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Municipal Solid Waste Management Practices and Challenges in the Southeastern Coastal Cities of Sri Lanka

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Abstract: Municipal solid waste management (MSWM) has become a major challenge in Sri Lanka for post-conflict development activities. Many urban areas are facing severe problems in managing 10 to 50 metric tons of waste per day. However, limited research has been carried out to identify the key issues and policy gaps in MSWM. This research studies the existing complexities of MSWM processes, practices, and emerging challenges in three highly congested urban areas in the south-eastern coast of Sri Lanka. A mixed method strategy using field observations, semi-structured interviews and secondary data sources was employed for the data collection. The study revealed that, although the MSWM systems in the urban areas include all necessary elements, their effectiveness and efficiency are not satisfactory due to poor or non-segregation of waste at the source of generation; lack of resources; absence of regulation to reduce waste generation and control polluters; absence of regular collection schedule; and lack of technical know-how and initiatives. The recommendations drawn from the study include feasible solutions and immediate measures required to improve the MSWM before the related environmental and public health problems become a social catastrophe. The recommendations will also greatly contribute in the achievement of developing sustainable cities.

Keywords: environmental hazard; municipal waste; segregation; treatment; waste management

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1. Introduction

One of the performance measures for the degree of good governance in an area is the state of the urban environment, in general, and of waste management in particular, which has an inter-relationship to social, economic, public health and many other dimensions of an urban living [1]. Waste management is linked to and contributes to the achievement of many of the Sustainable Development Goals (SDGs) of the United Nations such as Goal 3: Good Health and Wellbeing, Goal 11: Sustainable Cities and Communities, and Goal 12: Responsible Consumption and Production [2]. For the achievement of a target for Goal 11, "proportion of urban solid waste regularly collected and with adequate final discharge out of total urban solid waste generated, by cities" is one of the key indicators [2].

By 2025, the Municipal Solid Waste (MSW) is estimated to increase to "1.42 kg/capita/day (2.2 billion tons per year) generated by 4.3 billion urban residents globally" [3]. An urban council or municipality which cannot effectively carry out solid waste management is hardly able to manage more complex public services such as education, transportation, or health, since managing MSW is the most essential service a local authority can offer [3]. Solid waste management in an urban context has become an enormous challenge for local authorities in developing countries primarily due to increasing generation of MSW, difficulty in allocating and managing the higher cost for MSW within the municipal budget, lack of scientific understanding of technicalities associated in different stages of managing MSW, and the level of support from the public to enable a proper environment to solve MSW management problems [4].

The solid waste generated in a community can be categorized as agricultural waste, mining waste, industrial waste, construction waste, and municipal solid waste. Municipal solid waste includes biodegradable waste and non-biodegradable waste, which are generated from residents, business entities, institutions, and industries within a municipality [5]. In real world, the municipal solid waste management practice varies place to place depending on the topography, population density, transportation infrastructure, environmental regulations, availability of resources, and many other social and cultural factors [6]. Waste disposal includes landfill, incineration with energy recovery, and controlled dump. Similarly the most preferred options are waste diversion options that include reduce, reuse, recycle, and recover (4R). The '4R' concept has evolved to '10R' steps that include: Refuse, Rethink, Reduce, Reuse, Repair, Refurbish, Remanufacture, Repurpose, Recycle, and Recover [7]. In general, current waste management practices include landfill, incineration, composting, recycling, and waste treatment. Landfill is one of the oldest and has been the most common and largest preferred option practiced for managing municipal solid waste.

The key objectives of sustainable MSWM are to constantly improve the urban living environment, increase economic productivity, advance direct public health benefits, and facilitate safe, dignified and secure employment opportunities [8]. An integrated MSWM system consists of the key processes from the point of waste generation to final waste disposal including: 1. waste identification, 2. handling the waste at source, 3. separation and storage at the source, 4. collection from the source of generation, and 5. transfer or transport for final process of disposal/recycle/recovery [9,10].

Waste management system efficiency is mostly affected by poor route planning, lack of vehicles, improper collection method, poor and narrow road networks, and irregular collection scheduling [11–13]. However, there have been limited studies to understand MSWM practices and challenges specifically targeting MSWM collection efficiency and associated problems in the south-eastern coastal cities of Sri Lanka. This study aims to critically analyse the current practices, challenges and provide recommendations for effective and efficient management of municipal solid waste in the context of post-conflict development activities in the three congested coastal cities of the south-eastern Sri Lanka. The research will contribute to the improvement of the current solid waste management practices and help to overcome the challenges faced by many coastal cities.

The remaining part of this paper is structured with the following sections: solid waste management in the Sri Lankan context, materials and methods, analysis and findings, discussion, recommendations for improvement of MSW management, and conclusions. The section on analysis and findings includes subsections on current solid waste management practices, efficiency of MSW collection, and sources and quantities of municipal solid wastes. The discussion section includes subsections on the segregation of waste at the source of generation, reduction of waste generation, absence of effective regulation to control polluters and excessive waste producers, absence of a regular collection schedule and plan, and lack of technical know-how in MSW management. Finally, the recommendations are presented under the following subsections: waste management at the source of generation, efficient waste collection mechanism, and resource recovery and safe disposal.

2. Solid Waste Management in Sri Lankan Context

In Sri Lanka, MSW is expected to reach 1.0 kg/person/day by 2025 [14]. Various stakeholders are responsible for the management of solid wastes. In certain countries, national and local governments are accountable for managing the wastes [15], however, in some other countries the responsibility of managing MSW is given to municipal authorities, city corporations, and nongovernmental organizations [16]. In Sri Lanka, local authorities, either municipal councils, or urban councils, or pradeshiya sabahs (village councils) are responsible and have an obligatory function for managing the solid waste generated within their locality. In Sri Lanka, regulations for local authorities such as Pradeshiya Sabaha Act No. 15 of 1987, Urban Council Ordinance No. 61 of 1939, and Municipal Council Ordinance

No. 16 of 1947 are key legal provisions in relation to solid waste management (SWM). The legal provisions articulate the key responsibility of local authorities for the proper removal of nonindustrial solid waste and for providing suitable dumpsites [17]. At present, municipal councils collect 50% of the solid waste generated in Sri Lanka, while urban councils collect 17% and pradeshiya sabahs collect 33% [18]. The Sri Lankan government has taken steps to tackle waste management problems and recently drafted a national policy. The government also collaborated with international organizations to improve the solid waste management system in the country [19].

Since cities grow rapidly with increases in economic activities and standards of living, the amount of waste generated per capita increases due to enormous consumption of goods and services [3]. The accumulation of solid waste in most urban centers, especially in the bigger cities, has reached an alarming stage. There is a need for an integrated and improved sustainable MSW management system in Sri Lanka, since the worst disposal option, open dumping (around 85%), was found to be the most widely executed MSW management strategy [20]. While the remaining 15% of the collected MSW accounts for composting (10%) and recycling (5%), the MSW not collected by municipal councils are disposed inappropriately: dumping on streets, water bodies and backyards; open dumping; or burning [21]. However, Basnayake et al. [22] reported that the generation of MSW in Sri Lanka is 7210 tons/day and the collection efficiency is only 27%; recyclables make up close to 46% of the total collected waste (approximately 12% of total waste generated), and composting accounts for 25% of the total collected waste (approximately 7% of total waste generated) (Table 1).

Table 1. Key indicators related to Solid Waste Management in Sri Lanka.

Key Indicators	Current Status Measure	Ref.
MSW collection efficiency	27%	
a. Recyclable	46% [12% of waste generated]	[22]
b. Composting	25% [7% of the waste generated]	
c. Other	29%	
MSW collection at local authority level		
a. Municipal Council	50%	[18]
b. Urban Council	17%	
c. Pradesiya Sabahs	33%	
Open dumping percentage	85%	[20]
Composting percentage	10%	[21]
Recycling percentage	5%	[21]

MSW management in the urban areas of the south-eastern coast of Sri Lanka (Kalmunai, Akkaraipattu, and Ampara) is no exception and is in a crisis situation today with a huge quantity of MSW generated every day: 65 tons per day in the Kalmunai municipality, 30 tons per day in the Akkaraipattu municipality, and 25 tons per day in the Ampara urban council area. Although 60% to 80% of the MSW generated is collected on a daily basis, disposal options remain very crude, involving open dumping. These crude disposal practices, together with the inappropriate disposal of the MSW not collected by municipal/urban councils, are causing environmental pollution and public health hazard.

Figure 1 shows an integrated research framework to identify MSWM practices and challenges in the coastal cities of Sri Lanka. This framework was used to identify key problems in each step of MSWM from waste generation, waste collection, waste transport, to, finally, waste disposal/recovery (highlighted in italics in blue in each stage).

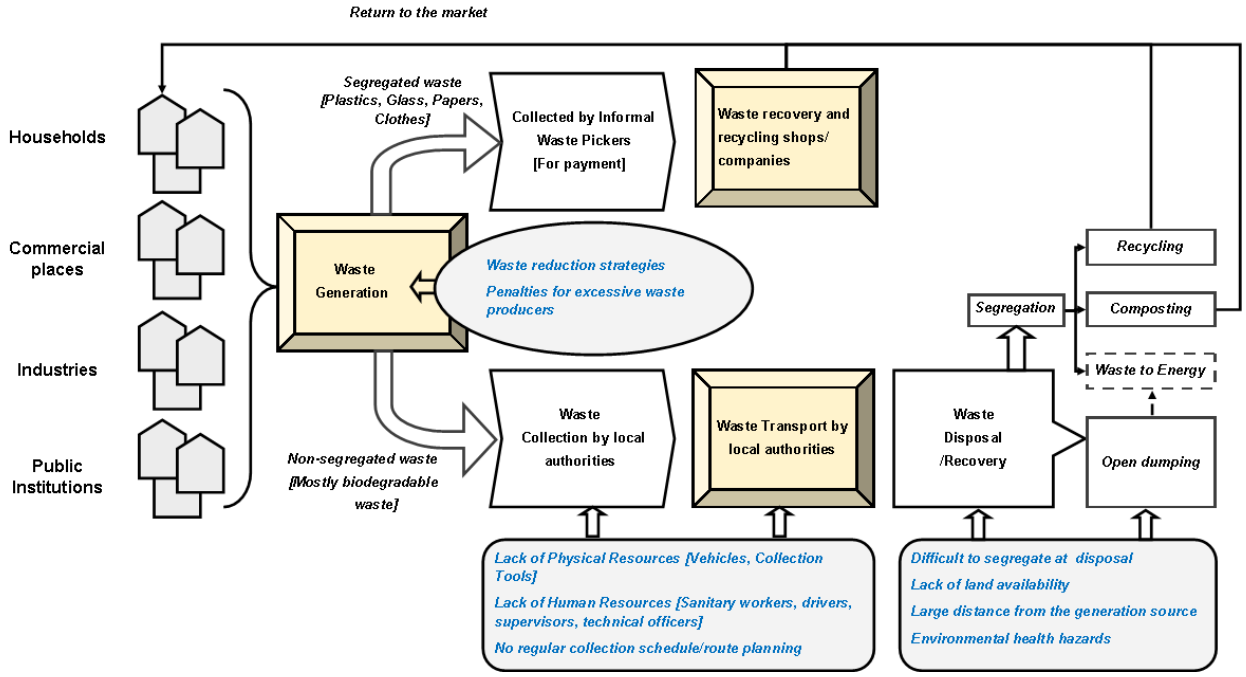

Figure 1. An integrated research framework for identifying MSWM practices and challenges in the coastal cities of Sri Lanka.

3. Materials and Methods

The Kalmunai Municipal Council (KMC) and Akkaraipattu Municipal Council (AMC) are the only two municipal councils in the southeastern region, among the three municipalities in the Eastern Province of Sri Lanka. Ampara Urban Council (AUC) is the only urban council in the southeastern region, among the four urban councils in the Eastern Province of Sri Lanka (Figure 2).

Table 2 presents demographic details for all the three study locations. Due to higher population density (which is more than ten times that of the average divisional population density of Sri Lanka) and rapid economic growth after the end of the civil war in 2009, the quantities and types of solid wastes generated within the municipality/urban locality have been rapidly increasing. KMC is the responsible local authority for managing solid wastes generated within the Kalmunai Municipality region. The municipality's area is divided into 13 urban areas and villages, but waste collection is carried out in 8 urban and suburban areas. Further, KMC is divided into four zones (Zones A to D), AMC into five zones (Zones A to E), and AUC into 10 zones (Zones A to J) for managing solid waste collection. According to the SWM division of respective local authorities, solid wastes have been collected from 45,000 households in KMC, 12,232 households in AMC, and 6983 households in AUC.

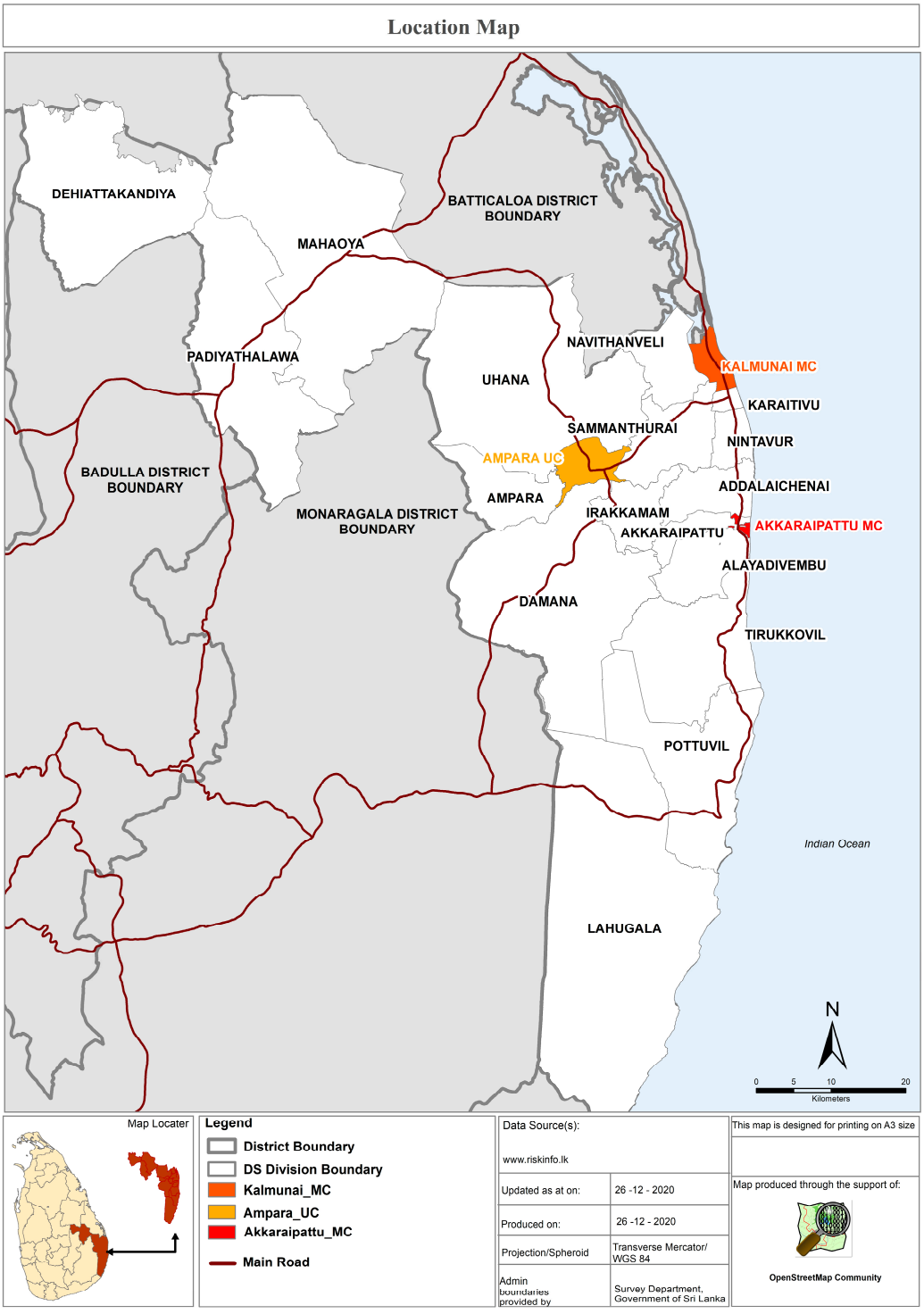

Figure 2. The study locations/area in a map within the Eastern Province of Sri Lanka.

Table 2. Demographic details of study locations (Sources: refs. [23,24] and SWM divisions' data of study local authorities).

Demography Details of Municipalities/Urban Council	KMC	AMC	AUC
Average annual population growth rate	1.44	1.44	1.44
Population density (persons/km^2) (country average: 325)	4521	783	703
Total number of households	45,000	12,232	6983
Number of wards within the municipality/urban council	23	12	10
Number of GN divisions under DS divisions	76	28	10
Number of zones for waste management	4	5	10
Amount of solid waste generated per day (MT)	65	30	25
Average MSW collection percentage per day		60–80%	

This research used a mixed method strategy with three different data collection techniques: semi-structured interviews with key informants, field observations at the MSW management sites, and secondary data sources such as reports and official communiqués with three local authorities: KMC, AMC, and AUC. A total of eight key informant interviews were done for each of the local authorities (24 in total in all three councils). The interview participants in each of the local authority included the municipal/urban council commissioner, municipal council engineer, technical in-charge for MSWM, solid waste collection supervisors, and management assistants at the council office dealing with MSWM. The observation locations for this study included: key MSW collection points, a waste dumping site in Pallakadu (20 km south of Kalmunai along the A4 Highway), the Periyaneelavanai composting plant, the Maruthamunai segregation centre, the Kalmunai Municipal Council, the Akkaraipattu Municipal Council, and the Ampara Urban Council offices. The secondary sources of data were obtained from the official reports produced by the SWM Units of KMC, AMC, and AUC.

The data obtained from all three methods were mostly in the form of qualitative data, along with statistical data sets on the quantity of monthly waste generation and collection, human resources, and assets in the local authorities and composition of waste types. The quantitative and qualitative data from the interviews and official communiqués from local authorities are analysed and presented in the following sections under analysis findings: current solid waste management practices, efficiency of MSW collection, and sources and quantities of municipal solid wastes.

4. Analysis and Findings

4.1. Current Solid Waste Management Practices

4.1.1. Waste Identification—Segregation and Storage at the Source

In residential areas, solid wastes are stored within their own residences. In residential apartments, wastes are collected by the building maintenance team. In commercial and institutional entities, stationary and portable containers are used to store waste. Waste separation is not regularly performed by the users at source, making the segregated collection of waste difficult in the urban areas.

4.1.2. Collection

The collection of MSW is done through primary and secondary waste collection mechanisms. The waste is primarily collected daily from house to house in municipal residential areas, public spaces, and institutions such as schools and government offices, using composters and trucks. Secondary waste collection deals with transferring wastes from collection points to dumpsites. However, municipalities have no sustainable collection mechanism for the proper collection of waste in both levels, due to a severe shortage of resources.

Primary Collection of MSW

In none of the areas studied are colour-coded bins or separate bags used to collect biodegradable and non-biodegradable wastes separately. MSW are collected daily on major

roads and in the common waste disposal places on bare lands, while weekly collection happens on internal roads. However, the collection of waste is not performed on a fixed day or at a fixed time. Further, there is no regular collection schedule available, and the public often need to guesstimate the date and time of the collection. The streets in commercial areas are swept daily and roads in residential areas are swept twice weekly. Figure 3 shows a sample monthly waste collection amount in the year 2017. It shows an average of 1200 MT of MSW is collected by the KMC every month.

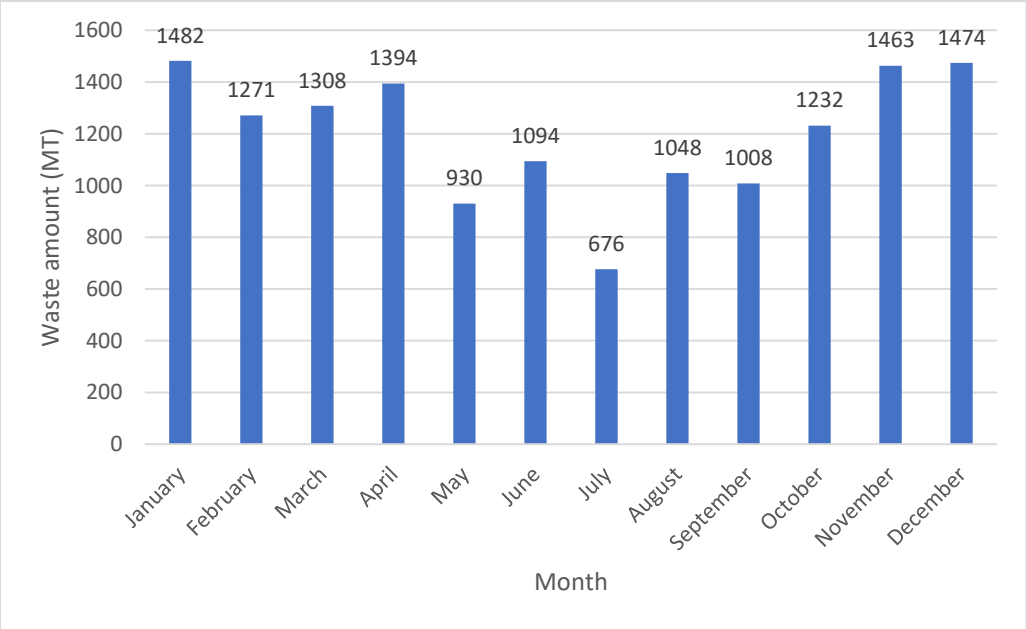

Figure 3. Sample monthly waste collection amount in metric tons for the year 2017 in Kalmunai Municipal Council (Source: KMC SWM Division 2017, reproduced by authors).

Secondary Collection of MSW

Mixed waste consisting of both biodegradable and non-biodegradable types are collected from residential, market, and commercial areas, as well as directly loaded from bins, containers, and bags into trucks and compactors. The councils use different types of vehicles for transporting and collecting MSW, including trucks, compactors, land masters, and tractors. Since there is hardly any segregation of waste by the public before the collection by the authorities, there is no separate schedule for the collection of specific waste in any of the councils. Non-segregation of waste before the collection or at the point of collection has been an ongoing problem, and neither do the councils educate the public enough nor do the public come forward to support the effort by authorities to segregate the waste at source.

4.1.3. Transport

Generally, municipal solid waste disposal sites are located away from the residential areas to make the sites environmentally acceptable. However, municipal councils have no disposal sites within their geographic boundaries that can be environmentally less hazardous to the residents. Therefore, KMC and AMC have to rely on disposal sites outside their areas and pay large sums of money for disposal.

4.1.4. Final Disposal

The disposal of MSW is the final phase of an integrated solid waste management system. Open dumping has been the most common method of solid waste disposal in all of the urban areas. The wastes collected in most of the areas are immediately dumped

within and outside the municipality. The wastes collected in particular areas such as Maruthamunai (Zone D) are sent to a segregation centre located in Maruthamunai, and the wastes collected from the market areas in Kalmunai are composted in a plant at Periyaneelavanai. KMC also sends the waste collected within its municipality to waste treatment plants in the Karaithivu and Addalaichchenai pradeshiya sabhas. KMC pays large sums of money for the disposal options; for example, up to the end of the year 2015, KMC's payment amounted to LKR 2.85 million and LKR 1.13 million respectively to the Karaithivu and Addalaichchenai local authorities for bringing solid wastes from KMC to their waste treatment plants. Similarly, AMC also sends its wastes to an open dumping site in Addalaichchenai pradeshiya sabha.

Composting

Only the municipal solid wastes collected from the market areas within the Kalmunai Municipality are composted in a compost plant in Periyaneelavanai. First, the biodegradable wastes are kept in bins until they have naturally decomposed. Then, composted wastes are transferred from bins to the sieve machine. Finally, sieved composites are collected and stored (Figure 4). The remaining wastes are sent to the dump yard.

Figure 4. Composting process at the composting plant in Periyaneelavanai in KMC.

Segregation

The segregation centre at Maruthamunai in KMC has a waste sorting system. Separated plastic bottles, glass bottles, tins, plastic material, and coconut shells are stored in different store rooms, and the segregated wastes are exported to the Ampara and Colombo areas. There is no recycling plant for the recyclable wastes collected in the study areas.

4.2. Efficiency of MSW Collection

Table 3 presents the details of monthly waste generation from households and commercial sectors together with amounts of home composting and waste collected from the three urban areas. There is a general correlation between the size of the population and the waste collection efficiency, as depicted in Figure 5. For example, the waste collection efficiency is greater than 85% when the population size of the zone is less than 5000 (most of the AUC zones shown in the figure). However, the collection efficiency declines to between 65% and 75% when the population size of the zones exceeds 5000. Therefore increasing the number of zones within a local authority with smaller population size could help increase waste-collection efficiency. Further analysis is needed in terms of resource allocation for each zone, the decision-making process, and the political influence from members representing the zones of municipal/urban councils.

Table 3. MSW details of study locations (Source: SWM division 2017).

Urban Zones	Population	No. of Households	Monthly Waste Generation and Collection (MT)				Collection Efficiency
			From Household	From Commercial Sectors	Home Composting	Collection	
Kalmunai Municipal Council (KMC) *							
Zone A	29,027	6800	522	80		350	58%
Zone B	23,115	6586	416	80		375	76%
Zone C	23,697	5557	427	120	100	290	65%
Zone D	31,774	8639	572	90	50	400	65%
	107,613	27,582	1937	370	150	1415	66%
Akkaraipattu Municipal Council (AMC) *							
Zone A	9445	2790	170	60		175	76%
Zone B	10,840	2790	195	70		228	86%
Zone C	9728	2504	175	70		175	71%
Zone D	6037	2554	109	50		150	95%
Zone E	11,472	2953	206	80		215	75%
	47,522	13,591	855	330		943	80%
Ampara Urban Council (AUC) *							
Zone A	2381	391	43	20		60	95%
Zone B	6000	929	108	5		75	66%
Zone C	8520	1407	153	70		150	67%
Zone D	4804	602	86	25		100	90%
Zone E	4931	811	89	25		100	88%
Zone F	2414	390	43	20		60	95%
Zone G	2406	396	43	20		60	95%
Zone H	4435	487	80	20		75	75%
Zone I	6799	903	122	30		100	66%
Zone J	3942	667	71	20		88	96%
	46,632	6983	839	255		868	79%

* Three local authorities where this study was conducted.

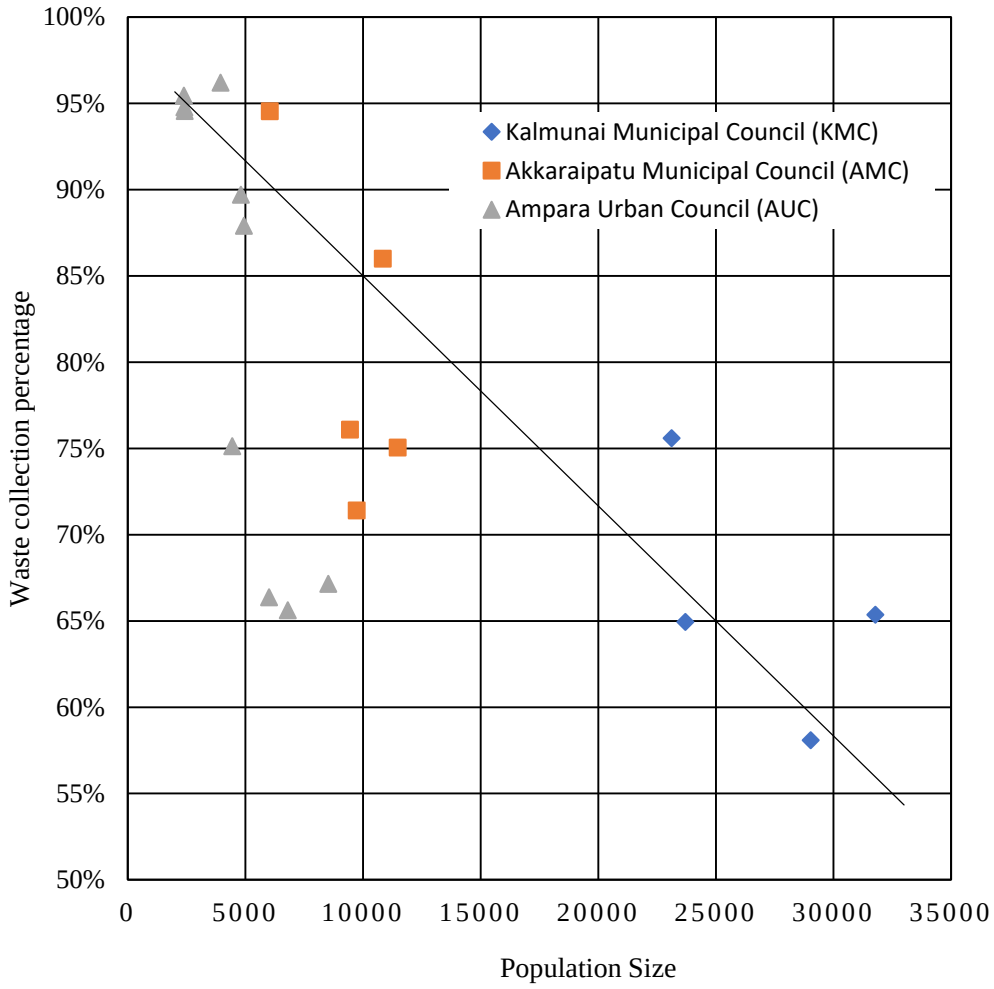

Figure 5. Percentage of waste collection compared to population size in the zones of local authorities.

Table 4 shows the human resource and vehicle capacity employed in MSWM by the three local authorities studied in this research. The waste collection efficiency is strongly correlated to the human resource and collection vehicle capacity. The zones with higher population size in KMC have employed six times less human resources and vehicle capacity compared to AUC, which has more than 88% collection efficiency in 50% of the zones (Table 2, Zones A, D, E, F, G, H, and J). Similarly, AMC, which has the zones with two times the population of AUC zones, but with two times less human resources and vehicle capacity, has 75% waste collection efficiency in three of the five zones (Zones A, C, and E). Furthermore, the higher population density in the KMC area (six times compared to AMC and AUC) and a narrow road network make it difficult for the KMC to employ large vehicles such as tractors and compactors. This further reduces the waste collection efficiency in the zones of highly congested areas with already existing limited resources.

Table 4. MSW collection efficiency (HR and vehicle capacity).

	Local Authority Area	KMC	AMC	AUC
A	Total No. of Households	45,000	12,232	6983
B	No of Employees in SWM Unit			
1	Supervisors	4	1	2
2	Development officer/management assistant	0	3	0
3	Drivers	13	10	10
4	Health labourers	57	30	55
5	Other minor staff	1	1	2
#	Total human resources	75	45	69
C	No. of Vehicles in SWM Unit			
1	Land master	2	0	0
2	Tractor	8	8	9
3	Compactor	2	2	1
4	Truck	1	0	0
5	Excavator	0	1	0
6	Bobcat	0	1	1
7	Gully sucker	0	2	1
8	Backhoe loader	0	0	1
9	Motor grader	0	0	1
#	Total vehicles	13	14	14
D	Human resource capacity for SWM/100 HH	0.17	0.37	0.99
E	SWM collection vehicle capacity/100 HH	0.03	0.11	0.20

4.3. Sources and Quantities of Municipal Solid Wastes

Major points of waste generation sources (PWGS) of MSW in the south-eastern region are households, market areas or commercial units, and public/private institutions. The three councils (KMC, AMC, and AUC) studied in this research are within the top 7% of local authorities (among top 23 out of 328 local authorities in Sri Lanka) that generate more than 30 MT of waste per day [25].

Table 5 shows the composition of MSW collected in all of the three urban areas. The collected MSW of KMC and AMC consists of 89% biodegradable wastes (food/kitchen waste, animal and plant matter), 3% plastic wastes, 6% metal wastes, 1% rubber, and 1% glass wastes. The biodegradable waste in AUC is 85% of the total, rubber waste is 2%, and glass waste is 4%. A study carried out in 2013 by Kularatne [26] in Vavuniya City in the northern Sri Lanka revealed that household waste comprised 80 to 90% organic (biodegradable) materials, whereas the organic content was only 66% in the mixed MSW collected by the urban council.

Table 5. Composition of municipal solid waste.

Type of Waste Collected	AUC	KMC	AMC
	Percentage of Total (%)		
Biodegradable waste	85	89	89
Plastic waste	3	3	3
Metal waste	6	6	6
Rubber waste	2	1	1
Glass waste	4	1	1

A previous study of solid waste characterization in the Kalmunai municipality, published by Ariyawansha et al. [27], in a post-conflict and -tsunami context estimated that

MSW consisted of 76% and 72% of long-term biodegradable materials in household generation and in collection, respectively. The percentages given in Table 5 were provided by the respective solid waste management units in 2019, which can be characterized in the context of post-conflict developments, after the end of civil war in 2009. Although there is a lack of detailed disaggregated data, an overall analysis shows that the percentage of metal waste has increased to 6%. It was reported in the recent area development plan for KMC that 60% of waste comes from residents, 24% from commercial places, and 6% from streets [28]. There was a high percentage of construction and demolition waste, which could be due to the reconstruction works after 2004 tsunami.

5. Discussion

Although the existing MSWM systems in the urban areas include all necessary elements (collection, transport, treatment, and disposal), it is evident that the effectiveness and efficiency of the existing systems are not at a satisfactory level. Specifically, solid waste management practices in the Kalmunai Municipality lack an effective approach, which has become the first and foremost problem faced by people within the KMC region.

5.1. Segregation of Waste at the Source of Generation

They key issue in managing MSW starts at the sources of generation, where generally very little effort is made to segregate waste by households and commercial entities. Fernando [29] highlighted many challenges faced by local authorities to implement an integrated SWM plan in Sri Lanka: insufficient land allocated for proper final disposal, lack of resources and technology, an inefficient work force, and low labour productivity. However, in KMC, non-segregation of waste by residents has been the key challenge, which leads to all other challenges highlighted by Fernando [29].

The Karaithivu pradeshiya sabha (a pradeshiya sabha is a third-tier local authority next to urban councils and municipalities in the Sri Lankan governing structure), a local authority adjacent to KMC with one-fifth the population of KMC, has managed to collect segregated wastes from residents. The main problem in KMC is a lack of adequate systems and resources to manage the large quantity of waste generated in the highly congested urban environment. The areas of KMC congested with high population require further divisions and resources to effectively handle the quantity of wastes generated every day.

5.2. Reduction of Waste Generation

The amount of wastes generated in households and commercial entities can be reduced effectively if the public is educated and made aware of effective methods of reducing waste. However, there are no initiatives or policies introduced to motivate domestic, commercial, and industrial sectors to reduce waste generation. Further, to the best of our knowledge, there is no effort to date to introduce any recycling methods in any of the councils studied in this research.

5.3. Absence of Effective Regulation to Control Polluters and Excessive Waste Producers

The absence of regulation to control the polluters and entities producing excessive waste compared to an ordinary household is making the situation worse. The level of waste management service required is proportional to the needs of entities that produce excessive waste. Therefore, the existing systems and resources are inadequate to manage the volume of services to collect and dispose of waste. For example, a study of MSW management in Taiwan reported that the most important factor for successful management of MSW was the policy of extended producer responsibility, which laid a foundation of recycling by producers and retailers [30]. Informal discussions with the residents revealed that they pay a small amount to the waste collectors when there is excessive waste to be collected from their premises. This shows that people are ready to pay for excessive waste if there is a proper system in place by the municipality.

5.4. Absence of Regular Collection Schedule and Plan

In many municipalities in Sri Lanka with inadequate MSWM systems, the wastes end up in public places such as streets, public playgrounds, beaches, and riverbanks. The main reason for such public places becoming polluted by waste is the absence of a regular schedule for waste collection that is communicated to the public. Day to day accumulation of solid wastes without proper management has resulted in eruptions of several garbage flocks, especially in the cities with condensed, urbanized dwellings in Sri Lanka. Daily collection of solid wastes from households is not accomplished in all scheduled areas by local government garbage vehicles, because of limited availability, mal-allocation and mal-distribution of resources without a proper management system. As a consequence, the over accumulated wastes end up in dumpsites near public places and busy streets. The recent Meethotamulla garbage dump collapse in the capital city of Sri Lanka, which killed many people and damaged the habitat, indicates the problem is a concerning subject. The dengue spread that is partially attributed to the garbage heaps also highlights the lack of coordination of all relevant stakeholders regarding this issue in the past.

5.5. Lack of Technical Know-How in MSW Management

Key informant interviews with MSW management staff at the councils revealed that there is a lack of expertise within the local authorities on devising MSWM policies and strategies that are technically sound and contextually appropriate. In recent years, there were externally funded projects in Ampara to improve SWM practices, such as the European-Union-funded Environmental Remediation Programme (ERP, Phase I and II from 2011–2016, EUR 12.5 million) with technical support from the United Nations Office for Project Services (UNOPS). However, there is a lack of continuity and sustainability of the initiatives due to periodic changes in council leadership and membership every four years. Most often, new members of the municipal councils have limited knowledge to innovatively solve MSWM problems and to foster successful partnership with key stakeholders who can support innovative initiatives. A multi-stakeholder participatory consultation is therefore required to formulate acceptable and appropriate policies at the municipality level.

6. Recommendations for Improvements in MSW Management

The solid waste management system is influenced by various factors such as technical, legal, socio-cultural, and environmental perspectives [31–33]. The recommendations are to solve the immediate complexities, while addressing the need for a long-term safer living environment.

6.1. Waste Management at the Source of Generation

6.1.1. Segregation of Waste at the Source

The public is not motivated to segregate waste at a household level as there is no regulation to control the collection of waste separately. This problem can be overcome by providing separate trash bags or bins to households, so that people are compelled to segregate their waste. A policy should be enforced not to collect wastes that are not properly segregated. In addition, regular awareness campaigns can be implemented through community-based organizations and divisional administrations.

The municipal/urban councils should give priority to initiate awareness programmes towards sustainable approaches to manage the waste at the point of generation, such as providing different bags or containers to segregate waste and for home composting within their premises. An incentive scheme for home composting as one of the priority solutions will help manage the large amount of biodegradable waste at the point of generation. This will also reduce the efforts and resources in the management of MSW. Further, a feasible module or prototype for urban home-based biogas production can be explored and introduced. Since there is less space in the household premises of urban areas, and almost 89% of the waste is biodegradable, innovative home-based biogas production solutions will reduce the problems of solid waste collection and disposal.

6.1.2. New Regulations to Control Excessive Waste and Polluters

Maintaining a robust policy and implementing a proper legal framework are important drivers in integrated SWM. Legal frameworks should be aligned with national policy, and it should be effective to manage multiple stakeholders [15,34]. For example, in order to control excessive waste generators and polluters, appropriate new regulations, such as a high levy, proportional to the percentage of waste collected to waste generated, should be introduced. A household tax tied to the amount of waste transported to landfills can be introduced, as there is currently no proper mechanism to fund waste management except the property tax imposed by municipalities, which is often not paid by the majority of residents [35]. This scheme would be similar to the "polluters-pay" principle wherein the entities or households who require more waste to be collected than the average amount of waste within the municipality should bear the additional cost. This scheme could also include concessions for those who treat the waste themselves, resulting in significant net reduction.

In certain areas within the municipality/urban council, people throw waste at night time onto the streets, though strict notice boards are displayed not to place their wastes in public places. Rigid regulations must be implemented for these people by imposing fines. Also, municipal/urban councils should implement strong monitoring mechanisms and law enforcement to control such misbehaviour from people.

6.1.3. Innovative Schemes for Waste Reuse and Recycling

Public awareness programmes should be conducted by local authorities and volunteer organisations to reduce waste generation. Waste reduction is a primary step in the management of MSW. Non-hazardous products can be reused in many ways, including:

- Educating and encouraging people to buy products which can be reused and/or which result in less waste.
- Purchasing products in bulk rather than buying them in smaller packets/containers, so that fewer food containers or packets end up in the dustbin, reducing the amount of waste for collection, which increases the efficiency of the MSW management system.

Many hazardous products cannot be recycled as they contain harmful chemicals. However, some specific efforts can help reduce waste through cautious handling of hazardous products, for example, persuading people to buy non-toxic products whenever possible and completely use up the purchased toxic products, so that there will be no hazardous material left for disposal.

Many of the items which are considered to be waste could be used for other purposes. For example, papers and envelopes can be used as scrap paper, cardboards and newspapers can be used as packing materials, plastic and paper bags can be reused in the shops or used as bin bags around the house, and wood can be reused in woodcrafts for making small garden objects.

6.2. Efficient Waste Collection Mechanism

6.2.1. Resource Allocation and Capacity Building

Institutional effectiveness is a key element in the solid waste management system, and inefficient administration significantly affects the waste management plan [16]. Several factors influence institutional effectiveness, such as institutional capacity, organization structure, level of collaboration, level of decentralization of authorities, and key stakeholder cooperation [36,37]. In order to manage the large quantity of the wastes generated in highly congested areas such as KMC, the areas should be divided into several smaller zones with manageable populations, and adequate human and physical resources should be allocated to handle the waste management problems. For example, a municipality can be divided into a number of urban councils consisting of several smaller zones for the waste management purposes.

The new local electoral system introduced in Sri Lanka in 2018, based on having an elected representative for each of the wards in a local authority, should help the municipal councils to manage the problem at the ward level. Such engagement and participation with

the community will assist the municipality to make communication a two-way process that will largely increase the social trust with the local authorities in executing their duties.

Commitment of staff (particularly supervisors and waste collectors) is very much essential in running a successful SWM system. Proper training and workshops have to be arranged for the staff members of SWM units to learn about waste collection, composting, and waste-dumping. The health conditions of the staff involved in waste collection should be monitored by regular medical clinics. Safety tools and uniforms must be provided to the workers and should be made compulsory to wear during the handling of wastes. The workers who are involved in the composting and recycling processes should get additional incentives.

Introducing waste management as a subject in the school syllabus will cause changes in the attitudes of students in the national level. Apart from that, awareness workshops and seminars can be organized in schools. Additionally, arranging special sessions and discussions among large waste generators in the council regions will be beneficial to manage the wastes efficiently.

6.2.2. Public Information Sharing Platform

Research studies have shown that public participation in solid waste management has improved the efficiency of solid waste collection and significantly reduced financial investment by municipalities for the waste separation and handling of hazardous materials [14,38,39]. The most influential factors that contribute to public participation in the solid waste management system include: easy access to waste facilities and a convenient recycling/separation method [40]. Xiao et al. [40]'s waste policy hierarchy demonstrates that knowledge is the key contributing factor, followed by social motivation for improving the efficiency of MSWM.

The public should be provided with accurate information on the schedule of collection, type of waste to be collected on a specific day, and any interruption in the schedule well in advance, to enable the efficient collection of MSW from households. The existing system requires significant improvements to make the public aware of the days and time of waste collection trucks approaching the households. A mobile phone app or social-media-based information-sharing platform can be introduced to provide regular updates and advance information on the collection schedule until a sustainable solution (an integrated municipal solid waste management system) is introduced. Since there is a lack of resources from the municipal councils, the introduction of a fixed schedule for waste collection remains a challenge. A very recent initiative by the Minuwangoda Urban Council (MUC), together with the Western Provincial Council (WPC), is a good example for public information sharing: they have launched a mobile app in a bid to streamline the garbage collection process in the local government area [41]. Such innovation initiatives can be done by universities and research organisations.

6.3. Resource Recovery and Safe Disposal

6.3.1. Segregation of Waste at Disposal

The segregation of MSW at the source of generation and promoting recycling or reuse of segregated waste materials minimize the volume of waste remaining for collection for disposal and the burden on landfills [34]. However, since it is not always possible to render the waste completely segregated at the source in congested cities, such as in the study locations for this research, the capacity for the segregation of waste at disposal needs to be increased.

6.3.2. Options to Convert Waste to Resources

Waste-to-Energy (WtE) projects are very limited in low-income and middle-income countries, because the opportunity cost of establishing WtE plants are very high; however, they have the ability to solve a multitude of problems that relate to MSW. The key options to convert waste to resources, such as composting and 'waste-to-energy' projects, should be devised as a long-term solution to waste management in the highly congested coastal cities in the south-east of Sri Lanka. The annual population growth in the large cities is

expected to be around 1.5%, and 90% of the waste collected in these areas is biodegradable waste. Sri Lanka's first ever WtE plant was just commissioned in 2021; it produces 10 MW energy using 700 MT of waste collected from Colombo, the capital city of Sri Lanka. The three larger cities in the south-east coast of Sri Lanka (KMC, AMC, and AUC) produce more than 120 MT per day, and all the remaining adjacent emerging cities in the coastal region can add up to a total of 180–200 MT (minimum) per day, which has the potential to establish a WtE power plant.

7. Conclusions

Waste management has become a daily talk in the public domain across Sri Lanka, particularly in the urban areas. Finding sustainable solutions to waste management continues to be challenging, which has resulted in many public health issues, environmental, social and economic problems across many communities.

This study in three coastal cities of the south-eastern region of Sri Lanka found problems in all facets and phases of managing municipal solid waste. Although the MSWM systems in the urban areas include all necessary elements, their effectiveness and efficiency are not satisfactory for several reasons, including the poor or non-segregation of waste at the source of generation, a lack of physical and human resources, the absence of regulation to reduce waste generation and control polluters, the absence of a regular collection plan and schedule, and a lack of technical know-how and initiatives.

The study also found that waste collection efficiency has a direct correlation with zoning size and resources deployed for the zones. The local authorities need to devise contextually appropriate solutions with sustainable waste management strategies that are economically viable, environmentally friendly, and socially unprejudiced. There is a delay in introducing new policy regulations, finding appropriate sustainable solutions, and solving emerging problems on a daily basis. Key recommendations drawn from the findings of the study include certain feasible solutions and immediate measures required to control waste management problems before they become a social catastrophe in the future.

Although this study was limited to three local authorities in the coastal areas, the findings would help local authorities in other parts of Sri Lanka to take proper actions to implement sustainable MSWM practices in the context of post-conflict development initiatives rapidly taking place throughout Sri Lanka. Future research in the MSWM areas, such as the public perception of local authorities in MSWM, policy implications due to poor MSWM in building sustainable cities, and the role of the private sector in MSWM need to be carried out to further understand the multiple dimensions of MSWM problems. The findings will help to improve MSW collection and management in the Sri Lankan context, which will assist in devising and implementing appropriate and effective solid waste management policies in the future. Such policy decisions will help to enhance the quality of healthy life and the environment for the Sri Lankan urban population.

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