From urban waste to sustainable value chains:
Linking sanitation and agriculture through innovative partnerships

Organic Waste System Assessment: Kaduwela Municipal Council

Prepared by the International Water Management Institute

April 2021

Knowledge and Linkages for an Inclusive Economy Grants Program
Australian Government Department of Foreign Affairs and Trade

This report presents the findings of an Organic Waste System Assessment for Kaduwela Municipal Council. This research was undertaken as part of Activity 1 within the project *From urban waste to sustainable value chains: Linking sanitation and agriculture through innovative partnerships*.

This applied research project in Sri Lanka connects the waste management, sanitation and agriculture sectors through the circular economy, to improve food security and environmental health. This project is a partnership between the Insitute for Sustainable Futures at the University of Technology Sydney (UTS-ISF), the International Water Management Institute (IWMI), Janathakshan (GTE) Ltd, Sabaragamuwa University of Sri Lanka (SUSL) and the Sri Lankan Department of Agriculture (DoA).

The project is funded through the Knowledge and Linkages for an Inclusive Economy Grants Program by the Australian Government Department of Foreign Affairs and Trade. This assessment was also supported by the and the CGIAR Research Program on Water, Land and Ecosystems (WLE).

Research Team

- Nilanthi Jayathilake
- Pay Drechsel

Peer Review

- Juliet Willets
- Keren Winterford

Citation

Jayathilake N., Drechsel P., Dominish E., Carrard N. 2021. Organic Waste System Assessment: Kaduwela Municipal Council. Report prepared by the International Water Management Institute.

Acknowledgments

The authors would like to thank all contributing organizations for their help and cooperation, in particular Kaduwela Municipal Council (KMC) and National Water Supply and Drainage Board (NWSDB) regional office, Jayawadanagama for providing valuable data for the study. Thanks are also extended to Methila Hewage, Imesha Waidyarathne and Naomi Carrard for their huge support in the data collection process.

International Water Management Institute
Colombo, Sri Lanka

Glossary

CEA	Central Environmental Authority
DFAT	Department of Foreign Affairs and Trade, Australia
DFS	Dried Fecal Sludge
FSTP	Fecal Sludge Treatment Plants
IWMI	International Water Management Institute
JICA	Japan International Cooperation Agency
KMC	Kaduwela Municipal Council
MC	Municipal Council
MOH	Medical Officer of Health
MSW	Municipal Solid Waste
NWSDB	National Water Supply and Drainage Board
O&M	Operation and Maintenance
OSS	Onsite Sanitation Systems
PHI	Public Health Inspector
SW	Solid Waste
SWM	Solid Waste Management
UNDP	United Nations Development Programme
WMA	Waste Management Authority

Table of Contents

List of Tables

List of Figures

Executive Summary

The objective of this scoping study was to identify feasible organic waste streams that may be available as potential feedstock supply for the recovery of resources such as agricultural inputs. This report presents empirical data on the current solid waste and septage management systems in the study area – Kaduwela Municipal Council (KMC) – including an analysis of volumes, locations and nutrient composition. The report follows a system approach in presenting the findings under the sections of generation/sources, collection/transport, treatment and disposal/reuse.

Solid waste

Data on solid waste collection was provided by KMC which is by far the main collecting entity in the study area. Apart from KMC, small private companies are engaged in collecting recyclables, such as metal, plastic waste, cardboard and electronic waste. Organic waste is also collected from selected hotels and restaurants informally by pig farmers. The reported data are KMC records which have been compared with literature findings.

KMC operates their waste management services in a way that prioritises resource recovery and recycling, which means they are well-placed to strengthen and expand organic waste recovery. KMC has been encouraging waste segregation at the source level since 2008, a practice which was adopted by all Sri Lankan municipal councils (MCs) in late 2016. It is estimated that most waste within the council area is generated by domestic properties, which account for 85% of the properties in the study area. However, as small enterprises, restaurants and residencies are usually nearby and served by the same collection truck, this makes disaggregation of data into different sources impossible. Types of commercial institutions that may be the most likely sources for larger volumes of biodegradable waste are supermarkets and vegetable markets followed by hotels and restaurants. In addition, there are individual institutions such as larger authorities, schools and temples that can generate significant amounts of biodegradable waste.

Data collected from KMC records shows a total daily solid waste (SW) collection of 71 tons, out of which about 42 tons (59%) is biodegradable waste. However, based on average per capita and census data, solid waste generation in KMC was estimated at about 200 tons/day, of which about 116 tons are collected, including a biodegradable fraction of 54% to 68%. This suggests that there is lower collection by the MC than would be expected based on estimated waste generation. Possible reasons for the lower collection could be that more waste is collected by private operators (especially of recyclables) and/or an underestimated share of home-based waste processing (e.g. burying, animal feed) plus seasonal variations that are not captured. However, it could also be that the actual waste generation is lower than the values given in the literature.

The waste recycling center is not able to process all of the waste collected in the MC, so private operators fill this gap. KMC practices multiple recycling options including composting, biogas production (pilot scale), selling of metal, glass and other recyclables, as well as directing waste to cement industries to be used as an alternative fuel. However, the compost plant and the biogas plant only absorb about 10 tons and 7 tons of biodegradable waste respectively on daily basis. Subsequently, about 25 tons of biodegradable waste (59% of the collected waste) and 25 tons of nonbiodegradable (nonrecyclable) waste (99% of the collected waste) are transported by private operators to various other locations where the waste is treated (e.g. to produce compost) or landfilled on private lands. Agreements with these private contractors stipulate that the MC has to pay a tipping fee of LKR 18,500 (USD 103) per load. At least nine truckloads of waste are redirected per day accounting for about LKR 166,500 in disposal fees to be paid by the MC on a daily basis.

Current resource recovery practices in KMC generate some revenue, however it marginally contributes to the cost recovery of the operation. Despite the existing revenue streams, such as waste collection fees, sales of recyclables and compost, the revenue generated from these avenues is relatively small. Currently, revenue is estimated to cover about 19% of monthly operation and maintenance (O&M) costs. Typically, the largest cost component associated with solid waste management (SWM) relates to workforce salaries and benefits. KMC also spends a significant amount on the disposal of SW to private operators.

Septage

With no existing sewer system in the municipality, onsite sanitation systems (OSS) serve the sanitation needs in KMC. Out of the systems that are more frequently desludged, ring-structured holding tanks or buffalo tanks, with or without soakage pits, are the most widely used. Older houses can have other tanks which are more seldom emptied. Desludging of these systems and septage transportation service are provided on demand by both municipal and private sector operators. Being well equipped with the resources to serve the demand, private sector dominates the collection and transportation of septage in the Kaduwela area (98% of the collected volume). For septage management, private sector operators have between 1 and 10 septic trucks with capacities ranging from 3,500 L to 13,200 L, whereas the council has only four trucks with capacities varying from 1,800 L to 5,000 L distributed over two district offices in the municipality (Kaduwela and Battaramulla district offices).

The volumes of septage collected were estimated to be about 181 m^3 daily by both private and public sectors based on the data obtained from November 2019 to January 2020. Although 181 m^3 is used as an average, daily septage collection volumes vary significantly between 60 m^3 and 445 m^3 over time. More data over a longer period are needed to see if, for example, variations of the volumes might be influenced by the frequency and the magnitude of rainfall in the study area. The demand for emptying the sanitation systems is higher in certain areas namely Kaduwela GN Division, Malabe North, Athurugiriya South, Battaramulla South, Asiri Uyana and Pahalawela.

Both public and private collectors commonly use one of the pumping stations of the Jayawadanagama Housing Scheme Sewerage system to discharge the collected septage. A disposal fee based on the volume of septage is charged for each load disposed of at the facility (LKR 150/m^3 for the municipality and LKR 225/m^3 for the private sector operators). On average, about 36 trucks are unloaded daily at the pumping station from different entities in the KMC area. However, Jayawadanagama pumping station was originally not designed to accept such volume of septage, hence it is often overloaded.

Current systems and procedures followed by the KMC do not support or encourage ring fencing a budget on septage management. This will hinder the capability of KMC to potentially invest in the improvement of the sanitation services. Unlike in SWM, disposal cost appears to be the lowest cost compared to other cost elements in septage management. At present, the only revenue generation related to septage management comes from septage collection services. There are indications that cost recovery in terms of O&M of septage management is about 27% which is relatively higher compared to the cost recovery related to SWM.

Scenarios for organic waste streams

This assessment explored opportunities for turning the selected waste streams into valuable resources. Five possible scenarios were developed under this assessment to understand the potential of resource recovery under different circumstances, and compared to the current situation. Scenario 1 estimates that 3.3 tons of compost could be produced per day if the production processes were improved to produce what is expected with the current input capacity of 10 tons/day. Scenario 2 considers opportunities to increase production at the compost plant to its design capacity of 20 tons/day. Scenario 3 explores an increase in processing capacity of the compost plant to enable use of all currently collected organic waste in the Kaduwela area, rather than a large portion of this going to private operators. Scenario 4 considers enriching the produced compost by adding a portion of dried faecal sludge (DFS), based on the assumption that the

DFS is produced from the total volume of septage collected in the KMC area. Scenario 5 considers an expanded collection of organic waste (80% of the estimated total waste generation) and value-adding to the compost by incorporating dried faecal sludge. Factors that need to be considered in terms of further developments related to each scenario are, in general, optimizing the operation of the compost plant, training and capacity development of the workforce engaged in waste management and improving coordination between actors. These are among the strategies that can be adapted by both SW and septage management sectors to ensure sustainable operations.

Conclusions

The findings of the study suggest scope to improve the performance of the SW and septage management systems. For instance, KMC could optimize waste management within its own available facilities, especially of organic waste. With effective space utilization and adapting better composting practices, the compost plant could double the current operational scale. The MSW practice that ends in private landfills without data transparency is not acceptable from an environmental perspective. Possibilities should also be further investigated in view of more holistic waste management. An integrated model that considers different recycling streams as an interlinked system could help to maximize cost recovery and minimize the amounts eventually landfilled. Value addition to composting, such as co-composting with dried septage sludge and pelletizing could increase the marketability of the product. For resource recovery in particular, there are opportunities for public–private partnerships that warrant further exploration.

1. Introduction

The project "From Urban Waste to Sustainable Value Chains: Linking Sanitation and Agriculture Through Innovative Partnerships" is funded under the **Knowledge and Linkages for an Inclusive Economy** (KLIE) Grants Program of the Australian Department of Foreign Affairs and Trade (DFAT). This project seeks to answer the question: "What are the enablers and barriers for public and private institutions in Sri Lanka to advance the implementation of sustainable and innovative value chains to improve sanitation, health and food security?" The project will establish the knowledge, linkages and policy foundations for enabling local entrepreneurs and policy-makers to implement innovative value chains that determine how organic urban waste and sanitation systems can be transformed to deliver smallholder farmers with agricultural inputs. The policy impact of the project lies in identified synergies between agriculture, health and sanitation sectors to drive organic waste value chains. Through partnerships with the government, research institutes, the private sector and NGOs, as well as an innovative stakeholder engagement strategy, the project aims to establish an evidence base for driving policy dialogue, reducing policy fragmentation and promoting coordinated action.

This report presents the findings from the first of four project activities. The main goal of the **waste supply assessment component of the project** is to scope and identify feasible organic waste streams (e.g. septage, sludge, food waste) from public and private institutions including analysis of volumes, locations and nutrient composition. This activity aims to provide a quantitative foundation on the organic waste supply for developing innovative organic value chains for public and private enterprises potentially interested in working with the KMC waste recycling facility. The project builds on previous applied research projects undertaken by IWMI in Sri Lanka that connect the sanitation and agriculture sectors through the circular economy using the Colombo suburb of **Kaduwela** (Figure 1) as an example**.** A system perspective has been adopted and the sections are divided into generation/sources, collection/transport, treatment and disposal/reuse.

2. Methodology

The information presented in this report is based on site visits, observations, analysis of the current waste management system operations and data obtained through formal and informal interviews conducted with stakeholders from 14 organizations based on context-specific structured or unstructured questionnaires.

2.1 Data generation

Data sources include:

- Academic papers, reports from research institutes working in the field of waste management, sanitation and food security;
- Reports from KMC (development plans, budget reports, maps, gully bowser vehicle log books, gully loading log books, the KMC web profile);
- Public utility data (such as from the Waste Management Authority, National Water Supply and Drainage Board, Central Environmental Authority (CEA), Ministry of Urban Development and Water Supply etc.);
- Interviews with experts and officials to complete data gaps or verify data (see Table 1);
- Site visits to the waste recycling facility of KMC and the Jayawadanagama pumping station over five months;
- Field data measurements for quantities of SW and the biodegradable fraction at the waste recycling facility of KMC. Data were collected for quantities of septage (i.e. a truck counting study) at the current main septage disposal facility (Jayawadanagama pumping station). The questionnaire for septage truck drivers focused on the volume of the truck, its point of departure, the truck owner, etc.; and
- Observations made on the SWM practices at the waste recycling center, including procedures followed, composting practices, recyclable segregation practices, disposal and so forth as well as the septage disposal procedures and practices at the Jayawadanagama pumping house.

TABLE 1. List of organizations interviewed/consulted.

Name of the organizations interviewed/consulted		No. of interviewees
1	Kaduwela Municipal Council (district office)	9
2	Battaramulla District Office	4
3	Athurugiriya District Office	2
4	National Water Supply and Drainage Board (NWSDB) regional office – Jayawadanagama (Jayawadanagama pumping station)	3
5	Waste Recycling Center of KMC	3
6	Central Environmental Authority (CEA)	2
7	Waste Management Authority (WMA), Western Province	1
8	Private septage collection service providers	4
9	Private operators engaged in solid waste collection and disposal	1
10	Janathakshan Gte Ltd	2
11	Poultry farmers and markets in the KMC area	3
12	Fish markets in the KMC area	2
13	Swine farmers in the KMC area	2
14	Hotels and restaurants in the KMC area	4

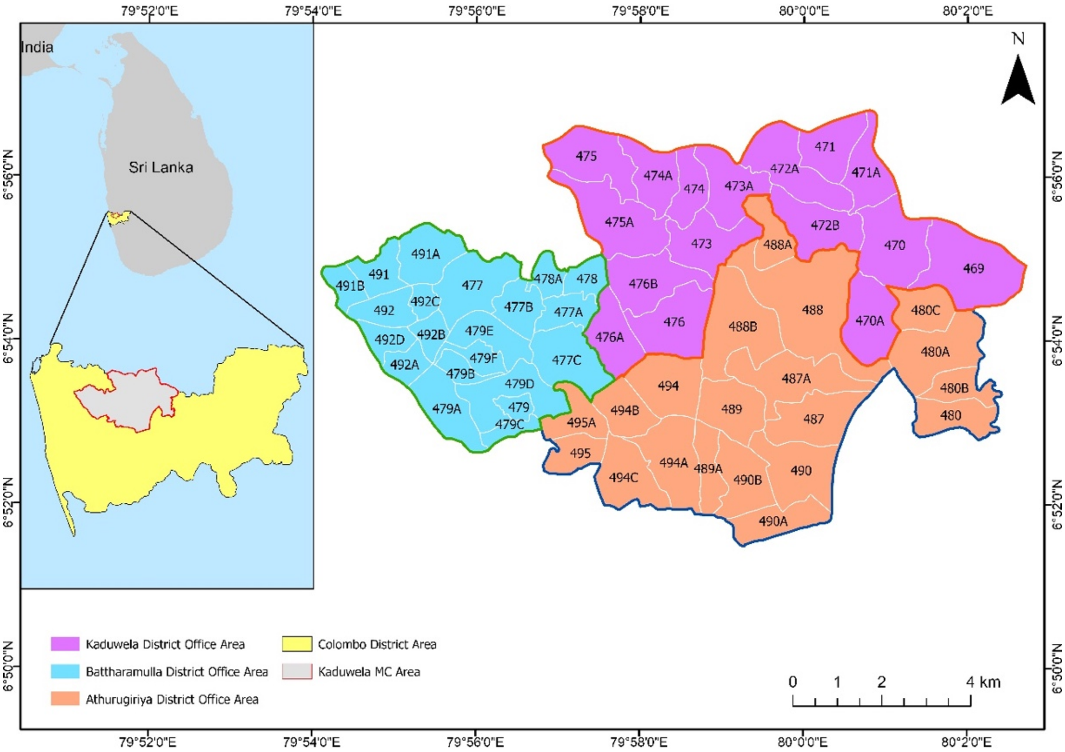
Information that was collected based on the empirical data and questionnaires was vetted through multiple site visits prior to the analysis and also compared with data from the literature. Common gaps among data from different sources or among empirical records and control calculations have been discussed wherever possible. Quantitative data analysis was conducted using Excel where multiple spread sheets were developed to tabulate and analyze the quantitative data collected on SW and septage. For instance in terms of SW, weighing bridge records on incoming and outgoing quantities of SW to and from the waste recycling center, recyclable waste quantities collected and the amount of SW transported by each private operator to different disposal locations were recorded and analyzed in order to derive the daily waste flow of the MCs. In addition SW volumes generated by different entities were categorized into different groups such as hotels, restaurants and supermarkets. The volume of SW was transformed into mass based on the densities estimated. Septage quantities collected and disposed of by both public and private operators were directly obtained from the Jayawadanagama pumping station and the volumes of septage relevant to the Kaduwela area were extracted from the record sheets that were maintained for the purpose of this research at the pumping stations.

2.2 Study area

The KMC is a suburb of Colombo District in Sri Lanka's Western Province. One of the country's major rivers, the Kelani River, flows through KMC. The municipality consists of 57 Grama Niladhari (GN) divisions[1] and is ranked top among municipal divisions in Sri Lanka in terms of size, with a land area of 87.7 km^2. It had a total population of 264,451 in 2018 distributed over 56,997 residential households (Budget Report of KMC, 2019). KMC is divided into three districts with KMC suboffices, namely Kaduwela, Battaramulla and Athurugiriya (Figure 1). Urbanization in KMC is high with most of the land classified as built-up area (Figure 2). Moreover, many national administrative services (institutions, ministries, public and semipublic services) are located within KMC, particularly in the Battaramulla and Pelawatte areas. Consequently, many families living in the city are engaged in government and private sector employment.

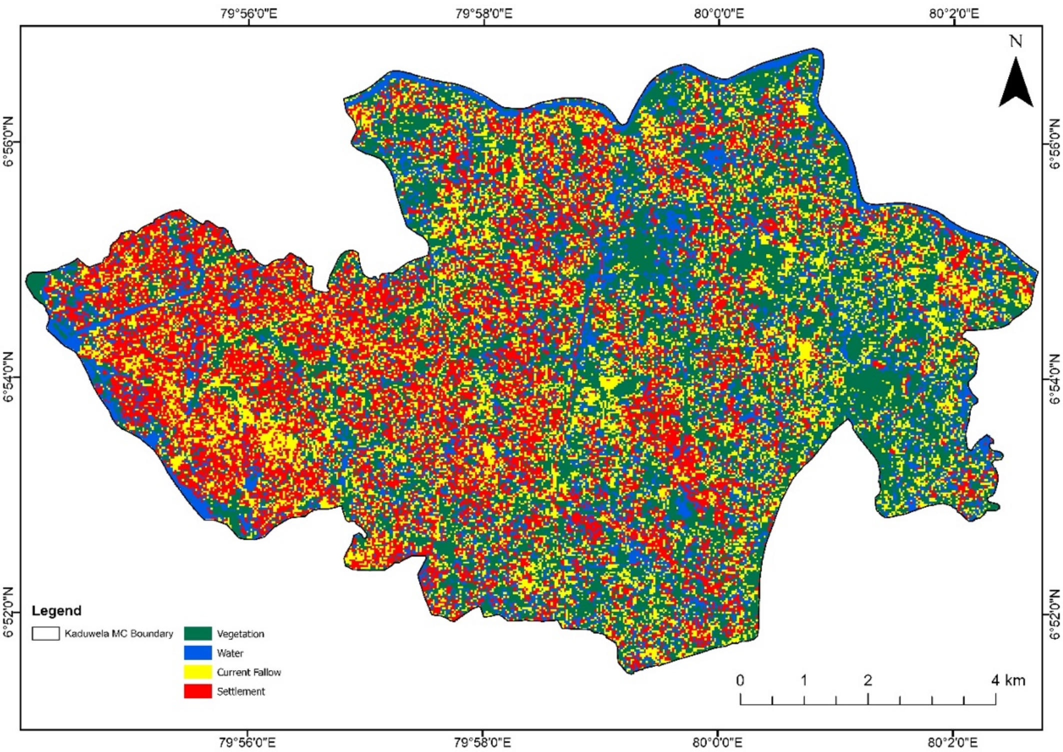
1 A Grama Niladhari (village officer) is a Sri Lankan public official appointed by the central government to carry out administrative duties in a Grama Niladhari division, which is the smallest unit of a divisional secretariat.

FIGURE 1. Administrative divisions of KMC.



Source: IWMI unpublished (2020).

FIGURE 2. Land-use patterns of KMC.



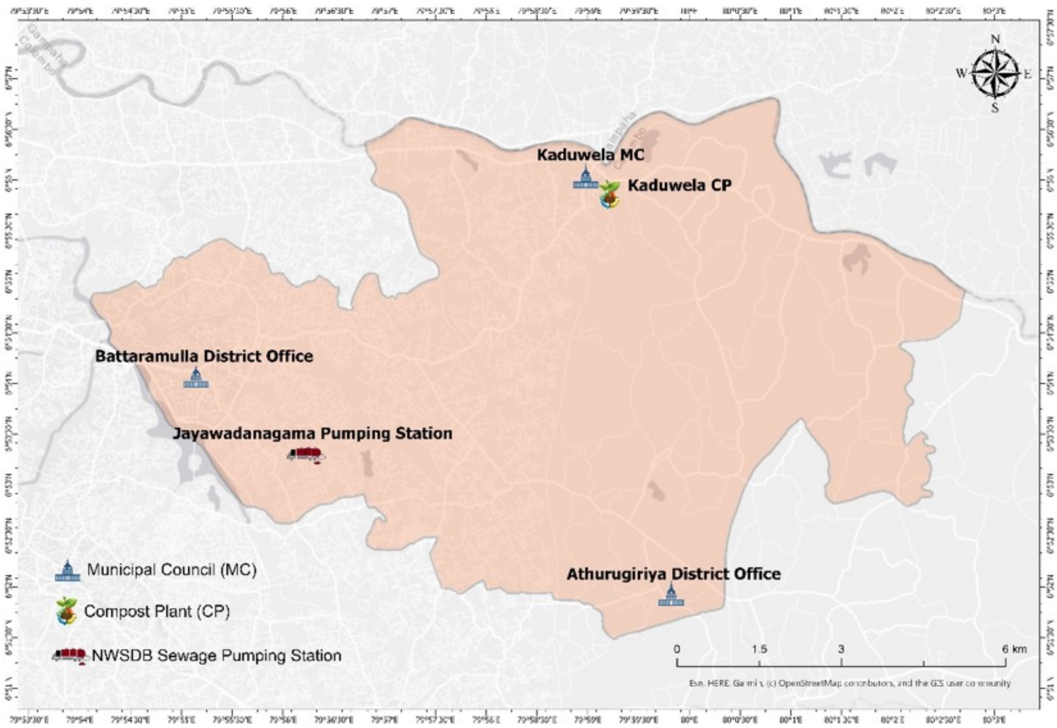
Source: IWMI unpublished (2020).

The amount of MSW collected in the Western Province constitutes 52% of the total collected MSW of Sri Lanka. Most of this comes from Colombo (JICA 2016). Kaduwela, in Colombo District, exemplifies the challenges of waste management under rapid urbanization. The rapid transformation has drawn investments in waste management.

With less than 3% of national sewer coverage in the country, most local authorities in Sri Lanka, including the KMC, depend on OSS to serve their sanitation needs. Septage management is often given less priority compared to the SWM at the local authority[2] level. Septage disposal essentially remains a huge challenge for most of the local authorities with Kaduwela being no exception. KMC lacks long-term solutions to dispose of the septage in a proper and sustainable manner.

Figure 3 shows important locations relevant to various solid and liquid waste management activities in the Kaduwela area in the current context.

FIGURE 3. Waste management locations in KMC.



Source: IWMI.

Disclaimer

Owing to available time and funding, the project had to set a system boundary, i.e. the KMC area, and rely on available KMC records. However, there are likely to be waste flows (and even more compost demand) cutting across administrative boundaries; unregistered local dumping sites and private contractors as well as an unquantifiable amount of uncollected (wild dumped or burnt waste). Given these factors we assume that our data might have an estimated error margin of at least 15% to 20%.

[2] Local authorities in Sri Lanka are divided into three different groups: municipal councils, urban councils and *pradeshiya sabha.*

3. Municipal Solid Waste

3.1 Waste management systems in Kaduwela

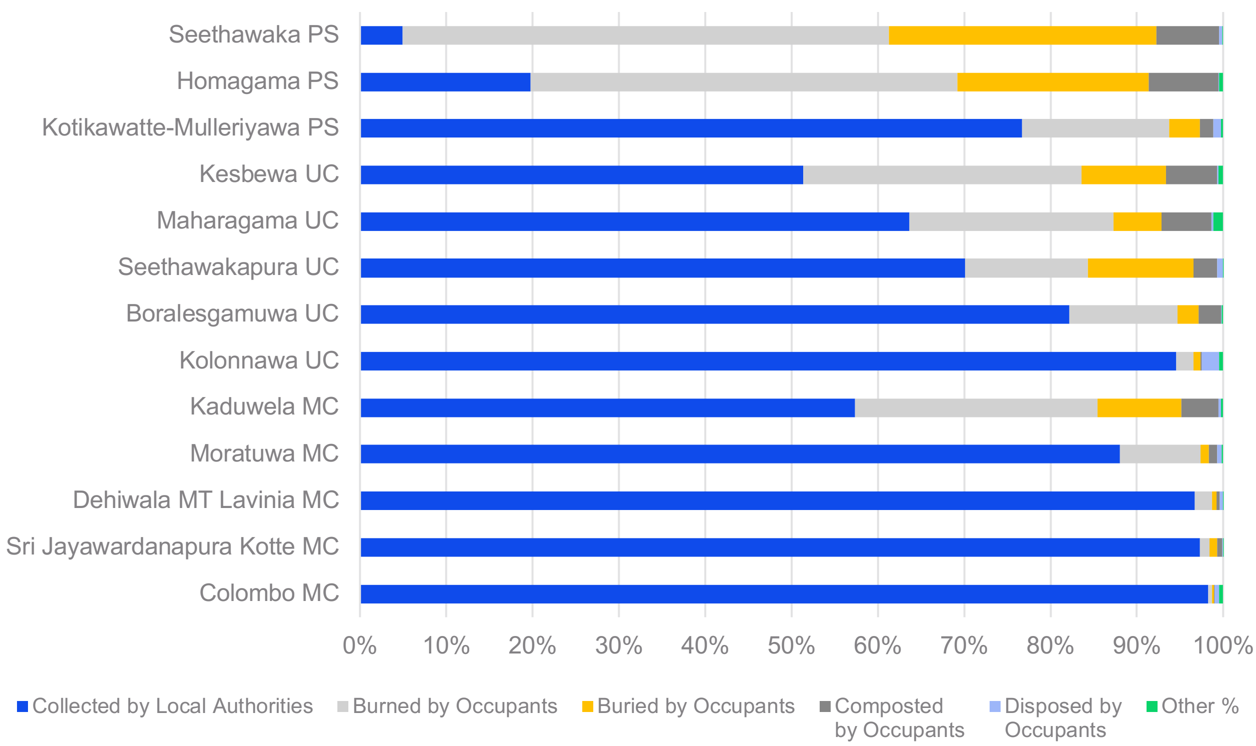
Waste generation and collection rates

The exact amount of MSW collected in Sri Lanka or Colombo varies source-wise. Estimates for urban areas in Sri Lanka assume waste generation of 0.72 kg to 0.85 kg/day/capita (AIT 2004; HARTI 2015; JICA 2016). Based on the 2018 population figure and a rate of 0.76 kg/day/capita (JICA 2016) about 200 tons of waste are generated daily within the Kaduwela area.

The waste collection rate in the Western Province that hosts major metropolitan areas is 51%, which is the highest among all the provinces of Sri Lanka (JICA 2016). However, the collection rate can vary in large margins on a rural to urban trajectory. The waste collection rate of the KMC is reported to be 58% and the rest is managed at the household level as households also burn or bury waste, or use organic residues for house-based animal feed, composting and/or as garden inputs (Figure 4). This contrasts with most MCs in Colombo District which have collection rates above 90%.

Collection rate can also vary significantly within one local authority area. A waste flow analysis by JICA (2016) for three other urban and suburban communities in the Western Province (Dehiwala-Mount Lavinia, Kesbewa and Katunayake) confirmed that high collection rates of over 90% can only be found in the city center.

FIGURE 4. Waste collection percentages of local authorities in Colombo District.

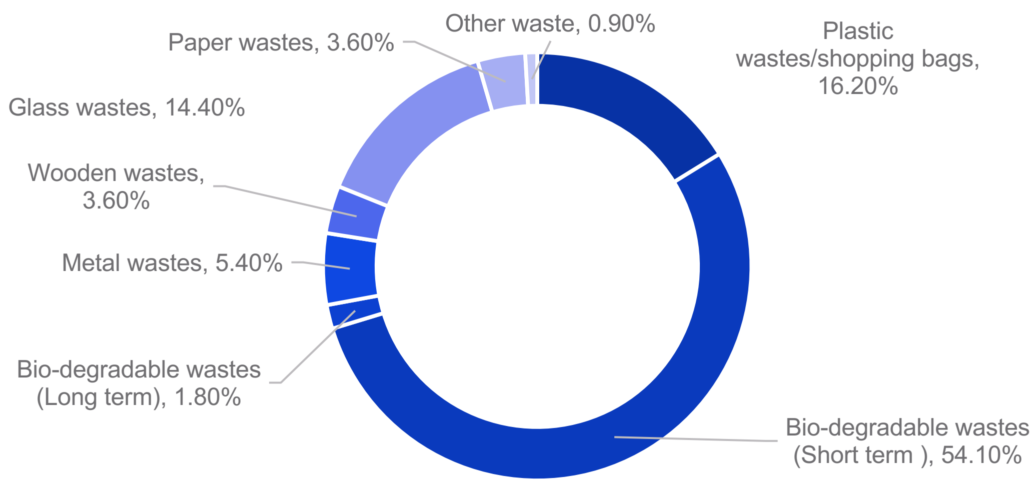


Source: Adapted from Census of Population and Housing 2012.[3]

[3] http://www.statistics.gov.lk/PopHouSat/CPH2011/index.php?fileName=H1&gp=Activities&tpl=3

The MSW of Sri Lanka typically consists of a very high percentage of perishable organic material which is about 65% to 68% by weight (Bandara 2011). In contrast, a 2012 national assessment conducted by the CEA on waste composition data at the local authority level estimated that 54% of MSW was short-term biodegradable waste for KMC.

FIGURE 5. Characterization of waste in KMC



Source: CEA 2012.

Based on the 2012 census, about 57.5% of the MSW is collected in Kaduwela (Figure 5), which translates into an estimated **116 tons/day**, including a biodegradable waste fraction of **63 tons to 79 tons/day** (Table 2). Table 2 summarizes the generated and collected SW quantities in KMC based on existing literature. These figures will be compared with the actual records from the Kaduwela recycling facility in Section 3.2.

TABLE 2. Summary of theoretical estimations of Kaduwela waste data based on available literature.

	Tons/day	**Data sources and assumptions**
Total waste generated	201	Based on generation rate of 0.76 kg/day/capita (JICA 2016) and a population of 264,451 (2018 data) (Budget Report of KMC 2019)
Biodegradable waste generated	109–137	Calculated from total waste generated and considering 54% and 68% organic fractions (CEA 2012; Bandara 2011)
Total waste collected	116	Calculated from waste generated (above) and 58% collection rate (2012 census)
Biodegradable waste collected	63–79	Calculated from total waste collected and considering 54% and 68% organic fractions (CEA 2012; Bandara 2011)

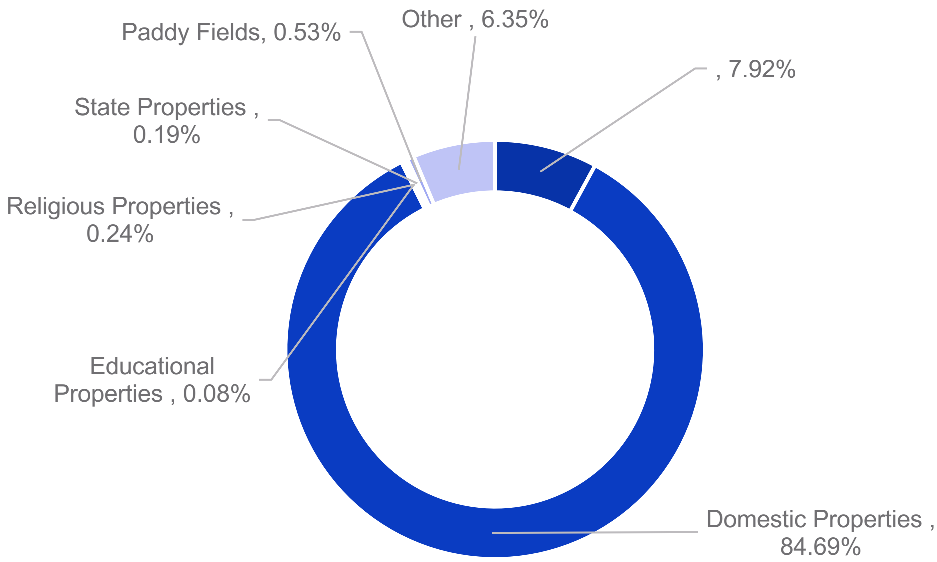
Waste sources

It is estimated that the largest waste contributors or the main waste source are the residents living in the area, as approximately 85% of the properties in KMC is domestic. The second largest waste source is likely to be commercial institutions, consisting mainly of hotels and restaurants, supermarkets and vegetable/fruit markets among others (Figure 6).

Public markets, especially vegetable and fruit markets, generate much organic waste. In Kaduwela, there are four public markets and three weekly fairs that can be considered as main waste sources, particularly in terms of organic waste. Otherwise, Nawagamuwa Pattini Devalaya, an historic temple located near

Kaduwela town, was also identified as a major organic waste source; the temple is unique to KMC where significant amounts of fruit waste and coconut shells are generated. Religious rituals performed at the temple are the reason for the generation of such specific waste streams. It is estimated that on average about 1.7 tons of organic waste are generated at the temple daily.

FIGURE 6. Percentage distribution of properties in the KMC area.



Source: KMC

A common practice in the larger Colombo area is that food waste generated in hotels and restaurants is sold or given away for free to swine farms as a pig feed. According to Reitemeier (2019), there are 159 of these farms in the Colombo District, raising about 12,750 pigs. Based on several local pig farmer interviews, it has been extrapolated that about 58 tons of food waste from the total district could be absorbed daily by this sector. As these transactions do not involve the KMC and are not accounted for in the waste collection data, it was difficult to obtain estimates of the actual amounts.

The study focus was limited to the waste that is collected by KMC. This also excludes agricultural waste which is not categorized as MSW unless it becomes market waste. In Sri Lanka agricultural waste is typically managed onsite or at the farm level. Apart from agricultural waste, animal waste such as fish waste and poultry waste are also not collected by the MC. KMC has a number of fish outlets and the current practice is for the associated fish waste to be transported to the Colombo central fish market in Peliyagoda where it is apparently processed as fish feed. On the other hand, poultry waste is managed at poultry farms as fertilizer for crops used as poultry feed.

3.2 Waste collection

In Sri Lanka, local authorities are statutorily responsible for the provision of MSW collection and disposal services within their administrative boundaries. KMC is responsible for services in Kaduwela. Waste collection service by KMC extends to the entire township; analysis of the waste collection coverage and routes showed that all the GN divisions in Kaduwela are serviced by KMC. However, this coverage does not imply a 100% waste collection rate as not all households in each GN are on the collection roster or using the service. There are also exceptions where private operators serve institutions, such as IWMI or larger schools, in collecting the waste generated within their premises. There are at least two of these private waste collectors operating in Kaduwela, but they only serve private organizations (not households) and data were not collected from them for this study.

Since 2017, waste has only been collected in a segregated manner.[4] Currently, general practice is that waste is at least separated into two categories (biodegradable and nonbiodegradable). In some cases, recyclables are also segregated into two or more categories at source, e.g. PET bottles, metal, glass or cardboard by certain households. However, most recyclables are in mixed form and further segregation is done by the waste collection truck staff as some resources can be sold to traders before delivery to the Kaduwela recycling facility. Waste collection vehicles are compartmentalized to accommodate transportation of organic and inorganic waste, while PET bottles or glass are collected in sacks. According to KMC only segregated waste is collected, however data on household compliance with the segregation policy is not yet available. It is important to note that waste management and recycling facilities that can absorb and manage fully segregated waste streams are only emerging in the country, and that currently parts of the sorted waste are again mixed on landfills or sent elsewhere. Kaduwela's compost plant can only accept a small fraction of the currently collected organic waste and is sending 59% directly to private operators (further details are given in Section 3.3).

Waste collection services are performed by all three district offices in KMC, namely Kaduwela, Battaramulla and Athurugiriya. Each district office has a health officer to support waste management at the suboffice level, whereas the Deputy Municipal Commissioner of the KMC oversees all activities in the municipal area. Waste is collected on a daily basis in different parts of the township according to a waste collection routine and map developed by the authorities. The collection vehicles are assigned to collect waste in a certain area on a particular day. In general, most areas are serviced once a week. However, waste collection in the city centers, especially in the densely commercialized areas, is performed more often, up to every day. Compactors and lorries are deployed to collect waste in these city centers. In addition, compactors are also allocated by the KMC to collect waste in specific entities such as the historic temple of Nawagamuwa Pattini Devalaya once a week.

TABLE 3. Resources available for waste collection in Kaduwela, Battaramulla and Athurugiriya.

Vehicle fleet	**Numbers**
Compactors	5
Lorries	6
Tractors	23
Human resources	
Laborers	190
Supervisors	No data

Source: KMC

KMC provides waste collection services to all the entities within the region, including domestic, government, commercial and religious institutions. In Sri Lanka, waste collection is usually provided as a free-of-charge service to the domestic sector, state properties, educational properties and religious properties with no exception in the KMC. However, both government and private institutions in the KMC are required to pay a waste collection fee to obtain the collection service. The charges are estimated based on two factors: waste category (biodegradable, nonbiodegradable and recyclables) and monthly waste volumes collected at each institution. The institution can opt to pay the charges to the MC on either a monthly, quarterly or annual basis. Prior to stipulating a collection fee, the Public Health Inspector (PHI) of the MC inspects each institution annually to estimate the average waste generation by waste type: biodegradable,

[4] The government introduced a new Circular to encourage waste separation, particularly in the MCs, in November 2016. Increased segregation practices were adopted by households from 2017 onwards. See: http://www.dailynews.lk/2016/10/31/local/97412

nonbiodegradable and recyclables. The waste volumes collected at each institution are estimated in cubes (1 cube = 100 cubic feet = 2.83 m^3) to an approximate value. Table 4 shows the typical waste collection charges required to be paid by government and private sectors for different categories of waste. Kaduwela District Office has recently initiated estimation of the waste weights (in kg) generated by institutions more accurately by means of weighing scales in case of smaller volumes or by using its weighing bridge for larger volumes. However, it is important to note that only entities that are registered as businesses with KMC were accounted for in this analysis, hence the entire sectoral contribution of SW may not have been reflected in these estimations. Otherwise, there are considerable numbers of unregistered businesses operating in the KMC area, but no information was available on their contribution to SW generation. As such, estimation can therefore be considered a representation of the sectoral contribution of the SW within the study area and suggests that a similar pattern can be expected if all the properties are taken into account.

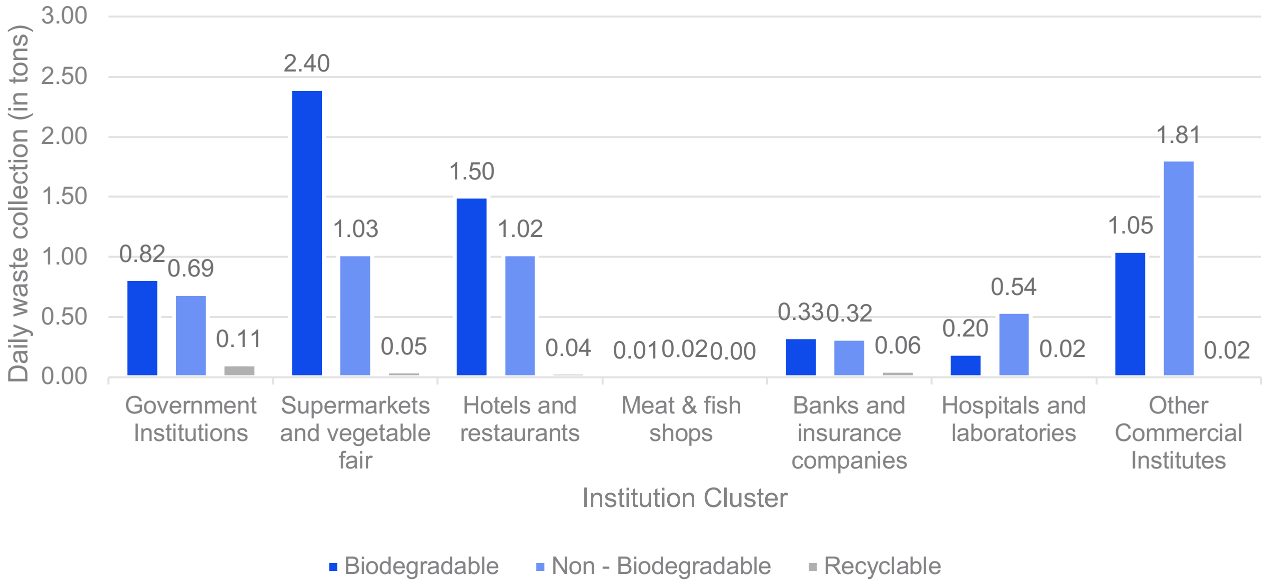
TABLE 4. Waste collection charges for different institutions.

Waste category	**Waste collection tax/cubea**		**Waste collection tax/kg**	
	Government institutions (LKR)	Nongovernment institutions (LKR)	Government institutions (LKR)	Nongovernment institutions (LKR)
Biodegradable waste	5,000.00	6,000.00	2.63b	3.16b
Paper	10,000.00	10,000.00	81.54c	81.54c
Plastic	10,000.00	10,000.00	61.15d	61.15d
Glass	2,000.00	3,000.00	2.98e	4.47e
Other nonbiodegradable waste	10,000.00	10,000.00	9.62f	9.62f

Note: The charges are given for 2020; a cube is the volume unit used for the common dump trucks (tippers) pulled by a: tractor; b: density of biodegradable waste is estimated as 0.66 tons/m3 based on the data collected; c,d,e: densities of the paper waste, plastic waste and glass waste were taken as 42.7 kg/m3, 57.0 kg/m3 and 234.0 kg/m3 respectively (see Alabdraba and Qaraghully 2013); f: density of nonbiodegradable waste is estimated as 0.36 tons/m3 based on the data collected.

Collection charges paid by each institution reflect the average amount of waste retrieved from the respective institution in a month. Figure 7 illustrates the daily amount of biodegradable, nonbiodegradable and recyclable wastes generated at different clusters of institutions that were derived from the monthly collection charges. In total, the biodegradable, nonbiodegradable and recyclable wastes collected on a daily basis from all the institutions amounted to 6.31 tons, 5.44 tons and 0.28 tons, respectively.

FIGURE 7. Amount of biodegradable, nonbiodegradable and recyclable waste collected from different types of institutions in KMC in 2019.



Source: Based on data from KMC (all district offices).

Figure 7 shows that supermarkets and vegetable fairs produce the highest amounts of biodegradable waste followed by hotels and restaurants. In fact, 69% of total waste generated from supermarkets and vegetable fairs and 58% of that from hotels and restaurants is biodegradable. Conversely, the cluster of other commercial institutions such as clothing shops and other small-scale businesses has the highest share of nonbiodegradable waste (63%). Typically, the foodservice sector (hotels and restaurants) contributes to the highest amounts of biodegradable waste. However, in this case, pig farmers collect the food waste directly from hotels and restaurants – thus, this part was unaccounted for in the waste estimations. For this reason, the actual waste generated by hotels and restaurants was not available. Hence if this was factored in, hotels and restaurants could possibly be the highest contributors to biodegradable waste generation.

Although domestic households are the largest contributors to waste collection, no information was available on the amount of residential waste. Attempts to fill this data gap by studying the waste collection routes was not possible as most areas are a mix of residential and commercial land use.

Essentially, the collected waste from all three districts is transported to the waste recycling facility of KMC which has a weigh bridge (Figure 8) to measure the daily waste quantities entering and leaving the facility. All the waste that is delivered to the site is measured through the weighing bridge to estimate the amounts of biodegradable, nonbiodegradable and recyclable waste and the records are maintained on a daily basis at the facility. According to the records of November 2019 collected by the KMC for this study on behalf of the research team, approximately 71 ±19.2 tons of waste are collected daily by the KMC, including all three districts – Kaduwela, Battaramulla and Athurugiriya (Table 5). This number is slightly higher than the 50 tons to 60 tons reported on the municipal website.[5] Average biodegradable waste, nonbiodegradable and recyclable waste collected on a daily basis are 42 tons (59%), 26 tons (37%) and 3 tons (4%) respectively. The 59% lies between the analysis by CEA (2012) of 54% for short-term biodegradable waste and the 65% to 68% reported by Bandara (2011).

[5] http://kaduwela.mc.gov.lk/si/?page_id=2233&lang=en

TABLE 5. Summary of theoretical estimations and observations of Kaduwela waste data.

	Theoretical estimations* tons/day	**KMC records tons/day**
Total waste generated	201	
Biodegradable waste generated	109–137	
Total waste collected	116	71
Biodegradable waste collected	63–79	42

** See Table 2 for theoretical estimation data sources.*

Table 5 shows both the estimated and recorded data, as the time span of the recording was short and likely influenced by the season. Thus, the estimated data might show the direction (over- or underestimation) of possible deviations.

The empirical figures of 71 tons of MSW and 42 tons of biodegradable waste are considerably lower than the 116 tons and 63 tons to 79 tons estimated based on literature data from the area (Table 2). There could be various reasons for the lower rate of collection, such as waste collected by private operators or a higher share of home-based waste processing (e.g. burning) than expected. Thirumarpan et al. (2015) reported from Batticoloa, for instance, that 30% of household food waste is disposed of via the urban council, 29% via animal feeding and the rest is mostly buried. Variations in collected amounts across months have not been captured in this study and thus might add further deviations from the annual average (see below).

Finally, the share of total recyclables[6] (such as metal, glass and paper) is rather low (4%) compared to CEA (2015)[7] data. Possible reasons for this variation could be the increase in informal businesses collecting and selling recyclables that are not captured in the waste collection records, as well as truck drivers selling recyclables before arriving at the station.

FIGURE 8. Weighing bridge at the Kaduwela recycling center and waste entering the station.

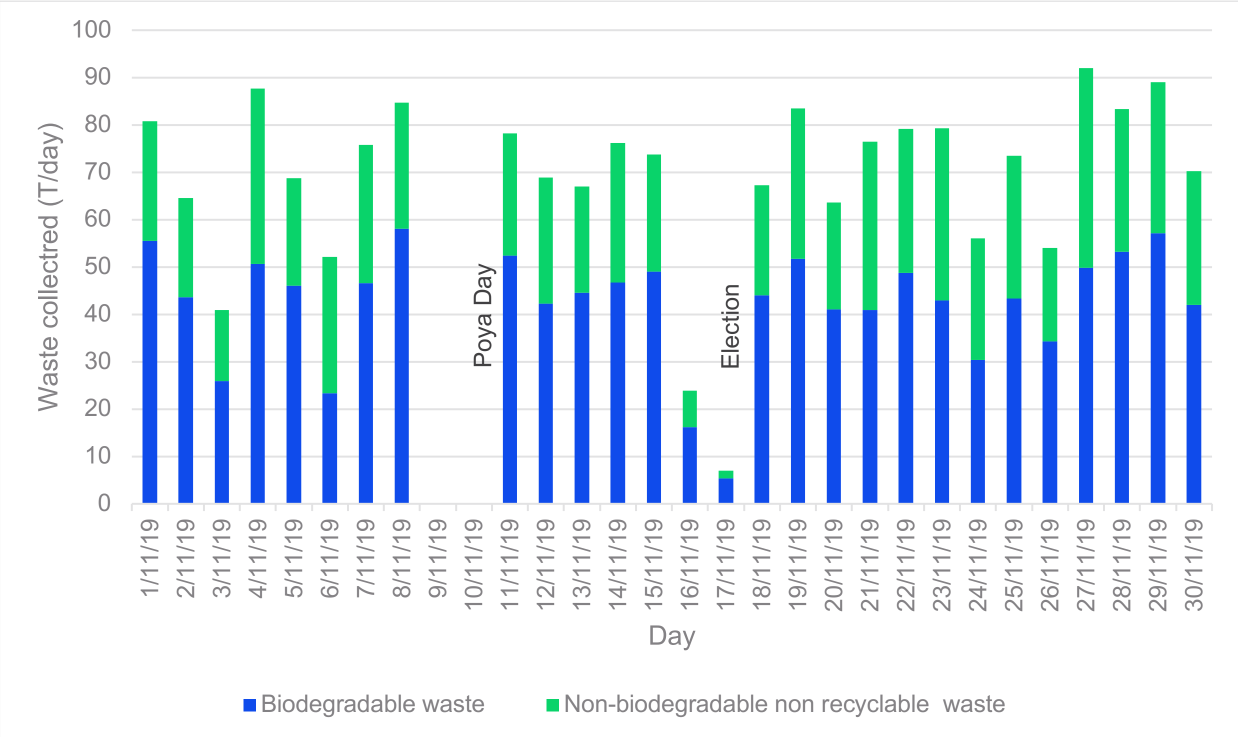
Photo courtesy: Elsa Dominish, ISF; Methila Hewage, IWMI

[6] Recyclable plastics have been excluded in this estimation as they have not been identified as a separate category in this analysis, but given as a total value including nonrecyclables such as shopping bags.
[7] https://www.unescap.org/sites/default/files/4_CEA_G%20Ajith%20W.pdf

Fluctuation of waste volumes over time and space

Daily waste volumes vary among collection areas due to variations in population density, wealth and proportion of residential and commercial entities. Thus there is hardly a day when the same amounts reach the collection facility. Figure 9 presents the fluctuation of waste that was delivered to the Kaduwela waste recycling facility during November 2019. According to the estimations, on average about 71 tons of SW are collected by the MC on a daily basis with a standard deviation of 19.2 tons across the days. The maximum amount of SW collected on a day in November 2019 is reported as 92 tons while the minimum is 7 tons. However, an important aspect to note is that the lowest collection amount (7 tons) was reported on the day after the election and the second lowest (23 tons) was reported on the day of the election. With the exclusion of such a specific event that only occurs occasionally, the standard deviation can be estimated as 12 tons and the minimum collection amount per day becomes 41 tons.

FIGURE 9. Fluctuation of waste collected in November 2019.



Source: KMC weighing bridge records.

3.3 Waste treatment and disposal

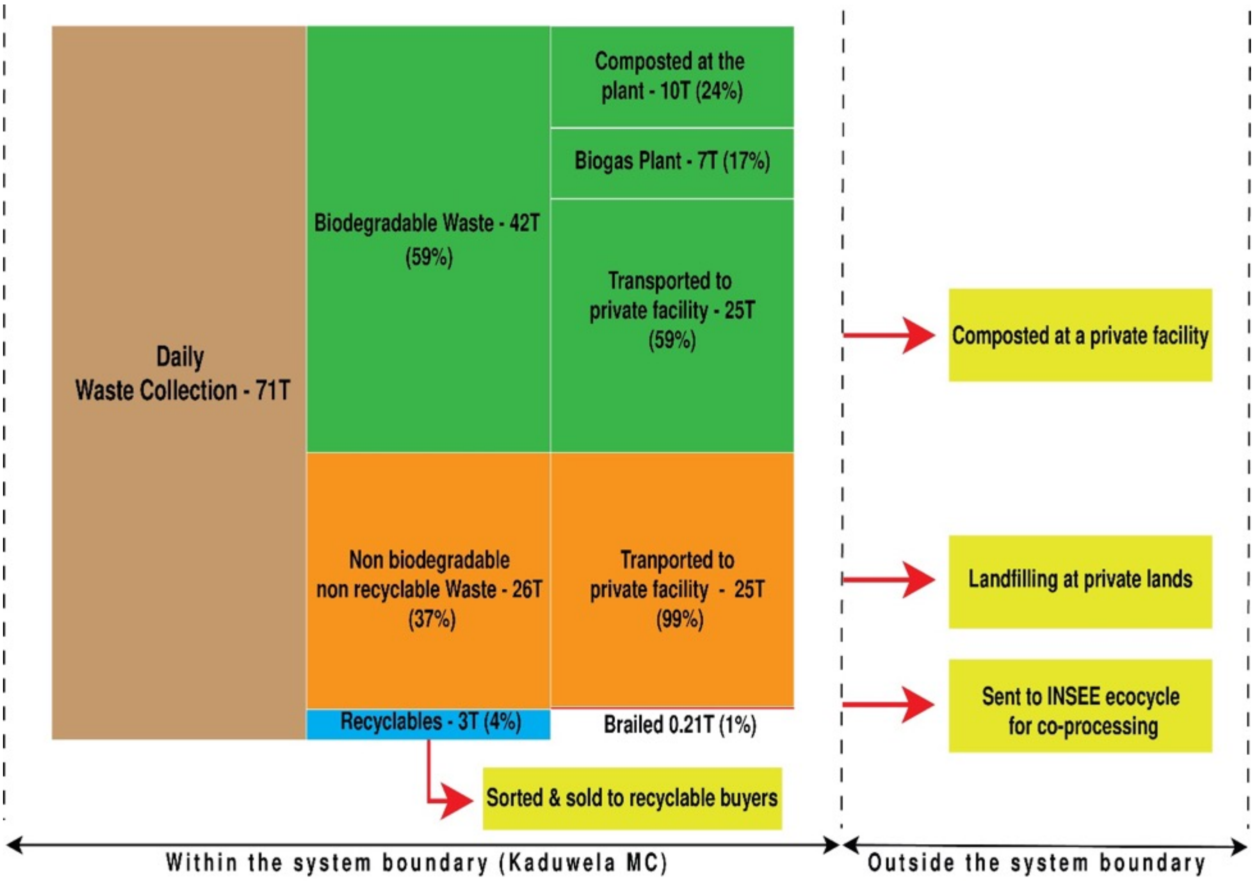
Most local authorities in Sri Lanka dump collected waste into uncontrolled landfills. However, there are some that operate compost plants and waste recycling centers in addition to an open dump to which the residual waste is directed. Unlike most other local authorities, KMC directs the waste not to a landfill, but first to its recycling center for composting of biodegradable waste, biogas production (pilot scale), sorting and selling of recyclables (metal, glass, PET bottles, cardboard boxes), or directing suitable waste to cement industries as an alternative fuel. Figure 10 illustrates the various recycling methods currently practiced by the MC including the fate of the unused or unsorted solid waste for each waste stream and the respective proportions of waste amounts estimated on a daily basis, based on data collected for this study.

Approximately 10 tons of waste per day (approximately one-quarter of collected biodegradable waste) are used for manufacturing compost.[8]

At present, it is likely that all the waste collected by KMC is transported to its waste recycling facility where the collection trucks are weighted through a weigh bridge. Exceptions are private waste collectors who dispose the collected waste at other designated places (e.g. Kerawalapitiya dumpsite) without passing the KMC waste recycling station.

The facility in Kaduwela was originally constructed as a compost plant and other components were added during later stages. However, due to space constraints, the waste recycling facility currently cannot accommodate all the waste delivered. Thus, KMC has arranged to transfer large proportions of biodegradable and nonbiodegradable waste elsewhere. Currently various private operators are engaged in transporting waste from Kaduwela to other locations where the waste is treated or disposed on private land.[9] Most recyclables are sorted and stored at the recycling facility until they are sold.

FIGURE 10. Daily waste flow diagram based on records from November 2019.



Note: Only the SW that is collected by the MC is accounted for in this flow chart. Hence this does not include agricultural waste, waste that is managed at the household or institutional level, waste collected by private operators, waste directed as animal feed or any other type of waste that is not collected by the MC.

---

[8] The same amount is stated here: http://kaduwela.mc.gov.lk/si/?page_id=2233&lang=en

[9] Data on these private operators or their locations are not easily available, especially when other waste is locally landfilled. It can be assumed that private dumping grounds are not (CEA) registered as they would likely fail common environmental standards.

Out of the total employee cadre assigned for SWM, about 45 workers are engaged in waste disposal activities such as operating the weigh bridge, unloading, sorting recyclables, operating machines such as the skid-steer loader (Bobcat), sieving machine and baling press machines and composting while about 100 workers collect waste (typically three per truck).

3.3.1 Composting

Kaduwela compost plant was established in 2006 to reduce the quantity of waste that is directed to landfills. Financial assistance for the implementation of the facility was provided by the CEA and the WMA of the Western Province and was provided from 2008 onwards by the Pilisaru project.[10] The plant is located on 3.5-acre plot and practices windrow composting that is common among many other local authorities in Sri Lanka. Initial design capacity of the plant was essentially 5 tons in terms of daily waste input. However, the capacity of the plant was expanded to 20 tons/day in a later stage.

As the plant is also absorbing other recyclables, space is limited and currently only about 10 tons/day of biodegradable waste are being composted. During field inspection it was observed that proper composting practices are seldom adhered to at the plant; instead the waste is piled up into large heaps and left for decomposition. Only some parts are composted with more care, through regular turning for example. Given that the operational procedures of the compost plant are not well organized, the quantity and quality of biodegradable waste processed to compost is not consistent. Quality checks by the CEA every 3 months provide alerts about possible neighborhood hazards, such as methane production and safe breathing, while the station monitors compost temperature; the WMA takes compost samples for quality analysis at random intervals (see below).

According to the records available, on average about 25 tons to 30 tons of compost are produced monthly at the plant.[11] This number is less than the 100 tons/month that would be expected based on the organic waste input of 10 tons/day. However, as described above, not all organic waste is treated in the same way – also depending on expected sales. In fact, even well-treated compost that has matured is only sieved and bagged when there is a demand for sale. It was noted that no value addition is carried out currently by KMC. Compost is sold under the brand name of *Saru Pohora* in 2-kg, 5-kg and 50-kg bags. The current price for a 2-kg bag of compost is LKR 10 (USD 0.056) whereas the wholesale compost price is LKR 7.50 (USD 0.042). Compost is sold directly from the compost plant or via retail shops and waste markets. For example, one of the retail shops is established in the public market. Compost buyers are mostly small-scale home garden farmers. Certain tea plantations have also been identified as main customers (ca. 10 tons/month) for compost produced at KMC. On the other hand, compost is often given away for free to schools and government organizations. It was observed that amounts of compost sales are not regular but differ significantly over months. On average the KMC sells about 8 tons to 20 tons of compost monthly, a number which differs widely among sources.

KMC has also taken various courses of action to promote its composting program further. They include:[12]

- Providing households with 200 bins necessary to produce compost at home annually;
- Explaining the importance and necessity of manufacturing compost fertilizers to the public;
- Disseminating the necessary knowledge for manufacturing fertilizers to local households; and
- Implementing the Green Bucket Project, supplying free bags for public awareness about waste segregation methodology and making home visits.

---

[10] https://www.unescap.org/sites/default/files/6_CEA.pdf
[11] In a March 2019 survey, the REACH project recorded 25 tons of compost/month of which 20 tons were sold (Eric Roy, personal communication).
[12] http://kaduwela.mc.gov.lk/si/?page_id=2233&lang=en

FIGURE 11. Composting at Kaduwela waste recycling center.

Photo courtesy: Methila Hewage

3.3.2 Biogas plant

The KMC biogas plant was established in 2019 to better manage the organic waste generated in the Kaduwela area. The United Nations Development Programme (UNDP) provided LKR 9 million in funding and KMC provided LKR 11 million; the pilot project was implemented by Janathakshan. The plant can process 10 tons of organic waste daily, particularly short-term biodegradable waste. However, currently only 7 tons of waste are fed into the plant daily. Electricity generation of the plant is expected to serve, *inter alia*, the compost conveyor and screen; it is estimated at 45 kWh for 3 hours of running. There are also plans to explore the potential of producing liquid fertilizer from the digestate. So far, the plant serves more for demonstration purposes while the station still depends on electricity from the grid (see Section 3.5.1).

3.3.3 Recyclables

In line with general practice, recyclables are occasionally segregated at source and collected as a mix of different kinds of recyclables or single types; otherwise recyclables are collected within nonbiodegradable waste.[13] However, some of the trucks start separating different recyclables while collecting in part to sell some material before it reaches the station. At the station, recyclables are segregated into different categories such as plastic, PET bottles, paper, cardboard, metal, glass and coconut shells. The sorted materials are weighted at the center and collectors are paid an allowance according to the weight of the materials collected. This is an informal practice followed by the KMC to motivate the waste collectors and to establish better collection. Table 6 shows the average amounts of recyclables collected on a monthly basis by the KMC.

[13] Some households segregate recyclables into two or more categories. Usually cardboard and paper are separated and often glass; some households also separate metal cans from hard plastics, like PET bottles, ice cream containers etc.

TABLE 6. Amounts of recyclable materials collected in tons/month (based on December 2018 to January 2019 data).

Polythene & plastic			**Coconut shell**	**Paper**			**Metal**						**Glass bottles (in numbers)**	**Recyclable batteries**
Plastic	PET bottles	Polythene		Cardboard	Newspapers	Wastepapers	Aluminum	Brass	Copper	Sheets	Iron grade 1	Iron grade 2		
13.65	6.22	1.98	18.12	19.44	1.09	14.03	0.76	0.07	0.07	8.32	5.21	0.26	2620	0.05

Source: KMC.

Table 7 lists buyers of different types of recyclables from the KMC.

TABLE 7. Buyers of different recyclable materials.

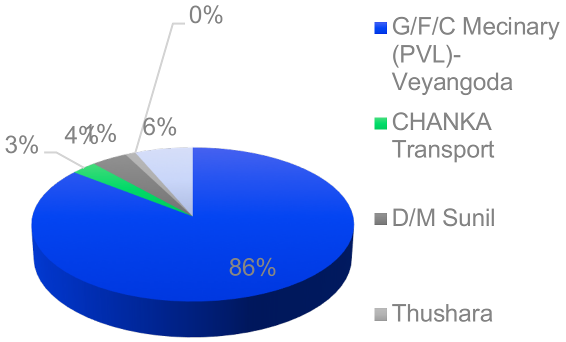
Recyclable materials	Buyer
Paper (cardboard & newspapers)	Neptune
Glass	Piramal Glass
Plastic and PET bottles	Beira Enviro Solution
Metals	Metal Collection Shops

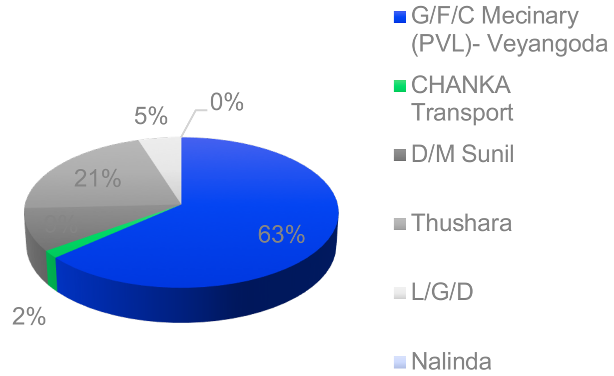
3.3.4 Disposal into landfills

Given that there is no space to self-manage collected waste, KMC currently transfers a significant proportion of the collected waste elsewhere. Previously KMC used the Kerawalapitiya landfill which is being operated by the Sri Lanka Land Development Corporation (SLLDC) as its disposal landfill. However, multiple private contractors now provide disposal facilities for KMC. According to KMC, a large portion of biodegradable (about 59% of the collected amount) and nonbiodegradable (nonrecyclable) waste (about 99% of what is collected) is transported by six private operators to their own sites that are located outside the KMC boundary.

Agreements with these private contractors stipulate that KMC has to pay a tipping fee of LKR 18,500 per load of waste transferred (a similar fee for both biodegradable and nonbiodegradable waste). Private operators bring their own trucks to the composting facility and transport raw biodegradable and nonbiodegradable (nonrecyclable) waste in separate trucks. All the trucks are measured through the weigh bridge and the private operators are paid according to the truckloads. At least nine truckloads of waste are transported daily from the municipal waste recycling facility to private landfills. This accounts for about LKR 166,500 in cost as a disposal fee incurred by the KMC daily. Figure 12 indicates the proportions of waste delivered to private landfills during November 2019.

FIGURE 12. Percentage of biodegradable and nonbiodegradable waste transported by private contractors in November 2019.





Source: KMC

A substantial amount of biodegradable and nonbiodegradable waste is transported by one particular private contractor, GFC Machinery (Pvt) Ltd located in Veyangoda which is about 40 km by road from Kaduwela city. Moreover, this private contractor operates his own composting facility at which the biodegradable waste transported from Kaduwela is used to produce compost, in addition to operating a private dumping ground.

3.3.5 Co-processing as an alternative fuel

A small proportion of nonrecyclable materials such as contaminated polythene bags, rubber items and cloth rags from Kaduwela is currently directed to INSEE Ecocycle for co-processing. INSEE Ecocycle, the waste management arm of INSEE Cement in Sri Lanka, runs an initiative to support waste management in various organizations by introducing co-processing of segregated nonrecyclable materials from MSW. Under this intervention many local authorities, including KMC, send their segregated nonrecyclables to Ecocycle. The quantity directed for co-processing however is minor compared to other disposal methods of the KMC. Before sending waste to Ecocycle in Puttalam, the waste is baled. The KMC is equipped with two baling machines of different scales to compress the materials.

3.4 Quality of compost

Qualitative assessment of compost product was conducted based on available secondary data. Recent compost quality reports were obtained from KMC, the WMA and other research studies. The WMA essentially provides advisory and monitoring services to the local authorities located in the Western Province, including KMC, to better manage their solid waste. As a part of its regular monitoring of the compost plants, the WMA conducts compost quality testing in a random manner. The quality reports are shared with KMC with suggestions on how to improve compost quality.

The WMA analysis focuses on physical, chemical and microbiological parameters and the results are compared with MSW compost quality standards stipulated since 2019 under SLS 1634: 2019. Tables 8 to 10 show the data compiled from the last few years as well as the SLS expectations or thresholds.

The data show significant variation between sampling dates reflecting the heterogeneity of samples as well as processes. Overall, results of the microbiological and heavy metal parameters are in line with the quality standards stipulated under SLS 1634: 2019. However, certain physiochemical parameters indicate deviations from the given standards (Annex 4). This could be attributed to the poor composting techniques practiced at the waste recycling center which result in poor decomposition of organic waste. Further analysis is required with more evidence to determine the possible reasons for the deviations corresponding to each parameter. It is of importance to note that the quality of compost is a key factor when it comes to the sales of compost. High variations in quality may not be favorable in maintaining a steady market.

TABLE 8. Test results of physiochemical parameters of compost.[14]

Parameters	**2015**	**2017**	**2018**				**2019**			**2020**	**Average values**	**SLS 1634: 2019**
	15 Sep	**31 May**	**4 May**	**26 Dec**	**2018 (n.d.)**	**2018 (n.d.)**	**Mar (from REACH project)**	**22 July**	**20 Sep**	**8 Jan**		
pH (1:3 v/v)	7.5	6.3	8.7	6.5	6.20	7.20	6.8	6.5	8.6	8.5	7.3±1.0	6.5-8.5
EC (1:1.5 v/v, dS/m 30 ^{0}C)	8.2	6.46	4.71	7.4	7.50	7.50	11.1	7.5	1.01	7.09	6.8±2.6	4
Moisture % (dry mass)	28.1	33.76	25	28.6	29.66	27.80	44	30.2	25	16	28.8±7.1	25
Sand %	28.02	17.7	3.84	12.2	10.0	16.9		16.96	13.44	13.04	14.7±6.6	20
Organic carbon % (d.w.b)	27.1	55.8	56.4	40	33.7	62.9	55.8	30.8	23.51	44.18	43.0±14.1	20
Nitrogen % (d.w.b)	0.84	0.98	2.33	3.64	1.96	1.12	2.2	0.38	2.89	2.73	1.9±1.0	1
Phosphorus (P_2O_5 % d.w.b)	1.09	0.27	1.2	1.12	3.36	3.82	1.1	0.52	3.4	1	1.7±1.3	0.5
Potassium (K_2O % d.w.b)	2.37	0.89	1.4	0.87	1.32	1.21	0.8	1.21	4	0.8	1.5±1.0	1
C/N ratio	32.26	56.95	24.2	10.9	17.10	56.01		81	8.1	16.2	33.6 ± 25.3	10-25
Magnesium (as Mg, % by mass)							0.2				0.2	0.5
Calcium (as CaO, % by mass)							1.9				1.9	0.7

Source: WMA, KMC and REACH project assessment on compost quality;[15] *blank fields: not measured; d.w.b. dry weight base.*

[14] Although heavy metals are chemical parameters, they are presented separately in Table 10 following the order of SLSI standards reports.
[15] Eric Roy, personal communication.

TABLE 9. Test results of microbiological parameters of compost.

Microbiological parameters	2017				2018		2019			SLS 1634: 2019
	3 July	26 July	9 Aug	29 Sep	14 May	29 Sep	Mar (from REACH project)	23 May	3 Dec	
PCC (presumptive coliform count)	ND	ND		50/g						
E. coli count (SLS 516: Part 3)	ND	ND	Free	0.7/g	ND	ND		ND	20/g	Free per g (MPN)
Salmonella (SLS 516: Part 5)	Absent in 25 g	Absent in 25 g	Free	Absent in 25 g	Absent in 25 g	Absent in 25 g	Absent per 25 g	Absent in 25 g	Absent in 25 g	Free per 4 g (MPN)

Source: WMA, KMC and REACH project assessment on compost quality; KMC; ND: not detected; blank fields: not measured.

TABLE 10. Test results of heavy metals of compost (all per dry mass).

Parameters	2017		2018	2019		SLS 1634: 2019
	9 Aug	9 Sep	16 July	March (from REACH project)	20 Sep	
Arsenic content as As, ppm	ND (LOQ 0.02 ppm)	ND (LOQ 0.02 ppm)	ND (LOQ 0.02 ppm)		ND (LOD 0.05 ppb)	5
Cadmium content, ppm, max	ND (LOQ 0.01 ppm)	1.3	ND (LOQ 0.01 mg/L)	0.74	ND (LOD 0.0028 ppm)	3
Chromium content, ppm, max	16	28	21	14.3	28.6	150
Copper content, ppm, max	105	128	163	77.2	44.1	
Lead content, ppm, max	25	43	43	20.1	ND (LOD 0.0016 ppm)	150
Mercury content, ppm, max	ND (LOQ 0.01 ppm)	0.02	0.37	0.16	ND (LOQ 0.06 ppb)	2
Nickel content, ppm, max	11	15	14	4.6	ND (LOD 0.008 ppm)	50
Zinc content, ppm, max	164	241	338	166	80.1	
Chloride (as Cl-, % by mass)				1		

Source: WMA, KMC and REACH project assessment on compost quality; KMC; blank fields: not measured.

3.5 Cost (O&M) and revenues of SWM

Typically, the largest cost component associated with SWM was for the salaries and benefits of the workforce engaged in the SWM activities. KMC also spends a significantly large sum of money on the disposal of SW. However, there are a few revenue generation streams related to SWM such as waste collection fees, sale of recyclables and sale of compost but the revenue generated is relatively small. With the implementation of proper strategies, revenues could be improved significantly, in particular compost sales.

Current cost recovery in terms of O&M is estimated to be about 19% (Table 11). However, the revenue generated via SWM is not essentially earmarked either for the O&M of the waste recycling center or for reinvestment to support and improve the waste management system of the KMC. Comparing the cost and revenue figures, as attempted in Table 11, shows that the station depends significantly on public subsidies.[16] However, given the limitations of data availability and different time periods, there are significant limits to any further interpretation.

TABLE 11. Basic monthly financial statement related to SWM in KMC.

SWM revenues:	Amount (LKR) (monthly)	Amount (USD) (monthly)
Collected waste collection fees	2,720,017	15,225
Compost sales (monthly average)	79,628	446
Recyclables sales	843,329	4,720
Total revenues	3,642,975	20,391
Total SWM expenditures	19,043,422	106,590
Profit/loss of SWM activities	(15,400,447)	(86,200)
Cost recovery	**19%**	

3.5.1 O&M cost of SWM

This study intended to estimate the O&M cost of current SWM activities performed by KMC based on the available data. Although efforts were made to identify individual expenditures incurred for different SWM activities such as collection, treatment and disposal, financial records were not available at KMC in terms of such breakdown. Therefore, the data obtained represent the total expenditures made throughout the entire SWM service chain. Table 12 shows the actual average O&M cost incurred monthly for SWM in KMC in 2019. However, certain cost elements such as capital maintenance costs have not been captured in this tabulation due to difficulty in obtaining respective data. Moreover, recurrent expenditures such as cost for water, electricity and telephone bills only reflect the expenditures at the waste recycling facility.

TABLE 12. O&M cost for SWM in KMC, 2019.

Cost element	Monthly average cost (LKR)	Monthly average cost (USD)
Salaries and allowances	9,391,004.89	52,564
Fuel	1,467,699.70	8,215
Electricity (of waste recycling facility)	30,129.63	169
Water (of waste recycling facility)	18,071.95	101
Telephone bills (of waste recycling facility)	1,759.30	10
Disposal of waste to private operators	7,253,542.50	40,600
Vehicle maintenance expenditures	881,214.60	4,932
Total O&M cost per month	19,043,422.57	106,590

Source: KMC.

[16] This is the general case in Sri Lanka. Most of the waste management services, including solid waste and wastewater, operate on public subsidies.

FIGURE 13. Percentage of cost distribution for SWM operations in KMC.

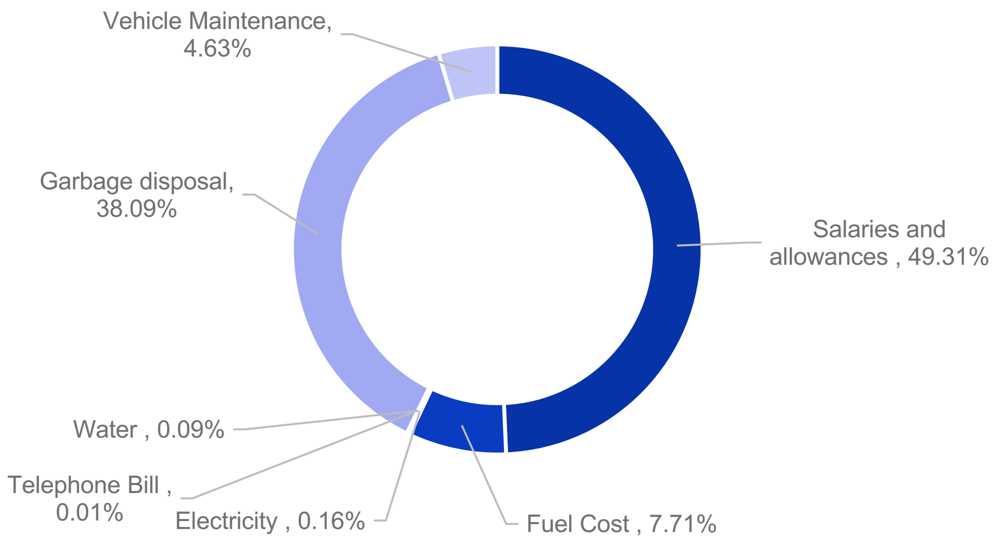


Figure 13 shows that the largest cost element is the salaries and allowances of the SWM workforce which is often the case in any local authority. A special case is the waste disposal fee that reflects the dependency of KMC on private land for its waste disposal. This practice draws a substantial amount of money from the KMC.

Typically, budget estimation for local authorities includes a separate budget allocation for SWM on an annual basis. Annex 5 shows the 2019 budget breakdown estimate for Kaduwela based on 2018 records.

3.5.2 Revenues generated from SWM

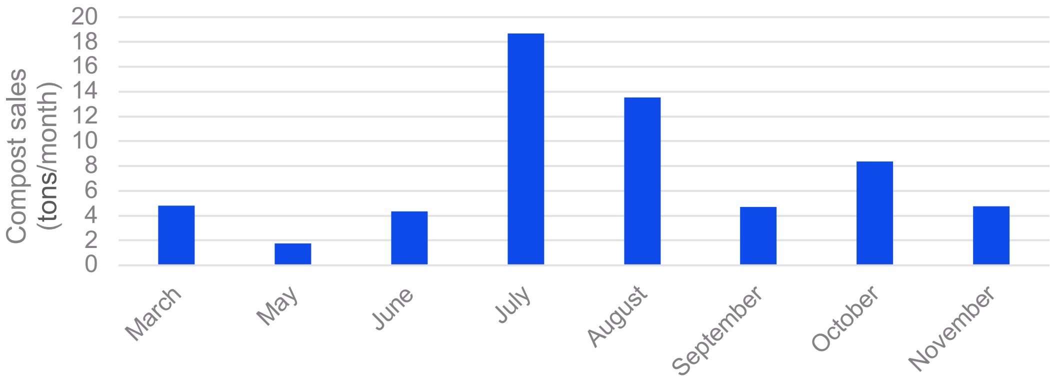
Waste collection fees from government and nongovernment institutions are the major revenue stream of the Kaduwela recycling station, followed by sales of recyclables and compost. Theoretically, waste collection from institutions is anticipated to bring regular income every month to KMC, which amounts to about LKR 2.7 million (USD 15,113) per month. However, due to different paying frequencies from different institutions, actual monthly revenue from waste collection varies.

Monthly compost sales data from March to November in 2019 revealed that the amount of compost sold in a month can vary significantly (Figure 14) and consequently the revenue generated from compost sales.

The remarkable increase in compost sales represents the bulk purchases from tea plantations; however, they are not regular. Revenues from compost sales range from a minimum of LKR 17,560 (USD 98.2) to a maximum of LKR 187,040 (USD 1,007.7).[17]

[17] In Sri Lanka, the average cost recovery potential of a compost plant can be as low as one-third of the O&M cost of the compost plant (Fernando et al. 2014). The cost recovery is estimated based on the revenue generated, not only from compost sales but also from recyclables and any other revenue generation streams, given that a compost plant essentially runs as an integrated waste recycling plant in a given local authority.

FIGURE 14. Monthly compost sales in 2019.



Source: KMC records.

Note: Data for April were not available.

Recyclables sales generate relatively higher revenue compared to compost sales. Table 13 shows the income generated by selling different types of recyclable materials in January 2019. As mentioned previously, there is a collection benefit involved that is distributed among the collectors. Considering this cost factor, the actual profit earned by the KMC from sale of recyclables is given as LKR 843,329.00.

TABLE 13. Revenue from the sale of recyclables in January 2019.

Type of recyclable materials	Unit selling price	Quantity (kg)	Income (LKR)
Plastic (basins, chairs) (kg)	45.00	13,631	613,395.00
PET bottles (kg)	22.50	6,804	153,090.00
Polythene (kg)	50.00	1,798.5	89,925.00
Coconut shells (kg)	12.00	18,741	224,892.00
Cardboard (kg)	18.00	19,323	347,814.00
Newspapers (kg)	17.00	944	16,048.00
Wastepaper (kg)	22.00	12,489	274,758.00
Aluminum (kg)	120.00	726.7	87,204.00
Brass (kg)	450.00	76.15	34,267.50
Batteries (kg)	70.00	55.1	3,857.00
Iron grade 1 (kg) – light material	42.00	5,079	213,318.00
Iron grade 2 (kg) – heavy materials	20.00	209.5	4,190.00
Copper (kg)	720.00	64.6	46,512.00
Sheets (kg) – roofing materials (kg)	17.50	8,603	150,552.50
Glass bottles (in numbers)	15.00	2,644	39,660.00
Total income (LKR)			2,299,483.00
Cost for collection (LKR) – distributed among the workers			1,456,154.00
Gross profit (LKR)			843,329.00

Source: KMC.

4. Septage

4.1 Sanitation systems in Kaduwela

There is no municipal sewerage system in Kaduwela city or the KMC. However, there is a small decentralized system in the Jayawadenagama Housing Scheme in Battaramulla, operated by the NWSDB, which serves approximately 700 housing units. The rest of KMC depends on OSS such as septic tanks and pit latrines to serve sanitation needs. However, there were no reliable data available on the percentages of different sanitation systems utilized by the residents.[18] Although there is a standard code of practice available for the design and construction of septic tanks and associated effluent disposal systems (SLS 745 part 2:2009), these standards are seldom followed for various reasons such as space constraints. Instead, various types of precast concrete tanks (e.g. horizontal cylindrical tanks, commonly called buffalo tanks, ring-structured concrete tanks) or prefabricated polyethylene (PE) tanks (e.g. Bio Cell) are commonly used among the urban population as sanitation systems.

Interviews with truck drivers indicated that out of the sanitation systems that are more regularly desludged, in Kaduwela, ring-structured holding tanks or buffalo tanks with or without soakage pits[19] are most widely used (Figure 15). These systems are prefabricated locally. Recently constructed houses have ring-structured tanks (capacity ranging from 3,000 L to 4,000 L) installed as their sanitation containments. Buffalo tanks (with a capacity ranging from 2,000 L to 7,000 L) are mostly used by residents living in close proximity to paddy fields or marshy lands where the installation of deep underground tanks would be challenged by the high groundwater level. On the other hand, many older houses can have deep locally constructed quadratic tanks with one or two chambers. Some of these are only emptied every 10 years or so depending on the number of household members (young people often move out and many houses have only older occupants).

FIGURE 15. Different types of sanitation systems: Ring-structured tanks and buffalo tanks.

Photo courtesy: Andreas Ulrich, IWMI

[18] Although details of sanitation facilities are available in the Census and Statistics Report of 2012, the data relevant to KMC do not appear to be reliable. Data suggest that the usage of "Water seal and connected to a piped sewer system" category is 91% and "Water seal and connected to a septic tank" is 6%, which is inconsistent with what was reported by stakeholders. This appears to be the case for many other cities as well.
[19] Soakage pit: A pit from which septic tank effluent is allowed to seep into the surrounding soil (SLS 745 part 2:2009).

4.2 Septage collection

Theoretically, OSS need to be emptied periodically. However, desludging frequency of a system depends on the containment volume, number of users, water consumption, prevailing weather, groundwater level and so forth as well as household willingness to pay for the service. This results in systems that are emptied as frequently as every 6 months compared to systems that are never emptied or empti ed only once in 20 years.

Desludging of OSS and septage transportation service is provided on demand by both municipal and private sector operators. Of the MCs, Kaduwela and Battaramulla suboffices have their own septic trucks whereas Athurugiriya suboffice does not provide a separate public septage collection service. Unlike in a typical local authority of Sri Lanka where septage management is a responsibility of the municipal health division headed by the Medical Officer of Health (MOH) with a team of PHIs, septage management of KMC is a task of the district officer who reports to the Deputy Municipal Commissioner. District officers of Kaduwela and Battaramulla suboffices are responsible for managing septage in their respective areas. Annex 5 gives the organizational structure corresponding to septage management in the municipality. However, regular inspection of OSS, granting approval for the new construction of sanitation facilities and prevention of environmental pollution associated with sanitation systems are statutorily handled by the PHIs of the MCs.

Public operators (Kaduwela and Battaramulla district offices) usually have only limited numbers of trucks (Table 14) to provide collection services, mostly to government institutions and residents, whereas private sector operators offer the service more widely based on the demand. Both Kaduwela and Battaramulla district offices generally each receive about two requests for emptying sanitation systems daily from different entities (residents, public places, commercial institutions among others). The general practice is that two workers are assigned for each septic truck to serve as driver and assistant.

TABLE 14. Resources available for septage collection (public sector).

Kaduwela district office	
No. of septic trucks	2 (1 x 4,000 L; 1 x 3,500 L)
Workers	Drivers (2), labor (2)
Battaramulla sub office	
No. of septic trucks	2 (1 x 1,800 L; 1 x 5,000 L)
Workers	Drivers (2), labor (2)

Similar to private service providers, an entity in need of obtaining septage collection service from KMC is required to pay a charge to the service providing agency, based on the type of entity (residential or commercial) and if the entity is located within or outside the KMC boundary. The KMC follows a formal procedure when offering the collection service; for example, a requestor should complete an application form and make payment prior to obtaining the service. Table 15 shows the charges set by Kaduwela and Battaramulla district offices for providing the service.

TABLE 15. Fee structure for septage collection by KMC.

Limits	Charges (LKR)
Kaduwela District Office	
Within KMC limits (residential)	5,461.20
Within KMC limits (business)	6,634.20
Outside KMC limits (residential)	7,807.20
Outside KMC limits (Business)	8,980.20
Battaramulla District Office	
Within KMC limits (residential)	3,894.95
Within KMC limits (business)	5,067.95

Source: Battaramulla District Office.[20]

4.2.1 Private sector operations

Given the limited number of public trucks, the private sector dominates the collection and transportation of septage in the Kaduwela area. Daily, private operators address 20 to 50 desludging requests with an average of 34 within the region. The market for septage collection in Kaduwela township is shared by five private operators with different business scales in addition to the public sector (MCs). However, their usual service areas extend beyond KMC limits. Aside from registering with KMC as a normal business, there is no interaction between the municipality and the private operators. Although the KMC is entrusted with septage management in the respective area, there is no formal process to monitor private sanitation service providers at the KMC.[21]

Evidently, the private sector is better equipped with the resources to serve the demand for septage collection than the KMC. Private sector operators have 1 to 10 septic trucks for septage management with capacities ranging from 3,500 L to 13,200 L. Septic trucks with larger volumes are commonly used as a temporary transfer station/storage depot to avoid frequent trips to the disposal locations. Desludging fees vary according to the collection volumes and the travelling distances. Table 16 gives an overview of the private sector operation in the septage collection and transportation business.

TABLE 16. Overview of private sector operations in septage collection.

Service providers	No. of gully bowsers	Volume of the gully bowsers (liters)	Number of employees	Average number of desludging services daily	Service area	Fee structure*
Operator 1 (Service Co)	6	4,000 (3) 5,000 (1) 6,000 (2)	12	10–15	Colombo, Bokundara, Godagama, Maharagama, Meethota, Padukka, Kaduwela, Biyagama, Battaramulla, Athurugiriya, Wattala, Ja-Ela	4,000 L–LKR 4,000 5,000 L–LKR 5,000 6,000 L–LKR 6,000

[20] http://kaduwela.mc.gov.lk/si/?page_id=2249&lang=en

[21] Currently there is no formal register of private operators at any level of government (not just the KMC) to enable coordination or engagement; however the CEA is currently developing a process to regulate private operators.

Operator 2 (Amarathunga Enterprises)	10	13,200 (3) 12,000 (1) 6,000 (2) 5,000 (2) 4,000 (2)	27	10–20	Kaduwela, Battaramulla, Maharagama, Kottawa	4,000 L–LKR 4,000 5,000 L–LKR 4,500 6,000 L–LKR 5,500 13,200 L–LKR 12,000
Operator 3 (Niroshan Enterprises)	4	Data not available	Data not available	10–15	Battaramulla, Maharagama, Kaduwela	LKR 3,500–4,000
Operator 4 (Wijekumara)	1	4,000	2	2–3 (max 5)	Pelawatte, Battaramulla, Kaduwela	LKR 4,500–6,500
Operator 5 (Indika Mataraarachchi) **	7	3,000 (5) 14,000 (2)	5	10–12 (only 2–3 trips within the MC area)	Athurugiriya, Homagama, Kottawa (mostly operate outside Kaduwela city)	LKR 5,500–6,000

** Fee structure indicates the starting fees for different volumes in some cases and others are given as typical ranges. Septage dumping fees might be added.*

*** Operator 5 mostly operates outside the KMC area.*

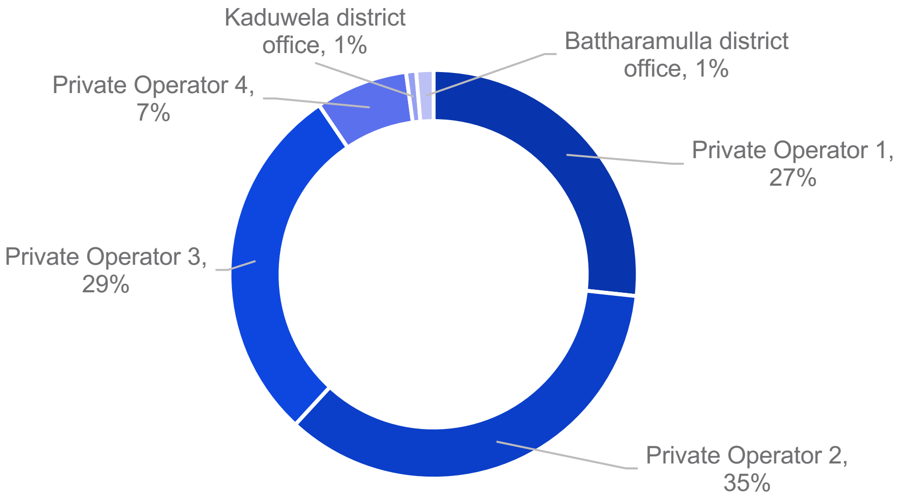
4.2.2 Septage quantification

In general, the KMC only maintains records of the number of septage collection turns performed by its own vehicles on a daily basis, together with collection locations and the corresponding fees on each day, essentially for recording financial transactions. Based on these data, volumes of septage collected by the KMC can be directly calculated. However, access to data records of private operators on collection volumes was limited in some cases, hence data were not readily available to estimate the total septage collection volumes in Kaduwela municipality. Therefore, field-based methods were used for the estimation of daily septage collection volumes.

Given that nearly all the septage collected in the Kaduwela area is disposed of at one location (the Jayawadanagama housing scheme sewer system), quantification of septage was based on the disposal volumes.[22] Subsequently, daily septic trucks unloaded at the disposal location were counted and recorded along with the truck volume, name of the service provider and the collection location for 2 months. The volumes of septage collected were derived based on the truck volume. It is estimated that on average about 181 m^3 of septage are collected daily by both the private and public sectors. However, this is an indicative figure of the collected volume and the realistic value may be slightly less than the estimated volume given because the septic trucks sometimes may not be full at the time of discharge. During the interviews with the operators it was emphasized that the operators try to load the septic trucks to the maximum possible level even with extending the emptying service to two or more entities. Therefore, the difference between the estimated and the realistic values is assumed to be marginal. Remarkably 98% of the volume is collected by the private sector. Figure 16 illustrates the percentage distribution of septage collection by different service providers.

[22] There may be cases of indiscriminate disposal of septage. However, there were no records of such cases, so they not captured in this study given the difficulty in tracking the cases, if any. According to the private operators dumping septage into public places was almost impossible due to the increased awareness of the public and high population density in this region.

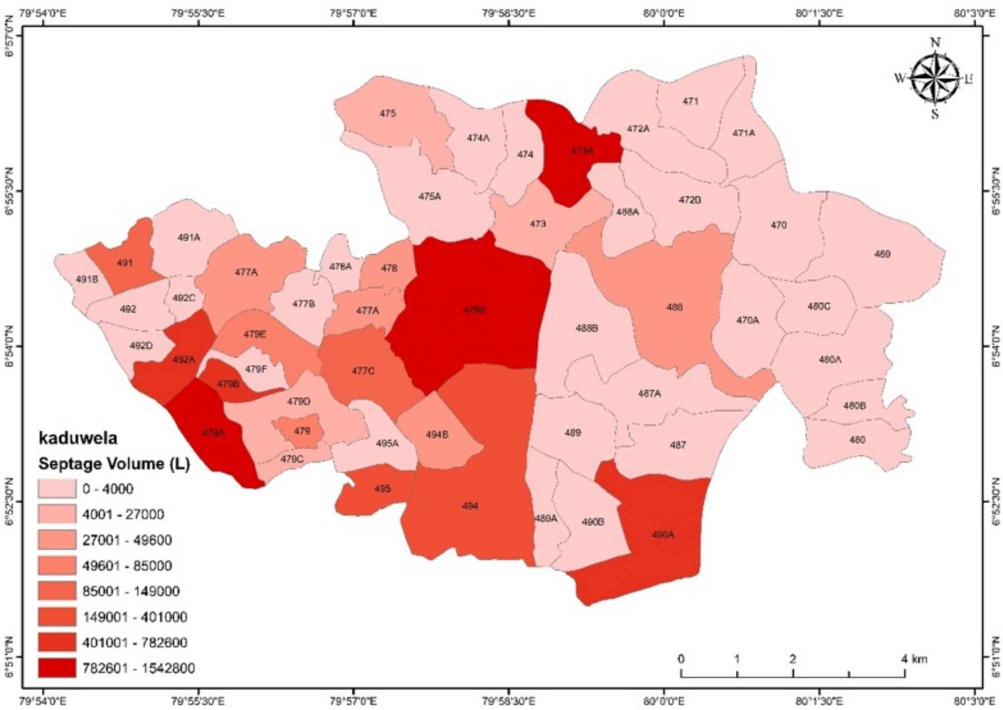
FIGURE 16. Percentage distribution of septage collection volumes by public and private sectors.



Note: There were no collections by operator 5 within the KMC area during data collection, hence the operator is not included in the figure.

Demand for emptying the sanitation systems is higher in certain areas within Kaduwela municipality. Figure 17 indicates the areas that have high demand for desludging namely Kaduwela GN Division, Malabe North, Athurugiriya South, Battaramulla South, Asiri Uyana and Pahalawela. Further analysis is needed to see how far the volumes correlate with population density, or other factors such as small tank volumes which require more frequent emptying.

FIGURE 17. Septage collection hotpots in KMC.

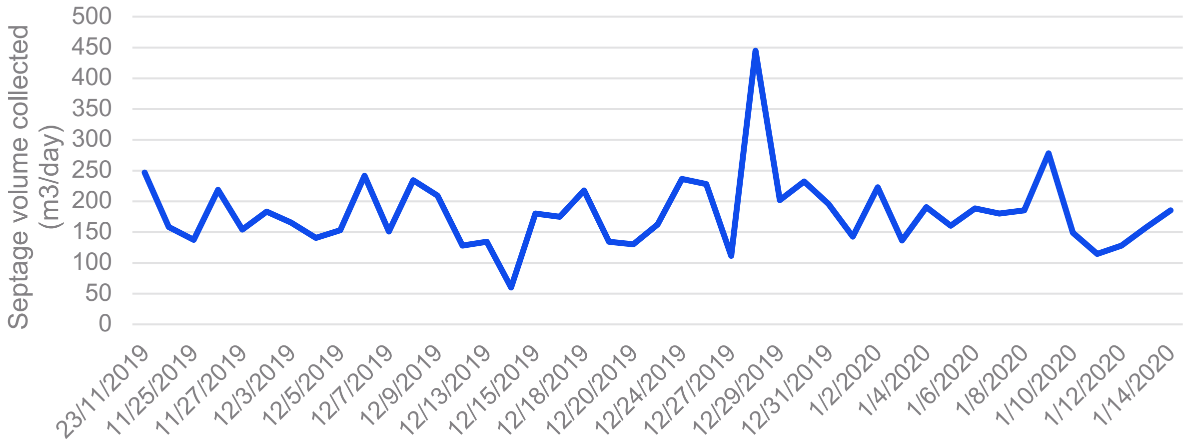


Source: IWMI

4.2.3 Fluctuation of septage volumes collected

Figure 18 shows the fluctuations of septage volumes discharged at the pumping station over 2 months. With an average of 181 m^3, daily septage collection volumes vary significantly over time – between 60 m^3 and 445 m^3. More data over a longer period are needed to see if, for example, variations of the volumes might be influenced by the frequency and the magnitude of rainfall in the study area (which can in some cases fill up the septic tanks more frequently).

FIGURE 18. Volume of septage collected in KMC and disposed of daily at Jayawadanagama pumping station .



Source: Jayawadanagama pumping station

4.2.4 Septage quality

Septage is highly variable in consistency and concentration which can be attributed to the type of sanitation system, number of users, climate, geographical nature of the area and other factors. Unlike wastewater, septage has not been on the national agenda until recently, hence only limited data are available on septage management in Sri Lanka, particularly on septage characteristics. Essentially, there were no data available on the septage quality in Kaduwela area or the septage disposed of at Jayawadanagama pumping station. However, septage quality analysis conducted elsewhere in the country is presented for reference. Table 17 gives the quality analysis of septage that was being received at different treatment and disposal locations such as wastewater treatment plants,[23] fecal sludge (septage) treatment plants (FSTPs) and pumping stations of sewer networks. Table 17 also indicates the standards stipulated under the National Environmental Act (NEA) No. 47 of 1980 for the discharge of effluents into inland surface waters (CEA 2008) to understand the level of treatment required for the septage before discharge into the environment. The analysis clearly indicates the variations of septage characteristics in different locations across the country.

[23] Apart from the treatment plants that are exclusively designed to treat septage, co-treatment with wastewater has also been recognized as a common treatment option in the country to treat septage.

TABLE 17. Characteristics of septage in Sri Lanka.

Testing parameter	Septage influent at Zoysapura, Ratmalana wastewater Treatment plant	Septage influent at Madampitiya pumping station	Septage influent at Kuliyapitiya FSTP	Septage influent at Kurunegala FSTP	Septage influent at Balangoda FSTP	Standards for discharge of effluent into inland surface waters
pH	7.6±0.1	7.4±0.1	7.5±0.1	7.6±0.1	7.2±0.1	6.0–8.5
Temperature (℃)	29	29	28	34	28.5	< 40
TSS (mg/L)	$1.8x10^4$	$2.3x10^4$	$1.5x10^4$	$1.6x10^4$	291±5	< 50
COD (mg/L)	$3.0x10^4$	$6.8x10^4$	$2.4x10^4$	$2.6x10^4$	$1.8x10^3$	< 250
BOD (mg/L)	$6.7x10^3$	$1.5x10^4$	$6.2x10^3$	$6.6x10^3$	490±18	< 30
Oil & grease (mg/L)	672	758	433	585	64	< 10
Color						
Yellow ($m^{(-1)}$)	24.8	23.1	20.4	16.5	12.3	< 7
Red ($m^{(-1)}$)	10.2	12.5	10.9	10.7	5.7	< 5
Blue ($m^{(-1)}$)	7.3	9.4	7.4	7	3.4	< 3

Sources: IWMI WB FSM Assessment 2019; CEA 2008.

4.3 Septage disposal

Both public and private collectors commonly use one of the pumping stations of the Jayawadanagama Housing Scheme Sewerage system to discharge collected septage. On the occasions that the pumping station is not available for septage disposal during repair and maintenance, septage is transported to another pumping station of Colombo's sewer network system located at Mount Lavinia, which is about 25 km away. Both these pumping stations are operated and maintained by the NWSDB.

Jayawadanagama Sewerage System located in Battaramulla serves a population of 3,600 to 4,000 people residing in the housing scheme. It consists of 5.8 km of sewer collection pipes and two pumping houses from which sewage is pumped into the sewer system of Colombo (JICA 2012). Each service provider is required to obtain a permit from the operating entity of the disposal site, which in this case is the Jayawadanagama regional NWSDB, to use the disposal facility. The disposal fee is based on the volume of septage and charged for each load disposed of at the facility – LKR 150/m^3 for the municipality and LKR 225m^3 for the private sector operators. On average, about 36 trucks are unloaded daily at the pumping station from different entities in the KMC area.

FIGURE 19. Discharging septage at Jayawadanagama pumping house.

Photo courtesy: Methila Hewage, IWMI

Jayawadanagama pumping station was not originally designed to accept any volume of septage so it is often overloaded. It appears that despite overloading, the pumping station continues to accept septage in order to discourage the indiscriminate disposal of septage given that there is no alternative septage disposal site for the service providers in close proximity. According to officials, this practice is not considered as a long-term solution.

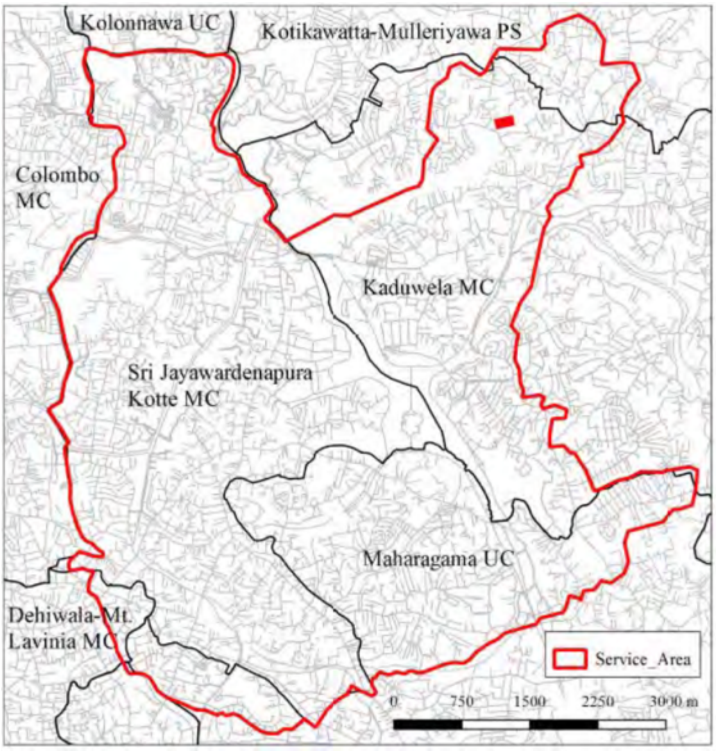
A new project has been proposed to collect and treat wastewater generated in Kotte city and surrounding areas through a sewer network with a Sewage Treatment Plant (STP). The service area (Figure 20) of this project covers approximately 2,920 ha; it comprises Sri Jayawardenapura Kotte MC and its environs, including parts of KMC, Dehiwala/Mount Lavinia MC, Maharagama UC and Kotikawatta-Mulleriyawa PS. As such, 13 GN divisions of KMC will be connected to a sewer network (JICA 2019).

The STP will eventually be located at Heenetikumbura near Kalapaluwa/Koswatta Road with capacity to treat 39,400m^3 of wastewater/day. However according to the project proposal it will only be completed in 2046[24] (JICA, 2019). The Japan International Cooperation Agency (JICA) will provide funding.

The STP has a provision to accept in addition 175 m^3 of septage daily from the surrounding local authorities including KMC. According to the proposed plan, septage will only be received at Main Pumping Station (MPS) No. 05 (located in front of Linear Park-Diyawannawa along Sri Jayawardenpura Mawatha). However, the current plans do not specify the quantity of septage each local authority is allowed to transport to the proposed facility and therefore establishment of individual solutions at the local authority level is needed to manage at least a portion of septage in the foreseeable future.

[24] The project will be implemented in three phases and the first phase is planned to be completed in 2029; by then 62% of the population in the service area will be served with a sewer network including low-income areas, priority areas and the areas around the STP. Subsequently, the second and third phases will cover 85% and 100% of the population respectively after anticipated project completion in 2046 (JICA 2019).

FIGURE 20. Service area of the proposed STP sewage system.



Source: JICA 2019.

4.4 Cost (O&M) and revenues of septage management

KMC currently does not maintain separate financial records on the costs and revenues associated with septage management. Current systems and procedures followed by the KMC do not support ring fencing a budget on septage management. Thus the budget allocation for septage management is distributed across various other general budget lines. For example, the Engineering Section of the MC is responsible for maintaining all the vehicles that it owns, hence it is given a common budget to perform all the O&M tasks associated with the vehicles including the septage trucks. In this context, various data sets were screened to extract financial data that were relevant to septage management in KMC. Table 18 gives a basic monthly financial statement related to septage management in KMC. At present, the only revenue generation related to septage management is from the septage collection service. Table 18 indicates that cost recovery in terms of O&M of septage management is about 27% which is higher compared to the cost recovery related to SWM.

TABLE 18. Basic monthly financial statement related to septage management in KMC.

Revenues:	**Amount (LKR, monthly)**	**Amount (USD, monthly)**
Septage collection service	90,581.39	507
Total expenditures	337,085.53	1,886.74
Profit/loss of septage management activities	(246,504.14)	(1,379.74)
Cost recovery	***27%***	

4.4.1 O&M cost of septage management

For basic understanding of the cost incurred on septage management in KMC, average values of cost elements were estimated based on the empirical data. Table 19 indicates approximate values of monthly O&M cost (without data on fuel) incurred for septage management based on the data gathered from Kaduwela and Battaramulla district offices.

TABLE 19. O&M cost of septage management in KMC.

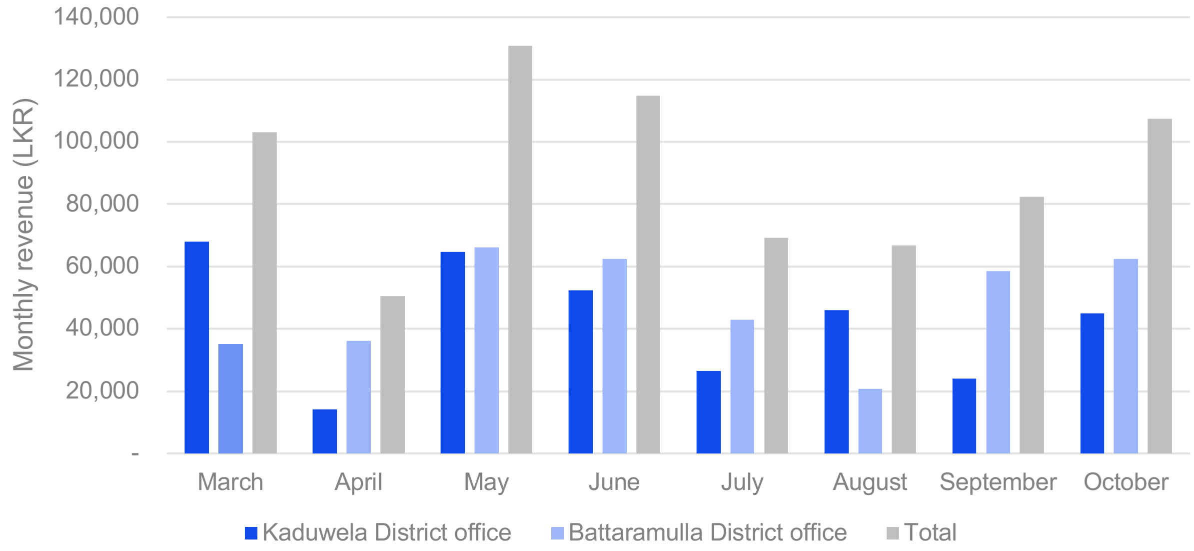
Cost elements	Monthly costs (LKR)
Salary (approx.)	264,000.00
Fuel cost (to be determined)	
Septic truck maintenance cost	58,573.64
Average septage disposal cost	14,511.90
Total (w/o fuel)	337,085.53

Unlike SWM, disposal cost appears to be the lowest cost compared to other cost elements in septage management. This is because disposal charges are kept at a marginal level especially for the government sector by the service provider (NWSDB) to discourage the indiscriminate disposal of septage.

4.4.2 Revenue generated from septage management

Figure 21 indicates the monthly revenue generated from septage collection in KMC from March to October 2019. The amounts vary in accordance with the collection services provided in a month.

FIGURE 21. Monthly revenue from septage collection in KMC (from March to October 2019).



5. Scenario Building

The study aimed to identify the avenues for transforming urban waste streams into valuable resources such as agricultural inputs. As such, five possible scenarios were discussed to identify the potential of compost and co-compost production as shown in Table 20. The current situation has also been included in Table 20 as the base case.

Scenario 1 is developed based on the assumption that the production process is improved to produce the amount of compost (3.3 tons/day) that would be expected with the current input capacity (10 tons/day), compared to current production levels which are less than expected (1 ton/day). **Scenario 2** assumes that compost production is increased to the designed input capacity of the compost plant (20 tons/day). **Scenario 3** is based on the assumption that all the organic waste collected in the Kaduwela area is processed, through expanding the capacity of the plant. **Scenario 4** is based on the same input capacity for compost as Scenario 3, but also estimates the amount of dried fecal sludge (DFS) that could be produced with the average volumes of septage collected daily in Kaduwela. From this the volumes of co-compost are estimated (compost value-added with DFS). **Scenario 5** is based on the assumption that a higher proportion of organic waste that is generated in Kaduwela is collected and the capacity of the plant is expanded to processes this, and the volumes of co-compost are estimated based on the same volumes of dried FS as in Scenario 4.

Although Kaduwela does not have an FSTP, a hypothesis of the availability of an FSTP, including drying beds to produce dried fecal sludge, was considered for Scenarios 4 and 5. Compost production was estimated based on the organic waste supply while the co-compost production was estimated based on the availability of both organic waste and DFS.[25] However, it is important to note that the calculated quantities of compost and co-compost (in Scenarios 4 and 5) cannot be provided at the same time given that both composting and co-composting require organic waste as an input. Production quantities of each of these options can be decided based on the knowledge of demand for each product. Given that Kaduwela has 56,997 households and assuming a desludging interval of septic tanks as 5 years,[26] the number of septage collection turns per day can be estimated as 32, which is comparable to the actual number of septage collection trips (about 36 turns by both public and private sectors). This implies that the septage collection rate at present is likely to be on the higher side in the Kaduwela area. It is therefore assumed in this estimation that the full potential of DFS production is captured with the current septage collection patterns. On the other hand, organic waste supply appears to be significantly higher compared to DFS supply resulting in DFS being the limiting factor in calculating the co-compost potential. However, it is important to note that varying desludging frequencies could suggest otherwise. Subsequently, many scenarios can be developed based on variables including desludging frequencies, capacities of the septic tanks and so forth.

---

[25] DFS or dried septage is commonly produced using unplanted drying beds. Typically, sludge is sun-dried for about 14 to 21 days, however the drying period may vary according to the weather conditions in the area.
[26] According to the *Septage management guidelines* developed by Oxfam (2008) for Sri Lanka, it is strongly recommended that a septic tank be pumped out at least every 5 years.

TABLE 20. Compost and co-compost production potential based on different scenarios.

	Baseline	**Scenario 1: Improve compost production to produce expected amount for operating input capacity**	**Scenario 2: Increase compost production to designed capacity**	**Scenario 3: Increase compost production to meet current collection**	**Scenario 4: Increase compost production to meet current collection and value add a portion with dried FS**	**Scenario 5: Increase compost production to meet expanded collection and value add a portion with dried FS[a]**
Assumptions						
Organic waste collection	Current rates (42 tons/day)	Current rates (42 tons/day)	Current rates (42 tons/day)	Current rates (42 tons/day)	Current rates (42 tons/day)	Expanded collection assumed 80% of generation (110 tons/day)
Organic waste input capacity for compost production (tons input/day)	As operating (10 tons/day)	As operating (10 tons/day)	Designed capacity of the plant (20 tons/day)	Expanded capacity to meet current collection (42 tons/day)	Expanded capacity to meet current collection (42 tons/day)	Expanded capacity to meet potential collection (110 tons/day)
Septage input capacity for DFS production (m^3/day)[b]	None	None	None	None	FSTP to treat septage collected (181 m^3/day)	FSTP to treat septage collected (181 m^3/day)
Outputs						
Compost production	1 ton/day	3.3 tons/day	7 tons/day	14 tons/day	14 tons/day	36 tons/day
DFS production		-	-	-	3.17 tons/day	3.17 tons/day
Co-compost production		-	--	-	13 tons/day (plus 4 tons/day of compost)	13 tons/day (plus 26 tons/day of compost)
Comments for further development		Need to enhance the operational efficiency & market demand	Need to better manage the available space, enhance the operational efficiency & market demand	Space constraint for expanding the capacity of the compost plant, so further land availability would need to be considered	Space is a constraint for expanding the capacity of the compost plant and implementing the FSTP	Space is a constraint for expanding the capacity of the compost plant and implementing the FSTP

Note: [a] optimal collection rate was assumed as 80% given that a portion of waste is self-managed. [b] Nikiema (2013) suggests that the amount of DFS that can be obtained from 1 m^3 of liquid septage is 10 kg to 25 kg. For the calculation it was taken that an average of 17.5 kg of DFS was produced per m^3 of septage (calculations based on an average of 181 m^3 of septage collected per day); [c] it was assumed that the organic waste: compost production ratio was 3:1 based on the local experience; [d] for co-composting organic waste and DFS, the ratio was assumed as 3:1.

6. Conclusions

KMC has implemented a package of SWM solutions to improve the effectiveness of SWM in the area. Table 21 provides an overview of the estimated quantities of the key waste streams in the KMC area.

TABLE 21. Summary of estimated quantities of key waste streams.

Total SW generated	Total SW collected	Biodegradable waste collected	Recyclables collected	Biodegradable waste composted at Kaduwela waste recycling center	Compost produced at Kaduwela waste recycling center
201 tons/day	71 tons/day	42 tons/day	3 tons/day	10 tons/day	1 on/day

However, the overall performance of these management solutions needs further improvement. The composting plant for example is underutilized (the plant runs at 50% of design capacity). It also appears that proper composting practices are not followed at the plant. **With more effective space utilization and adapting better composting practices (including regular training of the workers), the plant could double its current operational scale**.

It appeared that the largest cost element incurred by KMC on waste management is the SW disposal cost. **KMC should explore technical options, especially to manage the large organic waste fraction within its available facilities.** For nonorganic waste it will be difficult to find immediate alternatives given that land for public disposal sites is very difficult to find in a densely populated urban vicinity. However, this does not mean that private landfills can operate outside environmental safeguards.

To enhance organic waste use apart from composting, the biogas plant (which currently runs at small scale and at best at 70% efficiency) could be optimized, more food waste could be directed to pig farmers and waste minimization practices could be promoted, including household-based composting. All these measures would help to reduce the disposal (cost) of organic waste.

Possibilities should also be further investigated in view of more holistic waste management. An integrated model that considers waste management solutions as an interlinked system could, for example, maximize cost recovery. Value addition to compost such as co-composting with dried septage sludge and pelletizing could increase the marketability of the product. Some private compost producers are very successful and opportunities for public–private partnerships so far appear to be insufficiently explored (targeting compost demand beyond the study area).

Waste management is a costly operation and maximizing cost recovery is important and should be explored within an integrated waste management system of all resource recovery options and related input streams. The current financial records of Kaduwela indicate that the sale of nonorganic recyclables achieves a 10-times higher rate of revenue than compost sales. Hence, **an integrated model that considers a package of total waste management solutions appears to be attractive in terms of cross-financing and maximizing waste minimization as well as cost recovery**. Moreover, it may be useful to initiate a separate account or cost code for waste management O&M costs to better monitor the cost elements and thereby to identify where and how savings as well as cost recovery could be improved.

Current revenue generated from compost sales appears to be minimal with only 5% to 14% of what can be produced (theoretically about 150 tons/month based on the design capacity) being sold. **Value addition to compost such as co-composting with dried septage sludge and pelletizing could increase the marketability** of the product, potentially bringing more revenue. However adequate infrastructure should be in place to establish such interventions which need to be justified with the demand. Activity 2 under this project is intended to identify the demand patterns of various resource recovery and reuse products related to solid waste and septage management.

Private sector involvement in both SWM and septage management in KMC is remarkable. However, **coordination between the public and private sector could be improved**. For example, the KMC did not know that the private operator produces compost from the organic waste collected from KMC, i.e. it was a competitor. On the other hand, despite being the responsible authority for managing septage, awareness of the KMC on the scale and nature of the operation of the private septage collection service providers is low. Improved coordination can facilitate developing strategies and action plans towards sustainable SW and septage management at the local as well as provincial and national levels.

Scenarios were developed under this assessment to understand the potential of resource recovery under different circumstances. Section 5 discussed five scenarios that were built based on different criteria. In summary, Scenarios 1 and 2 considered the current operating level of the compost plant and the compost plant capacity as the limiting factors in estimating the potential of compost production, respectively. Scenarios 3 and 4 were essentially built on focusing on the collection amounts, provided that the compost plant can absorb the total organic waste supply. Scenario 5 is entirely based on a hypothesis considering an expanded collection of organic waste (80% of the total waste generation). Scenarios 4 and 5 also considered the existence of an FSTP in KMC that produces DFS that can be used to produce co-compost as a value-added product. Factors that need to be considered in terms of further developments related to each scenario are also discussed in Table 20. In general, optimizing the operation of the compost plant, training and capacity development of the workforce engaged in waste management and improving coordination among actors are among the strategies that can be adapted by both the SW and septage management sector in order to ensure more sustainable operations.

7. References

Alabdraba, W.M.Sh.; AL-Qaraghully, H.A.K. 2013. Composition of domestic solid waste and the determination of its density & moisture content: A case study for Tikrit City, Iraq. *International Review of Civil Engineering (I.RE.C.E.)* 4(2).

AIT (Asian Institute of Technology). 2004. *Municipal solid waste management in Asia*. A publication of the SIDA funded Sustainable Solid Waste Landfill Project. Bangkok: Asian Institute of Technology.

Bandara, N. 2011. *Municipal solid waste management: The Sri Lankan case.* Department of Forestry and Environment Science, University of Sri Jayewardenepura.

CEA (Central Environmental Authority). 2008. Regulation No. 1 of 2008 of 01 February 2008 National Environmental (Protection and Quality). Available at http://www.cea.lk/web/images/pdf/envprotection/1533_16e.pdf (accessed on September, 22 2020).

CEA (Central Environmental Authority). 2012. *Database of solid waste in Sri Lanka.* "Pilisaru" National Solid Waste Management Programme. Central Environmental Authority. (unpublished)

Fernando, S.; Drechsel, P.; Jayathilake, N.; Semasinghe, C. 2014. *Performance and potential of the public sector municipal solid waste compost plants in Sri Lanka.* SICARP International Agricultural Research Symposium 2014. Colombo, Sri Lanka: Sri Lanka Council for Agricultural Research Policy.

JICA (Japan International Cooperation Agency). 2012. *Data collection survey on sewerage sector in Democratic Socialist Republic of Sri Lanka.* Japan International Cooperation Agency.

JICA (Japan International Cooperation Agency). 2016. *Data collection survey on solid waste management in Democratic Socialist Republic of Sri Lanka.* Japan International Cooperation Agency.

JICA (Japan International Cooperation Agency). 2019. *Preparatory survey on Sri Jayawardenapura Kotte Sewerage Construction Project.* Japan International Cooperation Agency.

HARTI (Hector Kobbekaduwa Agrarian Research and Training Institute). 2015. *Municipal solid waste composting: potentials and constraints.* Research Report No: 174. Hector Kobbekaduwa Agrarian Research and Training Institute.

Kaduwela Municipal Council. 2019. *Budget report 2019.*

Nikiema, J.; Cofie, O.; Impraim, R.; Adamtey, N. 2013. Processing of fecal sludge to fertilizer pellets using a low-cost technology in Ghana. *Environment and Pollution* 2(4): 70-87.

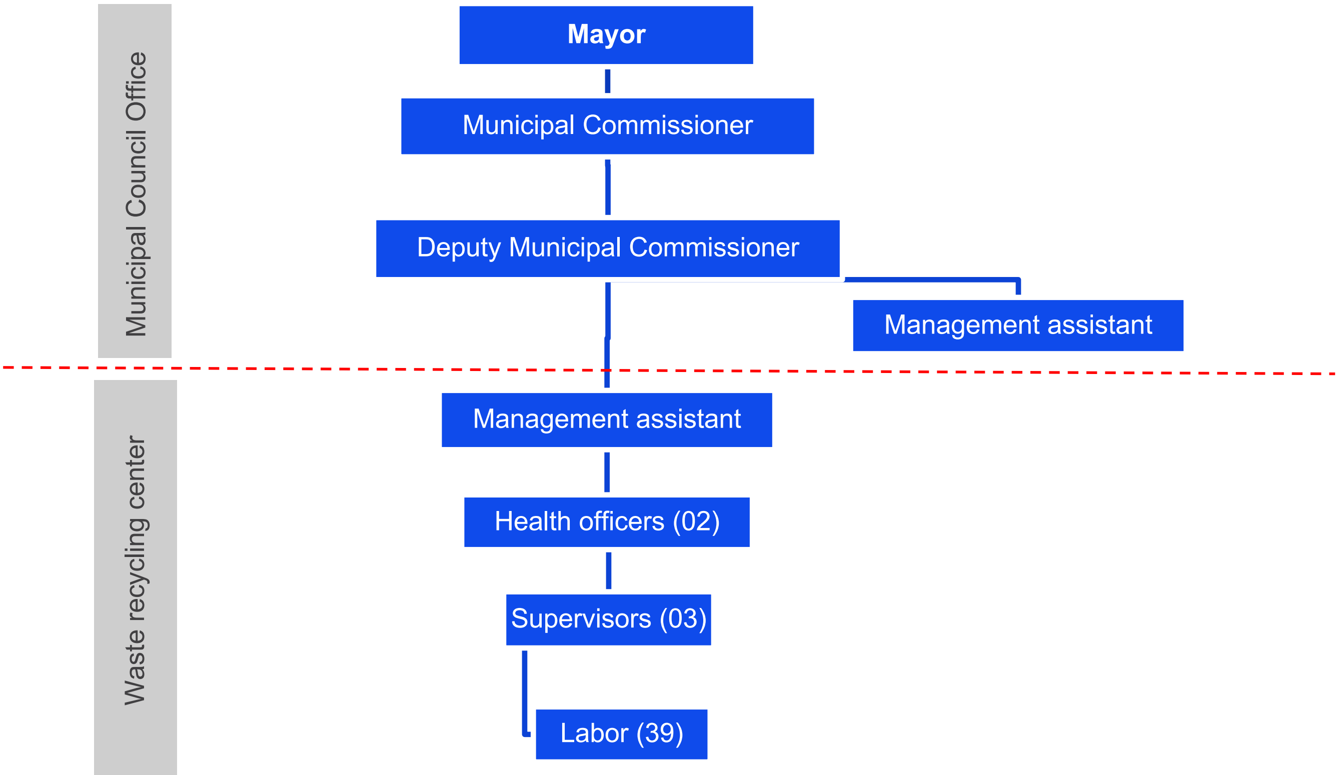
Reitemeier, M. 2019. *Feasibility of food waste reduction options in the context of urban Sri Lanka.* MSc dissertation. University of Hohenheim, Germany.

Oxfam. 2008. *Guidelines for the management of septage in Sri Lanka.* Submitted to Oxfam for the Sanitation Task Force by the Department of Civil Engineering, University of Peradeniya, Sri Lanka. 30p.

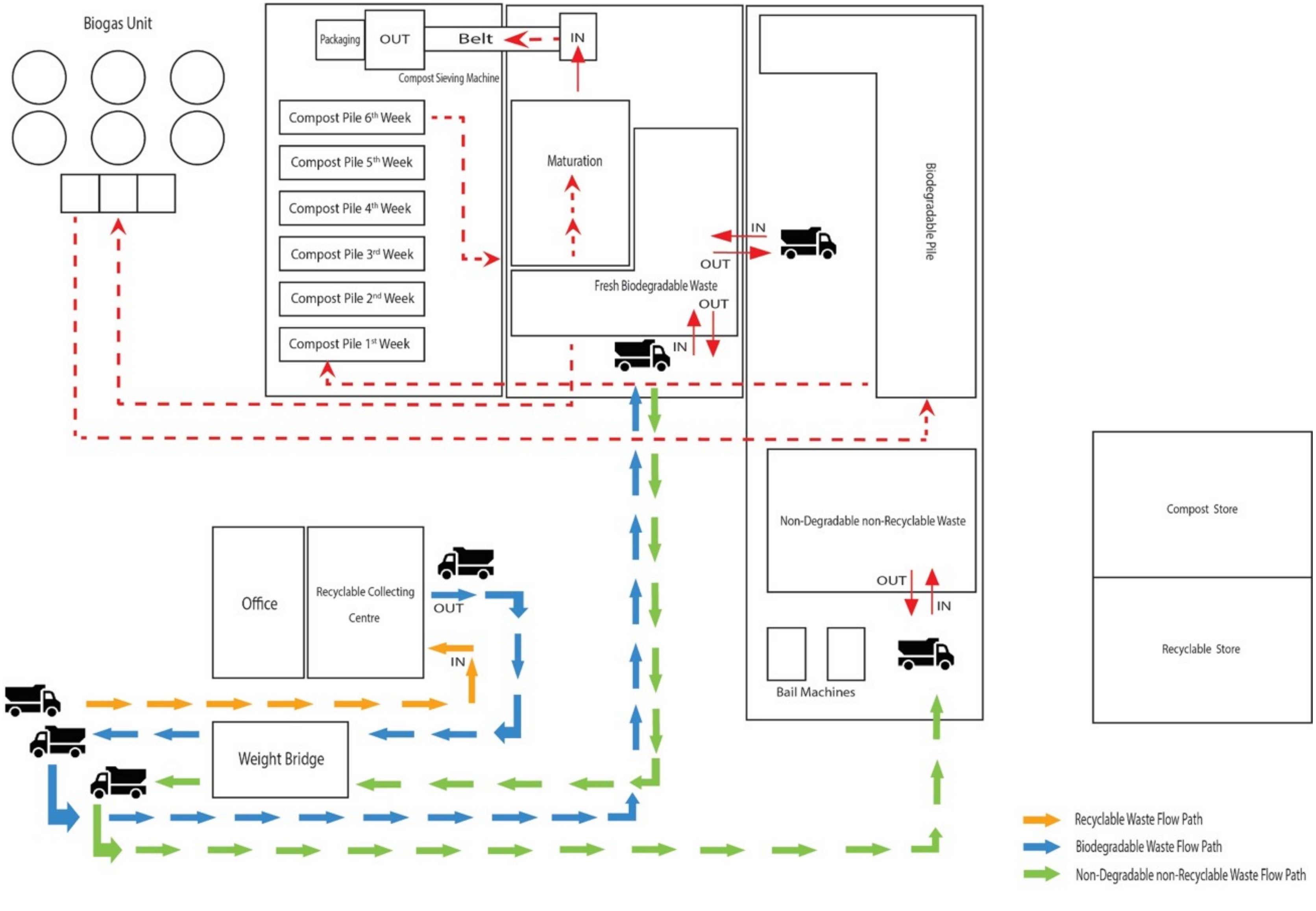
Thirumarpan, K.; Thiruchelvam, T.; Dilsath, M.S.A; Minhajkhan, M.S.M. 2015. *Household knowledge, attitudes and practices in solid waste segregation and management: A study in Eravur Urban Council area, Batticoloa district.* 5th International Symposium on “Emerging Trends and Challenges in Multidisciplinary Research", December 7–8. South Eastern University of Sri Lanka. Available at http://www.seu.ac.lk/researchandpublications/symposium/5th/abstract/pureandappliedsciences/39.pdf (accessed on March 20, 2020).

8. Annexes

Annex 1. Organizational structure for solid waste management at KMC.



Annex 2. Layout of the waste recycling center at KMC.

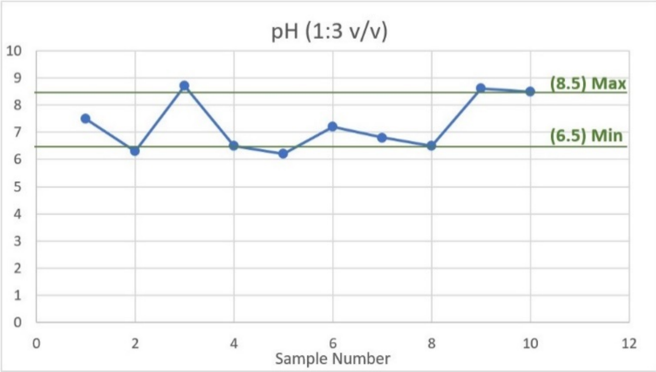


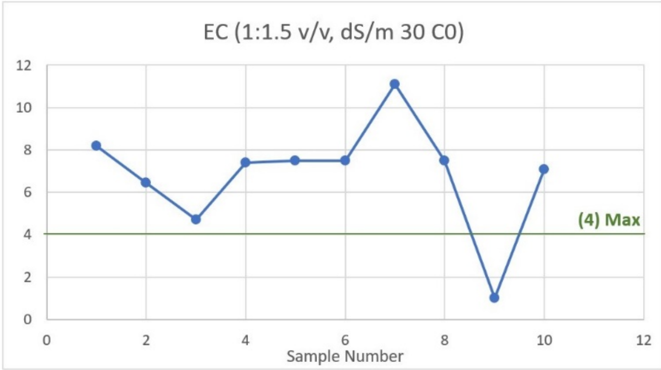
Annex 3. Number of employees assigned to perform waste management tasks at the waste recycling facility of KMC.

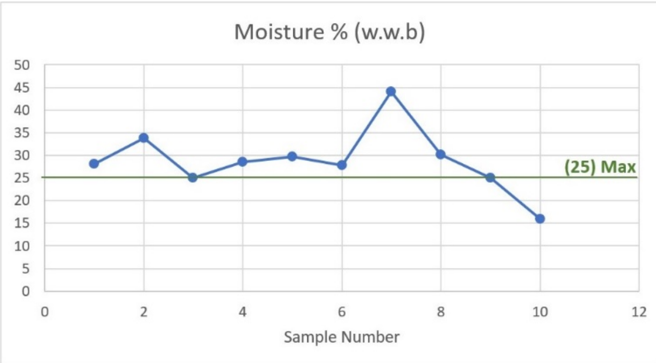
Working task	Number of employees
Loader driver	1
Assistant	1
JCB driver – BAKCO	1
Assistant	1
Bobcat driver	1
Three-wheeler driver	1
Compactor driver – collecting waste (in specific location – religious places – Nawagamuwa Devalaya)	1
Assistant	2
Supporting unloading of food waste and polythene	1
Iron Store's cashier – recyclable shop	1
Assistant	4
Plastic machine operator	1
Assistant	1
Compost sieving machine operator	1
Assistant	5
Service	1
Baling press machine operator – big machine	1
Assistant	4
Baling press machine operator – small machine	1
Assistant	1
Glass sorting	2
Office operation – operating weigh bridge, recording, supervising labors, reporting to the DC, managing the site	5
Truck 01 driver (tipper): collecting waste (in specific location – main road, weekly fair)	1
Assistant	1
Truck 02 driver (tipper): transporting to HOLCIM	1
Assistant	1
Biogas plant operator	1

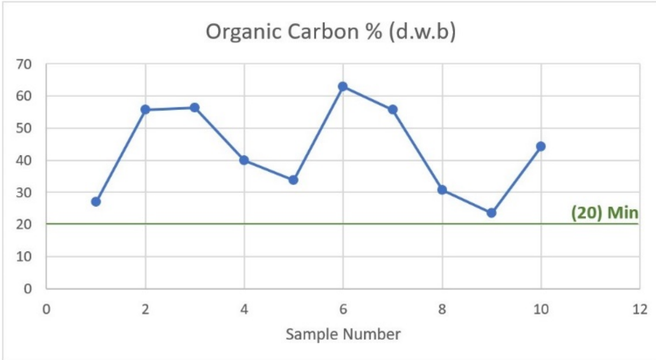
Annex 4. Compost quality vs compost standards in Sri Lanka.

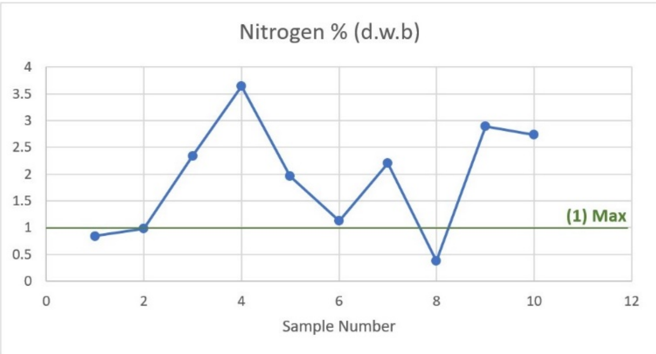
Sample number	1	2	3	4	5	6	7	8	9	10
Date	15/09/2015	31/05/2017	04/05/2018	26/12/2018	2018 1st	2018 2nd	/03/2019	22/07/2019	20/09/2019	08/01/2020

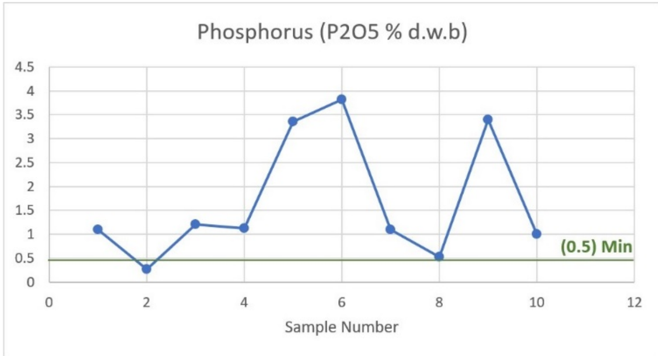

pH (1:3 v/v)
(8.5) Max
(6.5) Min
Sample Number

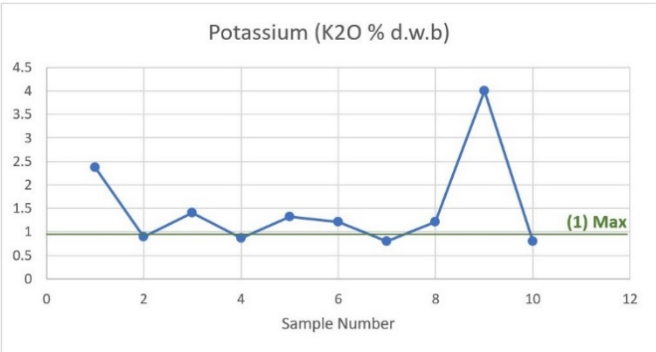

EC (1:1.5 v/v, dS/m 30 C0)
(4) Max
Sample Number

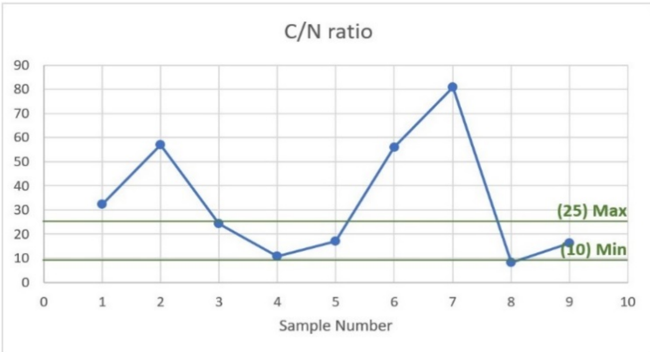

Moisture % (w.w.b)
(25) Max
Sample Number

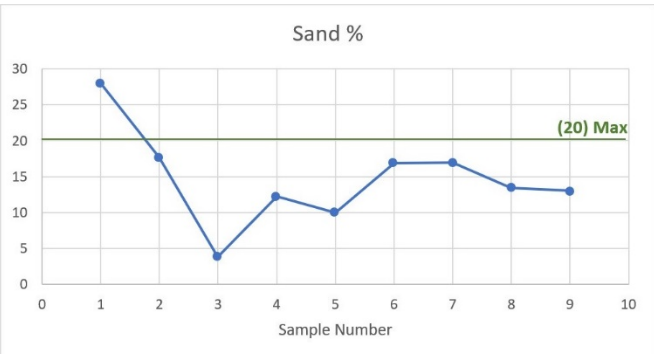

Organic Carbon % (d.w.b)
(20) Min
Sample Number


Nitrogen % (d.w.b)
(1) Max
Sample Number


Phosphorus (P2O5 % d.w.b)
(0.5) Min
Sample Number


Potassium (K2O % d.w.b)
(1) Max
Sample Number


C/N ratio
(25) Max
(10) Min
Sample Number


Sand %
(20) Max
Sample Number

Annex 5. Solid waste treatment, recycling and environmental management (extracted from 2019 budget report of KMC, in LKR).

Expenditure types	Details	Estimated 2019	Budget 2018	Actual until June: 2018	Actual 2017
Personnel emoluments	Salaries and wages	6,980,000	6,235,000	2,933,791	5,136,426
	Holiday pay and overtime	1,000,000	1,000,000	690,346	944,445
	Cost of living allowance	2,340,000	2,340,000	1,630,006	8,969,842
	Adjustment allowance	561,000	1,380,000	522,998	-
		10,881,000	**10,955,000**	**5,777,141**	**15,050,713**
Travelling	Local	25,000	25,000	-	-
		25,000	**25,000**	**0**	**0**
Supplies and requisites	Fuel & lubricants	700,000	940,000	150	232,976
	Mechanical & electrical items	5,000	5,000	-	-
	Awareness program	300,000	300,000	19,000	354,383
	Uniforms & sewing charges	5,000	5,000	-	-
	Purchase of compost bin	20,000,000	25,000,000	-	349,650
	purchase of compost bags	600,000	500,000	-	30,000
	Others	25,000	25,000	3,930	110,374
		21,635,000	**26,775,000**	**23,080**	**1,077,383**
Repairs & maintenance of capital	Vehicle repair	1,000,000	50,000	452,759	138,720
	Purchasing tires and tubes	600,000	25,000	2,900	31,381
	Plastic & polythene recycling center	50,000	50,000	-	-
	Others	10,000	10,000	3,830	3,600
		1,660,000	**135,000**	**459,489**	**173,701**
Transportation, requirements, others	Telephone charges	1,000	1,000	-	-
	Water bill and electricity bills	400,000	750,000	112,927	224,301
	Solid waste management project – allowances	39,560,000	28,836,000	6,034,562	5,922,802
	Solid waste management project – overpay	400,000	300,000	142,755	10,717
	Others (insurance)	20,000	20,000	39,772	2,227
		40,381,000	**29,907,000**	**6,330,016**	**6,160,047**
Grants, Subsidies & Contributions	Welfare Services	1,000,000	1,000,000	-	53,148
		1,000,000	1,000,000		53,148
Pensions, Retirement, Benefits &	Employees Provident Fund	1,000	1,000	-	-
	Employees Trust Fund	1,000	1,000	-	-
	Public Service Provident Fund	2,000,000	1,200,000	787,854	1,345,727
		2,002,000	**1,202,000**	**787,854**	**1,345,727**
Total Recurrent Expenditure		**77,584,000**	**69,999,000**	**13,377,580**	**23,860,719**
	Purchasing Machineries	500,000	500,000	-	-

Capital Expenditure	Developing Waste Management Centre	10,000,000	8,500,000	-	13,735,623
	The Environmental Sensitive Site	1,000,000	2,000,000	400	5,857
	Bio gas Project	40,000,000			
	Town Beautification	10,000,000	-	-	-
	Total Capital Expenditure	**61,500,000**	**11,000,000**	**400**	**13,741,480**
Total Expenditure		**139,084,000**	**80,999,000**	**13,377,980**	**37,602,199**

Annex 6. Organizational hierarchy in KMC related to septage management.