Municipal Solid Waste Composting: Potentials and Constraints

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FOREWORD

Small scale farmers and large scale agriculturists have come to realize the dangers inherent in the continual use of chemicals to enrich the soil. In the USA, certain large tracts of lands are reduced to desserts due to the misuse of agro chemicals in different forms. As a small country, we have the potential and we must shift from chemical to organic, a move which will benefit us mostly in economic terms and in improving the fertility of soil as well. Therefore, this research conducted by the EWRM division of the Institute is timely.

In certain parts of the country where large scale paddy cultivation is practised, hay is already used as manure. In urban areas the waste that is just dumped could systematically be treated to make rich organic manure.

What is opportune is to realize its urgency and act promptly. I very much appreciate the efforts made by the research team to study the current status of municipal solid waste composting. I strongly believe the findings and recommendations of the study will be helpful for policy makers in improving the usefulness of the ongoing projects as well as in designing effective programs in this field in future.

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Director

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ABSTRACT

Use of compost produced from Municipal Solid Wastes (MSW) in agriculture is gaining popularity in many parts of the world with the current trend towards organic agriculture. Many research studies have been conducted on impacts of soil application of MSW compost as a soil conditioner as well as a fertilizer. By now many local authorities in Sri Lanka are involved in producing compost from the organic fraction of MSW. Government is keen on expanding these projects and has invested a considerable amount of resources. If the country can produce agriculture grade compost from MSW, it will save the huge foreign expenditure that has to be spent on importing chemical fertilizer and it will be more beneficial towards the environmental stability. Considering many such factors, the Government of Sri Lanka in their new development policy "Mahinda Chinthana" is aiming to reduce imports of chemical fertilizer up to 15percent by 2015. Though it was expected to promote the use of compost in agriculture to compensate the reduced amount of chemical fertilizer, limited availability and difficulties in producing compost at farm level have been identified as major constraints for using compost in agriculture. Compost produced from MSW is important as an alternative to address the issue of limited production of compost.

The main objective of this study was to study the potentials of producing compost at the level of local authorities using municipal solid wastes and to examine constraints experienced by them in the production and marketing process. Experiences of other countries were studied by reviewing the literature. Five composting plants which are operating at different capacities in different parts of the country were studied during the fourth quarter of 2012. It was found that local authorities have the potential of producing the local requirement of compost though there is much more room for quality improvement. Government through various policies and programmes is trying to extend composting projects into other areas of the country. Financial analysis has proved positive results for the investment. Benefit Cost Ration is 1.44 and Economic Internal Rate of Return is 5% for municipal solid waste composting.

However, lack of quality standards for municipal solid waste composting, inadequate partnership between managers of the composting plants and the agricultural experts to improve quality for agricultural use were found to be major constraints for the successful function of this process. It is recommended that a suitable institutional arrangement to monitor the quality of MSW compost regularly to market the product with a government certification to create an assurance among the users regarding the quality of the product be formulated and implemented.

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CHAPTER ONE

Introduction

1.1 Overview

Present-day agriculture largely depends on the use of many agro chemicals such as chemical fertilizer, pesticides, and weedicides. According to the Central Bank of Sri Lanka the government expenditure of importing chemical fertilizer in the year 2011 was US $ 44,959 million (Central Bank of Sri Lanka, 2012). Part of these chemicals, mainly urea, seeps out of farmlands and pollutes natural water bodies creating short term and long term environmental and health issues for present and future generations. According to United States Environmental Protection Agency (2005), agricultural runoff is considered one of the major sources of non point source water pollution.

Chronic kidney disease of unknown etiology (CKDu) reported among large numbers mainly in farming areas of the country is a serious health issue that has caused death to many. It is believed CKDu has a link with unsystematic use of agro chemicals. Millions of public funds are spent on providing medicine and health services to the victims of the disease, causing it an extra burden to the economy of the country. Non-availability of an economically viable corrective method to address this type of water contamination aggravates the seriousness of the issue and further highlights the importance of moving towards more environment friendly crop production systems for the betterment of living beings.

Considering all these aspects the government of Sri Lanka in accordance with its new development policy *Mahinda Chinthana* aims at reducing import of chemical fertilizer up to 15 percent by 2015. To achieve this target the government has initiated many projects allocating a considerable amount of money to popularize organic farming to compensate the reduced amount of chemical fertilizer. Adding compost to soils is essential to improve soil structure and texture as it plays a key role in carbon storage and strongly influences nutrient retention and availability (Hamarashid *et.al*, 2010). According to a survey on MSW compost, organic C content from the total C in the composted MSW is 20% on average (He *et.al*, 1995). Soils of Sri Lanka are reported to have a deficiency in Carbon element (C) and compost is an excellent supplement to correct carbon deficiency. To encourage the use of compost in agriculture, training programmes have been conducted covering all parts of the country for farmers on compost production as well as on many values of using compost in farming.

Compost could be used in all types of crop cultivation including home gardening, paddy cultivation and in plantation crops such as coconut, tea and rubber cultivations. The export agricultural sector is another area of crop cultivation where there is a need for applying compost in addition to chemical fertilizer. According to the census of agriculture (Department of Census and Statistics, 2002), of the total agricultural land area which is 1,859,494 ha, the extent under cultivation is about 1,559,487 ha (Table 1.1). Therefore, there is a considerable potential for marketing compost if ongoing organic farming promotional programmes are successful.

Table 1.1: Land Use Pattern in Agricultural Holdings 2002

Type	Area (Ha)	%
Total Agricultural Land Area	1,859,494	100
Permanent Crops	914,983	49
Asweddumized Paddy	497,052	27
Temporary Crops	147,452	8
Forest Land	130,360	7
Lands under Roads, Buildings, etc.	78,266	4
Lands not classified elsewhere	61,470	3
Lands not Suitable for Cultivation	29,910	2

Source: Department of Census and Statistics, 2002

However large scale production of compost using traditional methods is generally limited to government agricultural farms and training centers. Domestic level compost production also takes place and it usually fulfills part of the requirement of their homegardens. To meet the country's compost requirement there is a need for more large scale compost production facilities since limited availability and difficulties in producing compost at household level has been reported a major constraint of using compost in agriculture (Hitihamu *et.al*, 2009). Composting projects that are being in operation at local authority level have the potential to meet the requirement of compost if the prevailing quality issues be addressed properly.

Potential benefits of MSW composting go much beyond its use as a fertilizer as it is considered a more preferred route of solid waste disposal as compared to other traditional waste disposal techniques. The traditional method of waste disposal adopts collecting and disposing of wastes at open dumping sites and this has resulted in many short term and long term adverse effects to human health and environmental sustainability.

According to the national solid waste management policy of Sri Lanka, solid wastes is expected to be managed in accordance with the 3R principles (Reduce, Reuse, Recycle) with special emphasis to minimize waste generation. To implement the policy into action, the national solid waste management programme, *Pilisaru* has been planned. The Central Environment Authority of the Ministry of Environment through its *Pilisaru* project evaluates the proposals submitted by local authorities for compost production; provides financial and technical assistance for implementation and utilizing the expert knowledge of members of the technical committee established under the National Committee on SWM (Fernando, undated).

By the end of 2011, there were about 100 composting plants operating in different local government areas. Most of these plants were small in operational capacity and about 80% of them had capacity of handling less than 10 tons of organic waste per day. An overview of composting plants operated by local governments is given in Table 1.1.

Table 1.2: Operational Composting Plants in Local Government Areas of Sri Lanka, 2011

Local Government Unit	Total No. of Plants	Plant Size		Technique Used		
		Small	Medium	Windrow	Semi aerobic trench	Others
Municipal Councils	16	12	4	15	-	1
Urban Councils	16	11	5	15	-	1
Pradesheeya Sabhas	68	58	10	63	2	3
Total	100	81	19	93	1	5

Note: Medium: less than 50tons per day and more than 10 tons per day
Small: less than 10 tons per day

Source: National Solid Waste Management Support Centre, 2011

Successful continuation of composting projects would derive multiple benefits such as providing compost for cultivation, a healthier and greener environment, saving of government funds due to extended life span of dumping sites, a reduction in the import of synthetic fertilizer and saving funds spent on health services.

However, there are reports indicating that many of these composting projects had experienced various problems such as social protests over odour and leachate, limited marketing avenues due to concerns over adverse effects to man and the environment, that affect their proper functioning and sometimes leading to abandoning of the project permanently or temporarily. In the Western Province only 1 per cent of the waste collected by the local authorities is composted (Jayaratne and Premakumara, unpublished). Besides, only limited investigation has been done regarding the sustainability of projects that produce compost from MSW at local authority level and the potential of the use of MSW compost in agriculture.

1.2 Objectives of the Study

The overall objective of the present study is to investigate the factors affecting the successful functioning of MSW composting projects.

Specific Objectives

1. To investigate the potentials and constraints of producing and utilizing compost produced from municipal solid wastes
2. To study the existing marketing arrangement and to make suggestions for market expansion for compost produced from MSW
3. To find out the costs and benefits of converting MSW into compost

1.3 Methodology Adopted

Methods of Data Collection

Data and information was collected by reviewing both published and unpublished literature and by conducting key informant discussions, using a semi structured questionnaire with managers, employees of the composting plant and the users of MSW compost.

Study Locations

Five composting plants operating in different capacities in different parts of the country were studied during the fourth quarter of 2012. This included the composting plants managed by Balangoda and Weligama Urban Councils, Kaduwela Municipal Council, Bandaragama Pradesheeya Sabha and the Kalutara composting plant.

Of the five composting plants selected, four are being managed by the respective local authority and the Kalutara composting plant is being managed by the Waste Management Authority, Western Province.

Type of Data and Information

Information collected from the study included views of the project management, residents of the area and staff employed in the composting plants regarding site selection, technology and process adopted and issues experienced in different stages of composting and marketing the final product. In addition, information was also collected regarding beneficial and harmful effects of the project as well as on suggestions and feedback of stakeholders regarding the MSW composting projects. Secondary data was collected to analyze the costs and benefits of converting MSW into compost.

CHAPTER TWO

Municipal Solid Waste Compost

2.1 Characteristics of Municipal Solid Waste in Sri Lanka

According to the description of the term, MSW, it is the non liquid waste material generated by public and private sectors through households, commercial establishments, agricultural activities, industries and institutions (Farrell and Jones, 2009; Ministry of Environment and Natural Resources, 2002). In addition, waste that is produced in public places and owned and managed by local authorities is also considered in this category. Description of waste generated in each sector is given in Table 2.1.

Table 2.1: Sources and Types of Municipal Solid Waste in Sri Lanka

Source	Description
Household	Waste generated from domestic activities, including food preparation, cleaning, fuel burning, yard sweeping, gardening, and miscellaneous household waste (e.g. old cloths, appliances etc)
Commercial	Waste generated by trade, service, processing, and some production enterprises
Markets	Waste from markets selling a high proportion of vegetables, fruits, meat and/ or fish
Institutions	Waste from schools, other education centres, hospitals, central and provincial government offices and religious institutions
Industries	Waste from various industries, including light and heavy manufacturing, fabrication, construction sites, power and chemical plants.
Construction and demolition	Waste originating from construction, rehabilitation and demolition activities etc. Typically they are used as clean fill at other sites or in low-lying areas.
Hazardous	Hazardous waste originating from various sources, including household items (batteries, spray cans etc). The management of sharps, clinical waste, body parts and highly infectious waste from hospitals is a major concern in the country.

Source: Adopted from Abeysuriya, 2007; NSWMSC, 2008

According to (Bandara, undated) composition of MSW of Sri Lanka typically includes very high fraction of perishable organic material which is about 65 – 66% by weight with moderate amounts of plastics and paper and relatively low contents of metal and glass. Composition of MSW generated in some selected cities of Sri Lanka is given in Table 2.2. Long term bio degradable items that takes about 2-3 months for degradation and short term biodegradable items that degrades within 2 months period are categorized under organic wastes.

Table 2.2: Municipal Waste Composition in Selected Cities in Sri Lanka

MSW Compositions (%) of Selected Cities in Sri Lanka (2002)							
Cities	**Biodegradable (Short Term)**	**Biodegradable (Long Term)**	**Plastics**	**Metal**	**Wood**	**Glass**	**Paper**
Batticaloa	46.79	10.61	8.26	2.90	17.12	2.20	16.45
Colombo	68.15	11.63	6.69	1.85	5.02	1.64	5.99
Galle	41.76	20.25	8.23	4.79	11.18	4.33	9.41
Jaffna	54.85	8.62	7.21	8.49	5.58	2.21	12.80
Kandy	54.83	17.95	4.02	4.46	6.36	5.35	11.08
Matara	56.81	18.60	6.90	3.07	5.78	2.07	8.50
Nuwara Eliya	60.53	9.73	8.46	2.12	8.92	2.90	8.72
Polonnaruwa	35.52	25.10	8.47	3.57	7.63	3.68	16.04
Trincomalee	27.98	20.06	4.33	12.51	22.04	1.85	18.04

Source: AIT,2004 (Cited in Bandara, undated)

2.2 Potential Markets for MSW Compost

Garcia *et.al* (2005) have evaluated the potential of decomposed MSW as an animal feedstuff and concluded that after heat treatment of 65°C for 20 minutes the waste material is effectively sanitized and suitable for animal consumption. However, MSW derived compost will not be of much use as animal feed since it almost certainly unable to eradicate Transmissible Spongiform Encephalopathies (TSE) and other zoonotic diseases present in the material. Even this waste material is safe enough to be used in animal feed production it will not be accepted by society (Farrell and Jones,2009).

Therefore, land application is the largest potential use of compost produced from MSW. Soil organic matter (OM) which is identified as rapidly declining in soils, mainly in arid environments of the world is a key soil quality indicator. Many studies have proved that MSW compost has the potential of at least transiently increase soil OM content and soil biological activity (Akram et al, 2009). Additional benefits provided by MSW compost include reduced erosion losses, improved structural stability of soil and decreased bulk density which will increase its water holding capacity, cation exchange capacity (CEC), and infiltration of water and air in heavy soils. (ibid).

Shiralipour *et.al* (1992) have identified agronomic and horticultural sector with a large potential market for MSW derived compost. By now MSW composting is being encouraged in many countries of the world and researchers have experienced the benefits of using MSW compost in the field (Porkhrel, 2005; Abigail, 1998; Barth and Kroeger, 1998). Many studies have shown that by adding reasonable amount MSW compost it could be used as a valuable source of plant nutrients (Table 2.3). The organic matter in compost also acts as a relatively long-term reserve for major nutrients such as nitrogen, phosphorous, and potassium.

Table 2.3: Typical Nutrient Content of MSW and Other Composts

Compost Type	pH	EC	OM	$NO^-_{3(mgkg^{-1})}$	NH^+_4	Total N	C:N ratio	P	K
MSW				71[a]		11	16	2817	3390
MSW				122[a]		14	12	3281	5559
MSW	7.9	7.0	33			14	9	5000	4100
Pruning Waste	8.1	0.2		16	8.27	10	33		
Mature Compost	7.2			2372	510	25	12		

All data in mg kg^{-1} dry mass unless otherwise stated.
EC indicates electrical conductivity and OM indicates organic matter
[a] Total mineral nitrogen,i.e.$NH^+_4 + NO^-_3$
Source: Farrell and Jones,2009

MSW compost is being used by landscapers while planting shrubs and trees to backfill individual planting holes. They use a mixture of 25 to 50 percent of compost and native soil for that purpose. However, composts with higher soluble salt contents should be applied at lower rates. Municipal compost mixtures are commonly used in repairing divots on golf courses. Further, municipal composts can be used to rebuild or repair poor soil in rough areas, parks, and other non specified turf areas and to stabilize slopes. Compost with a larger particle size (1/2 inch) is often combined with soil stabilization mats or netting and later they are over-seeded with native grasses to control erosion, especially along highway right-of-ways (Dickerson, 2010).

MSW derived compost also can be used to remediate brownfield sites, land that has been earlier used for industrial purposes or commercial purposes. One example is landfill capping after closure. However, due to health and safety concerns, using MSW derived compost for restoration schemes with possible public access such as housing schemes should be avoided until further field evaluation trials are completed to evaluate the benefits and environmental risks posed by using MSW compost in comparison to other substrates used for restoring non contaminated land(ibid). Municipal composts can be applied to new landscapes at a rate of up to 50 dry ton/acre (2,296 lb/1000 ft^2). Rates vary depending on the soluble salt content of the compost. After rough grading, the compost should be incorporated into the existing soil to a depth of 6 to 10 inches (Gouin, 1995).

2.3 Current Concerns on MSW Compost

However, certain research studies report mixed results as well as negative impacts of using MSW compost for agriculture and horticulture use. Mamo *et.al* (2005) by studying the growth of maize on a MSW compost added loamy sand soil has come up with increased soil water holding capacity without greatly increasing the estimated plant available water within the soil.

There are concerns regarding overloading of soil by heavy metals and other pollutants by long term use of MSW derived composts (Deportes, 1995). According to a three year field trial conducted in Punjab, Pakistan to evaluate the environmental and economic impacts of MSW compost applications to rice-wheat and cotton-wheat cropping systems, though all treatments with MSW compost have shown significant improvement in soil physical property the trial has not resulted statistically significant increase in OM content for any treatment. For the two types of treatments, MSW compost and fertilizer applications, the levels of DTPA extractable (plant available) heavy metals has increased in the top layer (Qazi *et.al*, 2009).

Logan et.al (1999) has reported occurrences of organic toxins in MSW compost. These are highly chlorinated toxic organic compounds that are known to be persistent in the environment (Muir and Howard, 2006). Feedstock with pesticides, household wastes such as oils and solvents and paper products due to printing ink are said to contribute organic toxins to MSW derived composts (Epstein, 1997).

Due to reaching of partially decomposed MSW compost to farmers, plant roots get damaged due to excess ammonia, organic acids, and other phytotoxic chemicals. The compost must be mature enough before utilizing for agricultural purposes. However, it is still possible to add immature compost to farming fields if added well in advance to planting.

2.4 Experiences of Composting Projects Implemented at Local Authority Level

According to past experiences, composting projects implemented by local authorities have many social benefits such as reducing health problems, improving scenic beauty, reducing environmental pollution, generating job opportunities while producing alternatives for chemical fertilizer (www.environmentlanka.com /sympo, 2010).

However, they have encountered problems related to transportation of waste, lack of space and limited facilities in compost yards, receiving mixed wastes, limited facilities for final disposal and lack of public commitment due to rigid attitudes and lack of knowledge (www.environmentlanka.com/sympo,2010). Odour is one of the major problems in MSW composts and it is due to the release of sulfur compounds such as hydrogen sulfide, methyl mercaptan and methyl sulfide in the early stages of composting. However, with maturity these sulfur compounds decrease (Basnayake, 2001).

The issues faced by the composting project of Kandy city were reported as existing practices; extreme fragmentation of regulations and enforcement; lack of funds, reluctance to impose new taxes or fees, vacillation as to who should conduct the management of solid waste - the government or the private sector; identifying how they can benefit from NGO and Foreign Government aid programs; and deciding if there should be a single unified national solid waste management system (www.bvsde.paho.org/bvsacd/iswa2005/cities). According to Japan International Corporation Agency (JICA), most composting operations have failed due to inadequate attention paid to operation and proper equipment maintenance by the local authorities and embarking on the venture with the misconception that all waste treatment costs can be recovered by the sale of compost.

CHAPTER THREE

Techniques Used in the Composting Process and Quality of Compost

3.1 Composting Process

Composting refers to the controlled decomposition of organic matter by aerobic microorganisms into stable humus like material. The composting process is managed with the aim of accelerating the decomposition, optimizing efficiency and minimizing any potential environmental and health issues that could develop. As illustrated in Figure 3.1, during the composting process, compostable material or feedstock undergoes a series of biological conversion processes while producing carbon dioxide, heat and water as by-products. The usable end product of composting is the compost, which is dark in color, peat like, has a crumby texture and an earthy odor, and resembles organic top soil. A good composting process eliminates most of common weed seeds and organisms that may be pathogenic to humans, animals or plants.

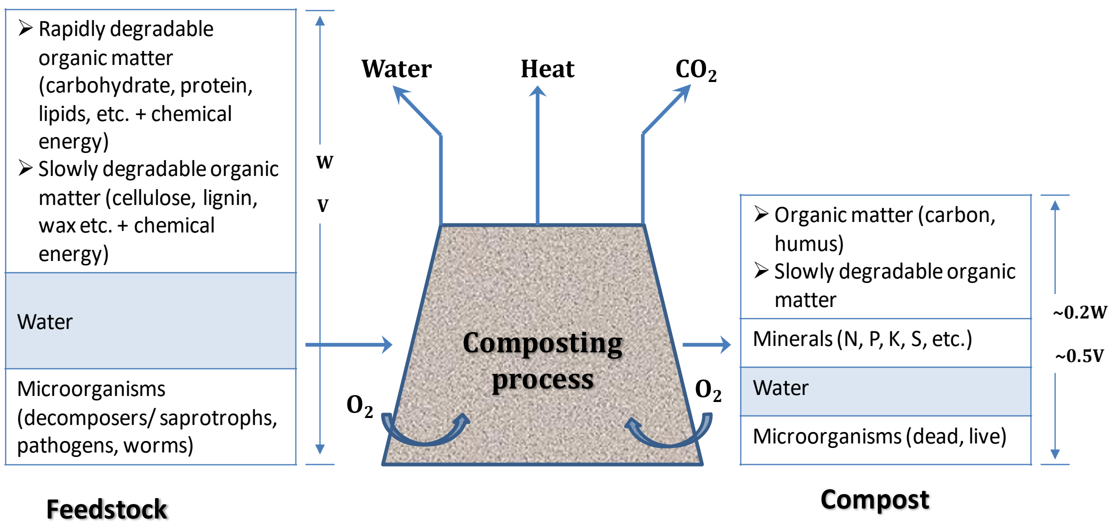


Figure 3.1: The Composting Process

Composting of organic fraction of municipal solid waste (MSW) can significantly reduce waste stream volume and has environmental and economic advantages. Thus, the National Solid Waste Management Policy (2007) has recognized composting of biodegradable materials in municipal waste as a MSW pre-treatment option when the cost of final disposal and other MSW treatment options are high. The policy further highlighted that household composting and backyard composting are forms of source reduction or waste prevention because the materials are completely diverted from the disposal facilities and require no municipal management or transportation. Thus, within a concept of waste recovery, the source separation and on-site composting of organic fraction of MSW can resolve some of the major economic issues faced by local authorities along with the environmental and social issues associated with disposal facilities. However, the performance of home compost makers and the quality of the compost products are issues to be further addressed for the successful implementation of on-site composting.

There are various technologies used in Sri Lanka for aerobic pre-treating of MSW prior to material and energy recovery and subsequent final disposal in landfills. In situ and centralized aerobic composting techniques are commonly used as a means of organic material recycling process in which the end products are recycled back to the environment through land application as a fertilizer or soil amendment. There are a number of in situ composting methods available in Sri Lanka (Annex 1). However, in this research, we have focused mainly on centralized type of aerobic composting which is widely used in MSW composting.

3.2 Centralized Composting of MSW in Sri Lanka

Until very recent past, municipal solid waste management delivery had traditionally been viewed as the collection and disposal of waste and it has been considered unsustainable. While collection would help remove waste from generators, collected waste is often disposed at open dumps without much concern for environmental pollution and implications on human health. Lack of suitable and adequate lands for safe disposal of MSW has been one of the major problems affecting urban areas, due to high population densities, resulting in haphazard and indiscriminate dumping of large quantities of MSW.

Due to the importance and gravity of the MSW issue, there have been several national and international support programs to uplift the SWM sector in the country. The first national level project; study on MSWM in secondary cities in Sri Lanka which was funded by Japan International Cooperation Agency (JICA), started in 2002 and continued for two years. By this project institutional capacities of seven local authorities (Kandy, Gampaha, Matale, Nuwara Eliya, Baddulla, Negambo MCS and the Chilaw UC) were strengthened. Secondly, as per the recommendation of the project, the National Solid Waste Management Support Center (NSWMSC) was established in 2007 as an affiliated institute of the Ministry of Provincial Councils and Local Government. The NSWMSC facilitates local authorities with technical support for development of all segments in SWM, and coordinates with government and non-governmental organizations to secure financial assistance for local authorities to upgrade SWM services. The financial support from JICA for MSWMSC has been reduced, and NSWMSC is now functioning as a government organization funded by the Ministry of Local Government and Provincial Councils.

At the same time, the Ministry of Environment and Natural Resources has launched a national level program in the name of PILISARU under the Chairmanship of the Ministry of Environment and Central Environmental Authority in participation with other government organizations, private institutions, NGOs and various technological specialists. The main aim of the PILISARU project was to solve MSW problem in 5 years starting from 2008. The PILISARU program was funded by the central government budget allocations up to Rs 5.675 billion for the first three years. The PILISARU program has funded hundreds of small, medium and large scale MSW management facilities such as treatment of organic waste by centralized composting, source segregation and resource recovery, and promoting recycling.

Another notable initiative is the Ampara Environmental Remediation Program (2006-2011) which was funded by the European Union (EU). The project implementing agency, the United Nations Office for Project Services (UNOPS) implemented several MSW improvement projects in the Eastern Province and the projected total expenditure is US $12.3 million. In addition, several non-governmental and international donor agencies work on the MSWM field on different scales.

Consequently, there has been a paradigm shift in the way that waste management is perceived. The emphasis is now on waste minimization and reduction at source, recovery of resources prior to disposal, and promoting recycling of waste materials with the ultimate goal being a national sustainable solid waste program.

Composting of municipal solid wastes in centralized facilities is becoming popular, in the frame of integrated municipal solid waste management and, in particular in the diversion of biodegradables from dumping/landfilling. The objective of MSW composting can be approached in two main ways:

1. The solid waste management approach, wherein composting is a way of treating organic waste within an integrated solid waste management system. Compost is seen as a by-product.
2. The marketing approach, wherein composting is a way of producing a valuable product that can be sold. Composting is the core of all activities.

With the initiative and incentives through the PILISARU program launched by the Ministry of Environment in 2007, there was a boost in setting up of centralized MSW composting facilities in the country. At the launch of the PILISARU program, the major aim of centralized MSW composting was focused on the first objective, wherein public health and environmental conservation were of greater importance. The capital expenditure for setting up composting facilities were drawn either from public funds through PILISARU or foreign/local donors. In addition, the local authorities were facilitated with adequate human resource training and awareness programs. However, with the later developments, local authorities opted to focus more on centralized composting as a business that can partially recover MSW service expenditure through compost sale (Perera et al., 2010).

The following section summarizes the technologies used in centralized composting of MSW in Sri Lanka, with special emphasis on the use of engineering principles and management strategies.

3.3 Techniques used in Centralized MSW Composting

Pre-processing

Pre-processing is typically performed by three actions; 1) sorting MSW and removing materials that are difficult or impossible to compost; 2) reducing the particle size of the feedstock material; and 3) treating feedstock to optimize composting conditions. The first aspect of the pre-processing, MSW sorting in Sri Lanka is generally practiced at three levels; 1) sorting at point of generation; 2) segregation at the collection by collection workers; and 3) manual sorting at a centralized facility. Among the pre-processing activities, however, only the manual sorting at the centralized facility is widely practiced in Sri Lanka which has to be changed to source separation for better quality compost production (Table 3.1). Generally mixed/comingled MSW requires extensive sorting and separation, which is generally done by manual labor. The degree of sorting depends on several factors, including the source of the MSW (residential, commercial, street sweepings etc.), quality of the final product, and the operations and technology involved.

Table 3.1: Advantages and Disadvantages of Source Separation Versus Commingling MSW

Source-separated materials	Mixed(commingled) waste
Advantages: ✓ Less chance of contamination results in higher quality compost. ✓ Less money and time spent on handling and separation of material at the site. ✓ Provide an educational benefit to residents and might encourage waste reduction.	**Advantages:** ✓ Usually collect with available equipments and workforce. ✓ Convenient for residents because no separation is required.
Disadvantages: ✓ Can be less convenient to residents. ✓ Might require the purchase of new equipment/machinery/vehicles and containers. ✓ Might require additional workforce for collection.	**Disadvantages:** ✓ Higher potential for contamination, which can result in lower-quality compost ✓ Higher processing and facility fee

Compost processing in Sri Lanka

At the local authority's level, composting practices range from simple open air static-pile composting to large-scale mechanized facilities. Figure 3.3 provides a brief overview of different composting techniques, and windrow composting is the most widely adapted method across the country.

Indoor composting in turned windrows is a common technique widely adopted for mixed MSW and garden waste. Although outdoor windrow systems are being used in some facilities, the system is less suitable for more problematic wastes such as food wastes, organic rich MSW or wastes very rich in perishables because of higher risk of odor, attraction of animals and hygienic reasons. The more damped MSW is being mixed with mature feedstock or dry garden waste, and generally protected under a roof to prevent excessive leachate generation. Static piles with forced aeration systems are not common in Sri Lanka; instead few LAs use passively aerated systems that were developed by the solid Waste Management Research Unit of the University of Peradeniya (Basnayake *et. al*, 2008).

Composting facilities are designed similar to industries where raw materials are being processed into final products. An engineered composting facility helps in smooth operational and post processing activities aiming a high level of efficiency. As illustrated in Figure 3.2, most of the centralized composting facilities are equipped with adequate facilities and machinery for composting, but generally have limited facilities for handling of rejects/waste.

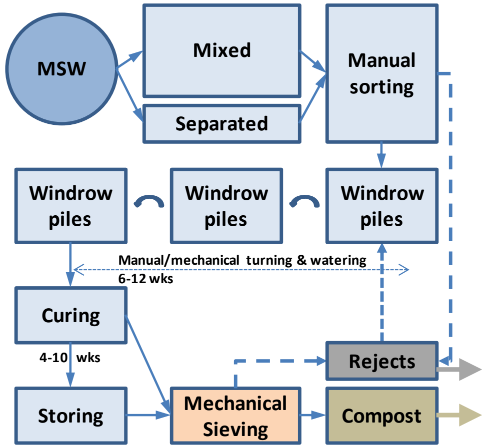
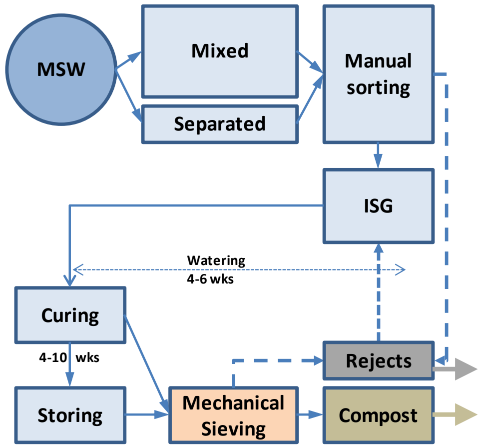
Technique	Process Flow	Examples
Windrow composting Examples: *Nagoda MSWM facility, Kalutara;* *Bandarawela MC;* *Anuradhapura MC;* *Balangoda UC;* *Kuliyapitiya UC;* *Wariyapola PS;* *Yatiyantota PS;*		
In-vessel composting (e.g. Inclined Step Grate Composter) Examples: *Nawalapitiya UC;*		

Figure 3.2: Common Methods of Centralized Composting of MSW

Except in few facilities, managers or supervisors have limited skills to operate and manage the composting facilities. Table 3.2 summarizes some of the key parameters that should be considered in compost manufacturing for market.

Table 3.2: Factors Influencing the Composting Process and Quality of Final Product

Aspect	Preferred condition	Remarks
MSW characteristics	Organic fraction of MSW	Kitchen waste, food waste, garden waste, paper and small amounts of non-degradable/ long-term degradable materials may be present
Particle size	25-75 mm for optimum results	Smaller particles increase the density thus reduce the air movement inside the pile, larger particles takes a long time to disintegrate and decompose
C:N ratio	25 to 50	C:N ratio above the limit prolong the decomposition and very low C:N ratio of feedstock may impend anaerobic condition and ammonia leaching
Blending & seeding	1-5 %	Addition of partly decomposed matter accelerate the decomposition at early stages, especially when the feedstock is garden waste
Moisture content	55% (optimum)	Higher moisture increases leachate generation and reduces aeration, dryness ceases the decomposition
Windrow size	2 m width and 1.5 m height and 3 m long	Wide and tall windrows restrict the air movement inside the pile
Mixing/turning	4-5 days (optimum) Weekly (recommended)	Low turning frequency reduces the aeration, mixing and disintegration and slower the decomposition
Maturing/curing	Weekly mixing/turning (optimum)	Continue pile mixing/turning until temperature drops to 40 °C or less, and add water while mixing/turning
Monitoring parameters		
Temperature	50-55 °C for first few days 55-65 °C for reminder period	Temperature below 50 °C during the composting caused by low C:N ratio, excessive moisture, dryness, compaction due to large pile si[illegible]oxins
pH	7 – 7.5 (optimum)	Not above 8.5 to minimize nitrogen losses via ammonia volatilization, very low pH at early stages indicates excessive, fast decomposable carbohydrates in feedstock
Maturity indices		
Stability	*Simple tests* • C:N ratio <25 • Self heating test *Advance tests* • Specific O_2 uptake rate • CO_2 evolution	Simple tests are cheap and easy but are low in accuracy Advanced tests are more accurate but require special equipment and skills to perform
Toxicity assessment (Phytotoxicity)	NH_4-N:NO_3-N ratio, Compost bioassays	Caused by the presence of organic chemicals such as lactic and acetic acid, herbicides, heavy metals, and pathogens

Source: U.S. Composting Council (2002).

3.4 Overview of Compost Processing Technologies

In any technology, processing methods should be chosen to maximize the speed of the composting process and to minimize negative effects, such as fly breeding, odor release and leachate runoff. The level of effort required for processing composting feedstock depends on the nature of the feedstock, the desired speed of production, the requirements for worm control, odor and leachate control, and the quality requirements for the finished compost. A facility's financial resources and available space are also important. Greater the speed of the process, the more odor and leachate control is necessary. In general, more resources and higher levels of effort are necessary to compost a MSW feedstock than a garden waste/trimming feedstock, largely because of the diverse nature of MSW. Compost processing occurs in two major phases: the composting phase and the curing phase;

1) Composting phase: Microorganisms decompose the readily available organics/nutrients present in the feedstock and most of the actual change in the feedstock occurs during this stage. Consequently, the most intensive degradation and change of phase of decomposition tend to occur here.

2) Curing phase: Once the rapid composting phase ends, the compost should be cured. Curing should take place once the materials are adequately stable. Testing for stability is an inexact science but oxygen uptake and CO_2 evolution tests can be considered to determine the degree of maturity of compost derived from MSW feedstock. A simple method of stabilization is monitoring the internal temperature of the compost pile once it is turned. If reheating of the pile occurs, then the material is not stabilized. Another method is to put the compost material in a plastic bag for 24 to 48 hours at optimum moisture level of 55%. If foul odors are released when the bag is opened, the materials are not ready for marketing. Reason for most of the negative feedbacks on MSW compost is due to marketing of immature composts and not due to containing heavy metals and toxic organics.

In Sri Lanka, many composting facilities use a concrete pad to collect and control any leachate that is produced during the first stages of composting. The most common way to handle leachate is to collect the leachate, dilute with water and reintroduce into the compost pile (e.g. Balangoda Composting Facility). However, this should not be done once the composting materials have passed the high-temperature phase (e.g. after 10 weeks of windrow composting), because harmful microorganisms can be reintroduced with the leachate.

3.5 Compost Manufacturing and Quality Control

In Sri Lanka, most composting facilities that process MSW feedstocks are designed and operated primarily to reduce the waste volume prior to final disposal. However, the viability of composting facility as a sustainable solution in MSW management hierarchy depends mainly on cost and benefit of composting, consequently the quality of marketable product. Therefore, it is crucial for LAs to change their main objectives from landfill diversion to product manufacturing, if a sustainable composting facility is to be established.

The use of the composted organic fraction of MSW as soil amendment may be a method of improving the low organic matter (OM) content of many cultivated soils in Sri Lanka, particularly in the areas where soil OM has gradually decreased over recent years and there is a chronic deficiency of soil OM. Compost intended for use as a growing method should meet more stringent quality criteria in comparison with compost used in reclamation of marginal and degraded soils or in other special uses such as landfill cover. The most important characteristics of MSW composts that may affect their use as a growing media/soil amendment are derived from their physical properties (air and water supply), and their chemical properties (pH, electrical conductivity and nutrient content) and also from the absence of toxic compounds, including heavy metals, hazardous organic compounds and pathogens. Accordingly, a good quality control procedure is necessary before the compost can become a recommended soil amendment for agriculture.

In order to market MSW compost successfully to many end users, concerns about potential threats to soil, plants, livestock, and humans must be addressed. One of the primary concerns of local consumers is the low nutrient value, presence of heavy metals and toxic organic compounds in MSW compost. At the market, the compost should be of a consistent quality, especially to customers who expect a certain quality product. This may not be as important to the one-time buyer. However, if the quality of the compost is good, the one-time buyer could become a regular customer. In addition, if some compost varieties are extremely poor in quality, customers' confidence in all composts may be reduced. Quality assurance (e.g. SLS standards) for consistent production of high-quality compost is a necessity for compost marketing.

This section primarily focuses on factors that affect the quality of compost and techniques that can be applied to improve the quality.

Factors Affecting the Compost Quality

The best method to obtain a quality feedstock from MSW for composting is to collect the compostable waste separately from the point of generation. For this, MSW point source separation has to be improved (Jagath *et. al*, 2002). In case public cooperation and law enforcement are not effective, waste sorting at centralized facility can be practiced. However, the quality of feedstock may be inferior to the source separated waste.

Changes in the compost feedstock also change the compost quality; feedstock material should be carefully controlled to ensure consistent compost quality. This may mean that some non-compostable materials should be rejected at the compost site if the product from these materials will be difficult or impossible to market. If accepted, attempts should be made to segregate these feedstocks and market the resulting compost separately. The following paragraphs mention some of the substances which have greater potential to be in compost, if adequate measures are not applied in feedstock selection, sorting, processing and final finishing.

Potential Toxic Biological Agents

Potential health and safety concerns at composting facilities include exposure to bioaerosols, potential toxic chemicals, and other substances. Bioaerosols are suspensions of particles in the air consisting partially or wholly of microorganisms (Gerba, 1995). The bioaerosols of concern during composting includes actinomycetes, bacteria, viruses, molds, and fungi. For instance, *Aspertgillus fumigatus* in decaying organic matter can be inhaled or can enter the body through cuts and abrasions in the skin (Tontti *et. al*, 2011). In susceptible individuals, however, it can inhabit the lungs and produce fungal infections. Another health concern at composting facilities is exposure to endotoxins. Endotoxins are toxins produced within a microorganism and released upon destruction of the cell in which it is produced. Because bioaerosols and endotoxins are both carried as dust, dust control measures should be incorporated into the design and operation, and final product processing of the facility. These substances may be present in small quantities in the finished product therefore proper guidance should be given for safe handling during application.

Potentially Toxic Chemicals

Some volatile organic compounds (VOCs), such as benzene, chloroform, and trichloroethylene present in mix MSW can pose risks to workers at MSW composting facilities (Gillett, 1992). Certain solvents, organic acids, paints, petroleum products and residues, and cleaners contain VOCs. The combination of periodic turning of window systems and elevated temperatures can drive VOCs from the composting material into the surrounding atmosphere. Workers are more likely than compost users to be exposed to VOCs, because most of the VOCS in the feedstock volatilize from composting piles within the early few days. To avoid worker exposure to VOCs in enclosed spaces, adequate ventilation is required in composting facilities. Although, control technologies developed for odor control may be applied to VOC control, the best method of controlling VOC emissions is to limit their presence in the feedstock.

Heavy metals

Out of all hazardous/toxic substances that may be present in MSW compost, heavy metals have been the focus of most attention. Contamination of MSW compost by heavy metals can cause harm to public health and environment and is the major concern leading to its restricted agricultural use in some countries. Mixed waste composting is therefore not an option for sustainable waste management, but this issue has not been taken seriously by some of composting manufacturers. Although composting of mixed waste may lead to production of compost contaminated by heavy metals, the general perception is that the composting of source separated organic waste may not contain elevated levels of heavy metals. For instance, the following table shows the compost quality of eleven MSW compost samples analyzed for different parameters (Karunarathna *el. al*, 2013).

Table 3.3: Quality Parameters of Eleven MSW Compost Samples Randomly Picked from Composting Facilities in Sri Lanka (Karunarathna *et. al*, 2013); Heavy Metal Quantities are in ppm.

Parameter	Sample code											max	min	Ave
	a	b	c	d	e	f	g	h	i	j	k			
pH (1:1)	8.1	7.3	8.9	8.6	8.3	8.3	8.9	8.0	8.2	8.1	7.9	8.9	6.9	8.1
EC (dS/m) (1:5)	4.1	6.7	8.1	8.9	1.6	2.1	8.5	7.3	6.5	5.9	5.3	8.9	1.3	5.1
Moisture (%)	17.0	7.6	23.0	26.0	34.0	41.0	11.0	27.0	30.0	26.0	31.0	41.0	7.6	27.2
Organic Carbon (%)	22.6	31.3	41.7	32.4	29.9	32.1	44.3	42.1	28.1	32.7	25.1	44.3	21.9	31.8
Total N (%)	1.0	0.1	1.0	1.6	1.0	1.0	1.0	0.9	1.8	1.6	1.5	1.8	0.1	1.1
Total P -P_2O_5 (%)	0.9	0.0	1.1	1.4	0.7	0.8	1.0	1.0	1.1	1.3	1.0	1.4	0.0	0.9
Total K - K_2O (%)	1.5	1.3	2.2	2.3	0.5	1.6	2.0	1.7	1.7	1.7	1.5	2.3	0.5	1.5
Carbon: Nitrogen (C/N)	23.4	36.3	41.1	20.2	30.9	33.2	44.5	46.0	18.0	20.6	16.2	46.0	16.2	29.2
Cadmium (Cd)							15							
Chromium (Cr)							185							
Copper (Cu)							80							
Lead (Pb)							130							
Mercury (Hg)							1							
Nickel (Ni)							30							
Zink (Zn)							190							

Source: Karunarathna *et. al*, 2013

The content, behavior and significance of heavy metals in composted waste materials is important from two potentially conflicting aspects of environmental legislation in terms of: (a) defining end-of-waste criteria and increasing recycling of composted residuals on land and (b) protecting soil quality by preventing contamination. Thus compost quality guidelines should consider the effects of heavy metals in compost and amended soil as a basis for achieving a practical and sustainable balance between these different policy objectives, with particular emphasis on agricultural application.

Generally, all types of municipal solid waste (MSW) compost contain more heavy metals than the background concentrations present in soil and will increase their contents in amended soil. Total concentrations of heavy metals in source-segregated and garden waste/ yard trimming compost are typically below standard limits for agricultural use and below risk-based thresholds that affect human health. Moreover, there is general consensus in the scientific literature that aerobic composting processes increase the complexation of heavy metals in organic waste residuals. Metals get strongly bound to the compost matrix and organic matter, limiting their solubility and potential bioavailability in soil. Lead is the most strongly bound element and Ni the weakest, with Zn, Cu and Cd showing intermediate absorption characteristics. The availability in soil depends on the nature of the chemical association between a metal with the organic residual and soil matrix, the pH value of the soil, the concentration of the element in the compost and the soil, and the ability of the plant to regulate the uptake of a particular element. Therefore, bad effects on the environment, human health, crop quality and yield, and soil fertility, from heavy metals in source-segregated MSW or garden waste/ yard trimming compost are minimal.

3.6 Technical Constraints of Composting Municipal Solid Waste in Sri Lanka

This section highlights few technical constraints faced by centralized composting facilities in Sri Lanka.

The most common technical issue is the receiving of mixed and unsorted MSW at the centralized composting facility. The mixed waste is often contaminated with household hazardous compounds and materials such as batteries, small electronic appliances, and discarded electrical bulbs, discarded pharmaceuticals and chemical waste from small industries. The manual sorting can only separate apparently visible and proportionally large hazardous particles from the mixed MSW, leaving the small hazardous materials to mix with bulk feedstock. It has been observed that the contamination with household hazardous waste is a major source of heavy metal found in compost. The issue can only be solved, if very strict regulations and monitoring mechanisms are established to prevent co-disposal of hazardous and non-hazardous solid waste at household and commercial (trade) sector. Separation of hazardous waste at the centralized facility requires special machinery and instruments which are not appropriate for small and medium scale composting facilities.

Generally, the mixed MSW and biodegradable waste collected by LAs has the water content far above the optimum amount of moisture required for composting. The high moisture in the composting feedstock and endogenic moisture generated from rapid degradation at the initial phase of decomposition generate excessive amounts of leachate that cannot be disposed by recirculation. Thus, the management of excessive leachate produced in early stages of composting, especially in commonly practiced window composting, has become the major issue faced by compost facility management. The issue is very common in the wet zone of the country where rain occurs for at least half of the year. Thus, investments on additional leachate storage and treatment facilities are essential to overcome the condition.

Disposal of pre-rejects and post-rejects from composting process is another problem faced by most of the centralized composting facilities. Recent research revealed that the portion of rejects in the form of non-recyclable plastics and inert can be 40 to 50% of incoming MSW weight. If the composting facility has not been established as part of integrated MSW management strategy, often such rejects are stockpiled in and around the composting facility. The storing of rejects usually occupies the space required for proper compost facility management.

Composting feedstock shall undergo thermophilic (temperature between 65 and 75 °C) stage at least for a week to destroy pathogen and weed seeds present in the MSW. However, composting piles smaller than 1.5 m in height and width often cannot reach high temperatures and thermophilic state may not be maintained for a considerable time period. This problem can be avoided by constructing larger windrow piles using the waste collected for several days when the daily receiving amount is less than two tonnes.

The national survey on MSW in Sri Lanka reveled that most of windrow composting facilities have not been designed with adequate expertise consultation. The common practice is to replicate the system established in other LAs; however, site specific conditions and operational procedures are often missed out in the designing process. This has ultimately lead to malfunctioning of facilities and producing inferior quality compost at the end.

CHAPTER FOUR

Case Studies

4.1 Balangoda Urban Council

Balangoda Urban Council is the oldest Urban Council in the Ratnapura district and was initiated as a sanitation board. By now it is being n governed by nine governors and a special commissioner. Its current population is 35,855 and the generation of waste per day is about 0.9kg per person. Prior to initiation of a proper solid waste management programme, municipal solid waste collected from the urban council area was disposed to a marshy land which was situated close to the Dorawela Oya flowing across the Balangoda town.

A need of a proper solid waste management was felt strongly in 1999, when an epidemic of diarrhea, typhoid and many other diseases caused basically due to polluted water, mosquitoes and flies were reported. Therefore, major objectives of the project were to create cleaner and nicer environment, groundwater protection and minimizing the chances of spreading vector-borne diseases. Composting project is closely monitored by the Chairman of the Urban Council and a permanent work supervisor has been appointed for the project under the Public Health Inspector (PHI).

4.1.1 Strategies Adopted for Solid Waste Generation Reduction

Large scale public awareness programmes have been conducted to provide information on the 3R concepts (waste Reduction, Reuse, Recycling) included in the National strategy on solid waste management developed by the Ministry of Environment.

a) School 3R Societies

In the Balangoda urban council area, special programmes have been conducted targeting school children to change their attitude regarding waste disposal at household level. Resource centers have been established in 10 schools to include children of all religions and cultures. The school resource center is managed by its 3R society which comprises 50 school children. These societies conduct programmes to popularize the 3R concept in the school system and to create awareness on benefits of waste separation at household level. School children are expected to bring non degradable wastes from home to school's resource center. Members of the 3R societies are expected to buy these non degradable materials and mark the point cards. 3R societies were paid a sum of Rs.1000/= as initial expenses by the urban council. According to the point system, those who earn 1000 points are eligible to receive either Rs.1000/= or school equipment worth that amount or a bank deposit equivalent to the amount. In appreciation of the students committed to the cause, they are awarded an Environmental Friendly badge at the 3000 point level, an environment lover badge at the 5000 point level, Nation Friendly badge at the 10,000 point level. At the 15000 point level, they will be awarded the badge of Global Lover. If students reach 20000 points they are expected to be awarded a Presidential Green Award.

b) Village 3R Societies

In Balangoda Urban Council area, four village 3R societies function as a pilot project. Each society has 25 households and they are actively involved in 3R concepts. Members of these societies are expected to take measures for reducing generation of waste, separating of non degradable waste at household level and selling those items to the purchasing centers. They are eligible to receive Rs1000/- on the completion of a point card. By considering the points accumulated by each member, loan facilities are expected to be granted to members if they wish to initiate any type of self employment. For members engaging in home gardening, compost is given free on requirement. In addition, members get the opportunity of receiving knowledge and advice on various farming issues from agricultural experts.

c) Recycling Centers

A plastic and polythene recycling center has been established at the Balangoda Composting Plant. The Central Environmental Authority has provided financial and technical assistance for this center.

d) Garbage Tax

Using the power entrusted on local government authorities regarding the disposal of waste from 2008, the Balangoda Urban Council has adopted collecting a garbage tax from commercial establishments such as guest houses, supermarkets, retail and wholesale shops, food cabins and other commercial establishments with more than five employees within the urban council area. However, establishments that practice waste separation were released from paying this tax. Due to continuous awareness programmes which highlight the importance of adopting above 3R concepts, it has been able to reduce the unsorted amount of waste from about 25MT which was generated in the year 2000 into 12MT by year 2012 saving considerable space and labour hours spent on sorting.

4.1.2 Composting Project

Funding

Initially Rs.1.4 million grant has been given by the World Bank through the Environmental Action Project Phase 1 to construct a composting plant. To rehabilitate the access roads to the composting plant situated about 3km away from the Balangoda city, the provincial government granted Rs.1,000,000/=. The Chief Minister of the Provincial Council has granted another Rs.500,000 to build a fence around the compound. Later the Central Environmental Authority has granted Rs.7.4 million for building the night soil plant.

Production of Compost

Municipal and household waste collected from the Balangoda Urban Council area is received at the composting plant. Considering the importance of delivering waste material to composting plants at the early stage of decomposition, waste collection is being practiced on a daily basis. Highly perishable material such as animal waste collected from slaughter houses and fish markets are collected after collecting waste from other places and they are transported in separate containers to avoid mixing with other waste. Average composition of solid wastes generated from the Balangoda Urban Council consists of 65-70% degradable products, 20-25% non degradable, recyclable products and 10-15% of material that has to be used in land filling. Industrial waste is not included in waste collected from this urban council.
At the composting plant manual sorting is done to separate the degradable portions. Open windrow technique is being used and sorted degradable waste is being piled to windrows. Average dimensions of these windrows are 12 x15 feet.

Figure 4.1: Waste Piles at Maturation

These piles are kept for 6 weeks for maturation. After about 6 hours, leachate starts to leak from these piles. Biological oxygen demand as well as acidity is high in this leachate and therefore it has a bad odor and its a source of fly infestation. Leachate is treated after being collected through a lined drain to a concrete tank by adding pure water at a rate of 1:1000 ratio. This treated water is used to moisten the garbage piles. During dry periods, piles are moistened once in every ½ hour. This process creates a favourable environment by maintaining temperature for bacteria growth and their actions.

To maintain a desirable C: N ratio which is 25 : 1 external application of animal waste is required. Animal waste collected from fish market, farms and slaughter houses is being added to the center of garbage piles on the second day of maturation. In the Balangoda composting plant, about 1500kg of animal waste is added to 14000kg of garbage. After 6 weeks, garbage piles are turned using a bobcat machine to provide aeration to accelerate the decomposing process. Pelicans are indicators of aerobic condition and fly control. In the absence of pelicans, larvae of flies are removed manually by collecting and discarding them to the leachate dump. Temperature inside the garbage pile during the 1st week should be about 700C to prevent the growth of harmful fungi such as Aspagillus. If fungi growth was not managed properly, users of final compost would develop skin irritations. Garbage piles are turned again in the 8th week (2 weeks after 1st turning). After 2nd turning, degraded compost is dried to reduce its moisture content to about 8%. When the moisture content is reduced to 8%, degraded waste is sieved through 4mm sieve to separate non-degradable part from compost.

Biochar produced from four mills in the area is being mixed with the sieved compost to remove the 'Se' content to a certain extent. To provide the Phosphorous requirement, 15% of rock Phosphate is added while night soil is added according to wish of the bulk users at a rate of 30%. Required C and N elements are added through addition of animal waste to the decomposing waste. To maintain the quality of the final product, samples are tested for basic nutrients at the soil testing centers of the Department of Agriculture in Gannoruwa and Makadura. Once in every six months compost samples are sent to the Industrial Technological Institute (ITI) to detect heavy metal contamination. The capacity of the composting plant is to produce 50MT per month, but the current production per month is around 30MT.

Staff turnover at the plant is very low and to enhance their social recognition National Vocational Qualifications (NVQ) have been prescribed for the municipal solid waste operation assistants. Workers employed in the project are on casual or contract basis. Most of the employees are residents of the neighbouring households and there had been only few households around the plant before initiating this composting plant. Villagers have benefited by getting employment, developed infrastructure facilities etc. Due to these benefits, so far the project has not received any social objection from the villagers. Workers were given necessary items for their safety during their work at the composting plant. No incidence of sicknesses linked to their work at the composting plant has been reported..

Sales and Marketing

Main consumers of compost produced in the Balangoda Urban Council are the Urban Development Authority of the Western Province, Urban Council of Balangoda, tea estates, vegetable farmers, CIC company and farmers from the eastern part of the country. Wholesale marketing is done via fertilizer dealers while retail marketing is done at the sales center located at Balangoda city and at the composting plant. Marketing avenues are being sought by the project managers and they have to take up the challenge of constantly searching for new customers since there are no regular MSW compost users who purchase in large quantities.

Constraints Experienced during the Project

a) Leachate should be treated properly before releasing to the environment.
If not it can pollute water resources. At the initial stage of the project, when leachate was released to a canal without treating, farmers who cultivated

paddy lands along that canal had developed burning sensations on the skin and experienced bad odor.

b) Human hair and batteries disposed from households and commercial dwellings have been identified as a major obstacle in the composting process. As a result of vigorous public awareness programmes by now, almost all the barber shops and other shops in the Balangoda urban council area dispose items containing heavy metals in separately.

4.2 Weligama Urban Council

The Weligama Urban Council initiated its composting plant in 2006 with the aim of minimizing the adverse impacts of open dumping. About 18 MT of waste is collected daily from the Weligama Urban Council area. The composting plant is located at Kapparatota which is a very populated area close to the Weligama city. Composting plant and the home garden occupy about 8 acres while the rest of the 18 acre land is used as an open dump.

4.2.1 Strategies Adopted for Solid Waste Management

Public awareness programs have been conducted to encourage waste separation at household level. Special programmes have been conducted at school level and the council has provided a bag to dispose things that cannot be used in compost making and these items are being collected once a month. High decomposing material such as food items and animal waste is collected in the morning. In addition to encourage source separation of waste, the council charges a tax on unsorted garbage collected from commercial dwellings.

4.2.2 Composting Project

Funding

Initial funds for the construction of the composting plant have been granted by the Ministry of Provincial Councils. In addition, few NGOs had also provided financial assistance for this purpose.

Production of Compost

Municipal solid wastes collected from the area consist of 80% of decomposable material and 10% recyclable material. Only 10% of waste goes to the open dump. Hospital waste and factory waste are not collected by the urban council. Technology used for composting is the open windrow system. The leachate of the decomposing piles are collected through ditches and used to moisten the piled waste.

To increase the 'N' content in the final compost, fish and meat residues are added to the center of piles. In addition, poultry manure and cow dung received from the home garden of the composting plant is also added at the 1st turning of the decomposing waste.

Availability of labour for this project is very satisfactory but the staff turnover is very low. To protect the health of the workers they were directed to medical clinics once a month and they were provided protective items such as gloves, boots, sanitary masks and welfare facilities such as safe sources of drinking and bathing water and resting facilities etc. There were no records of its workers being contracted of any disease or illnesse related to their nature of work.

Sales and Marketing

Most of the users are vegetable growers in the area and growers of plant nurseries and landscaping. Marketing of compost is done by the sales center at the composting plant. Packets of compost are available and 2kg, 5kg and 25kg bags are priced at Rs. 20, 40 and 225. So far they have not received any complaints regarding the quality of the compost produced by them. Average retail sale is about 30,000kg per month.

Constraints Experienced during the Project

Residents of the area complained about the bad odor and various impacts of water pollution caused by the leachate of open dump. Further, neighbouring land owners complained that their value of land had fallen due to this composting plant situated in an urban setting. However, it was informed that the Urban Council is planning to plant fast growing trees such as bamboo in the boundaries of the land to reduce the odor issue.

4.3 Bandaragama Pradesheeya Sabha

Bandaragama Pradesheeya Sabha in the Kalutara district consists of 103 *Grama Niladhari* divisions and it covers the two Divisional Secretariats; Bandaragama and Milleniya. The total extent of the Pradesheeya Sabha is 93.2km^2. Open dumping was adopted by the Pradesheeya Sabha until the Deldorawatta Waste Management Center came into operation in 2007 as a sustainable solution for the serious issue of disposing municipal solid wastes collected from the area. Currently the composting plant receives 10 to 12 tons of waste on a daily basis from households, street sweeps and waste collected from weekly fairs and commercial enterprises. About 10 tons of waste is mixed waste while about 2 tons are received after source separation.

4.3.1 Strategies Adopted in Solid Waste Management

To manage solid waste generated in the area, the Pradesheeya Sabha has conducted many programmes. To promote home composting, composting barrels have been distributed among more than 200 households with the financial assistance of the Ministry of Provincial Councils. In addition, garbage bins have been distributed to promote waste separation at household level. Further, public awareness programmes have been conducted covering the whole Pradesheeya Sabha area. Special programmes for pre-school children and school children have been conducted to train them to separate waste at household level.

4.3.2 Composting Project

Funding

Financial assistance has been provided by the Pradesheeya Sabha, the Ministry of Provincial Councils and the Pilisaru project of the Central Environmental Authority (CEA). Since its inception, the total cost spent on the composting project to the end of year 2012 is estimated about Rs.6,816,819.00.

Production of Compost

Compost plant and the bio gas plant are located at the Deldorawatta Waste Management Centre which is located in the interior of Bandaragama. Mixed waste is sorted manually at the plant and technology used for composting is the open window technique. Leachate is treated by collecting it to tanks via lined drains and by mixing with water at a ratio of 1:1000. This treated leachate is used to moisten the piled waste kept at maturation.

Upto now the plant has not practiced external incorporation of nutrients. However, it has obtained analytical test reports from the Horticultural Crop Research and Development Center, Gannoruwa and the Industrial Technological Institute (ITI) of Sri Lanka to perform necessary quality improvement.

Staff turnover is very low though employees of the composting plant work on contract basis. All of them undergo individual health check-ups to identify diseases. They were given treatment as well as advice on preventing measures. The Pradhesheeya Sabha is providing rain coats, gloves, masks, boots etc. for their safety. To motivate the workers, letters of appreciation have been given to those who have higher attendance.

Sales and Marketing

Retail marketing is done at both Pradesheeya Sabha and the composting plant. A compost packet of 2kg is priced at Rs.25/= and 5kg Rs.60/=. Wholesale price for 1kg of compost is Rs.10/= and has to be purchased at the composting plant itself. During the year 2011, income received from compost marketing is Rs.213,840/= and Rs.20,300/= from selling the recyclable items. However, they produce compost only for the existing demand though they have a potential of producing more compost.

Constraints experienced during the Project

Since the composting plant is located in a remote area away from the residential area, no serious complaints have been received so far. However, people of the area reported that by evening and on rainy days they had to suffer from the bad odor.

4.4 Kaduwela Municipal Council

Kaduwela is located close to the capital city of Sri Lanka, Sri Jayawardenapura Kotte. The total population of the Kaduwela Municipal Council is about 290,000 and generation of waste per person is about 0.8kg per day. The composting plant was initiated in 2006 with the objective of reducing the quantity of waste that goes to open dump sites, which created many social and environmental issues. Financial assistance for this project was provided by the Central Environmental Authority and the Waste Management Authority of the Western Province. Initial capacity of the composting plant was 5 tons of waste per day and currently it uses 25 tons of waste per day.

4.4.1 Strategies adopted in Solid Waste Management

Daily collection of waste is about 45-50 tons and about 50% and 10% of it consists of short term degradable material and long term degradable material. Recyclable component accounts for about 15% and the remaining portion goes to the dumping sites for final disposal. Waste collected by the Kaduwela Municipal Council does not include hospital waste. During transport, fish and meat waste is collected in separate containers. Public awareness programmes have been conducted by organizing pocket meetings and distributing handbills.

4.4.2 Composting Project

Funding

Funds for the composting project have been provided by the Waste Management Authority of the Western Province, Pilisaru project of the Central Environmental Authority and the Kaduwela Municipal Council.

Production of Compost

Composting plant is located in a 3 ½ acre land and open dumping is done by the side of the compost plant. From the total waste reaching at the waste management center, only the waste separated at household level is composted currently. Open windrow technique is used for compost making and 5' piles are made by the workers manually. To reduce the odor and protect the moisture within the piles, paddy husk and saw dust are mixed with decomposing waste. Animal waste is added at the center of piles.

Quality of the compost is tested at the Horticultural Crop Research and Development Institute once in 3 months.

Workers employed in compost manufacturing have been recently absorbed to the permanent carder. They were given basic necessities for their safety and other facilities such as drinking water and sanitary facilities. To motivate the workers 25% of the revenue received from the compost business is shared among them at the Sinhala/Hindu New Year considering their attendance at work.

Sales and Marketing

Vegetable growers of the area and tea plantations are the main customers. Marketing is done at the composting site as well as at the fertilizer shop at the

Kaduwela market. Current prices of compost is Rs.11.50 per kilogram and the wholesale price is Rs.9/= per kilo of compost.

Constraints Experienced during the Project

Neighbouring wells have been polluted due to leachate and residents who were affected due to leachate of the open dump have been provided pipe-borne water facilities by the municipal council.

4.5 Waste Management Authority (WMA) of the Western Province-Kalutara

The Waste Management Authority of Sri Lanka came into operation in 2004 with the prime objective of finding a permanent and immediate solution to the waste problem in the province. Since then, the Authority has initiated short term, mid-term and long term projects on waste management by providing financial and technical assistance. The Authority had received financial grants worth Rs. 5 million from the Provincial Specific Development Grant for this purpose. To enhance the legal structure in waste management in the province the Waste Management Authority had received short term technical assistance from USAID/USAEP. Further, the Authority has formed clusters of Local Authorities to facilitate participatory projects in the Province. The composing plant at Kalutara is operational since early 2011.

4.5.1 Composting Project

Funding

Funds for this project have been granted by the Solid Waste Management Authority of the Western Province and by now they have invested about Rs. 70 million for buildings and Rs.90 million for equipment.

Production of Compost

About 60 percent of the waste collected from the Kalutara Urban Council is compostable and only about 40% is compostable from the Kalutara Pradesheeya Sabha. The composting plant is equipped with four conveyer belts to facilitate waste separation (Figure 4.3). It takes about 4 man hours to sort 1MT of waste with the conveyer belts. However, 100 percent sorting could not be expected and only recyclable items are separated from the mixed waste received at the composting plant.

Composting plant is established at the same site which was used as a dumping site for more than 50 years. Due to this, people had not resided in the vicinity. Therefore, the composting plant has been not subject to much public criticism.

Figure 4.2: Conveyor Belts used for Waste Separation

The composting plant has the capacity of handling 60 tons of waste per day though currently it process only about 30 tons of waste collected from both Pradesheeya Sabha and the Urban Council of Kalutara. Average composition of waste collected from the Pradesheeya Sabha is significantly different than the waste collected from urban council areas.

Every three months, quality of the final compost is tested at the Horticultural Crop Research and Development Institute. The Atomic Energy Authority performs the heavy metal analysis. However, estimation capacity is limited to 100 tons per month. Up to now quality improvement is not practiced.

Cost of salaries and welfare expenses are borne by the Waste Management Authority. It provides an annual medical scheme worth Rs.200,000 which covers the entire family of the workers. In addition, workers were given protective gear such as gloves, masks, and boots twice a year. Overall health of the workers is screened by the health camps conducted by Public Health Inspectors every 6 months. Other financial incentives they receive include an year-end bonus payment and encashment of unutilized leave.

Sales and Marketing

Main users are tea growers and marketing is done by the fertilizer dealers. Current price of a 50kg compost bag is Rs.510/= at the composting site and Rs.530/= at the market.

Farmers mainly depend on the technical expertise and agricultural officers' of the Department of Agriculture as well as officers attached to Agrarian Service Centers in their respective areas. Since, MSW composting projects function separately, farmers are concerned over the suitability of this MSW compost for cultivation purposes.

CHAPTER FIVE

Financial Analysis of Producing Municipal Solid Waste Compost

5.1 Economic Analysis of Composting Municipal Solid Waste

Economic analysis was performed using the data obtained from the Balangoda Urban Council to find the incremental benefits due to composting (Table 5.1).

Following cost components were considered in the analysis.

1. Capital cost for construction of composting plant
2. Machinery cost and other equipment related to composting
3. Management cost (Labour, Transportation, loading, unloading, sorting, pilling, electricity, water etc). It should be noted that costs for open dumping were deducted to calculate the actual cost of composting
4. Production of compost (cost of nutrient enrichments, packaging, etc)
5. Cost of management of the recycling product sales center

Table 5.1: Cost Components Considered in the Analysis

1. Capital Cost	**Rs.**
1. Building cost/ construction cost	12.5 million
2. Equipment cost	
Tractors	4 million
Bobcats	2.9 million
Other Machinery	1.0 million
Mamoties………etc	0.7 million
2. Recurrent Cost	
Labour	
Salary for labourers (for each activity) ex. Collecting, sorting, loading unloading, packaging etc	351900 per month
Overtime payment/day (for above each activity)	5000 per month
No of Supervisors/wages	15000 per month
Transportation charges of garbage handling/loading/ sorting/pilling	350000 per month
Electricity and other costs…..	10000 per month
3. Production compost	
Amount of waste generated per day	27 MT
Amount of compost generated (Kg/day)	1400
Cost of packaging	Rs. 35 per 50 kg
If enriched with inorganic nutrient, amount of money spent for 1kg of compost	Rs.7.00 per kg
Price of compost/kg	8.00 per kg
4. Recycling	
Income from recycling products (Rs/day or Rs. /month)	Rs.45000 per month
5. Sale center management cost	Rs. 20000 per month

Source: Balangoda LA, 2012

Benefits considered in the analysis included the following components

1. Market value of compost
2. Earnings by selling recycling products

Assumptions and conditions used in the analysis are as follows:

1. Incremental benefits of compost production were taken into account because the cost of waste management is an essential expense that these authorities have to bear to maintain a healthy environment without considering any profits
2. Lifespan of the composting plant is 25 years
3. Composting mechanism and the generated waste to compost ratio in the year 2012 is assumed to be prevailing until 2037
4. The discount rate was taken as 7% as stipulated by the Central Bank of Sri Lanka in 2012.
5. Waste generation amount remains unchanged during the period 2012 to 2037.
6. Land value for composting and dumping was taken as same and was not included in the calculations
7. Government policies regarding this mechanism remain unchanged during the total period of the project
8. The extended environmental benefits of composting of municipal solid waste such as benefits as a soil conditioner , reduction of land degradation, provision of micro nutrients and reduction of water pollution due to reduced usage of chemical fertilizer were omitted in the analysis due to lack of data

Results of Cost Benefit Analysis

Calculated Net Present Value (NPV) for composting is Rs. 16340892.8 and Benefit Cost Ration (B/C ratio) is 1.44. Overall, the investment for waste management via composting has generated positive results with the positive value of NPV and also it has shown more than 1 for B/C ratio. The Economic Internal Rate of Return (EIRR) indicates the financial viability of capital investment. The IRR is 5% in the project. The investment can be earned within 9 to 10 years period of the project. All the values such as NPV, B/C ratio and EIRR will be much higher when this analysis includes the environmental benefits.

CHAPTER SIX

Findings, Conclusions and Recommendations

6.1 Findings

1. In all composting plants surveyed, the composting projects continue to function with sufficient encouragement from the respective politicians as well as personal commitment of the officials attached to the project. Continuous political backing is essential for the success in all activities such as finding funds for initial investment, getting a land for the composting plant and marketing the final product.

2. Collaboration of managers of the MSW composting plants with the agricultural officers regarding the quality and the nutrient content of the produced compost is very limited. Promising developments can be observed currently in Bangladesh where local government authorities as well as the Ministry of Agriculture are supporting and promoting composting and the use of compost in agriculture (Zurbrügg, 2002).

3. Though government has invested huge amounts of money on these composting projects, making it compulsory to produce compost from MSW in all local authorities, government intervention in improving its quality for agricultural use and making a suitable marketing arrangement is still not adequate. Currently the burden of marketing the product also has to be borne by the respective local authority. Many large and small composting schemes have failed due to inadequate attention paid to marketing and the quality of the product (ibid).

4. Majority of the composting plants do not fully utilize their MSW for composting due to limited marketability. This situation sends larger proportions of waste to open dumping sites.

5. Social objections were less when these composting plants are located on same lands which were earlier used as open dump sites. It was observed that when the land is selected in a less populated area within the area of waste collection and when the project has contributed to develop infrastructure facilities and create employment for the neighbouring families it was able to get the support of the society. In the event when open dump sites located adjacent to the composting sites are not maintained in a sanitized way, social objection is directed towards the waste composting process as well.

6. Waste separation is still at a poor level in most of the composting plants, and little effort has been taken to avoid heavy metal contamination in the final compost. However, with higher level of public awareness, volume of waste generated as MSW could be reduced and it has reduced the time taken for sorting of waste.

7. Lack of quality assurance for MSW compost is a barrier in promoting its use in agriculture. If a quality assurance could be given by the government at least about the status of heavy metal content, marketability of the product is much higher.

6.2 Proposed Channels of Marketing

It was learnt during the key informant discussions and focus group discussions that the main constraint for marketing of compost is the consumers' doubts regarding the quality parameters such as soluble salts, heavy metals and toxic microbes. Since testing regular batches of compost by individual producers is not practical due to high cost of testing facilities for heavy metals etc, it is proposed to establish packaging centers at central locations. Local authorities can be paid for the carbon content in each batch of compost, because carbon is the most cost effective element to analyze. At those centers, necessary quality should be tested and suitable enrichment also could be done according to the most popular type of crop in that area. Responsibility of proposing the most suitable composition for each crop type could be handed in to research institutes that are currently working on that particular crop. After doing so, compost could be marketed under one brand with government's quality assurance. This will build trust among the users. Marketing facilities could be arranged through Agrarian Service Centers at village level with subsidized chemical fertilizer.

6.3 Conclusions

1. The success of MSW composting projects is largely observed with high level of political and managerial commitment towards project activities.
2. Functioning MSW composting plants do not produce compost to their full capacity as marketing avenues are currently limited for compost produced from MSW.
3. Community participation in source separation of waste is at a lower level in many areas and it could increase considerably through frequent public awareness programmes.
4. Government involvement in composting MSW is limited in assuring its quality for agricultural use. However, government assistance is necessary to monitor the quality of MSW compost regularly and to create an assurance among the users regarding its suitability in using agricultural purposes.

6.4 Recommendations

1. Composting plants should preferably be located in previous garbage dumping sites and indirect benefits to the residents such as employment opportunities at the project, developed infrastructure facilities should be considered.

2. The Government should make necessary policy changes to make composting MSW operate as a complete package that assures systematic collection of sorted wastes, purchasing of recyclable wastes, and implementation of legislations to reduce waste generation.

3. Public awareness programmes regarding the importance of separating degradable and non degradable items at household level should be strengthened. It should adopt suitable legislations that will be beneficial towards this task.

4. Current composting programmes should strengthen in getting the contribution of all stakeholders including compost producers, agricultural experts and users to improve the quality of MSW compost as a soil amendment as well as a nutrient supplement.

5. Government intervention is needed in assuring suitability of MSW compost for different purposes such as in cultivation of horticultural crops, plantation crops, floriculture and etc.

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Annex 1

On-site Composting of Household Organic Waste

In Sri Lanka, the pit method is the most common and traditional way of composting of degradable waste in-house. Solid waste originates from kitchen and food wastes are co-disposed with garden sweepings/trimming in a pit at the backyard of the dwelling. The decomposition in the pit method resembles the natural decomposition except the fact that the feedstock is mixed and turned a few times a year. The decomposed material at the bottom of the pit is traditionally used in home gardens. The pit composting system is among the best alternatives to reduce the waste generation at the source, especially in rural or semi-urban areas in Sri Lanka. The heap method is a popular method used for composting garden waste and yard trimming, but has limited application for MSW of Sri Lanka.

Jeewakotu is another popular on-site composting method where waste is packed in an above ground structure made out from live sticks (e.g. *Gliricidia sepium*). Opposite to the pit method, *Jeewakotu* can diffuse more oxygen to the feedstock thus create a more favorable condition for rapid decomposition, but required regular watering in dry weather, especially in the dry areas of the country. Although *Jeewakotuwa* was originally introduced to make organic manure with yard trimmings at home gardens, now it has become a popular method to manage food waste in schools and model farms.

Pit method and *Jeewakotu* are not popular on-site composting methods in urban and semi-urban areas in the country due to inadequate space in small backyards in urban dwellings. Instead, home composters are becoming popular among urban households. Over the last few years, Sri Lankan government and NGOs are promoting home composters to reduce the recyclable organic waste in MSW stream. There are different types of home composters available in the market as well as supplied through local authorities at a subsidized price. However, due to faults in design and inadequate knowledge on compost making among households, the success of home composters remains low. The following figure summarizes the technical features and a brief analysis on on-site composting methods follows.

Annex Figure 1: Common Methods of On-site Composting of Organic Waste in Sri Lanka

Pit composting	Advantages; ✓ Easy to construct and minimum operation & maintenance requirement ✓ No or minimum cost of construction Disadvantages: ✓ Requires a relatively large area ✓ Use of meat & fish waste is not recommended ✓ Requires a relatively long time to decompose	
Jeewakotuwa	Advantages; ✓ Easy to construct and minimum operation & maintenance requirement ✓ Relatively low cost of construction Disadvantages: ✓ Requires a relatively large area ✓ Use of meat & fish waste is not recommended	
Home composters	Advantages; ✓ Composters are available at subsidized price & in markets ✓ Small land area requirement Disadvantages: ✓ Purchasing and transport cost ✓ Requires basic skills to operate ✓ Difficult to fabricate in-house	

In-situ composting reduces the amount of waste flow into the MSW stream and recycle the valuable materials in organic waste back into the garden. However, there are some common problems associated with in-situ composting; lack of knowledge on composting process that leads to use of inappropriate feedstock such as non-degradable and fibrous organics, difficulty in managing leachate, fly and worms , and irregular feeding/unloading of compost (Lekammudiyanse and Gunatilake, 2009). Thus, some local authorities are reluctant to promote in-situ composting as a segment of integrated solid waste management.