Food waste from restaurants and noodle shops

There was no concise information on city or country waste generation when this project was started in 2009. Therefore, the authors directly contacted the Urban Development Administrative Agency (UDAA) of four major cities: Vientiane Capital, Luangprabang, Savannakhet, and Champasak. As shown in Table 2.2, total waste generation in Vientiane Capital is higher than other cities, but the per capita waste generation rates of all the cities are almost the same (0.6-0.7 kg/capita/day).

In addition, the project members investigated quantity of food waste generation in four major cities in 2010 (Figure 2.4). Due to limitations of budget, only food waste analysis was applied as food waste is the major waste composition for this study.

Table 2.2 Generation rate of municipal solid waste in four cities in 2008

Provinces	Population (persons)	Generation rate (kg/capita/day)	Total amount of waste (tonnes/day)
Vientiane Capital	330,798	0.64	212
Luangprabang	70,481	0.60	42
Savannakhet	65,724	0.64	42
Champasak	72,955	0.7	51

Figure 2.4 Food waste analysis in Vientiane Capital, Luangprabang, Savannakhet and Champasak

There are various factors and conditions that may affect the results of this study, e.g. numbers of immigrants from rural to urban areas, tourists, students, and temporary workers. In addition, this data may not reflect the current waste generation rate and the quantity of waste that being self-disposed. However, the data can significantly demonstrate the situation of food waste generation in different cities.

As shown in Tables 2.3, 2.4, 2.5, and 2.6, food waste generation rates from small restaurants are higher than other sources. Altogether, food waste generation in Vientiane Capital was approximately 130 tonnes/day, in Luangprabang was 36 tonnes/day, in Savannakhet was 54.5 tonnes/day, and in Champasak was 45 tonnes/day. Food waste in Lao PDR contains a high percentage of liquid. Large portions of this waste are not discarded to the collection system of the city. Some of them are used for animal feed or are thrown away in empty spaces.

Table 2.3 Food waste generation in Vientiane Capital

Sources	Numbers	Generation rate (kg/day)	Total (tonnes/day; estimate)
Hotel & restaurant	79	45	4
Restaurant	169	45	8
Small Restaurant	676	55	37
Household	38,000	2.1	81
Total			130

Table 2.4 Food waste generation in Luangprabang

Sources	Numbers	Generation rate (kg/day)	Total (tonnes/day; estimate)
Hotel & restaurant	21	48	1
Restaurant	104	48	5
Small Restaurant	312	42	13
Household	6,345	2.6	17
Total			36

Table 2.5 Food waste generation in Savannakhet

Sources	Numbers	Generation rate (kg/day)	Total (tonnes/day; estimate)
Hotel & restaurant	13	40	0.5
Restaurant	68	40	3
Small Restaurant	204	60	12
Household	15,687	2.5	39
Total			54.5

Table 2.6 Food waste generation in Champasak

Sources	Numbers	Generation rate (kg/day)	Total (tonnes/day; estimate)
Hotel & restaurant	17	42	1
Restaurant	82	50	4
Small Restaurant	230	60	14
Household	11,000	2.4	26
Total			45

2.2.3 Waste composition

Data on waste composition in Lao PDR is lacking. Therefore, the authors conducted a rough estimation of waste composition at landfill sites of three major cities (Luangprabang, Champasak and Savannakhet). Waste pickers were involved in waste separation and weighing (Figure 2.5). Waste composition of Vientiane Capital City was obtained from a previous study.

As shown in Table 2.7, the composition of the waste from the four major cities is slightly different. However, biodegradable waste (e.g. food and garden waste) is the largest waste composition in all cities.

Figure 2.5 Rough estimation of waste composition in four major cities in Lao PDR

Table 2.7 Waste composition in four major cities

Waste fraction	Vientiane Capital* (%)	Luangprabang (%)	Savannakhet (%)	Champasak (%)
Food, Vegetables	30	51	54	62
Wood/Grass/Trees /Leaf	19	23	16	21
Paper	6	8	9	4
Plastic	13	9	15	6
Glass	6	6	2	2
Metal	3	1	1	1
Textile	2	1	1	1
Other	21	1	2	3
Total	100	100	100	100

* Waste composition from Vientiane Capital is cited from a previous study in 1998

2.2.4 Waste separation at source

Some restaurants, for example, the Elephant restaurant in Luangprabang, initiated a waste separation at source program. Recyclables such as plastic, paper, glass and food waste are separated. Recyclables are sold or given to waste pickers. High quality food waste is used as animal feed. Leftover food that is not suitable for animals is composted. Approximately, 50 – 70 kgs/day of food waste is separated. This practice helps avoid housefly outbreaks in the restaurants. The Eravanh hotel in Pakse has an agreement for exchanging food waste of the hotel with animal dung from farmers. Farmers use the food waste for animal feed and the hotel can use animal dung for greenery areas.

Many small restaurants and noodle shops separate food waste for farmers. The contracted farmers pick-up food waste on a daily basis after, or a little before the shops are closed. The collected waste is used as animal feed. Restaurants discard leftover food that not suitable for animals to waste bins.

Some households separate food waste for pets. However, only small numbers of pets can be kept at home. Therefore, many of food waste were discarded to waste bin together with other waste.

2.2.5 Waste collection and transport

At present, the collection and disposal of municipal solid waste in four major cities (Vientiane Capital, Luangprabang, Savannakhet and Champasak) are much better than other cities. So far, there is no service or mechanism for waste separation at the household level. On self-initiative, some households separate valuable materials (e.g. plastic, paper, glass, and metals) and sell to waste buyers, or donate to waste pickers.

Waste collection service in urban areas of Lao PDR is responsible by UDAA. Some cities, such as Luangprabang, transfer waste collection service to designated waste collection companies. Each city has a numbers of trucks that generally collect waste from each household once or twice a week. The fee for collection service is about USD 1.25 – 2.25 per month per household. However, only around 30-40% of residents pay the waste collection fee. Residents who did not pay claimed that they did not produce waste, and some burned waste by themselves.

Based on UDAA records, approximately 40-70% of waste generated (on average) is being collected and transported to landfill (Table 2.8). The collection rate in Savannakhet is higher than other cities (70%). The coverage of waste collection service is highly dependant on the numbers of waste collection trucks and received waste collection fees by residents. Local governments could not increase the coverage of their services due to various constraints, including lack of supporting funds from the central government, insufficient numbers of trucks for waste collections, residents that could not or are not willing to pay for waste collection,

difficulty of access to some communities, low awareness of residents on sanitary issues, lack of local regulations, and so on.

Table 2.8 Waste transported to landfill

	Vientiane Capital	Luangprabang	Savannakhet	Champasak
Estimated waste generation in municipal area (tonnes/day)	300	50	42	60
Collection and disposal in landfill (tonnes/day)	180	30	30	25
Coverage (%)	60	60	70	42

Source: Personnal communication with Urban Development Administratve Agency of each city in 2009

2.2.6 Waste disposal

At present, there are only five landfills in Lao PDR (Vientiane Capital, Luangprabang, Thakhek, Savannakhet, and Champasak). These landfills are very simple and do not meet environmental standards due to budget constraints. Landfill covering is not regularly practiced. Therefore the conditions of landfills are similar to designated dumpsites (Figure 2.6). Table 2.9 presents the capacity of landfills in Lao PDR. Landfill sites in Lao PDR are relatively small, except for Vientiane Capital. Sometimes, burning is applied to reduce the volume of waste and recover landfill space.

In 2010, approximately 180 tonnes per day of solid waste was disposed in the landfill of Vientiane Capital (Table 2.8). The quantity of waste disposal in landfill of other studied cities ranged between 25-30 tonnes/day. The rest of the waste generated is self-disposed of in rivers and empty space, or often openly burned in backyards.

Table 2.9 Landfills in Lao PDR

Landfills	Vientiane* Capital	Luangprabang**	Thakhek**	Kaisone** Savannakhet	Pakse** Champasak
Date started	2007	2002	2000	2000	2000
Site area (ha)	550	15	9	13.5	13.5
Disposal area (ha)	100	3.5	2.2	4	2.2

*Source: *Personal communication with UDAA of Vientiane Capital, **UNDP, 2002*

Figure 2.6 Landfill conditions in Lao PDR

Recently, most vehicles and equipment used for waste collection and landfill operation are out of date. Local governments do not have sufficient budget for purchasing new vehicles, equipment, and upgrading the landfill sites, therefore, they are looking for international support such as the Norwegian Agency for International Development (NORAD), Japan International Cooperation Agency (JICA), and Asian Development Bank (ADB).

Some private sectors such as markets and waste collection companies must pay disposal fees to the landfill operation unit. In Vientiane Capital, the disposal fee is USD 5.4 per tonne of waste (UDAA Vientiane Capital, 2009, personal communication).

2.2.7 Organic waste utilization

Waste that is being disposed in the disposal site contains high organic matter (Figure 2.7). This waste could be used for animal feed, improving soil quality for cultivation, and generating energy for household use. However, no such activity was implemented in Lao PDR during the surveys.

Figure 2.7 Landfill of unsorted waste that contains high organic matter in Lao PDR

III.
Guides for Improving Municipal Solid Waste Management in Lao PDR

III.

Guides for Improving Municipal Solid Waste Management in Lao PDR

As described in the previous section, solid waste is generated everyday from everyone in society. In the case of Lao PDR, the average waste generation was estimated at 0.6 - 0.7 kg/person/day (pesonnal communiciation with UDAA of four major cities). The generation rate tends to increase from expansion of urbanization and economic development, especially in tourism and the changing of consumption patterns. However, responsibility for the solid waste treatment is heavily dependant on local authority, which basically has a lack of capacity, in terms of personnel and budget.

Each city has few staff responsible for solid waste management and most of them do not have degrees or certificates on either solid waste management or environmental management. While budgets for landfill development of most cities have relied on international support, budgets for waste collection and disposal have relied on waste collection and disposal fees. Nevertheless, residents are not willing to pay for waste collection. Therefore, the common waste disposal technology in Lao PDR is open dumping, and sometimes open burning is applied. In addition, a large quantity of valuable waste is being buried or burnt.

Many people see waste as dirt and unwanted items. Therefore, they try to throw it away from their home without making any effort to separate and treat it properly. Actually, everyone can contribute to improve municipal solid waste with a simple practice such as discarding waste properly into waste bins, reducing waste generation, and separation of waste prior to disposal. However, Laotians are not familiar with this approach. The following are some guides for improvement of municipal solid waste management in Lao PDR.

3.1 Raising awareness of residents

Most Laotians are not familiar with waste management, even the simple manner of throwing waste into waste bins. Therefore, awareness raising is the top priority prior to improvement of municipal solid waste management in Lao PDR. Information on waste management should be disseminated to waste generators and all residents. Residents tend to ignore that they generate waste, and the waste deteriorates the quality of the environment. Therefore, most of them do not realize that it is their responsibility to keep the city clean. Public education on solid waste is not only to increase the awareness of people, but also to change their attitude on waste management, especially to understand the impact of throwing the waste in surrounding areas.

There are several practices for education on solid waste that could be introduced in Lao PDR. Some examples are as follows:

(1) Workshops and Training

Workshops and training on solid waste management should be conducted for all relevant stakeholders prior to transfer the solid waste disposal technologies and proper solid waste management. The topic of the workshop and training may include the following topics:

- Waste separation at source
- 3R (reduce, reuse, recycle) systems
- Composting techniques for kitchen waste
- A technique for biogas generation from kitchen waste
- Fuel briquette making
- Waste management and climate change
- Others topics related to solid waste management

(2) Seminar and public hearing

Seminars for presentation and discussion on solid waste management in the community and the city should be organized from time to time. Residents, local governments and/or academicians can share their thoughts and observation about the existing waste management system and willingness for improvement. The seminars can also dissiminate the potential technology for improving solid waste management in Lao PDR or experience in other countries.

(3) Poster

A poster is a good tool for public education. It should be posted in communities, schools, hospitals, public areas, super markets and if possible at each household. The poster should have attractive designs and including key message. For example:

"A good man loves his nation; a wellbehaved person does not throw waste all over the place"

"Waste is money (resource)"

"The city will not be cleaned if 100 persons throw waste and only 1 person keeps cleaning, but the city will be cleaned if everyone helps to clean''

(4) Brochure

A brochure is a simple explanation by words and pictures about waste disposal. It is very useful for communicating with people in a city. The text written in a brochure must be simple, clear, and short with pictures. The brocure must be attractive and trustable. It should be distributed to every household.

(5) Radio and TV broadcasting

An FM channel is most popular and very attractive for the young generation. This radio channel should have a slot for announcements or advertisements of solid waste management activities.

Also, TV channels should include news, discussion, simple games, or very short drama related to the waste management activities. This program will help a community to understand about proper waste management and the impact of improper management.

(6) School education

The education and activities on waste separation at source for sale, composting, and so on should be included in a school's program, especially in nursery and elementary schools. Students in higher level education can play a role in awareness raising upon the leadership of the school, college, or university teachers and UDAA staff.

It can be expected that waste managmenet in Lao PDR will be improved once residents can understand more about their role and contribution to solid waste management. Then, they will participate and cooperate in any waste management activities including waste separation at souce, utilization of waste, and so on.

Apart from awareness raising, local governments may consider issuing domestic regulations to enhance actual implementation of proper waste management, because many less disciplined people may not volunteer to improve the waste management system.

3.2 Introducing waste separation at source

Waste separation at source is widely practiced to increase the percentage of resource recovery in developed countries such as European countries, the United States of America, Japan, and so on. It could help in reducing the volume of waste transported and disposed of in final disposal sites, making transportation easier, increasing recovery rates of valuable waste, extending lifetimes of landfills, keeping the city clean, minimizing the risk of water clogging and flooding, avoiding soil and water pollution, and so on. However, this practice is not yet established in Lao PDR. As shown in Figure 3.1, various types of waste are being discarded together.

Figure 3.1 Unsorted waste disposal in Lao PDR

As shown in Table 2.7, waste in Lao PDR comprises some types of waste that are very difficult to be degraded, especially plastics and foam that may take hundreds of years to be degraded. Fortunately, most of this waste can be recycled and thus has market value. Many wastepickers collect and sell this waste to waste buyers. However, the recyclables that are segregated from waste bins or landfill sites are dirty (Figure 3.2).

Figure 3.2 Sellable waste that is segregated from disposal sites

For Lao PDR, separation of recyclables or sellable waste could be easily practiced. However, local governments should organize awareness raising campaigns to promote the actual implementation citywide. As shown in Table 2.7, these wastes (paper, plastic, glass, metal) accounted for 28% of waste in Vientiane Capital, 24% in Luangprabang, 27% in Savannakhet and 13% in Champasak. Separation of sellable waste helps to reduce the workload of local governments on waste collection and disposal.

Separation of biodegradable organic waste such as kitchen waste and plant residues should be considered and implemented once the treatment facility is available such as farms for animal feed. Composting, anaerobic digestion, and/or fuel briquette facilities can also be used. As shown in Table 2.7, these wastes accounted for 49% in Vientiane Capital, 74% in Luangprabang, 70% in Savannakhet, and 83% in Champasak. However, the separation of biodegradable organic waste is meaningless if all waste is collected and transported to a final disposal site. Figure 3.3 shows existing food waste separation for animal feed in Lao PDR.

Once these two types of waste are separated at generation sources and processed for recovery, it could reduce waste for disposal in landfill up to 77-98%. Anyway, actual practice could result in less waste reduction, depending on the commitments of residents on separation and a supporting mechanism to utilize the waste.

The remaining non-valuable waste is discarded to collection and disposal by local governments. Residents should bring the waste to collection points and keep the surrounding area clean. Figure 3.4 is an example of waste discards at collection points in Lao PDR.

Simple and cheap containers such as plastic bins can be used for waste separation at source. If possible, residents should label the bins to avoid mixing of waste. An example of a waste bin arrangement is shown in Figure 3.5.

Figure 3.3 Food waste separation for animal feed

Figure 3.4 Waste is waiting for transporting to landfill

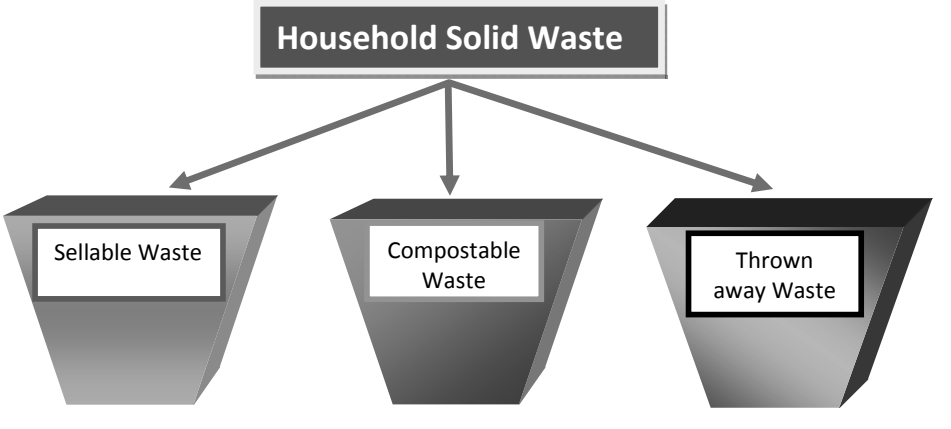

Figure 3.5 Example of waste bins arrangement for different types of waste

3.3 Increasing waste collection efficiency

Collection of waste for disposal is a fundamental practice to keep the city clean. Waste from each household or building should be collected by waste collection staff and transported to a final disposal site or waste utilization facility.

Collection system

The process of solid waste collection is a multiphase process that comprises at least five phases as shown in Figure 3.6. Firstly, an individual household must discard waste into a waste bin, which may be kept inside or outside the house. Secondly, a collection crew will bring waste to the truck. In this phase, the collection system should be designed to support the waste separation system (if any). For example, different types of waste should be collected on different days, different times, or with different trucks. Collection of organic waste and sellable waste can be offered to private sectors, for instance, waste buyers can take part in buying sellables directly from households, and farmers may take part in organic waste collection for animal feed. The local governments will then collect only the remaining thrown away waste or organic waste for centralized composting. Thirdly, the truck must collect the waste from households in the most efficient way. Fourthly, the collectors will continue collecting waste from other communities. Finally, the collection crew transports waste to a waste treatment facility or a final disposal site.

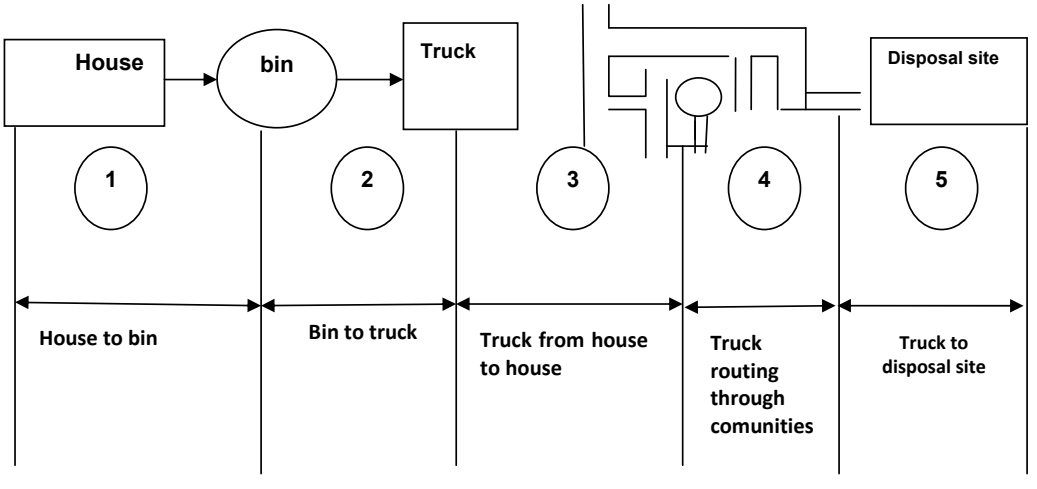

Figure 3.6 Five phases of municipal solid waste collection

Phase 1: House to bin

The house to bin phase is the first phase for waste collection. Unfortunately, many Lao residents, especially low-income groups, do not throw waste into bins but litter it around or burn it.

Phase 2: Bin to Truck

There is an agreement between a family and collectors about fees and the period of collection during the week. Generally, waste collection frequency is 2-3 times a week. Problems are:

(1) The road conditions are inconvenient, rough and narrow. Sometimes, a lot of waste in high density residential areas is left uncollected because the truck cannot access the community due to poor infrastructure. Small vehicles for waste transfer such as tricycles should be used for waste collection in these areas, and the waste is then transferred to the main truck (Figure 3.7).

Figure 3.7 Tricycles for waste transportation in the narrow street

(Designed and manufactured by University of Lao PDR in 2005)

(2) The capacity of truck is not enough, thus resulting in a delay of waste collection service. The collection time schedule is always delayed because the capacity of trucks is not sufficient to collect all waste in the designated route. Some waste is being left uncollected. Therefore, residents in that area are not willing to pay a waste collection fee and dispose of waste in front of other people's houses, throw it in empty spaces, and so on.

(3) There is falling or scattering of waste during transfer from waste bin to the truck. In Lao PDR, residents use locally available waste bins such as bamboo baskets and plastics (Figure 3.8). Waste is not packed properly. Often, waste falls and is scattered on the road while the crew is throwing waste onto the truck. This problem could be avoided if waste is properly packed in a bag before disposal in the waste bin. In addition, a countermeasure to prevent animal access should be applied, such as putting a barrier around the bin.

Figure 3.8 The bamboo basket use as the waste bin and the waste is not packed properly

Phase 3 Truck from house to house

The numbers of waste collection trucks in Lao PDR are not sufficient and many of them are out of date (Figure 3.9). Routing design can be an alternative to minimize travelling frequency of trucks between the town and the final disposal site. So far, there is no study on the routing system for efficient collection in the four studied cities.

Figure 3.9 Waste collection truck in Lao PDR

Phase 4 Truck routing through communities

Routing design is important to improve waste collection efficiency and reduce cost for fuel. An example of an efficient route plan is shown in Figure 3.10. A study on the collection routing, especially in the city or community, will help to reduce idle time (no waste collection). The following criteria can be applied for route planning (Vesilind et al, 2002).

1) Routes should not overlap and should be continuous.
2) The starting point should be close to the truck garage.
3) Heavily traveled strests should be avoided during rush hours.
4) One way streets should be looped from the upper end of the street.
5) Waste should be collected toward the downslope.
6) Clockwise turns around the block should be used whenever possible (driving lane in Lao PDR is right-hand side).
7) Long straight paths should be routed before looping clockwise.

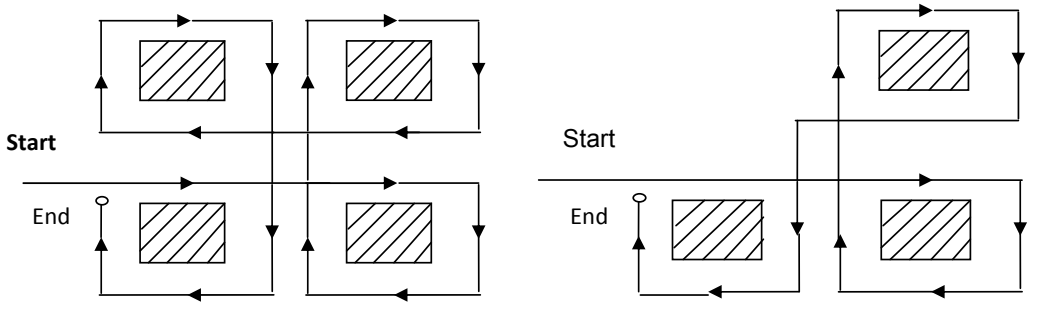

Figure 3.10 An example of efficient route design

Phase 5 Truck to Disposal site or waste utilization facility

It is also important to design the routing for waste collection that would also minimize the total time to a final disposal site or waste utilization facility. In some cities, waste transfer stations and a front-end separation facility should be established to reduce numbers of trucks going to a final disposal site. This results in reducing fuel and maintenance cost for waste collection trucks.

3.4 Establishing front-end waste separation facility

Front end separation refers to mass collection and separation of valuable waste before disposal. It is labor intensive, but could be applicable in Lao PDR, where labor cost is low. This system is worth implementing if waste separation at source is not successful. In front end separation, large item waste is separated (usually by hand) on a conveyer system and then

recyclables are further segregated. The front-end separation facility can be established near the town or close to a waste utilization or disposal site. Figure 3.11 and 3.12 shows an example of front-end separation.

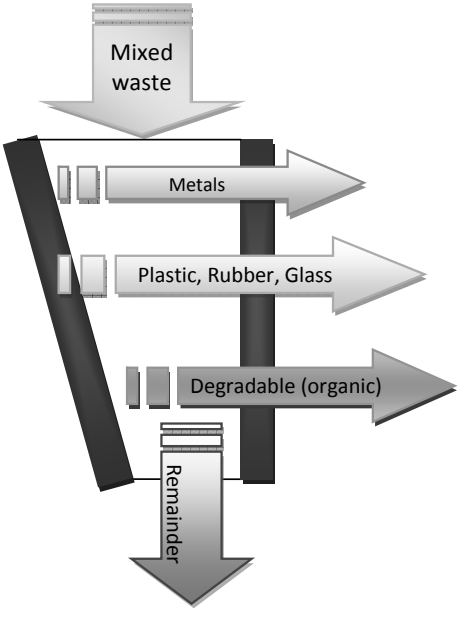

Figure 3.11 An example of a front-end waste separation system

Figure 3.12 Hand sorting at a front-end separation facility in Seoul, South Korea

Once the front-end separation facility is located near the town it could reduce cost for transportation. Most front-end-separation systems in developing Asia are located at a waste disposal site, as it is convenient to handle the waste or process the waste, to a utilization facility. This facility could contribute to extracting valuable resources that have economic value and extend the lifetime of a landfill.

2.5 Improving organic waste management

Organic waste here refers to food waste, plant residues, and papers. Sellable paper is considered as recyclables, but some papers are inferior quality, and are being disposed in landfill. As shown in Table 2.7, organic waste accounted for approximately 50-80% of municipal solid waste in Lao DPR. This waste could be efficiently managed by the 3Rs (reduce, reuse, recycle). Unfortunately, this waste is being disposedof in landfill, which could significantly contribute to soil, air, and water pollution because water in food waste (so-called" leachate") can dissolve heavy metals and other hazardous substances, and damage soil and water resources. In addition, degradation of these wastes under anaerobic conditions in a landfill generates methane, a potent greenhouse gas, which is emitted to the atmosphere.

(1) Reduce

Reduction of organic waste generation in Lao PDR can be practiced through avoiding over demand for food preparation. Refering to Lao's culture, Lao families love to celebrate, such as parties, weddings, holidays, and so on (Figure 3.13). The quantity of food left over after the ceremony and daily meals are a symbol of wealth and good fortune. Housewives can play a major role in calculating food needs for the daily meals of family members and participants of each event. This practice could reduce the quantity of food left over after the meals.

Figure 3.13 Celebration event in a Lao family

(2) Reuse

Once food is already cooked and some is left over, proper collection and storage of leftover food for the next meals should be practiced to avoid disposal of food waste. In addition, leftover food can be distributed to others or given to farmers who collect food waste for animal feed.

Food waste collection for animal feed is already practiced by farmers and restaurants. Local governments may promote this practice by contributing policy support such as giving a certificate to restaurants and farmers practicing reuse of waste for animal feed.

Introduction of a waste collection fee based on the volume of waste discards could help minimise waste. However, a side effect is that open dumping may be increased because residents do not want to, or cannot pay a waste collection fee.

(3) Recycle

Recycling is a process to recover valuable materials which require processing. There are many technologies for organic waste utilization applied in this region. Some technologies that would be applicable in Lao PDR are described in the next Section.

IV.
Appropriate technologies for organic waste utilization (recycling) in Lao PDR

IV.
Appropriate technologies for organic waste utilization (recycle) in Lao PDR

Biodegradable waste, which accounted for approximately 50-80% at final disposal sites in Lao PDR, could be reduced by separation of this waste and delivering to a waste utilization facility. The practice of food waste collection for animal feed already exists. Therefore, this section will describe other alternative technologies for recycling of urban organic waste.

Regarding the economic conditions and capacity of local governments, both in terms of personnel and budget, simple and cheap technology would be more appropriate than advanced technology. In addition, a small scale facility is more appropriate than a large scale facility, as it requires less investment.

Some technologies that are applied in neighboring countries, such as composting, anaerobic digestion, and fuel briquettes would be applicable in Lao PDR. Some details of each technology are described as follows:

4.1 Composting

Composting is a process to enhance degradation of organic matter under aerobic conditions. The final product is compost, which is applicable for soil amendment. Composting techniques range from simple windrow composting to a complicated in-vessel system that requires advanced machinery and automatic control. Unfortunately, there was no functioning composting facility in Lao PDR when this study was conducted.

The windrow composting technique does not require a high capital investment, and would be appropriate. This method can be applicable from a very small scale at the household level with less than 1 kg waste input per day, to a large scale at the municipality or sub-regional level. It is recommended that Lao PDR start with household composting and small scale centralized composting facilities. Lessons learned on urban composting in Cambodia and Thailand would be useful for decision making, implementation, and operation of composting projects.

4.1.1 Household composting

Figure 4.1 is example of household composting in Phitsanulok, Thailand. The system is very simple and does not require much space for operation. Residents need to adjust the wet and dry ratio of waste composition in the composting bin. All yard and gardening waste can be mixed with kitchen waste. Liquid should be drained before mixing in the composting bin. For this composting scale, residents do not need to worry about the quality of output, as it is very small scale and if the composting pile is smelly, more volume of garden waste should be put into the composting pile. The mature compost is fine and looks like black soil. Residents can use compost for gardening or use it as a starter to shorten composting time of next batches.

Figure 4.1 Common household composting in Thailand

The cost for the simple composting technique is very low as it uses only healthy soil as an external input. A disadvantage of this technique is the time requirement, which is approximately 3-4 months. Residents can shorten the time of composting by adding selective beneficial microorganisms such as EM (effective microorganisms), matured compost, and so on. In addition, finely chopping of waste enhances the rapid degradation of the waste. Thus, the time requirement for composting is shortened.

How to do composting

A simple composting process is described below:

- Composition
  (1) Food waste from kitchen that is already drained of liquid
  (2) Vegetables, grasses, fruits, and tree leaves
  (3) Soil (good quality soil is more appropriate, as it has more microorganisms and earthworms)

❖ Composting procedure

(1) Find a place for composting. It should be dry and isolated from the home.
(2) Find an unused bamboo basket, wooden box, or concrete ring for use as the composting container. However, it is also possible to not have any container.
(3) Put in soil as the first layer. Then follow this by grass, leaf, vegetable, and fruit waste. Liquid should be drained, before mixing in the composting pile.
(4) Cover the last layer by soil or leaves to prevent houseflies and vectors.
(5) Add biodegradable waste (at any day and any time) until the container is full.
(6) If the composting generates foul odor, add soil or plant residues to adjust the moisture content of the pile.
(7) When the container is full, turnover the pile once a week to enhance circulation.
(8) When the organic waste is completely degraded (3 to 4 months), the compost can be used for flower, vegetable, or tree growing.
(9) Residents can use the compost as a starter for the next batch of composting, as there are some beneficial microorganisms in compost.

Figure 4.2 is an example of a rapid composting method called Takakura home composting (THM). This composting technique is suitable at the individual household level in urban areas. It is well adopted in Japan, and then replicated in many cities in developing Asian countries. THM takes one to two weeks for fermentation and another two weeks for maturity. Basically, this technique uses locally available effective microorganisms to enhance fermentation, as so called “seed compost”. The equipment required includes a breathable container, a cardboard or porous material for inner lining of the container, a shredder, and a cover sheet.

Figure 4.2 Takakura home composting in Bangkok, Thailand (Photo: Toshizo Maeda)

4.1.2 Small scale centralized composting

Figure 4.3 is an example of small scale centralized composting in Cambodia. This composting can manage from 1 tonne per day of organic waste to many tonnes per day. A simple composting technique is also applicable for this type of composting. The operator needs to turnover waste regularly (once a week) to avoid anaerobic conditions of the composting. However, there is no need for turnover if a static aeration system is installed, such as the composting facility in Muangklang Municipality of Thailand (Figure 4.4)

Figure 4.3 Small scale centralized composting (windrow) in Cambodia

Figure 4.4 A static aerated composting system in Muangklang Municipality Thailand

The most important elements of municipal composting are supplying of quality organic waste input that has minimal non-degradable contamination, and finding users of compost. Securing quality organic waste input is a critical issue when large scale composting is implemented. Therefore, the implementer should start from a small scale facility and plan for scaling up once the system is well established.

Finding users is a critical issue for composting in many developing Asian countries. Many projects are successful in making compost, but later on are terminated as the facilities could not secure sufficient income for operation. Subsidies from the government, at least as much as the cost for waste disposal, should be allocated.

In addition, rejects from composting facilities should be treated properly. Sellable items could be separated for sale and non-valuable items should be transported to a final disposal site.

4.2 Anaerobic digestion

Anaerobic digestion is a process of biodegradation under free oxygen conditions. This process generates gas that contains approximately 50% methane. Methane can be recovered and used as an alternative energy source for cooking, electricity generation, and operation of machines. In general, methane that occurs under anaerobic conditions of landfill is released to the atmosphere and contributes to global warming. Once this gas is released to the atmosphere, its global warming potential is 21 times[1] higher than carbon dioxide.

The anaerobic condition under a landfill system is similar to anaerobic digestion because both systems lack oxygen. However, the landfill site in Lao PDR is too small and shallow. Therefore, the quantity of methane gas in the landfills is not sufficient to be captured and utilized on an economically viable scale.

Therefore, separation of organic waste and processing in an anaerobic digestion tank is a good approach to decrease waste to landfill, to avoid methane emissions to the atmosphere, recover methane for energy use, and to recover nutrients for soil amendment.

Anaerobic digestion for urban organic waste would be applicable in Lao PDR as the National Government launched the Lao Biogas Pilot Project (LBPP) in 2007 (Figure 4.5). The project was approved by the Ministry of Agriculture and Forest which was implemented by the Department of Livestock and Fishery. This project was funded by the Netherland Development Organization (SNV) for 4 years (2007-2010). Currently, more than a thousand biodigesters for manure are implemented in Vientiane, Savannakhet, and Xiengkhuang (Table 4.1). The objective of this project is to improve the livelihoods and quality of life of rural families and reduce the impact of biomass resource depletion.

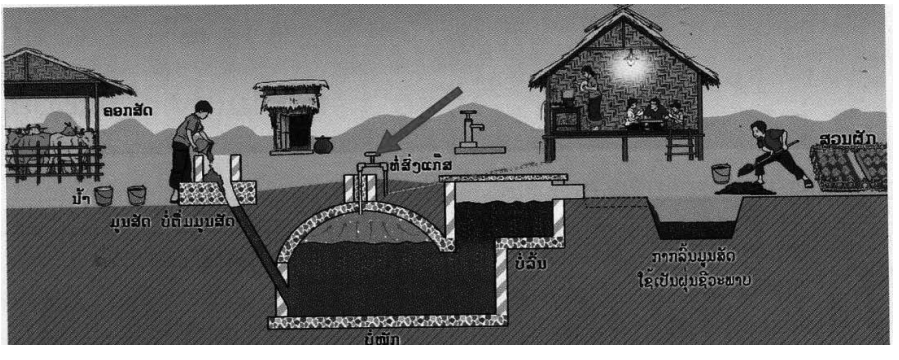

Figure 4.5 Family biogas system (Photo by LBPP)

[1] This value is officially used for national greenhouse gas inventory. There is a reference that methane has 25 times higher global warming potential than carbon dioxide (Foster et al, 2007)

Table 4.1 Numbers of biodigesters implemented in Lao PDR during 2007-2009

Province	2007	2008	2009	Total
Vientiane	110	81	162	353
Savannakhet	0	57	359	416
Xiengkuang	0	50	210	260
Total	110	188	731	1,029

Even though, this project is implemented in rural areas, in-country experts are available. Therefore, there is a high potential to test and modify digestion systems that are effective for urban organic waste.

Based on the Lao's experience on the National Biogas Project (NBP), the advantages of anaerobic digestion are summarised as follows (Figures 4.6 and 4.7):

- Providing alternative energy for heating, cooking, lighting, and running machines
- Improving sanitary conditions of the community
- Recovering organic matters for soil amendment
- Avoiding deforestation for firewood
- Saving time for firewood searching for women and children
- Minimising health risk due to smoke
- Improving family economic conditions as the biogas project can contribute to reducing the use of chemical fertilizer, increasing crop productivity, and securing energy sources
- Contributing to national energy security agenda and decreasing dependency on the importing of energy
- Contributing to the greenhouse gas mitigation target of the country

Figure 4.6 Lao family before and after using biogas (Photo by LBPP)

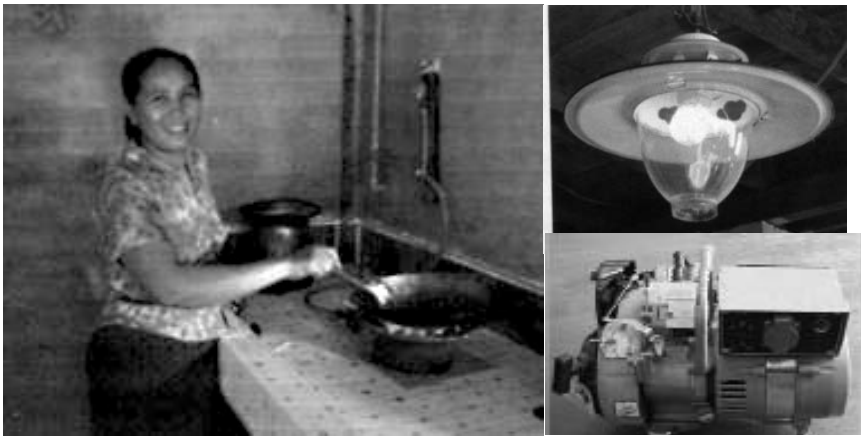

Figure 4.7 Utilization of biogas for cooking, lighting and engine operation in Lao PDR (Photo by LBPP)

The cost for implementation of anaerobic digestion system is higher than composting. As shown in Table 4.2, the LBPP provided a fixed cost of 1,860,000 Lao KIP (232.5 US$) which is sufficient for purchasing equipment and experts, and the participants must cover the remaining cost for construction. The construction cost varies, depending on the size of the digester.

Table 4.2 Cost of anaerobic digesters that are implemented by LBPP

Digester size	4 m^3	6 m^3	8 m^3	10 m^3
Total cost (Lao KIP)	3,651,000	4,232,000	4,894,000	5,584,000
Household cost (Lao KIP)	1,791,000	2,372,000	3,034,400	3,724,000
Project subsidy (LK)	1,860,000	1,860,000	1,860,000	1,860,000

(Note 8,000 Lao KIP = 1 US$)

How to build a biodigester

The LBPP modified the biodigester and made it suitable for Lao PDR. The model is a hybrid of German, Chinese, Indian, and Nepalese designs (Figure 4.8). A small biogas system comprises 6 important components as follows:

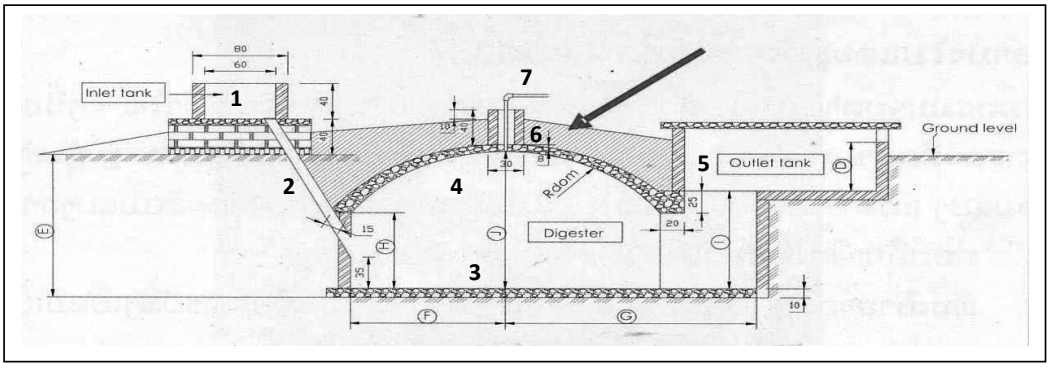

Figure 4.8 The LBPP biogas digester model (Photo by LBPP)

(1) Inlet tank

Inlet tank is made of concrete and used for putting animal dung and other organic materials, into the digester (Figure 4.9). At a farm, this tank can be connected to an animal house for collecting the animal waste into the digester. It would also be possible to connect with a toilet. For this case, a pilot test may be required.

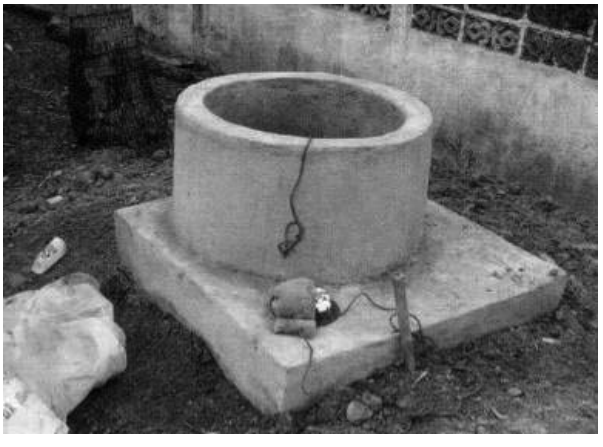

Figure 4.9 Inlet tank (Photo by LBPP)

(2) Inlet pipe

The inlet pipe is made of PVC with a diameter of 100 mm. This pipe connects the inlet tank and the digester (Figure 4.10)

Figure 4.10 Inlet pipe (Photo by LBPP)

(3) Digester

The digester is the tank where animal dung and organic matter decay under anaerobic conditions and produce biogas (Figure 4.11). It is made of brick masonry that is coated with cement. In rural areas where bricks are not available, natural stone can be used, but it requires skillful workers to make the wall smooth.

Figure 4.11 Digester (Photo by LBPP)

(4) Gas storage tank

A dome shaped digester is used for collecting the gas (Figure 4.12). This tank is made of bricks and coated with cement.

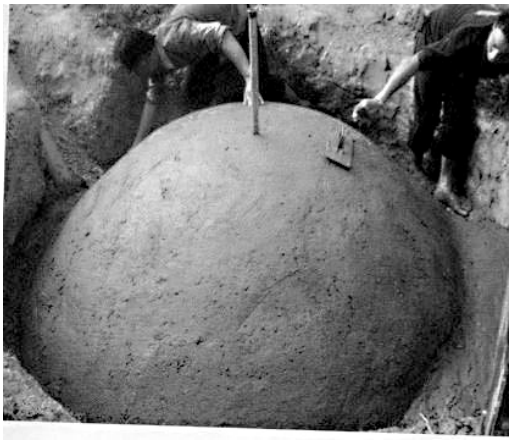

Figure 4.12 Gas storage tank (Photo by LBPP)

(5) Outlet tank

Outlet tank is used for storing the digested animal dung and other matter (slurry) that overflow from the digester (Figure 4.13). The slurry contains nutrients and organic matter that are useful for cultivation.

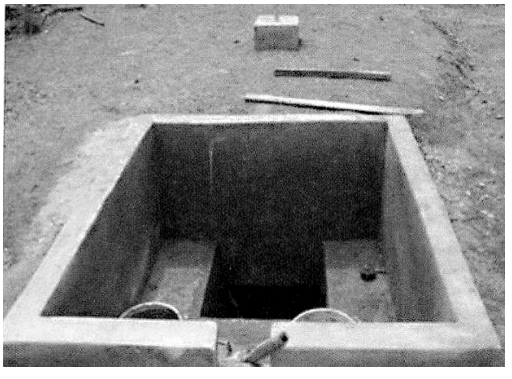

Figure 4.13 Outlet tank (Photo by LBPP)

(6) Gas piping system

The gas piping system consists of PVC pipe and valves that are used for delivering biogas to a kitchen or house. PVC pipe is available in local market (Figure 4.14). In the system, a filter and a pressure gauge should be installed to purify the gas, and check the pressure of gas inside the digester.

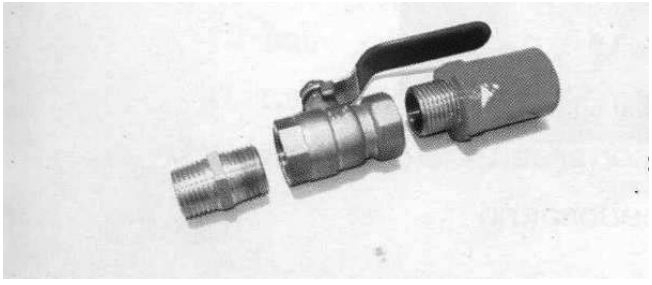

Figure 4.14 Gas piping system (Photo by LBPP)

After completing the construction, cow dung must be added into the digester as a starter. The quantity of cow dung for each size of digester is shown in Table 4.3. Farmers must dilute the cow dung with water with a ratio of 1:1 (Figure 4.15). After settlement of the starter, farmers can dispose of cow dung in the digester every day, according to the suggested quantity for each size as shown in Table 4.3.

Table 4.3 Dailly filling of animal dung and biogas production

Digester size (m^3)	Amount of animal dung as the starter in the first day (kg)	Amount of animal dung for daily input (kg)	Water for dilution (L)
4	1,800	20-40	20-40
6	2,300	40-60	40-60
8	3,000	60-80	60-80
10	3,800	80-100	80-100

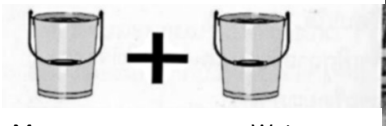

Figure 4.15 Daily filling with animal dung (photo by LBPP)

Estimation of biogas generation from different sizes of digesters is shown in Table 4.4. When compared to other types of fuels, 1 m^3 of biogas is equal to 5 kg of fire wood, 1.6 kg of charcoal, and 1.6 KWh of electricity (Table 4.5). Therefore, it is estimated that a digester of 2 m^3 can generate biogas that is available for 3.5-4 hours of cooking or 8-10 hours of lamp use (Table 3.4). If a family needs more energy, they can scale up to a larger size of digester; however, they need to secure enough animal dung for input.

Table 4.4 Biogas production

Digester size (m^3)	Size of family (person)	Daily gas production (m^3)	Availability of gas for stove use (hr)	Availability of gas for lamp use (hr)
2	2-5	0.8-1.6	3.5-4	8-10
4	5-7	1.6-2.4	5.5-6	12-15
6	7-10	2.4-3.2	7.5-8	16-20
8	10-12	3.2-4.0	9.5-10	21-25

Source: LBPP project report

Table 4.5 Comparison of biogas energy and other fuel source

Type of fuel	Unit	amount
Firewood	Kg	5
Charcoal	Kg	1.6
Gasoline	Litre	0.75
LPG Gas	Kg	0.45
Electricity	KWh	1.6
Biogas	m^3	1

Source: LBPP Project report

Even though this project was implemented with animal dung, the technology can be modified and used for anaerobic digestion of food waste in Lao PDR. To confirm this availability, the National University of Laos conducted a pilot test of anaerobic digestion of food waste as follows:

Pilot design of household scale anaerobic digestion tank

Two different sizes of household scale anaerobic digesion tanks were developed as shown in Figure 4.16. The sizes of the tank was 0.168 m^3 (168 Litres; made of plastic) and 0.260 m^3 (260 Litres; made of used metal tank). This model is very simple and is composed of a main plastic tank for digestion, a waste inlet which made of plastic pipe, and a pipe to deliver gas from the tank to a cooking stove.

Figure 4.16 Biogas digester for family use

For establishment of the digestion environment, 30 kilograms of animal manure was mixed with 20 litres of water (3:2). On a daily basis, 8 kilograms of food waste (e.g. food, vegetables, fruits) from household are chopped and mixed with 0.4 litre of water and fed into the digester. The quantities of starter and daily waste input for different sizes of digesters are shown in Table 4.6.

The result showed that 8 kilograms of food waste can generate 0.15 m^3 of biogas and 12 kg of food waste can generate 0.20 m^3. This experiment showed that the biogas generation rate from food waste is lower than the rate from animal manure, by more than 50%. Further experiments are required to find a suitable scale, dilution ratio, and retention time of a biogas tank, that effective for food waste in Lao PDR.

Table 4.6 Gas generation from food waste (including vegetables and fruits)

Digester size (m^3)	Animal dung for starter (kg)	Daily food waste input (kg/day)	Water for dilution (L/day)	Gas generated (m^3/day)
0.168	30	8	0.4	0.15
0.260	50	12	1	0.2

4.3 Fuel briquette

A fuel briquette is a block of flammable material that is used for starting and maintaining a fire. It can be used as an alternative to firewood, charcoal, and kerosene. The briquette is produced from the high calorific value organic and plant residues. Table 4.7 presents calorific value of organic and non-organic waste. Amongst organic waste, wood and paper have high calorific value, but lower than plastic and rubber. However, waste that has fossil origin, such as plastic, should not be used for fuel briquettes due to health concerns and non-biogenic carbon dioxide emissions.

Table 4.7 Typical heat values of municipal solid waste composition

Component	Heat value (kj/kg)
Organic	
Wood	18,608
Paper	16,747
Garden waste	6,513
Food	4,472
Non-organic	
Plastic	32,564
Rubber	23,260
Leather	17,445
Metal	698
Glass	140
Dirt, ash	7.0

Source: Modified from Solid waste Engineering (Vesilind et al., 2002)

There is a possibility to produce fuel briquettes in Lao PDR. As shown in Table 2.7, urban waste in Vientiane Capital, Savannakhet and Champasak is comprised of 25% wood and paper, and that of 31% in Luangprabang.

Under this project, the National University of Lao conducted an experiment to develop a simple fuel briquette press (Figure 4.17). An individual household can make this equipment by themselves. Figure 4.18 shows examples of briquette made from paper, charcoal waste, and saw dust. In addition, any type of organic waste such as leaves, vegetables, grass, and rice straw can be used for briquette making. Agricultural waste which has high calorific value can be mixed with urban waste for fuel briquette making. Table 4.8 presents heating values of some agricultural waste in Lao PDR.

Figure 4.17 Simple briquette press made of wood

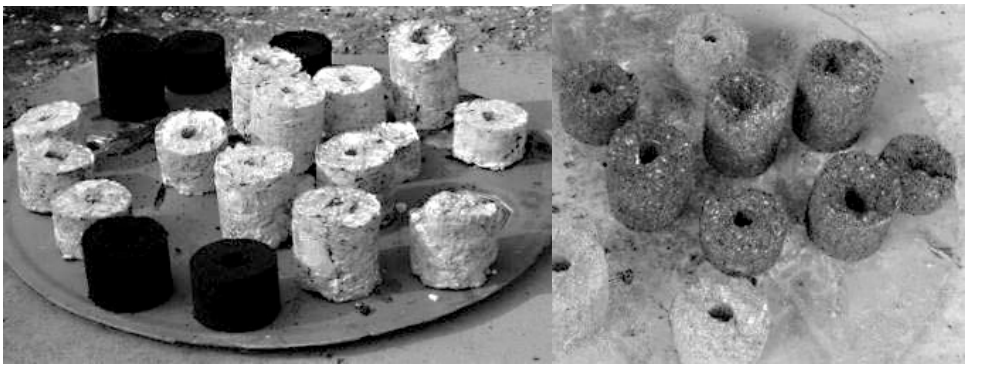

Figure 4.18 Fuel briquettes made of different waste material (paper, charcoal waste, saw dust)

Table 4.8 Heating value of some types of agriculture waste in Lao PDR

Type of waste	Heat value (Kj/kg)	Quantity (ton/year)			
		Vientiane Capital	Luangprabang	Savanhakhet	Champasak
Rice husk	14,270	64,041	18,140	126,204	66,885
Rice straw	15,200	213,966	60,604	421,657	223,466
Sugarcane	17,800	14,018	none	3,184	473
Corncob	18,040	1,250	7,432	2,380	1,008
Sawdust	18,000	none	1347	13,610	1813

Source: Agriculture statistic 2006 and analysed by authors

A simple process for briquette making is described as follows:

1) Sort burnable waste such as plant residues and paper
2) For green residues, it should be dried for a few days before using for briquette making materials
3) Grind selected materials into a small size
4) Mix materials together and soak in water until it is soft enough for pressing into briquettes
5) Put materials into a mold and press to form the briquette shape, and dehydrate (Figure 4.19)
6) De-mold and dry the briquettes for few days

Figure 4.19 Fuel briquette making by using a manual press

The advantages of fuel briquettes are: using burnable organic waste for replacing use of firewoods, saving landfill space, easy making by residents, having market potential, saving cost for fire wood or charcoal[2], and to some extend keeping good sanitation of the street and public spaces.

The disadvantages of fuel briquettes are: fluctuation of heating value when the briquette is made of material that does not mix well; sometimes it may produce more smoke and gases than charcoal.

[2] Some urban residents in Lao PDR use charcoal for cooking.

V.
Conclusion

V. Conclusion

Solid waste management is a serious environmental problem in Lao PDR. However, local residents are not well informed and trained to dispose of the waste in an environmentally sound manner. As a result, approximately, 42-70% of waste is being collected and disposed in designated open dumping sites. The rest is being self-disposed by means of dumping or burning. Therefore, awareness raising should be prioritized.

Local governments do not have sufficient budget and personnel to improve the collection service and disposal treatment. Therefore, the 3Rs (reduce, reuse, recycle) should be promoted to reduce the workload of local governments on waste collection and disposal. Separation of recyclables (13-28% of municipal solid waste) and organics (49-83% of municipal solid waste) can significantly reduce the workload of local governments on waste collection and disposal.

In order to ensure efficiency of organic waste utilization, separation of either recyclables or organic waste should be practiced at a generation point source. Otherwise, a front-end separation system could be applied to increase the quantity of waste for recovery, and minimize waste to disposal site.

Food waste collection for animal feed that is being practiced by farmers should be credited and promoted by local governments, as it can significantly reduce the workload of local governments and enhance reuse of resources in a sustainable manner. However, this practice is limited to high quality food waste due to a concern over animal health.

As Lao PDR is an agricultural based country, windrow composting, that is very simple and low cost, should be promoted to implement at the household, community, and city scale to minimize waste to a final disposal site. Even though Lao PDR does not have in-country experience, lessons learned from Thailand and Cambodia would be useful to ensure successful implementation.

Anaerobic digestion for manure is widely adopted through the national biogas program. However, anaerobic digestion techniques, that are suitable for urban food waste in Lao PDR, should be further investigated.

As firewood and charcoal is widely used for cooking, fuel briquettes would be a good alternative to utilize paper, garden, and dried organic residues. In addition, the equipment for briquette making is very simple and cheap, enabling residents to make them.

In addition, involvement of private sectors on waste collection and utilization of waste and promotion of community based waste management, in collaboration with academia and schools would help to overcome the budget and personnel constraints.

References

CIA [Central Intelligence Agency] (2012) The World Factbook: Laos. Available online at https://www.cia.gov/library/publications/the-world-factbook/geos/la.html (accessed on 13 June 2012)

Foster, P., Ramaswamy, V., Artaxo, P., Berntsen, T., Betts, R., Fahey, D.W., Haywood, J., Lean, J., Lowe, D.C., Myhre, G., Nganga, J., Prinn, R., Raga, G, M, S. and Van Dorland, R. (2007). Changes in Atmospheric Constituents and in Radiative Forcing. In: S. Solomon et al. (Editors), Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge, U.K. P.129-234. Available online at http://www.ipcc.ch/pdf/assessment-report/ar4/wg1/ar4-wg1-chapter2.pdf (accessed on 30 May 2012)

SEA [Sanitation and Environment Agency] (2000) TA No 333 LAO Interim Report 11/2000

Tchobanoglous, G., Theisen, H., and Vigil, S.A. (1993) Integrated solid waste management: engineering principles and management issues, McGraw Hill International editions, Civil Engineering series. McGraw Hill Inc, Singapore, pp 977.

UNDP (2002) Terminal Evaluation: *MCTP/UNDP/NORAD Lao/96/006. Solid waste management in secondary urban centered of Laos. 92P.*

Vesilind, P. A., Worrel, W. and Reinhart, D. 2002. Solid waste engineering. Brooks/Cole, Pacific Grove, CA, USA. pp 427.

National University of Laos
Faculty of Engineering
Lao-Thai Friendship Road, Sisatanak District, P.O. Box 3166 Vientiane Capital City, Lao PDR
Tel: +856-21-770070 Fax: +856-21-314382
URL: http://www.nuol.edu.la

Institute for Global Environmental Strategies (IGES)
2108-11 Kamiyamaguchi, Hayama, Kanagawa, 240-0115, Japan
Tel: +81-46-855-3720 Fax: +81-46-855-3709
E-mail: iges@iges.or.jp URL: http://www.iges.or.jp