TOWARDS SUSTAINABLE OPERATION AND MANAGEMENT OF CENTRALISED COMPOSTING IN SRI LANKA

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This report presents three case studies in the context of centralised large-scale composting facilities in Sri Lanka in order to reveal the factors and approaches that led to positive results under different type of operational modality, i.e., 1) single municipal operation, 2) provincial operation, and 3) joint consortium operation (operated by two municipalities). This report is expected to enhance the capacity of local authorities in Sri Lanka and other countries, and also raise the level of knowledge on composting as well as planning and decision-making skills for successful implementation of composting facilities.

The case studies in this report identified the following critical factors for replication:

- There is no single solution for all cities. Composting system, technology to be applied, and operational modality should be selected based on the assessment of the capacity of the responsible agency and practical negotiation with potential partner(s) who could fill the capacity gaps (e.g. financial and technical insufficiency) in addition to the self-capacity development. Collaborative relationship tends to continue when win-win situation among the partners maintains.
- Implementation of source segregated waste collection is a prerequisite for successful composting operation. To do so, improvement of collection service, enforcement of rules and regulations, and continuous awareness raising and education are essential.
- Private operator and provincial authority is relatively better at efficient operation of a large scale composting facility with qualified staff, equipment, and enough finance, which could bring improvement of compost quality, innovation of value-added product, and proactive marketing, than operation by small individual local authority. However, involving multiple actors in the management is not always easy because they intervene in the decision-making process.
- Therefore, responsibilities among key actors should be clearly identified and officially agreed or approved by relevant authorities when the composting system is managed by multiple actors.
- For the successful operation of the composting systems, at least, the operational cost should be covered by the direct income including compost sales and tipping fees. In addition, a reduced MSW management cost resulting from diverting the biodegradable waste from landfill/dumpsite to compost and other co-benefits such as mitigation of adverse impact on health, environment and climate can be calculated and subsidised to cover the loss.

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1. INTRODUCTION

1.1. Objective

The growing population, rapid urbanization and industrialization in Asia have all contributed to acceleration of waste generation. Waste management, therefore, is one of the growing concerns of local authorities (LAs) in Asia. In general, the biodegradable fraction of municipal solid waste (MSW) accounts for 50–80% of total waste collected in Sri Lankan cities (Samarasinha et al., 2015). In highly urbanised cities, the readily biodegradable food waste, fruit and vegetable waste as post-harvest losses, and kitchen waste together account for the largest share of biodegradable waste, whereas garden waste is the most common biodegradable waste type found in rural and semi-urban areas. Composting of the biodegradable fraction of MSW can significantly reduce the waste stream volume (25–70%) to be disposed of at landfills and open dumpsites, and offers environmental and economic advantages (Karunarathna et al., 2014). Also, composting can be a preferred MSW pre-treatment option from the financial point of view because the costs of landfilling and other MSW treatment alternatives such as incineration and large-scale anaerobic digestion are much higher in developing countries (Parthan et al., 2012).

Household and community composting are commonly practiced in Asian countries including Sri Lanka, though many cases have come to light of large-scale composting failing due to improper source segregation, lack of continuous government support, lack of sense of ownership among concerned stakeholders and failure to transfer local expertise to successive or other LAs, and so on. In this context, IGES Centre Collaborating with UNEP on Environmental Technologies (CCET), during its involvement in activities in Sri Lanka, noted several case studies of successful large-scale composting. Considering the merits of composting, CCET proposed compiling a body of successful case studies in Sri Lanka, by involving various actors as well as consideration in order to enhance the capacity of LAs in Sri Lanka and other countries, and also raise the level of knowledge on composting as well as planning and decision-making skills for successful implementation of composting facilities.

This report presents three of the case studies identified as "good practices" in the context of centralised large-scale facilities. Although many examples of good practices with small-scale composting at the household or backyard level can be found in Sri Lanka, this report analyzes the operation of large-scale composting facilities which treat biodegradable waste generated from one or more municipalities in order to reveal the factors and approaches that led to positive results under multi-sector, differing responsibility and mutually-collaborative circumstances. Each case represents a different type of operational modality, i.e.,
1) single municipal operation, 2) provincial operation, and 3) joint consortium operation (operated by two municipalities). The biodegradable waste discussed here includes kitchen wastes such as vegetable and fruit peel and leftover foods, and garden waste such as grass and plant trimmings. It also includes waste from local fresh markets and daily fairs, or "Pola" in Sinhalese. The CCET team visited all the compost facilities to obtain information relevant to the report, and analysed the key findings, challenges, knowledge, and lessons learnt in each case study, which are presented herein

1.2. Composting

Composting refers to the controlled decomposition of organic matter by aerobic microorganisms into a stable, humus-like material, managed with the aim of accelerating decomposition, optimising efficiency and minimising any potential environmental and nuisance issues that can occur in the process.

As illustrated in Figure 1-1, 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 end product is compost, which is dark in colour, peat like, has a crumby texture and earthy odour, and resembles organic top soil. Good composting eliminates most of the common weed seeds and organisms that may be pathogenic to humans, animals, or plants.

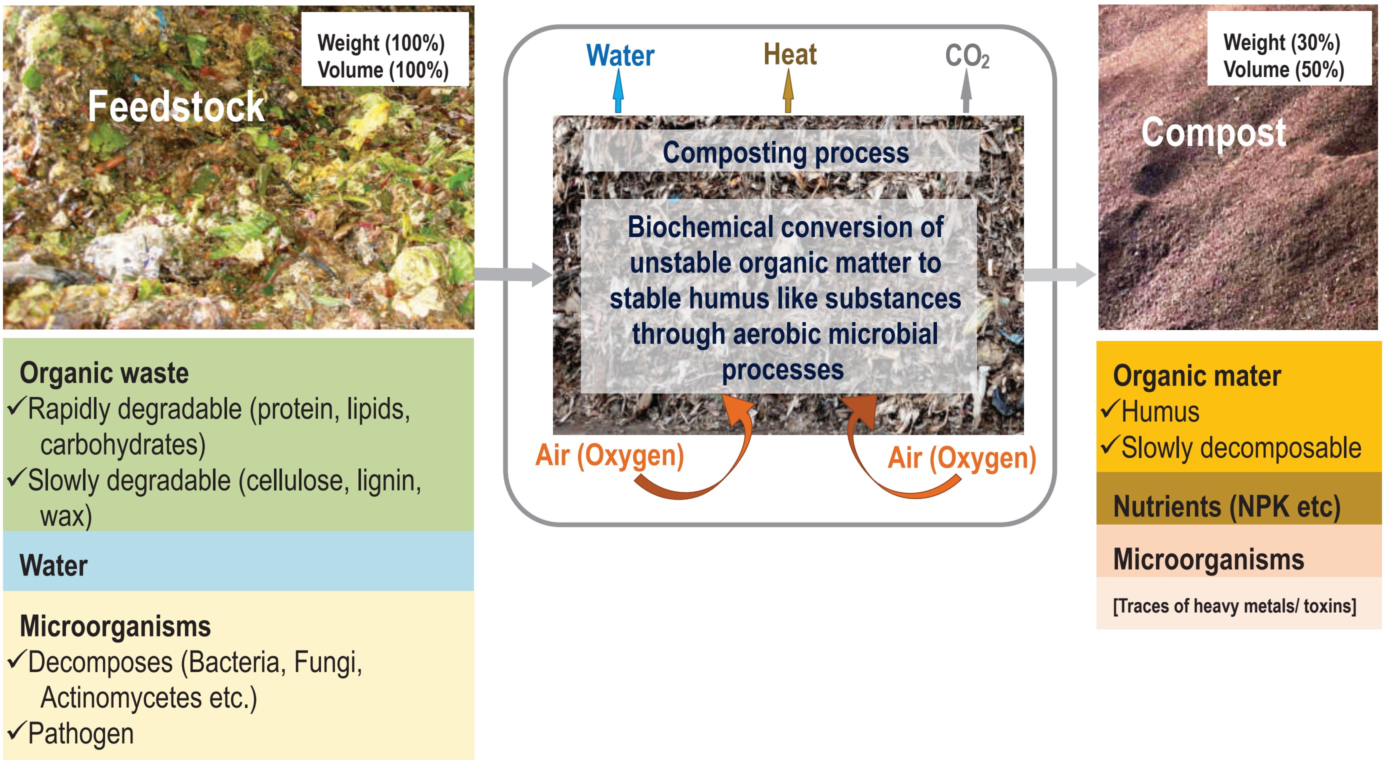


Figure 1-1 A schematic view of MSW composting process (Source: author)

1.2.1. Benefits

In the context of integrated MSW, large-scale composting in centralised facilities has become popular in Sri Lanka in particular for Local Authorities (LAs) that recognize the twofold outcomes of diverting the treatment of biodegradable waste from dumping or landfilling to composting, which are:

1. Reduction of pollution and infectious diseases
   - ✓ Air pollution and groundwater pollution at dumpsites and uncontrolled landfill sites is reduced.
   - ✓ Emission of greenhouse gases such as methane and carbon dioxide generated through anaerobic decomposition of biodegradable waste at dumpsites and uncontrolled landfill sites is reduced.
   - ✓ Risk of infectious diseases spreading by wild and domestic animals and flies attracted by food waste at dumpsites and uncontrolled landfill sites is reduced.

2. Compost with market value as an end product
   Good compost is used primarily as a soil additive or mulch by farmers, horticulturists, landscapers, nurseries, public agencies, and residents to enhance the texture and appearance of soil, increase soil fertility, improve soil structure and aeration, increase the ability of the soil to retain water and nutrients and moderate soil temperature, reduce erosion, and suppress weed growth and plant disease.

In general, however, MSW compost is not favoured by commercial farmers, especially rice and vegetable farmers, who believe it has far less direct nutritive benefits. The MSW compost sold at the market is generally made without proper sorting of waste feedstock at the origin and inappropriate operation at the facility, which leads to poor quality. Due to low demand, MSW compost is sold at minimum prices and used for home gardening, including floriculture and gardening. As an alternative to compost, organic rice farmers to a lesser extent and vegetable growers to a greater extent tend to use cattle manure.

To improve the quality of MSW compost, some LAs and entrepreneurs develop value-added quality compost, through which not only sales revenues but also the environmental benefits will be increased. The value of compost depends on its quality, which is in turn determined by many factors, such as nutritional value, feedstock quality, applied technology, processing conditions, and storage conditions (Samarasinha et al., 2015). Sri Lanka established a compost quality standard (SLS 1243:2003) to improve the quality of compost to safeguard consumers and expand the marketing potential, though there is no obligation for producers to meet this standard.

1.2.2. Required Technology and Techniques

There are various techniques and technologies available for large-scale composting, which all need to fulfill several requirements: 1) sorting of MSW and removing materials that are difficult or impossible to compost, 2) reducing the particle size of the feedstock material, 3) applying optimal composting conditions to feedstock, and 4) treating leachate.

1) Sorting: Although conventional municipal waste collection practices focused on cleansing and removal of waste from residences, the ideology has evolved – due to concerns from both waste generators and collectors about environmental conservation and 3Rs – into the source segregated waste discharge and collection practiced today. This change in discharge and collection practice helps raise the quality of compost and reduce operational costs for manual sorting at composting sites, which requires 3–5 workers over 2–3 hours to treat one vehicle load (2.5 metric tonnes) of waste every day. To facilitate source segregation, LAs should recommend, within budgetary constraints, that collection of biodegradable waste be frequent enough to prevent waste from causing foul odour or an environmental nuisance at source.
2) Reduction of particle size of feedstock: Generally, feedstock particle size reduction is not necessary as kitchen and market waste particles are in an acceptable range (< 15 cm). On the other hand, garden trimmings and more bulky biodegradable waste such as banana stems which are too large to handle need to be shredded into small particles. At centralised composting facilities, large waste particles are manually cut into small pieces with a knife. However, shredding of all waste is problematic as it mashes everything into a slurry due to the high moisture content.
   As an alternative to reducing feedstock particle size, some facilities mechanically shred mature compost before sieving it. However, shredding of mature compost to smaller particles creates new issues such as the disintegration of undecomposed or immature organic particles and mixing of small inert particles with the end product compost.
3) Treatment of feedstock: Feedstock conditioning such as moisture control, bulking to increase porosity, and nutrient balancing are important aspects of composting. In Sri Lanka, some composting facilities apply an affordable and efficient method in which the larger fraction of decomposed waste is extracted after sieving and used as a bulking agent for fresh feedstock. This mixing of backend sieving residues lowers the moisture content of feedstock, increases porosity, and mostly obviates the need to balance nutrients for municipal biodegradable waste owing to the beneficial mix of different types of feedstock, i.e., kitchen waste, vegetable and fruit waste and garden waste.
4) Leachate treatment: Excess moisture is formed due to the compaction and degradation of biodegradable waste at the early stage of composting, which oozes out as leachate and needs to be collected and treated as an integral part of a well-planned composting facility. Composting facilities generally employ two ways to treat leachate: 1) lowering of feedstock moisture content by mixing with dry backend refuse, and 2) collection or diversion of the leachate from fresh composting masses into tanks for further treatment or recirculation back into the dried composting piles to supplement water.

1.2.3. Policy and Strategy

Sri Lanka, a lower-middle-income country with a GDP per capita of 4,073 USD (2017) and total population of 21.4 million (Central Bank of Sri Lanka, 2020), has achieved steady economic growth and infrastructure development in its urban and rural areas. At the same time, however, rapid expansion of the economy and urban population has brought about environmental and health problems. One study estimates a total of 5,976 Metric Tonnes Per Day (MTPD) of municipal solid waste is generated, which is expected to grow at 1.2% per annum (NSWMSC, 2015). In this context, urban waste management, also known as Municipal Solid Waste (MSW) management, has been identified as a key environmental and social issue.

In response to this issue, the Ministry of Environment and Natural Resources issued *the National Strategy for Solid Waste Management* in 1999 to provide directions to improve solid waste management in the country, which suggests policies be formulated to encourage waste avoidance, reduction, re-use, recycling, treatment and final disposal. Another important directive is *the Technical Guidelines on Municipal Solid Waste Management*, published by Central Environmental Authority in 2004. Following this was the *National Waste Management Policy*, introduced by Ministry of Environment and Natural Resources in 2007 to ensure integrated, economically feasible, and environmentally sound solid waste management practices at all levels – national, provincial and local, which was subsequently revised in 2018 to both accommodate growing concerns over the promoting Polluter Pay Principle as well as involving the private sector in waste management activities. It was approved (Sri Lanka on 2019-09-03) by the Office of the Cabinet of Ministries.

Consequently, there has been a paradigm shift in the perception of waste management from being an LA-led role of removal and disposal while avoiding any public nuisance[1] to one emphasising waste minimisation and resources recovery, with the ultimate goal of a national sustainable solid waste management programme. Based on the *National Waste Management Policy*, the Ministry of Environmental and Natural Resources launched a national programme, called PILISARU, under the Chairmanship of Ministry of Environment and Central Environmental Authority. Aimed at solving the country's MSW issue within five years starting in 2008, and with central government funding of 5.675 billion LKR (43.6 million USD) for its first three years, the programme set about developing large-scale composting facilities through a process of mechanization, which continued, through extension, to 2015. Initially, compost bins were provided at subsidised prices to start improving compost production at the LA level, and together with technical inputs from National Solid Waste Management Support Center (NSWMSC) and financial support through PILISARU and international donor agencies such as European Union (EU) and Japan International Cooperation Agency (JICA, 2003), the number of establishment of MSW composting facilities accelerated throughout the country to 156 as of 2019 (see Figure 1-2).

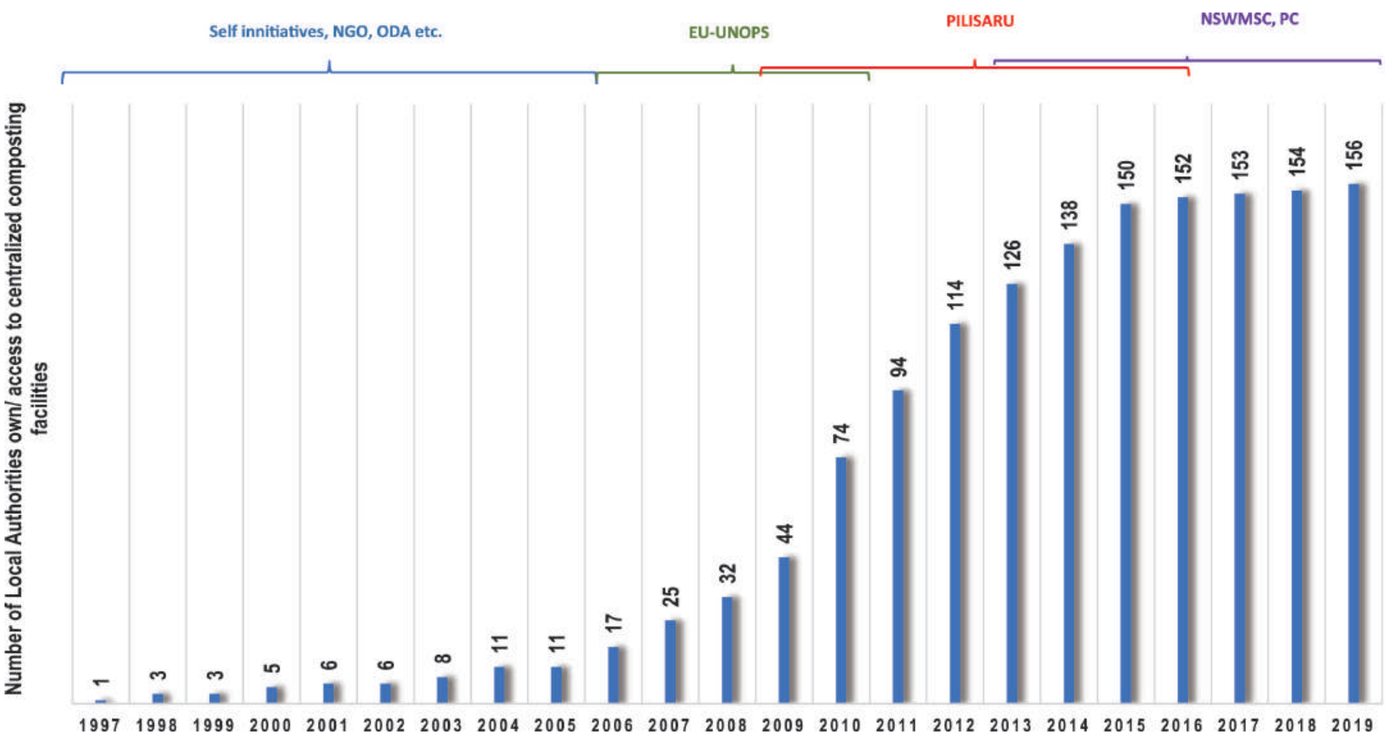


Figure 1-2 Centralised composting facilities installed in Sri Lanka (1997-2016)[2]

1 All MSW generated within LA boundaries is considered the property of the LA, according to Municipal Council Ordinance (No. 29, 1947), Urban Council Ordinance (No. 61, 1939) and Pradeshiya Sabha Act (No. 15, 1987)

2 Data from PILISARU, UNOPS, and NSWMSC reports (2000 to 2018)

Separately from the recent change in perception over MSW management, home and garden composting had long been traditionally practiced. The start of large-scale composting can be traced back to the 1990s, with the advent of a small composting facility established by Weligama Urban Council, which thereafter expanded its daily capacity to 2–3 metric tonnes of biodegradable waste and is still in operation today.

According to Environmental Impact Assessment (EIA) and Initial Environmental Examination (IEE) (National Environmental Act No. 47 of 1980: Schedule 772/22) which is one of legal frameworks for processing and disposal of hazardous waste and related activities[3], an EIA/IEE shall be conducted prior to project implementation only if the waste handling or disposal amount exceeds 100 MTPD. Since most composting facilities in Sri Lanka have capacities below this, an EIA/IEE is not usually conducted. However, it is mandatory to obtain permission from all concern stakeholders prior to implementing each project. Each facility also needs to obtain an Environmental Protection License from the Central Environmental Authority (CEA) for scales exceeding 10 MTPD (or at any scale if the operator is the LA), or from the relevant LA (if the operator is not an LA) prior to its commencement, which licenses need renewing every other year (CEA regulation No. 1533/16 of 2008).

2. CASE STUDIES

Three cases of large-scale composting were selected, based on their operational modality: 1) single municipal operation in Kuliyapitiya Urban Council, 2) provincial operation in Kalutara District, and 3) joint consortium operation (operated by two municipalities) in Kandy District. The cases were then analysed in the aspects of efficacy, technical feasibility, financial sustainability, environmental impact, and sense of ownership. Figure 2-1 shows the locations of the selected three composting facilities and Table 2-1 provides a summary of the three composting facilities and their operations.

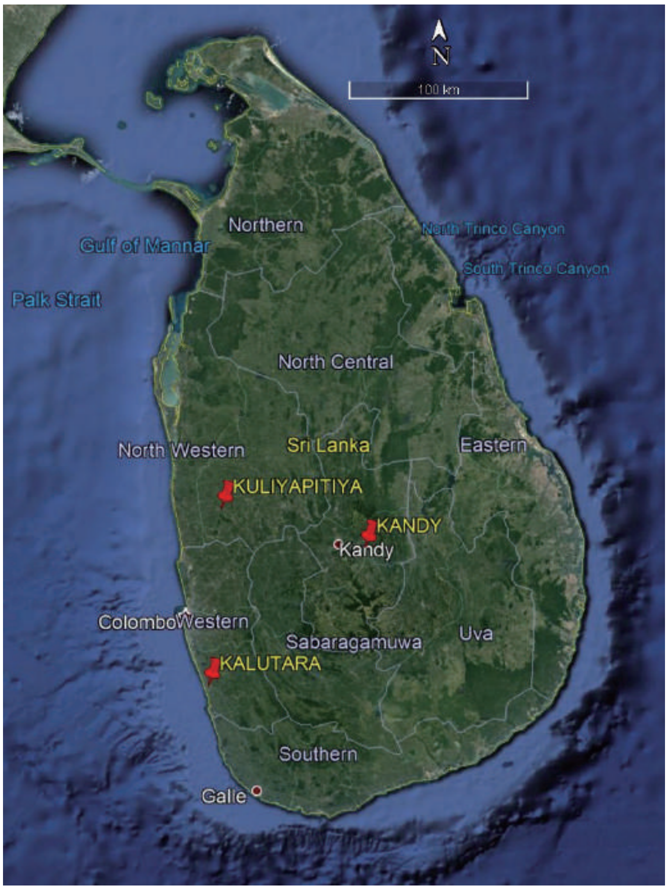


Figure 2-1 Case study locations (from google map)

3 Regulated under the National Environmental Act. No. 47 in 1980 and amended by Acts No. 56 in 1988 and No. 53 in 2000

Table 2-1 Highlights of three case studies

Name of facility, location	Description	Operational modality	Type of technology used	Estimated waste generation & collection at LA	Compost production capacity
Environmental Preservation Centre, Kuliyapitiya	One of the first integrated solid waste management models to include composting, recycling and landfilling facilities. Established in 2009 with technical assistance from JICA and NSWSC with PILISARU funding.	Single municipality management-Kuliyapitiya Urban Council (KUC)	Windrow	Generation: 10 MTPD Collection: 9 MTPD	10 MTPD
Mihisaru Compost Facility, Kalutara	Large-scale composting facility established in 2011 under PILISARU and later developed and improved by WMA-WP. Waste from Kalutara PS (KPS), Kalutara UC (KUC) and 4 other LAs was initially treated (currently waste from KPS, KUC, and Kalutara Bodhi is treated).	Provincial government management-Waste Management Authority of West Province (WMA-WP)	Windrow	Generation: no data Collection: KPS: 12 MTPD KUC: 35 MTPD	22–38 MTPD
Kawashima Composting Facility, Kandy	Established in 2015 with financial assistance from JICA and LA funds. Operated by consortium of KPS and PPS with waste from KPS, PPS and other LAs.	Joint consortium - Kundasale PS (KPS) and Pathadumbara PS (PPS)	Automated Screw Augur type	Generation: KPS- 60 MTPD PPS- 35 MTPD Collection: KPS-15-20 MTPD PPS-5-10 MTPD	25 MTPD

2.1. Municipal Operation, Kuliyapitiya Urban Council

2.1.1. Background

Kuliyapitiya Urban Council (KUC) is the second largest township in Kurunegala District, North Western Province of Sri Lanka. Located 82 km NE of Colombo, it is a small LA with only 3.8 km^2 of land area and population of 6,554, as of 2018 (Figure 2-2).

Until 2008, all solid and liquid waste was openly disposed of on a barren patch of land at a corner of the city through creating piles on the ground and then burning it in order to recover the space for the next disposal (left photos of Figure 2-3). The smoke from

Country	Sri Lanka
Province	North Western
District	Kurunegala
Size	3.8 km^2
Climate	Tropical (28-33°C)
	2,800 mm average annual rainfall
Topography	Flat terrain (~ 30m above MSL)
Land use	Residential & home gardens
	Coconut plantations
Population	Residential 6,554 (2018)
	Floating 5,000 (2018)
Dwellings	1,422 (2018)
Waste generation	10 MTPD (estimated)
Waste collection	9.0 MTPD

Figure 2-2 Location and description of Kuliyapitiya Urban Council

Figure 2-3 Kuliyapitiya waste disposal facility (before and after 2009) (Source: author)

the dumpsite created a highly unpleasant environment and represented a high health risk to nearby residents approximately 200 m away. While KUC came under heavy pressure to close the dump site and create a new one, locating a new one was not possible due to the limited land resource within the city.

2.1.2. Initiative

As a result of a nationwide survey conducted by NSWMSC, it was identified that KUC was one of the LAs requiring urgent assistance. At the inception of NSWMSC and PILISARU in 2008, the Chairman, council members and staff of KUC unanimously agreed to put forward a proposal to PILISARU to establish an integrated solid waste management system within the city, with technical assistance from NSWMSC. The technical proposal was approved by the Ministry of Environment, which made a total capital investment of 22,214,844 LKR (185,123 USD) to establish an Environmental Preservation Centre (EPC) at the dumpsite (right photos of Figure 2-3 and Figure 2-4). The EPC, which consists of resources recovery facilities and a windrow composting facility, was developed based on prior experiences in Sri Lanka and other countries, and supported by NSWMSC, which sourced and financed consulting on the facility design. The design itself was conducted by experts from the University of Peradeniya with guidance from Japanese experts using the capital investment from PILISARU.

The EPC was designed to be a role model for many other LAs to follow, and planned such that the composting system alone would not provide a sustainable solution, due to the presence of waste that cannot be recycled or decomposed, as well as the need to address leachate and sewage issues. Therefore, planners proposed an integrated waste treatment and disposal facility with a small biogas unit for fresh, highly perishable food waste (e.g., fish market waste), a composting facility for biodegradable waste, a recyclable material recovery facility to sort and recover non-degradable waste, and a small semi-engineered landfill facility for remaining residual waste disposal. Table 2-2 shows the investment cost of each facility in the EPC.

Figure 2-4 Environmental Preservation Centre (EPC) (Source: author)

Table 2-2 Investment cost of the Environment Preservation Centre (EPC)[4]

Facility	Area	Funded by	Year	Investment LKR (USD)
Composting buildings (windrow)	675 m^2	PILISARU	2008	7,820,001 (65,166)
Semi-engineered landfill site for residual waste	1,650 m^2	PILISARU	2008	
Worker's restroom/office with sanitary facilities	24 m^2	PILISARU	2009	14,394,843 (119,957)
Leachate & sewage treatment facility	400 m^2	PILISARU	2009	
Access road, fencing, biogas unit, machine & equipment	1,057 m^2	PILISARU	2009	
Material Recovery Facility (MRF)	221 m^2	PILISARU	2009	

2.1.3. Collection Activity

A full-scale windrow composting facility with a biodegradable waste capacity of 10 MTPD was installed in the EPC. After full operations commenced in 2009, the biggest challenge was to sort mixed MSW received through the conventional collection system, as is normally practiced in centralised composting facilities. This required the facility management to employ 5–6 workers per day to sort the incoming waste into degradable and non-degradable, and meant KUC had to spend more time and labour on separation than initially planned at the project inception.

Based on the logic of waste segregation at source reducing the burden on the facility and the level of contamination of recyclable waste (e.g., paper, cardboard, plastics) during discharge and transport, KUC developed short-term and long-term action plans to implement source segregated waste collection for the entire city, starting with the Bell Collection scheme, introduced to a single city ward as a pilot project. The scheme employed a vehicle to collect biodegradable waste from households, hotels, restaurants, and offices, using music to announce its presence and thus have garbage bins brought to the collection vehicle. This meant no waste remained on the streets, and kept the towns clean (Figure 2-5).The waste generators are duly warned that collection is declined by the workers if waste is not correctly separated at source, but mixed waste disposed of at public places is collected separately. Workers on the vehicle inspect the waste bins before emptying them to ensure waste is completely segregated. The residents willingly cooperate in the source segregation owing to its regularity and service consistency. Owing to support and encouragement received from city authorities, especially in the political, administrative and public health sections, workers could more effectively implement source segregated collection.

With the success of the source segregated waste

4 Data extracted from Annual Budget Report of KUC (2008 to 2009)

Figure 2-5 Bell collection (Source: author)

collection pilot project, KUC expanded the scheme to two further council wards in 2010. In 2014, reusable polysack bags (50 L) were distributed among households to facilitate separation of waste into degradable and non-degradable types. With continuous efforts in public awareness raising activities and support from JOCVs, all biodegradable waste collected from the two wards can be directly heaped up into composting piles without the need for waste sorting at the facility. As of 2016, KUC implements source segregated waste disposal and collection throughout the entire city with six tractors. Because the collected waste is correctly segregated, manual sorting at the composting facility is rarely needed, which enabled a reduction in the labour requirement from 18 persons in 2009 to 10 by 2015. Acknowledging the positive steps taken by KUC to implement source segregated waste collection, a skid steer loader to support composting operations was donated by PILISARU, which resulted in a further reduction in the labour cost for waste handling.

2.1.4. Processing Activity

First, the collected waste is unloaded on the open ground outside the roofed area of the composting facility, where each waste load is thoroughly inspected and non-biodegradable waste is manually removed. Using the skid steer loader, the biodegradable waste feedstock is filled into a wooden pen (2 m wide, 4 m long and about 30 cm high) to form a block-like pile until it reaches a maximum height of about 2 m (Figure 2-6). Forming piles of fresh waste outside the building attracts cranes and other birds which helps prevent fly breeding as they consume any fly larvae in the feedstock.

The first turning is performed after two weeks, followed by weekly turning. While the loader turns the heavy waste pile, small tasks such as spreading and compacting the waste on the pile are performed manually, and watering is needed especially when the pile starts to mature after about 10 weeks of initial decomposition.

Leachate ooze from new waste piles (first five weeks) is diverted to a treatment plant through a concrete

Figure 2-6 Piling up composting feedstock using wooden frame and skid steer loader (Source: author)

drainage system (Figure 2-7). When excessive amounts are generated during the rainy season, operations including initial waste piling are carried out under the roof. The leachate treatment facility is a locally built coconut coir brush-based system mimicking attached-growth biological treatment. It was designed to treat not only leachate from the composting facility, but also treat partially decomposed sewage collected from city households and offices. Treated wastewater is reused at the composting plant whenever watering is required.

After mature compost is sieved by a 4 mm mesh trommel screen in accordance with Sri Lankan standards, the sieved fractions are packed into 25 kg polyethylene bags and sealed. The residue and larger fractions are mixed with incoming fresh waste to control moisture and increase bulk. The small amount of residue, comprised of plastic particles and inert matter, is disposed of at a semi-engineered landfill (Figure 2-7).

This composting activity has created employment for a total of nine permanent staff who were recruited from nearby communities by KUC. One person works at the compost sales outlet, another operates the skid steer loader, and the others, including female staff, support daily operations such as sorting, watering, compost sieving and packaging. Overall management of the site is handled by a trained municipal supervisor who also handles record keeping. All staff are supplied with protective gear such as gloves, boots and detergents to prevent contamination and infection. Moreover, all staff have undertaken National Vocational Training (NVQ level 2) in order to safely handle the machinery. The challenge is to maintain the machinery in good condition because maintenance costs including for servicing, repairing and spare parts such as tires and mechanical wear are very high.

Differing from other LAs, most of the workers in the EPC are young and educated. They work under a flexible

Figure 2-7 Leachate treatment (left) and residue waste disposal facility (right) (Source: author)

Table 2-3 Summary of composting at EPC

Item	Description of Composting Facility
Type of Facility	Windrow Composting
Production Capacity	Up to 10 MTPD
Particle size of finished compost	Less than 4 mm
Duration of production	12 to 15 weeks
Annual waste input (A)	1,977 MT (2017)
Annual compost production (B)	494.2 MT (2017)
Composting rate (=B/A)	25%
Equipment	1 skid steer loader 1 trommel sieve with capacity of 100 kg/hour 1 four-wheel tractor and trailer 2 water and leachate pumps

schedule with duties beginning in early morning and continuing until late afternoon, and are free to return home for lunch or take brief breaks, which results in a comfortable work environment. Operations continue over weekends and holidays, which helps to avoid backlogs and overloads, and overtime and holiday work is also recompensed. In addition, KUC carries out health checkups for all workers at least once annually. This unique, caring work environment enables KUC to attract young workers from neighbouring villages, who consider it homey and have decorated the garden and facility using recycled items. Due to the staff's dedication, the facility is professionally managed and the neighbouring communities can live unaffected by nuisances such as flies and foul odours.

2.1.5. Financial Analysis

In Sri Lanka, MSW composting is perceived as the foremost way of reducing amounts of biodegradable waste. Although the produced compost is used mainly by households for gardening by many LAs, KUC investigated means to earn extra income from compost sales in order to partially cover the costs incurred by the EPC, as well as ways to reduce amounts of waste disposed of at the dumpsite. The solution was to offer all the compost produced at the facility for purchase, while reserving some for occasions such as community events where it is distributed free of charge to the community. Consequently, the focus was redirected to raising the compost quality, which was achieved through source segregated waste collection, proper processing, and regular quality testing at least every six months via government-approved laboratories. Disclosure of the test results gives the operators visibility of any issues that need rectifying in the manufacturing process and helps build confidence in the buyers as well as raise recognition in the compost market.

The compost produced can be directly purchased at sales outlets in the city (Figure 2-8), by payment at the KUC office, or bulk purchase at the EPC. Direct unit sales at the EPC are restricted to prevent fraud and ensure accountability of the sales process. Maintaining all financial records at the EPC enables full financial audits at the end of each year.

Table 2-4 shows a summary of a financial audit conducted by the authors. Direct cost analysis shows that KUC bears a net loss of about 1,158 LKR (6.8 USD) for each metric tonne of compost produced, with the highest cost element in operations incurred

Table 2-4 Summary of financial status of the composting facility for 2016–2017[5]

Item	Value	Units
Waste received at EPC	1,977	MT
Compost produced	494.2	MT
Compost sold	107.5	MT
Compost stored	386.7	MT
Income		
Selling price of compost	8,000 (47)	LKR (USD)/MT
Total income (including compost stock)	*3,953,600 (23,256)*	*LKR (USD)*
Expenditure		
Personnel remuneration	3,978,504 (23,403)	LKR (USD)
Services (electricity, water)	16,174 (95)	LKR (USD)
Fuel and lubricants	325,563 (1,915)	LKR (USD)
Consumables	90,600 (533)	LKR (USD)
Machine repair and maintenance	114,795 (675)	LKR (USD)
Total expenditure	*4,525,698 (26,622)*	*LKR (USD)*
Total profit [loss] for processing one metric tonne of compost =((total income – total expenditure) / compost produced)	**[1,158 (6.8)]**	**LKR (USD)/MT**
Note: 1 USD = 170 LKR		

5 Result of the auditing by the author

Figure 2-8 Compost sales centre (Source: author)

by salaries and wages of workers, comprising about 88% of total expenditure. Possible routes to increasing the profit ratio include finding a way to improve work efficiencies and raising sales amounts by improving the compost quality and expanding the market.

The produced compost satisfies all national standards (SLS 1243:2003) except for substantial amount of fine inert, soil and sand for use as agricultural compost. Distribution of separate bags for households to fill with biodegradable waste has partly solved the issue but waste from other sectors still forms a considerable amount of the inert fraction. At present, KUC is studying technical solutions from NSWMSC, Universities and research institutes.

2.1.6. Supportive Activity

The main focus of supportive activity was the gradual change in collection scheme from a scheme based on mixed waste to waste segregation at source, which started in 2009. To promote a new collection scheme, KUC established an internal task force drawn from council members, public health inspectors, development officers and supervisors of the waste collection division, and performed outreach to the community via community meetings, posters, and placing of billboards in residential areas. Formal awareness campaigns were organised in schools, and government and private institutions in the city, and in 2017, large printed billboards displaying the central message of city policy on waste segregation and collection were placed in public places.

KUC's decision to seek expert assistance from NSWMSC and Japan Overseas Cooperation Volunteers (JOCVs) together with public awareness campaigns, led to greatly enhanced source segregated waste collection. Since 2009, KUC has received JOCVs to work with the community in introducing sound waste management practices involving source segregated waste discharge and recycling, and the volunteers make use of various methods to raise awareness, through demonstrations and hands-on activity-based instruction, to help impart an understanding of source segregation at home to the local population. Once the entire residential community within the KUC area had adapted to source segregation, KUC developed strategies to target inbound commuters to the city, such as workers, traders, shoppers, and others.

2.1.7. Outcomes and Lessons Learned

This case study presents a case of successful initiation and implementation of a large-scale composting facility and associated facilities as part of integrated MSW management, with a particular focus on source segregation and composting in a small city of Sri Lanka.

The first and foremost challenge for KUC in initiating the project was securing the financial resources for capital investment for the EPC. KUC's strong commitment to a long-lasting solution to MSW management in line with the national MSW policy led to advancement of the proposal. Being aware of its lack of in-house technical capacity to formulate a winning proposal for PILISARU, the decision made by the KUC leader to seek technical assistance from NSWMSC was a turning point. As a small local authority with limited financial resources and technical expertise, KUC sought assistance and resources from outside the city. As a result, it gained financial and technical support from the national government through NSWMSC and PILISARU, which assured steady progress and full implementation of KUC's waste management action plan. Under such leadership, KUC was able to transform MSW management from one premised on the conventional "collect and dump" practice to "recycle and recover" through source segregated waste collection. Support from NSWMSC and PILISARU was secured as KUC was able to demonstrate agreed-upon incremental targets, such as implementation of source segregated waste collection, uninterrupted operation of composting facility, and minimization of impact on nearby communities.

Of the targets mentioned above, promotion of source segregation represented a different kind of challenge owing to the lack of established practices within the community. This was overcome by raising public awareness on the need for correctly segregated recyclables by explaining the direct benefits, such as reduction in waste disposal, along with the indirect benefits for the city, such as improved cleanliness and compost quality. Improvements in the collection method and service also helped.

The strategic approach of recruiting young workers from neighbouring communities had two benefits: 1) it provided the workers with a sense of ownership of the facility due to the job opportunities, and 2) it helped maintain good public relations between KUC and the community, which helped minimize any potential NIMBY (Not in My Back Yard)-related issues.

According to the financial analysis of the composting operation (Table 2-4), though KUC has yet to show a profit, the deficit has been minimised at 1,158 LKR, when offset against income per metric tonne of compost produced, which proves that the value of total compost produced can recover 87% of the total expenditure. In addition, KUC has been able to reduce the amount of waste disposal at the semi-engineered landfill site by 85%. In more detail, the amount of daily average biodegradable waste that enters the facility is approximately 5.4 MT, which is converted into 1.0–1.4 MT of sieved compost and 0.5–0.6 MT of residues (slowly decomposable matter) that is disposed of at the semi-engineered landfill site. In other words, an estimated mass balance of 4.7–4.8 MTPD of biodegradable waste is treated at the EPC instead of being disposed of at the dumpsite, which would otherwise incur a cost of 1,500–2,500 LKR per MT of solid waste including biodegradable waste, resulting in a saving of 7,350–12,250 LKR. Diverting the biodegradable waste from being disposed of at the dumpsite to composting also reduced levels of pollution, greenhouse gases, and health risks while extending the life of the existing disposal sites.

The salient feature of this case study is that the overall benefits of the composting scheme far outweigh conventional open dumping in terms of the financial, social, and environmental aspects. As a government agency, the LA is not compelled to carry out public service activities with the intention of making a profit, which presents a problem for KUC regarding the unsold compost stored in the facility. Finding clients quickly to sell the stored compost is important to raise the usage efficiency of the space compared to use as storage, thus enabling sustainable operations, though storing compost has the benefit of raising its quality due to extended maturation.

Capitalising on the success of the EPC, KUC's long-term vision is to make Kuliyapitiya a zero-waste city, free from any waste requiring landfilling. Citizens perceive the positive changes achieved in the system to date and have willingly supported KUC in its efforts to improve the sanitary state of the city and final disposal site.

2.2. Provincial Operation, Kalutara

2.2.1. Background

Until 2009, all solid waste collected from urban and rural areas in and around Kalutara city was disposed of on low-lying marshland, or "Pohorawatta" near the city centre. This dumpsite, which was mainly used by Kalutara Urban Council (KLUC) but also accepted small quantities of waste from Kalutara PS, consisted of a 3.5 hectare area and involved a high risk of water, land, and air pollution of the neighbouring communities and adjacent wetland environment. Despite attempts by LAs to apply an end-of-pipe solution to open dumping, no long-lasting improvements resulted owing to the lack of technical knowhow, insufficient capital investment in waste treatment and disposal, and inefficient law enforcement to minimize the pollution.

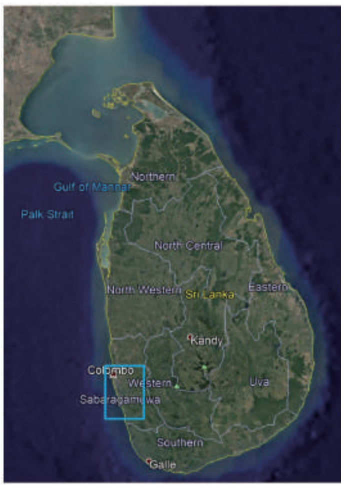
An attempt to rehabilitate Pohorawatta dumpsite was initiated by Urban Development Authority in 1997 with the installation of a small composting facility with capacity of 4 MTPD at the site. However, operations stalled after two years as KLUC lacked sufficient workforce and support programmes, such as source segregated waste collection, staff training, and compost marketing strategy. In the meantime, public discontent fermented into protests which placed KLUC under heavy pressure to find an appropriate solution to reducing the volume of waste disposed of at the site.

2.2.2. Initiative

After the inception of PILISARU in 2008, the need for upgrading the waste management system in Kalutara District was identified by CEA, WMA-WP and by LAs in Kalutara District. As finding suitable land to locate new waste management facilities was a common problem among most urban LAs in Kalutara, PILISARU and the LAs around Kalutara city considered sharing one large MSW composting facility at Pohorawatta dumpsite. KLUC then agreed to contribute a portion of land within the dumpsite, and PILISARU agreed to provide the funding for a large-scale centralised composting facility, which led to the signing of a formal agreement to share the facility between KLUC and three neighbouring LAs (Kalutara PS, Panadura PS, and Panadura UC). The first agreement among PILISARU, WMA-WP, the LAs and the residents around the site stated that KLUC owns and operates the composting facility and accepts biodegradable waste from the three LAs. KLUC also agreed to accept biodegradable waste from Kalutara Bodhi, a renowned Buddhist pilgrim site worshiped by several thousand people, especially on public holidays. On the other hand, the non-recyclable portion of waste from KLUC and the other LAs was to be disposed of at the proposed sanitary landfill slated for construction by PILISARU in 2012 for shared use by all LAs in Kalutara District.

With stakeholder consensus achieved, the composting facility was constructed by PILISARU in 2010 at a cost of 90 million LKR (750,000 USD). It occupied about 1.5 hectares of the dumpsite and could compost 35 MTPD of biodegradable waste. Soon after operations began in 2011, however, KLUC faced the challenges in staffing and finances due to the large-scale nature of the facility. At this point, managerial responsibility was taken over by the Waste Management Authority of Western Province (WMA-WP), which brought in its own manpower and additional equipment, and developed a marketing strategy and overall management plan. WMA-WP, which is responsible for overall SWM in terms of regulatory reinforcement, management, planning and monitoring in Western Province of Sri Lanka, invested about 50 million LKR (416,667 USD) to upgrade the facility (Table 2-5) now called Mihisaru facility. Figure 2-10 shows the change in Pohorawatta dump site before and after the facility construction.

In addition to physical infrastructure, WMA-WP developed a master plan aiming to recover at least the project investment and operational costs. Major decisions relating to capital investment, machinery purchases, and repair and maintenance are made by WMA-WP's administrative staff, and the general management of the facility is closely supervised by the authority's zone manager dispatched to Kalutara District. The zone manager also supervises and coordinates MSW management activities in Kalutara zone, which consists of several LAs. Production targets follow marketing plans, which are set annually by WMA-WP, and the responsibility for achieving them is jointly assumed by the zone manager. A team of workers takes care of production, with the zone manager assisting in facility management to guarantee a steady supply of biodegradable waste from the LAs.



Country	Sri Lanka
Province	Western
District	Kalutara
Size	82.8 km^2
Climate	Tropical (23-30 °C)
	2,500 mm average annual rainfall
Topography	Flat terrain (~ 10m above MSL)
Location	6°34' 4.91" N 79°59 15.54" E
Land use	Residential & wetlands
Population	Kalutara PS 126,789 (2018)
	Kalutara UC 37,081 (2018)
	Floating 20,000 (2018)
Waste collection	Kalutara PS 12 MTPD (estimated)
	Kalutara UC 35 MTPD (estimated)

Figure 2-9 Location and description of Pohorawatta, Kalutara

Table 2-5 Investment of Mihisaru composting facility[6]

Facility	Funded by	Year	Investment LKR (USD)
Composting buildings (windrow)	PILISARU	2010	90 million (750,000)
Office and worker rooms	PILISARU	2010	
Leachate recirculation system	PILISARU	2010	
Machinery (Wheel loader, 2 skid steer loaders, a tractor & trailer)	PILISARU	2010	
Access road, fencing, biogas unit	WMA-WP	2011	50 million (416,667)
Weighbridge	WMA-WP	2011	
Building accessories and services	WMA-WP	2011	
Material Recovery Facility (MRF) in a 221m^2 area	WMA-WP	2009	

Figure 2-10 Change in Pohorawatta MSW dumpsite (from google map)

2.2.3. Collection Activity

The tasks of collection and transport of municipal waste to Mihisaru composting facility were the responsibilities of the LAs, which had their own collection methods such as bell collection, door-to-door collection, and curbside collection. However, prior to establishment of the composting facility, none of the LAs segregated their waste, and once operations began in late 2011, all LAs brought mixed waste to the facility, which required over 20 workers onsite to sort, placing a heavy budgetary burden on WMA-WP. During the first two years (2011–2013), over half of the collected waste was directly disposed of on the adjacent ground due to the limited sorting capacity. The protests, by residents neighbouring Mihisaru composting facility, concerned the issue of waste brought from LAs outside Kalutara city. As a result, Panadura UC and Panadura PC developed separate MSW management plans and discontinued waste disposal at Mihisaru facility. As of 2018, it receives about 22 MTPD of biodegradable waste from Kalutara UC, Kalutara Pradeshiya Sabha and Kalutara Bodhi, which fluctuates seasonally, dropping from November to December and from

6 Data extracted from reports at Mihisaru facility (2008 to 2011)

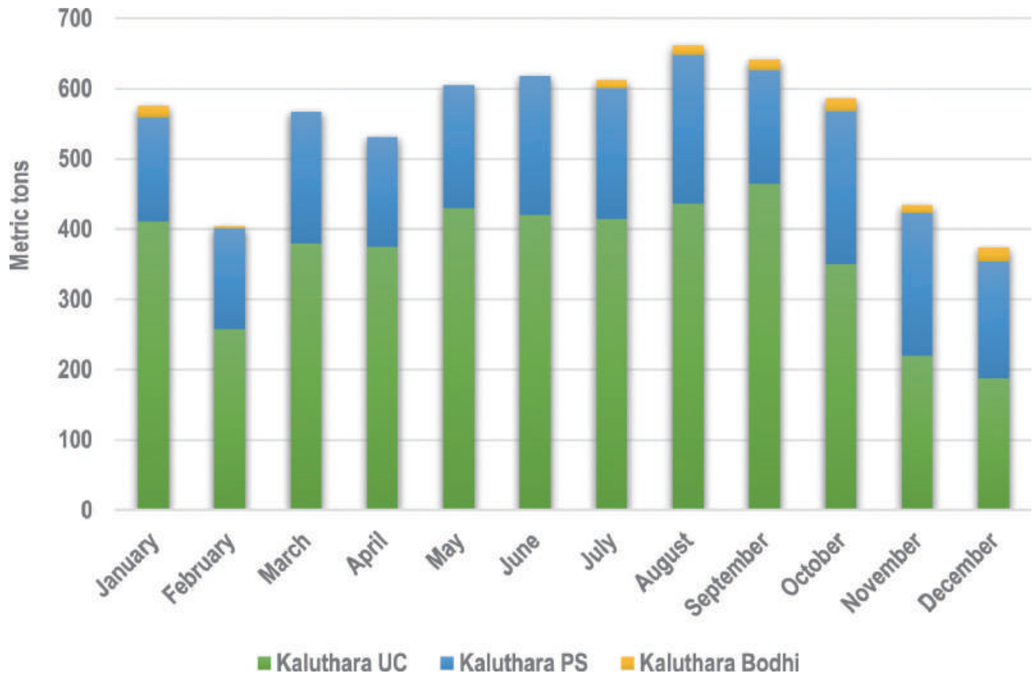


Figure 2-11 Amount of biodegradable waste received at Mihisaru composting facility (2018)[7]

February to March due to the two rainy seasons (Figure 2-11).

The public protests and the lack of political commitment slowed down the project of construction of the sanitary landfill on the government-owned land in Panadura, Kalutara District. The construction did not start until 2015.

On the other hand, in 2014 WMA-WP amended the waste collection policy so that the composting facility would accept only source-segregated biodegradable waste. A waste tipping fee of 250 LKR/MT was also made chargeable to all LAs except KLUC. Imposing a tipping fee was intended to partially recover operational costs and also encourage the LAs to reduce waste volumes by promoting on-site biodegradable waste management strategies such as home composting and biogas within their districts.

Following this, a waste segregation law imposed by WMA-WP was endorsed by the LAs. The enforcement of mandatory source segregation enabled the LAs to curtail the waste generators unwilling to adopt source segregation. Correctly segregated biodegradable or non-biodegradable waste was collected at given times on different days of the week, and presently, biodegradable waste is collected four times a week and the non-biodegradable and recyclable waste is collected once a week (Figure 2-12). Imposing this strict rule left no other option for waste generators but to separate waste into two categories at home, and meant WMA-WP was able to roll-out highly effective source segregated waste collection throughout all involved LAs by 2015.

Figure 2-12 Source segregated biodegradable waste collection in Kalutara Urban Council (Source: author)

7 Data from reports at the Mihisaru facility of WMA-WP (2018)

2.2.4 Processing Activity

First, the biodegradable waste is unloaded onto the floor, where it is inspected to determine if amounts of non-biodegradable waste are below 5% of the feedstock by an inspector. The waste is then transferred by wheel loader into a large windrow pile. Each pile is formed into a large, elongated shape (5 m wide, 12 m long and 2.5 m high) containing about 50 metric tonnes of composting feedstock. While the wheel loader and the skid steer loader perform all heavy and bulk handling operations, activities such as compost screening, packaging, general cleaning and miscellaneous tasks are performed manually by trained workers. Feedstock piles are mechanically turned by backhoe loader once a week in the first two months of the active composting period and once biweekly during the one month maturation period (Figure 2-13).

Considerable amounts of leachate are usually generated during the first 4–5 weeks of composting, which is collected through open concrete drains that lead to large underground concrete tanks. Once the initial water in waste evaporates during first few weeks and leachate generation ceases, appropriate amounts of diluted leachate are mixed in while turning the windrows, with the excess leachate pumped to a biogas system (30 m^3) where it is co-digested with perishable waste and turned into biogas (methane) for use in the kitchen.

After three months of processing, the matured compost is ready for sieving, which is performed using in large trommel screeners of a 4 mm mesh. A portion of the matured compost feedstock is maintained without turning or watering as intact compost piles to meet peaks in demand. Generally only 2–3 MT of compost is produced per day in routine operations to cater for ongoing demand. The sieved fraction of compost is packed into 10, 20, and 50 kg bags, sealed and stored for sale. The residual fraction consisting of long-term biodegradables, plastic film and other large inert particles is moistened and left to further decompose for another month before a second screening is performed to recover any partially decomposed matter. The residuals, mainly plastic waste and non-degradable inert matter, are then disposed of at the disposal site. In general, about 1,000 MT of compost is produced

Figure 2-13 Processing biodegradable waste at Mihisaru composting facility (Source: author)

Table 2-6 Summary of composting at Mihisaru facility[8]

Item	Description of Composting Facility
Type of Facility	Mechanical Windrow Composting
Production Capacity	35 MTPD feedstock and 10 MTPD compost
Particle size of finished compost	Less than 4 mm
Duration of production	12 to 20 weeks
Annual waste input (A)	6,612 MT (2018)
Annual compost production (B)	1,197 MT (2018)
Composting rate (B/A)	18%
Equipment	1 backhoe loader 1 skid-steer loader with capacity of 250 kg/hour 1 four-wheel tractor & trailer 2 trommel sieving machines 6 water and leachate pumps

annually, with the majority sold in bulk lots at the facility.

The most challenging task is to maintain and improve the quality of compost while also achieving the objective of waste reduction. According to national standards, while the moisture content of compost should be less than 25% (SLS 1243:2003), it is still 30–40% after three months of composting in reality, particularly during the rainy season. Therefore, the mature compost piles are maintained for a further 4–6 weeks without sieving to lower the moisture level, which also helps maintain a buffer stock to cater for unexpected demand for bulk quantities. Another factor affecting quality is contamination of the feedstock with soil and sand. Mihisaru compost meets all requirements of SLS 1243:2003 except sand and soil which is generally higher (around 30%) than the SLS requirement of 10% owing to the soil and sand swept up with the biodegradable waste at the daily vegetable markets (or POLA) and vegetable sales stores. Fragmented plastic films and polystyrene from items such as yoghurt cups are broken into tiny plastic particles (microplastics) and enter the final product. Although plastic does not chemically or biologically interfere with the compost quality, the mix of plastic reduces the compost physical quality. According to regulations, waste containing over 5% non-biodegradable items should not be collected, but in reality there is no proper mechanism to control this problem at source. WMA-WP therefore chooses to inspect incoming waste and manually remove plastics and soil clods, which guarantees Mihisaru compost is of high quality despite the additional labour overhead for this pre-sorting. To maintain consistent quality levels, regular testing is conducted by accredited laboratories at least every four months, and the results are used to assist in marketing efforts by displaying nutrient content and product quality on the compost packages (Figure 2-14). This practice has raised the level of confidence in farmers and agricultural officers, which in turn has helped maintain a steady demand of Mihisaru compost in the region.

The staff, 21 in total, including a site manager, site supervisor, management assistants, machine operators, and skilled labours, are all employed by WMA-WP. The site manager is responsible for overall management of the facility, a supervisor and two management assistants manage production activities, two people operate machines, two are security guards, and the rest are laborers. Six of the staff are female, who mainly work in the packaging section as the other activities mostly require heavy physical labour. The workforce is divided into several small teams, such as waste handling and pile maintaining team, sieving and packaging team, and general maintenance team in order to enhance collaboration between male and female workers and increase individual efficiency.

8 Data extracted from reports at Mihisaru facility (2018)

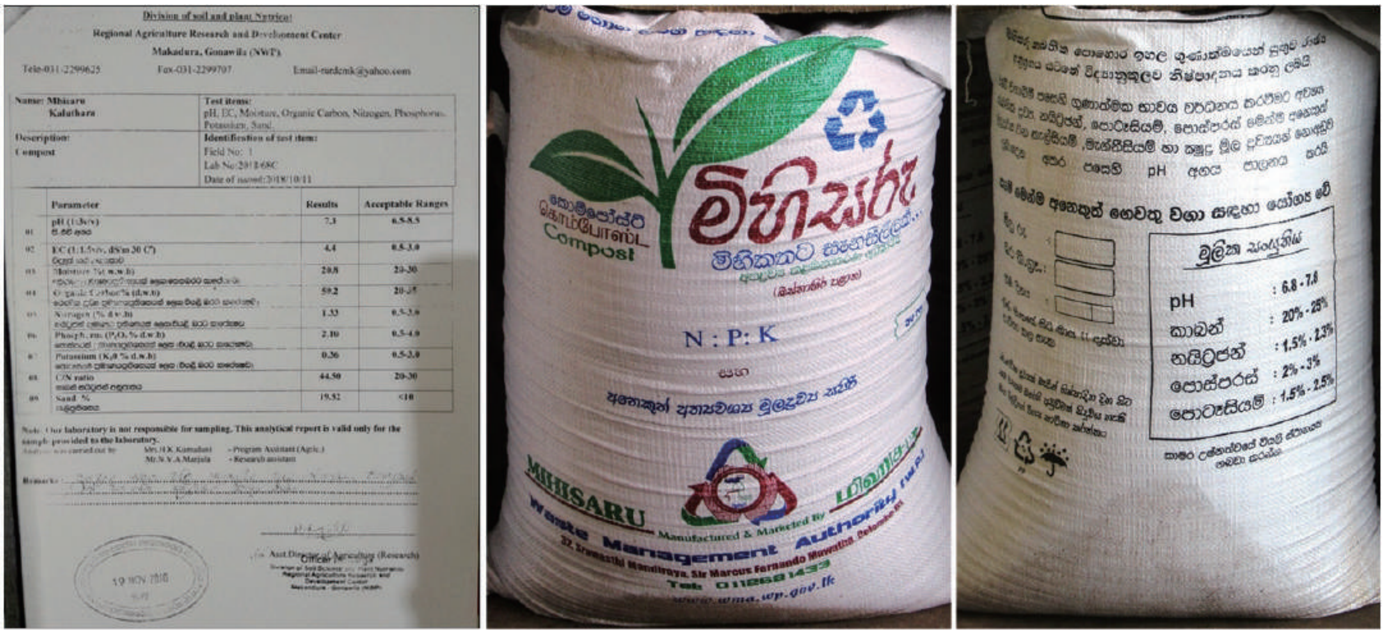


Figure 2-14 Pacakge of Mihisaru compost (Source: author)

Regular training sessions are held at the facility for the staff conducted by WMA-WP, with assistance from NSWMSC and various resource personnel. The site manager, supervisors, and some of the skilled workers become trainers to train workers from other composting facilities in Western province. The training programme also helps in career advancement, such for promotion to higher grades and NVQ certification. Facilities onsite include male and female rest areas, toilets, washrooms, and guard rooms.

2.2.5. Financial Analysis

One of WMA-WP's goals for the facility was to generate sufficient revenue to ensure financial viability of composting operations, thus the compost is produced to be sold. As discussed above, Mihisaru compost has become one of the high quality composts in the market, which has been achieved by maintaining a consistent supply, quality, and competitive price regardless of the season, which is where other operators tend to fail. In terms of annual sales, compost sales rise during the cultivation seasons from May to September and January to February (Figure 2-15).

Besides efforts in quality control, WMA-WP assists in finding new markets for the compost, through newspaper advertising, agricultural exhibitions, and promotions during training and public events. During 2018–19, exports were also initiated to Maldives and the Middle East, which generated about 3 million LKR (17,650 USD). While currently suspended due to issues including the Easter Bombing in 2019 and COVID-19, WMA-WP intends to resume exporting operations once it is logistically feasible.

Unlike many other composting facilities in Sri Lanka, the unit price in bulk of Mihisaru compost is lower than by sac, or 8,000 vs. 11,000 LKR (47 vs. 65 USD)/MT. The availability of bulk purchasing has created business opportunities for owners of rubber, tea, and coconut plantations and several distributors in the area, who purchase a few metric tonnes for reselling in smaller bags in rural agricultural areas in Western and Southern provinces. The steady supply, high quality and reasonable price attract customers from adjacent districts of Western and Southern provinces such as Galle and Matara, over 100 km away. There is also steady demand for small packages (e.g., 10 kg) from small-scale vegetable farmers and households for home gardening. All these efforts combined result in sale of all the compost produced.

Tipping fee is another important source of revenue. WMA-WP charges 250 LKR/MT (1.47 USD/MT) for LAs other than KLUC in order to partially recover expenses and also to promote waste reduction efforts. According to the brief financial analysis (Table 2-7), earnings of 11 million LKR (64,706 USD) were achieved from compost sold versus the estimated cost

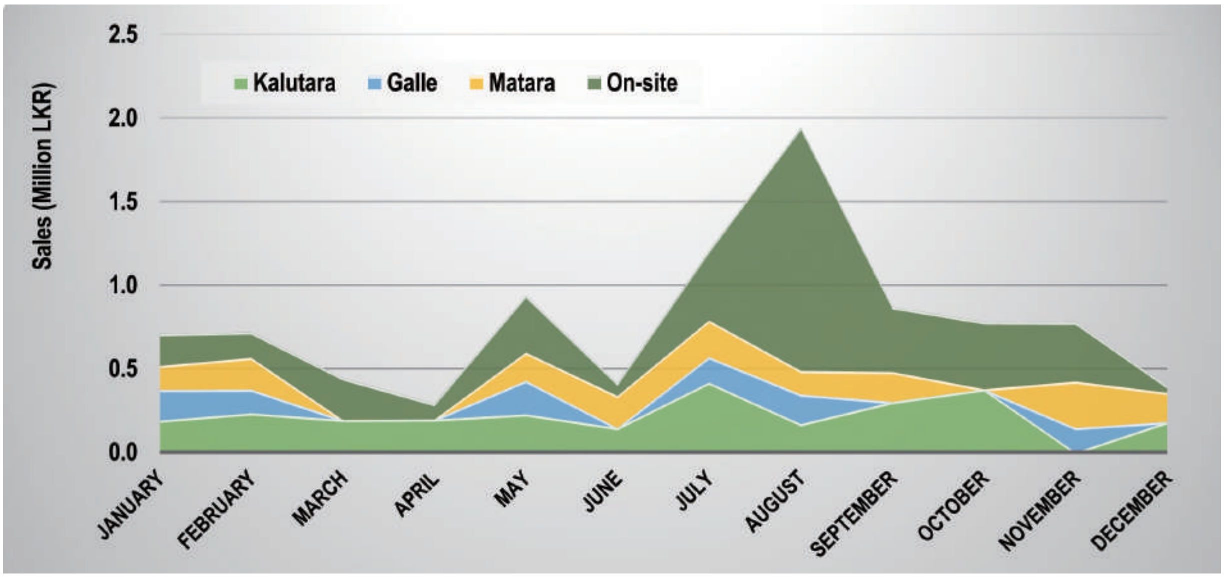


Figure 2-15 Amount of compost sales by buyer's location (2018)[9]

Table 2-7 Summary of financial status of composting at Mihisaru facility for year 2018[10]

Item	Value	Units
Waste received at composting facility	6,612	MT
Compost produced	1,997	MT
Compost sold	997	MT
Compost stock	Approximately 1,000	MT
Income		
Selling price of compost	8,000–11,000	LKR (USD)/MT
Compost sales	11,000,000 (64,706)	LKR (USD)
Tipping fee (250 LKR/MT)	710,800 (4,181)	LKR (USD)
Value of compost stock	8,000,000 (47,058)	LKR (USD)
Total income (including compost stock)	*19,710,800 (115,945)*	*LKR (USD)*
Expenditure		
Total expenditure (Personnel remunerations, electricity, water, fuel and lubricants, consumables, Machine repair and maintenance)	*14,000,000 (82,353)*	*LKR (USD)*
Total profit [loss] for processing one metric tonne of compost =((total income – total expenditure) / compost produced)	**2,860 (16.8)**	**LKR (USD)**
Note: 1 USD = 170 LKR		

of production of 14 million LKR (82,353 USD), which results in a deficit. However, almost half of the compost produced is stored as buffer stock, with a minimum value of about 8 million LKR (47,058 USD). If it were sold quickly, it would provide a profit of 2,860 LKR/MT (16.8 USD).

2.2.6. Supportive Activity

At the beginning of the project, KLUC and KLPS launched a series of awareness-raising programmes under the direct supervision and monitoring of WMA-WP. WMA-WP also provided the LAs with technical assistance such as training of collection workers and development of zonal waste management plans.

9 Data extracted from reports at Mihisaru facility (2018)
10 Result of the auditing by the author

2.2.7. Outcomes and Lessons Learned

It is widely recognised that most LAs in Sri Lanka are incapable of investing in new infrastructures due to limited budget allocated by the central government. Generally, large budget is not often allocated for infrastructure improvements or recruitment of additional workforce. Revenue generation through MSW management within LA areas is very limited throughout the country and most LAs are incapable of collecting enough garbage fees or garbage taxes. Any new development or additional activity in the MSW sector is perceived merely as an extra burden on its budget. Further, although the Sri Lanka central government initiated PILISARU to finance waste management infrastructure development, taking into account the political and financial autonomy of individual LAs and lack of suitable land and in-house technical capacity in some LAs, it is generally a challenge to realize a sustainable impact from any project.

Sometimes, however, intervention from central and provincial governments, which have sufficient financial and technical resources in addition to higher authority, can solve problems with a single solution. First, WMA-WP decided to intervene in the composting facility management at a time of visible public dissatisfaction (protests) over the LAs' insufficiencies in waste management. While Mihisaru centralised composting facility was supposed to be managed by KLUC with support from the LAs, KLUC was faced with the realization that MSW management could not be sustained without sufficient financial and technical capacity. Indeed, the involvement of provincial government is only effective if they are empowered by law to mediate in any issues in the LAs within the province.

Second, the waste segregation rules, which were determined by an overarching authority, i.e., WMA-WP, along with technical assistant in public awareness campaigns managed to facilitate behaviour change. LAs are usually reluctant to fully implement source segregated waste collection programmes because a fraction of the community, especially the commercial and trade sector such as restaurants and hotels, regard it as an extra burden, despite needs and benefits, such as higher final compost quality, reduced labour costs and sorting time, and minimization of the nuisance factor of residual waste disposal. This case study clearly showed that direct involvement of WMA-WP resulted in the rapid establishment of a source segregated waste collection system through legal enforcement and public awareness activities targeting not only the community but also LAs.

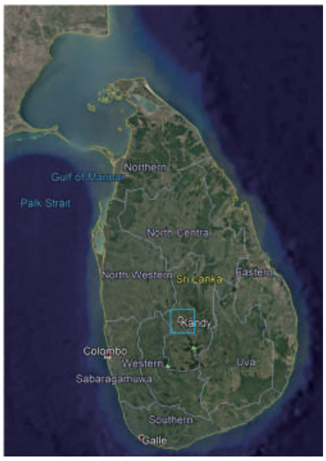
Third, the steady revenue generated from composting with source segregation has enabled WMA-WP to run facility operations and maintenance smoothly, through providing the level of qualified technical expertise as would normally be required in an MSW composting facility of this scale. In addition, this case study has proved that an appropriate waste source control programme and correct processing mechanism can together produce quality compost that can be sold in local, regional, and even international markets.

2.3. Joint Consortium Operation, Kandy District

2.3.1. Background

Kundasale Pradeshiya Sabha (KPS) and Pathadumbara Pradeshiya Sabha (PPS) are both suburban Local Authorities near Kandy city, in Kandy District of Central Province, Sri Lanka (Figure 2-16). Due to the proximity to Kandy, working people reside in these LAs. In the late 1990s, many of the administrative offices were shifted from Kandy city to Pallekale township in KPS, and thereafter the residential population has gradually grown with many small townships emerging in both LA areas. As a result, KPS and PPS were challenged with ever-increasing demands for MSW services.

Previously, KPS collected mixed waste from small townships and households in semi-urban areas, and disposed of it illegally in an abandoned 5-acre limestone quarry which is outside the KPS boundary. Since the dumpsite area was owned by Mahaweli Authority, KPS appealed to Mahaweli Authority to transfer ownership of the land in 2005. Mahaweli Authority was only able to provide KPS with about 1 acre (4,048.58 m^2) of land, as the government prohibited the use of any larger area due to its proximity to government-owned reservation land. KPS thereafter disposed of all collected waste (approximately 15–20 MTPD) at this small dumpsite, which subsequently became full. To resolve the issue, KPS therefore needed to either relocate the disposal site to a



Country	Sri Lanka	
Province	Central	
District	Kandy	
Climate	Tropical (25.5 °C)	
	2,125 mm average annual rainfall	
Topography	Valley (~ 508 m above MSL)	
Location	7°28' 10.08" N 80°38' 30.38" E (composting facility)	
LA statistics	Kundasale PS	Pathadumbara PS
Size	84.8 km^2	42.5 km^2
Land use	Residential (35%) & agriculture (65%)	Residential (25%) & agriculture (75%)
Population	Residential 137,940 (2018)	Residential 82,000 (2018)
	Floating 40,000 (2018)	Floating 20,000 (2018)
Municipal Waste	Generation 60 MTPD (estimated)	Generation 35 MTPD (estimated)
	Collection 15-20 MTPD (estimated)	Collection 5-10 MTPD (estimated)

Figure 2-16 Location and description of Kundasale PS and Pathadumbara PS

new location or dramatically reduce amounts of waste to be disposed of at the dumpsite. To reduce amounts of waste, one option was to construct a composting facility that could handle a large portion (i.e., 15 MTPD) of the incoming waste.

In parallel with this, Pathadumbara PS (PPS), a small LA adjacent to KPS, was struggling to provide a quality waste management service for its citizens as it only possessed a small anerobic digestor with 10 MTPD capacity for collected organic waste and a small open dumpsite at the same location. Public discontent (protests and complaints) were also mounting over inappropriate operations of the anaerobic digestor as well as on-site waste burning at the dumpsite. As a result, PPS requested different government and donor agencies for technical and financial assistance to establish a waste treatment facility. In 2013, the Ministry of Local Government and Provincial Councils (MoLG & PC), through JICA, invited Kawashima Co., Ltd., Japan to conduct a study to establish a modern mechanical composting system in PPS. They identified two shortcomings; 1) the land owned by PPS was not suitable for establishing a mechanised composting system, and 2) the amount of biodegradable waste collected by PPS for the mechanical composting system was insufficient. Therefore, PPS was faced with the dual needs of sourcing alternative land to establish a composting facility and a higher volume of biodegradable waste. Of these, the issue of sourcing land proved challenging for PPS owing to public resistance.

2.3.2. Initiative

PPS entered into a series of discussions with KPS to install a single modern, large-scale mechanical composting facility, as suggested by Kawashima, which led to the creation of a joint consortium in 2014 between KPS and PPS, which formulated a joint proposal for the benefit of both LAs. The proposal identified the project management structure and responsibilities of each party, with KPS allocated as major land contributor within the dumpsite area and PPS to assume the leadership role in negotiation with JICA and other stakeholders. After the joint consortium was formally approved by NSWMSC under the Ministry of Local Government and Provincial Councils (MoLG & PC), the technology provider, Kawashima, conducted a rapid feasibility study, which led to JICA donating 105.1 million LKR (700,666 USD) to import machinery and equipment from Kawashima Co., Ltd, Japan, with a provision that such investment for site infrastructure would solely cover the composting facility itself.

As shown in Table 2-8 , both LAs had completed the preliminary infrastructure development by the end of 2015, which included land clearing, preliminary land preparation, rasing the existing structure, site leveling, and providing infrastructure for services such as electricity and water, and access to the site. The joint consortium invested again during 2016–2017 to cover the import tax, site servicing and infrastructure development, while accepting donations of a skid-steer loader and trommel sieving machine from NSWMSC and Central Provincial Council, respectively (Figure 2-17).

Table 2-8 Investment of Kawashima composting facility [11]

Item	Funded by	Year	Cost (LKR)	Cost (USD)
Land preparation	KPS (50%) + PPS (50%)	2015	2,800,000	18,667
Electricity and water supply	KPS (50%) + PPS (50%)	2015	696,450	4,643
Kawashima plant (1st installment)	JICA	2016	100,000,000	666,666
Kawashima plant (2nd installment)	JICA	2016	5,100,000	34,000
Payment of import tax	KPS (50%) + PPS (50%)	2016	12,215,376	81,436
Office and compost storing facility area	KPS + Central Provincial Council	2017	1,487,166	9,914
Extension building for compost production	KPS + Central Provincial Council	2017	20,143,470	134,290
Skid steer Loader (01) Trommel Sieve with conveyers (100 kg/Hour)	NSWMSC Central Provincial Council	2017 2016	1,800,000 800,000	12,000 5,333
Total			**145,042,462**	**966,949**

Figure 2-17 Kawashima composting facility at Kundasale PS (Source: author)

Both LAs appointed members to the Project Steering Committee, comprised of the technical or development officers from each LA, Divisional Secretariat, and representatives from CEA. Then, an operational and management team comprising part-time and full-time employees from each LA was formed. Executive-grade officers, drawn from municipal secretaries and technical officers were placed in charge of project management. Project management and operations were planned in accordance with the government administrative and financial rules and regulations. The environment officer of KPS is responsible for planning, implementing, and monitoring the sources of segregated waste collection, and KPS has allocated five four-wheel tractors and 30 workers for waste collection activities. In PPS, an environment officer under the supervisions of the development officer performs planning, implementation, and monitoring duties related to source segregated waste collection activities, employing three four-wheel tractors and 13 workers.

2.3.3 Collection Activity

The LAs within the consortium implemented source segregated waste collection in 2016. While both LAs took similar approaches, they adopted individual routes to implementation. PPS had implanted source segregated waste collection well before the joint consortium was formed as it used to treat biodegradable waste in the anaerobic reactor and also conducted annual public awareness campaigns on the need for source segregation for correct operations of the composting facility. PPS also refuses to collect non-segregated waste from households or other sources,

11 Data extracted from the annual budget reports of KPS (2015 to 2017)

and instigates legal action against violators of the related by-laws.

Conversely, prior to 2016, KPS had collected mixed waste daily from townships and on alternate days from households, and started implementing source segregated waste collection at the commencement of Kawashima facility operations. The new waste collection aimed at collecting different types of waste on different days – biodegradable waste on alternate days from households and daily from major townships. Other recyclable waste and non-recyclable non-degradable waste is collected once weekly from households and on alternate days from townships.

The new mechanical composting facility was designed to treat 25 MTPD of biodegradable waste, based on a projected increase in waste amount over the next 20 years. Unlike a windrow composting facility which can be scale-up or down at any stage in operations, Kawashima composting system is configured to handle fixed amounts of waste and cannot be efficiently run above or below capacity. In the two LAs, the total amount of biodegradable waste collected was about 8 MTPD in 2017. Therefore, the consortium was advised by Kawashima to secure further 17 MTPD.

To reach the target capacity, the consortium approached neighbouring LAs to deliver correctly segregated biodegradable waste to the composting facility, for a tipping fee of 500 LKR (3 USD)/MT. The timing was propitious as most of the LAs were seeking alternatives to disposal of biodegradable waste due to the lack of functional MSW composting facilities in the Kandy area. In response, since 2017, sufficient amounts of biodegradable waste have been secured from Gangawatakorale PS, Poojapitiya PS, Panvila PS, Waththegama UC, Medadumbara PS, and Gampola UC (Figure 2-18), all of which were willing to implement source segregated organic waste collection. The LAs were also ordered to deliver their waste to the composting facility separately, by NSWMSC and CEA, in order to protect the environment and reduce the public nuisance caused by open dumping.

The facility received 22 MT of biodegradable waste every day, consisting of 14–15 MTPD from neighbouring LAs, 5 MTPD from KPS, and 2 MTPD from PPS in 2017. As the facility has no weighbridge, the waste weight is estimated based on vehicle dimensions multiplied by the average biodegradable waste density (500 kg/m^3).

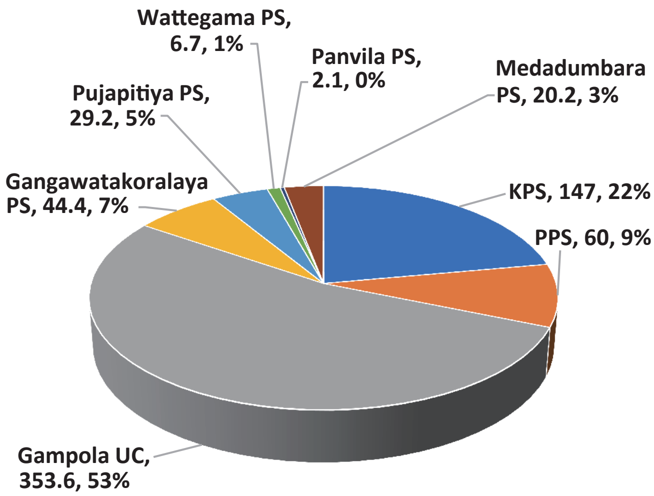


Figure 2-18 Biodegradable waste received from different LAs (MTPD, %) [12]

2.3.4. Processing Activity

The Kawashima composting facility applies automated technology through the entire process (Figure. 2-19, Figure 2-20). Composting is carried out inside a roofed building 12 m wide, 36 m long, 1.8 m deep with a concreted bed to accommodate 778 m^3 of composting feedstock. The biodegradable waste is unloaded to the bed from the front end. Unloading, waste piling and feeding to the trommel sieve, and residual waste handling are performed by a skid-steer loader. The labour staff handles general maintenance tasks such as cleaning the floors and drains, machine operation and compost packaging. The Kawashima composting system is designed for durability and low-maintenance operations, thus the mechanical components only require replacing if they fail, which is handled by Kawashima under a guaranteed repair service as per agreement with KPS.

The waste is mixed with a screw arguer fixed to a conveying system that automatically moves back and forth while the augur moves horizontally. It takes 3.5 hours to complete a full cycle of mixing throughout

12 Data from reports at the Kundasale Composting facility (2017)

Waste unloading to beds

Screw turner on compost beds

Turning augur

Beds after turning

Trommel sieve with conveyer system

Figure 2-19 Processing at Kawashima composting technology (Source: author)

Bucket for spray

Dirty water pump

Screw unit

Spray pipe for dirty water

Driving motor (four-wheel-drive)

Control panel for remote control

Figure 2-20 Components of Kawashima composting system (Source: a report from Kundasale composting facility)

the bed, and two mixing cycles are performed every day. The screw movement is generally set to automatic and activates at set time intervals, but can also be manually activated and controlled. Supplementing optimal operations, a network of perforated PVC pipes laid at the base of the bed supplies air from a series of aeration blowers installed outside the building. Unless the turner is operating, the blowers continuously pump air from beneath, thus maintaining optimum aeration. After three weeks of sequential mixing and air blowing, the rapid biodegradation process is complete and the composting feedstock is removed from the rear of the bed using the skid-steer loader and piled up for a further 9–10 weeks to mature. Mature compost is then sieved through a 4 mm mesh trommel sieving machine. On average, 4 MT of biodegradable waste produces 1MT of sieved compost. Large, partially decomposed dry matter remaining after sieving is recycled back through the system along with fresh incoming waste, which helps accelerate decomposition and lower the moisture level of the feedstock.

The facility is designed to operate with moderately dry waste (50–60% moisture) and no extra machine was installed to lower the high moisture in biodegradable MSW (70–80%). Waste with high moisture content tends to generate large amount of leachate which can block the airways of the aeration system and create an anaerobic condition within the beds, leading to formation of foul odours. This was the problem faced by the facility due to its insufficient area for drying the mature waste, especially during the rainy season when the mature compost feedstock needs to be dried inside before being sieved. To solve this problem, the piled waste was covered with a waterproof fabric and kept outside for about 7–8 weeks without mixing. However, this led to the generation of leachate and unwanted anaerobic condition which delayed the maturation and drying. Bad odours spread up to 200 m away from the facility and led to complaints from nearby residences directed at the facility management and CEA. Although the issue was temporarily resolved through use of an odour control enzyme sprayed onto the mature waste pile once weekly, it was not finally settled until an additional space to handle the waste was constructed. This option was chosen owing to the high costs incurred in spraying (15,000 LKR per daily application) over the investment funds of 20 million LKR, or 110,000 USD required for the construction (150 m^2).

As shown in Table 2-9, 14 people have been employed by KPS and PPS, including three officers in management positions, one management assistant, one operation supervisor, two machine operators, two male watchmen, and five laborers (two male and three female) to work in the facility. The project head and deputy, who visit the facility twice a week, are considered part time workers as their waste management duties are shared across other respective LAs. These officers have also visited Kawashima Co.

Table 2-9 Workforce at Kawashima composting facility

Project Position	Project Responsibilities	Male	Female	Employed & Paid by
Project head	Planning and decision making [Management position]	1		KPS
Deputy project head	Planning and decision making [Management position]		1	KPS
Head of project implementation	Support for decision making and implement programme coordination [Management position]	1		KPS
Management assistant	Support for administration and record keeping [supervisory position]		1	PPS
Work operations supervisor	Supervising of work implementation and all plant activities, including sales		1	PPS
Machine operators	Operation of Kawashima system and loader	2		KPS
Skilled labour	Manual operations, assistance in sales and sanitary works	2	3	KPS (3) and PPS (2)
Watchmen (Guard)	Security for entire property	2		KPS
	TOTAL Persons	**8**	**6**	

Table 2-10 Summary of composting at Kawashima facility

Item	Description of Composting Facility
Type of Facility	Automated aeration by screw mixture and air blowing (Kawashima)
Production Capacity	25 MTPD feedstock and 5 MTPD compost
Particle size of finished compost	4 mm
Duration of production	12 weeks
Annual waste input (A)	Approximately 7,500 MT (2018)
Annual compost production (B)	Approximately 1,800 MT (2018)
Composting rate (B/A)	20–25%
Equipment	Screw augur system Mechanical air blowers 1 Skid-steer Loader Trommel Sieve with conveyers with capacity of 2 MTPD

Ltd. in Japan to study their composting system and obtained the required training in all aspects of system operation and maintenance. The head of project implementation is stationed at the facility and manages all daily activities. All machine operators and skilled labours live nearby. The operation staff received training on machine operation and waste handling by Kawashima Co. Ltd. during the first three months, and further, all workers have undergone training and participated in educational programmes at various composting facilities in Sri Lanka in operating skid-steer loaders and trommel sieves, general operations, and occupational health and safety.

A summary of compost processing activities is given in Table 2-10. Because the trommel sieve system has a maximum capacity of 2 MTPD, which is below the daily throughput of matured compost (5 MTPD), a large portion of the produced mature compost is stocked without sieving. However, this has not interfered with production processes as compost sieving is performed continuously in times of bulk demand.

2.3.5 Financial Analysis

Sales of compost began in 2016 at a small outlet in Kundasale city offering compost in different weights (5, 10 and 50 kg), and sales in bulk quantities were promoted via leaflets distributed among citizens in KPS and PPS. Until late 2017 production was limited to 10–15 MT/month owing to the small amount of waste received at that time. The target clients are small-scale vegetable growers and home gardeners, while commercial vegetable growers from nearby areas purchase bulk quantities (2–4 MT).

When the facility started receiving larger quantities of waste from neighbouring LAs, the former marketing mechanism was no longer adequate, which led the consortium to inviting bulk purchasers to invest in making value-added compost. As a result, the Biocarbon® company entered into an agreement with the consortium to buy a minimum of 10 MT of waste per month at a rate of 4,000 LKR/MT (23.5 USD). Biocarbon®, which had previously invented a compost pelletising technique based on farmer preferences, then installed a pelletising machine at the composting facility, as per the agreement, with an investment of 1.5 million LKR (8,800 USD). The private company produces compost pellets by employing two in-house laborers, purchases electricity from the composting facility, and sells compost to other buyers at a nominal price of 5,000 LKR/MT (30 USD). In other words, KPS continues to sell the compost to the former buyers. KPS is attempting to source other potential wholesalers such as nursery owners and commercial planters through compost retailers in the city.

As shown in Table 2-11, the income from compost sales is negligible compared to the tipping fees generated, which provide a reasonable revenue that accounts for over 95% of direct income. Though the potential annual income from the compost production is about 9.3 million LKR (54,845 USD), only 1.5% has been recovered as direct revenue because the major portion of production was stockpiled. Biocarbon® has agreed to increase the amounts purchased from late 2020, which will enable to convert the stock into direct revenue. In the meantime, the consortium has forwarded a proposal to raise the tipping fee from 500 LKR (2.9 USD) to 800 LKR (4.4 USD) to all neighbouring LAs through the

Table 2-11 Summary of financial status of Kawashima composting facility for year 2018[13]

Item	Value	Units
Waste received at composting facility	7,348	MT
Compost produced	1,837	MT
Compost sold	28	MT
Compost stored	1,809	MT
Income		
Unit price of compost	4,000-5,000 (23.5-29.4)	LKR (USD)/MT
Compost sales	138,720 (816)	LKR (USD)
Tipping fee from member LAs (500 LKR/MT)	2,495,890 (14,682)	LKR (USD)
Value of compost stock	9,185,000 (54,029)	LKR (USD)
Total income (including compost stock)	*11,819,610 (69,527)*	*LKR (USD)*
Expenditure		
Personal remunerations	4,413,528 (25,962)	LKR (USD)
Services (electricity, water, repairs)	322,173 (1,895)	LKR (USD)
Fuel and lubricants	94,772 (557)	LKR (USD)
Consumables	158,100 (930)	LKR (USD)
Total expenditure	*4,988,573 (29,345)*	*LKR (USD)*
Total profit [loss] for processing one metric tonne of compost =((total income – total expenditure) / compost produced)	**3,719 (21.9)**	**LKR (USD)**
Note: 1 USD = 170 LKR		

Central Provincial Council, due to inflationary pressure.

2.3.6. Supportive Activity

Once the project was approved, a series of joint awareness programmes were conducted from 2015 by the KPS-PPS joint consortium, in order to provide support for and get consent from the nearby residents. The campaigns involved two male and the two female technical officers appointed by the two LAs, who made individual house calls within a 1 km radius of the site and along the hauling road.

Also in the same year, an environment monitoring committee was established, comprised of a CEA officer, technical officers and project head from the consortium, friars from the village temple, government officers of the village (Grama Niladhari and Samurdhi Niladhari), as well as representatives from nearby communities. The committee conducts ongoing monitoring of activities, keeps regular assemblies, makes visits to the facility to raise awareness and build consensus, and performs a customer care role by handling complaints from neighbouring communities. Establishing the composting facility within the open dumpsite caused no public objections at the outset owing to prior awareness of the neighbouring community on the intention to convert the dumpsite into a less problematic facility. Two of the environment committee members – youths from the neighbourhood – also gained employment in the consortium as composting site supervisors, and all site laborers were hired from nearby communities. Creating employment opportunities in the nearby communities has helped the consortium maintain good public relations. As a result, the neighbouring residents have exhibited a willingness to cooperate in activities based on the understanding that environmental degradation and other issues caused by open dumping at the site would not continue after the composting facility was established.

13 Result of the auditing by the author

2.3.7. Outcomes and Lessons Learned

This case is a good example of an effective solution to the MSW disposal issue by sharing the resources and responsibilities among LAs that faced similar MSW management challenges, without direct involvement of the provincial or central government in the facility management. Instead of the mutual and informal resource sharing as can often be seen in Sri Lanka, the two LAs formed a formal joint consortium with the support and approval of relevant government stakeholders, with investment and technical support provided by the donor and the government agencies. In terms of improvements to management, the joint consortium also highlights the dedication and professional approach exhibited by the LA officers. The project heads from both LAs have acted beyond their ordinary office duties, taking part in additional activities such as project formulation, development of the consortium agreement, negotiation with donor agencies to expand and upgrade the infrastructure, coordination with government agencies, and obtaining support from the neighbouring communities, to ensure successful project implementation.

Differing from the conventional perception of composting as forming a segment of MSW within an LA, the joint consortium, which has expanded its services to neighbouring LAs in exchange for the tipping fee, which formed the major part of the revenue of the composting operation, has made it possible to convert the traditional MSW composting into a financially viable and sustainable operation. The neighbouring LAs were compelled to implement source segregated waste collection despite the ingrained belief that sorting at the facility is easier than raising public awareness on source segregation.

In addition, an innovative marketing strategy was proposed and implemented by the motivated officers in charge of the facility. While conventional composting involves a sales outlet only for the local community and small-scale buyers, making pellets from compost as a value-added product represents a new type of business model within the MSW compost industry. The joint consortium has developed a simple partnership with a private entrepreneur, in the form of a tender agreement. Sharing of infrastructure at the composting facility with the private company ensures efficient operation of the business and reduces compost transportation costs.

With the collaboration of neighbouring LAs and the private sector, the joint consortium operation has served a greater area and population beyond its own limits and contributed to reducing environmental pollution and health issues.

While reasonable success has been achieved up to date, several challenges remain unsolved. Small LAs such as KPS or PPS have limited budgets for capital investment and often rely on the national government or donor funding, thus delays in procuring funds for some of the urgent and essential infrastructure hampered smooth operations. However, based on the success of Kawashima composting, interest in this technology has since accelerated in recent years in Sri Lanka. NSWMSC, under the leadership of Ministry of Local Government and provincial councils, has already invested in constructing nine Kawashima composting facilities for several major LAs, of which five are to function as joint consortium operations involving one or more LA.

Acronyms

Acronym	Complete name
GDP	Gross Domestic Production
USD	United States Dollars
MSW	Municipal Solid Waste
MTPD	Metric Tonnes Per Day
NSWMSC	National Solid Waste Management Support Center
LA(s)	Local Authority
PS	Pradeshiya Sabha
UC	Urban Council
CEA	Central Environmental Authority
WMA-WP	Waste Management Authority of Western Province
EPC	Environmental Preservation Centre
JICA	Japan International Cooperation Agency

Glossary of Terms

Term	Definition
Centralised composting	Biodegradable waste is collected from number of households, markets and institutes and then taken to a central facility for composting.
Compostable waste	The biodegradable fraction of waste. This includes food scraps from households, restaurants and canteens, green waste from gardens and parks, contaminated or wet paper and cardboard to a certain extend. However, hardwood and lignified plant materials and animal bones, hair and other keratinised organics are not generally considered compostable.
Composting	The aerobic decomposition of biodegradable wastes under controlled conditions of temperature, moisture and aeration and their reconstitution into humus by the action of micro- and macro-organisms, involving the bonding of nitrogen onto carbon molecules, fixing proteins and carbohydrates in forms readily available to plants.
Composting feedstock	The mixture of biodegradable materials that is be subjected to composting.
Compost	The odorless, stable and humus-like material rich in organic matter as well as plant nutrients.
Home composting	Biodegradable waste generated by householders is used to produce compost for their own use, sale or exchange in small quantities with others. Usually, householders use a composter that may be purchased from the market, provided by local authority or made at home.
Local Authority (LA)	A local authority is a form of political (public) administration which delivers public services to people residing within its administrative geographical boundaries. The local authority is the lowest tier of political administration in Sri Lanka, and is further sub-divided into three categories, i.e., Municipal Councils, Urban Councils and Pradeshiya Sabha (legislative bodies), depending on the population density, urban infrastructure and revenue status.
PILISARU	The National Solid Waste Management Programme launched PILISARU during 2008–2015 by Central Environmental Authority (CEA) under the Ministry of Environment & Natural Resources. The programme was funded by Central Government budgetary allocations, and the funds are used to upgrade the waste management sector nationally.
Screening	Sorting of waste to remove contaminants and to separate desired particle sizes using equipment such as a trommel or screen.
Source segregated collection	The collection of wastes by material type from the point of waste generation.
Windrows	Regularly turned elongated piles of waste being composted to increase aeration, loosen the pile, regulate the temperature and increase waste homogeneity. Windrow composting usually relies on natural processes for air supply to the waste, though such process can be automated.

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