National Plastic Waste Inventory for Sri Lanka: A Material Flow Approach

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Foreword

Plastic plays a vital role in today's society because of its versatility in various aspects of our daily lives. However, it's crucial to consider both the positive and negative aspects of plastic. Considering the critical impact of plastic pollution, intergovernmental negotiations are underway for a global treaty on plastic waste management.

As the responsible agency, the Ministry of Environment, has developed the National Action Plan on Plastic Waste Management 2021-2030 based on the National Policy on Waste Management. This action plan outlines actions for Sri Lanka to follow based on the principles of 3Rs, covering the entire lifecycle of plastic waste management from importation and processing to final use or collection and disposal.

The one of the goals of this action plan is to establish an inventory and monitoring mechanism for all entries and exits of plastic in the country, with the objective of making the inventory dataset available. It serves as an indicator for examining the utilization patterns of plastic when monitored periodically.

This national plastic waste inventory was prepared using an approach based on Material Flow Analysis (MFA) and it was validated through main stakeholders. The MFA technique makes it possible to understand the movement of plastic waste from its places of origin, via formal and informal waste management systems, and ultimately to its recovery or disposal. It also comprises an evaluation of the possibility that plastic waste would leak into the environment at several stages of the waste management system, such as collection, handling, sorting, and landfill disposal.

This initiative is part of the project titled "Marine Litter and Micro-plastics: Promoting the Environmentally Sound Management of Plastic Wastes and Achieving the Prevention and Minimization of the Generation of Plastic Wastes." The project was commissioned by the Secretariats of the Basel, Rotterdam, and Stockholm (BRS) Conventions on behalf of the Norwegian Agency for Development Cooperation (Norad). Sincere thanks are extended to the Institute for Global Environmental Strategies (IGES), the United Nations Environment Programme (UNEP), University of Peradeniya (UOP), main stakeholders and project staff for their tremendous support in completing this important task.

Together, strides are being made towards a more sustainable and responsible approach to plastic waste management in Sri Lanka.

B.K Prabath Chandrakeerthi

Secretary

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Executive Summary

This document presents the methodology and findings for a national plastic waste inventory for Sri Lanka. It has been prepared as part of the project titled "Marine litter and micro-plastics: Promoting the environmentally sound management of plastic wastes and achieving the prevention and minimization of the generation of plastic wastes," commissioned by the Secretariat of the Basel, Rotterdam and Stockholm conventions (BRS) on behalf of the Norwegian Development Agency (NORAD).

A material flow analysis (MFA)-based approach has been used to develop the inventory. The MFA approach allows the mapping of flows of plastic waste arising from sources of generation (e.g. householders and businesses), through the formal and informal waste management systems and to its disposal or recovery. It also incorporates an assessment of the potential leakage of plastic waste into the environment at various points in the waste management system (e.g. collections, handling, sorting and landfill disposal).

The inventory focuses on macro plastics (i.e. plastic items and fragments above 5 mm in size) generated by municipal sources, as this is the most common fraction of plastic waste and is considered to be the source of plastic waste that poses the greatest risk of mismanagement and leakage into the environment. Due to the limited availability of data on many issues associated with plastic waste management in Sri Lanka, the estimates produced by the inventory are subject to considerable uncertainty. However, they provide an initial assessment of the scale of plastic waste management and pollution and can be used as a basis for planning strategic efforts to reduce plastic pollution in Sri Lanka. Key outputs from the inventory are shown in Table 1.

Table 1: Summary of plastic waste inventory, Sri Lanka (tonnes per year)

Description	Tonnes per year			
	MC	UC	PS	National
Total plastic waste generation	67,663	26,143	155,231	249,037
Per capita plastic waste generation	0.0286	0.0189	0.0091	0.0195
Total collected	61,305	23,538	96,228	181,071
Plastic waste collected by formal mixed waste collection	41,238	13,683	44,341	99,262
Plastic waste collected by informal mixed waste collection	6,867	64	3,486	10,416
Plastic waste collected by formal recycling collections	3,355	1,624	1,031	6,011
Plastic waste collected by informal recycling collections	9,845	8,167	47,371	65,383
Proportion of waste collected	*91%*	*90%*	*62%*	*73%*
Total plastic waste recycled	12,499	5,906	8,370	26,775
Proportion recycled	*18%*	*23%*	*5%*	*11%*
Total plastic waste disposed to designated disposal sites	39,563	10,682	46,632	96,877
Plastic waste disposed in controlled landfills	-	-	*9,326*	*9,326*
Plastic waste disposed in uncontrolled landfills	*39,563*	*10,682*	*37,306*	*87,550*
Recyclables taken from landfills by informal recyclers	3,537	513	527	4,577
Net disposed (after waste plastics removed by informal recyclers)	*36,026*	*10,169*	*46,105*	*92,300*

Description	Tonnes per year			
Total plastic waste leakage from the waste management system	34,862	10,135	56,453	101,450
Leakage during collections	1,770	760	6,461	8,992
Leakage during transportation	32	90	277	400
Leakage during sorting	1,131	682	12,177	13,991
Leakage from designated disposal sites	31,927	8,602	37,539	78,068
Proportion of all plastic waste leaking from the waste management system	*52%*	*39%*	*36%*	*41%*
Total uncollected	6,358	2,605	59,003	67,965
Proportion of plastic waste uncollected	*9%*	*10%*	*38%*	*27%*
Total unmanaged	41,219	12,740	115,456	171,561
Proportion of plastic waste mismanaged	*61%*	*49%*	*74%*	*69%*
Total Plastic waste traded	-	-	-	3,660
Total imports	-	-	-	*3,588*
Total exports	-	-	-	*72*
MC: Municipal Councils (*n* = 24), UC: Urban councils (*n*= 41), PS: Pradeshiya Sabha (*n*= 276)				

The flow of waste plastics is illustrated schematically in Figure 1. In summary:

- The total estimated municipal plastic waste generation in Sri Lanka is approximately 250,000 tonnes annually. The majority of this is generated in rural areas. Plastic waste generation in urban areas is significantly lower than in rural areas.
- Approximately 181,000 tonnes per year (73%) of plastic waste is collected by a combination of formal and informal collection systems.
- The informal waste recycling sector is active in Sri Lanka and is estimated to collect 65,383 tonnes of source segregated plastic waste, as well as an estimated 10,416 tonnes of plastic waste as part of mixed waste collections (although only a small part of plastic in mixed waste is separated for recycling). However, formal source segregated recycling services by LAs are thought to account for a much lower proportion of waste plastic recycling (22.5%).
- Approximately 27,000 tonnes of all plastic waste are estimated to be sent for recycling. This is equivalent to 11% of the estimated total plastic waste generation. Recycling levels are thought to be highest in the urban areas, and relatively low in rural areas.
- Approximately 97,000 tonnes of plastic waste are sent to designated disposal sites annually. There are a small number of controlled disposal sites in Sri Lanka, located in the Pradeshiya Sabha areas. However, most of the "disposed waste" is sent to uncontrolled dumpsites with limited controls.
- An estimated 67,965 tonnes per year (27%) of plastic waste is not collected at all. Instead, these materials are typically either burnt, dumped, or buried on site.
- A further 101,450 tonnes (41%) of plastic waste are estimated to leak from the waste management system during collection, transporting, sorting, and landfilling.

- In total, approximately 171,561 tonnes which is about 69% of plastic waste generated in Sri Lanka each year is unmanaged plastic. This includes uncollected plastic waste that may be buried and burnt and fractions that escape into the broader environment before entering or from within the waste management system.
- Full details of the methodology, data sources and findings can be found in the main body of this document.

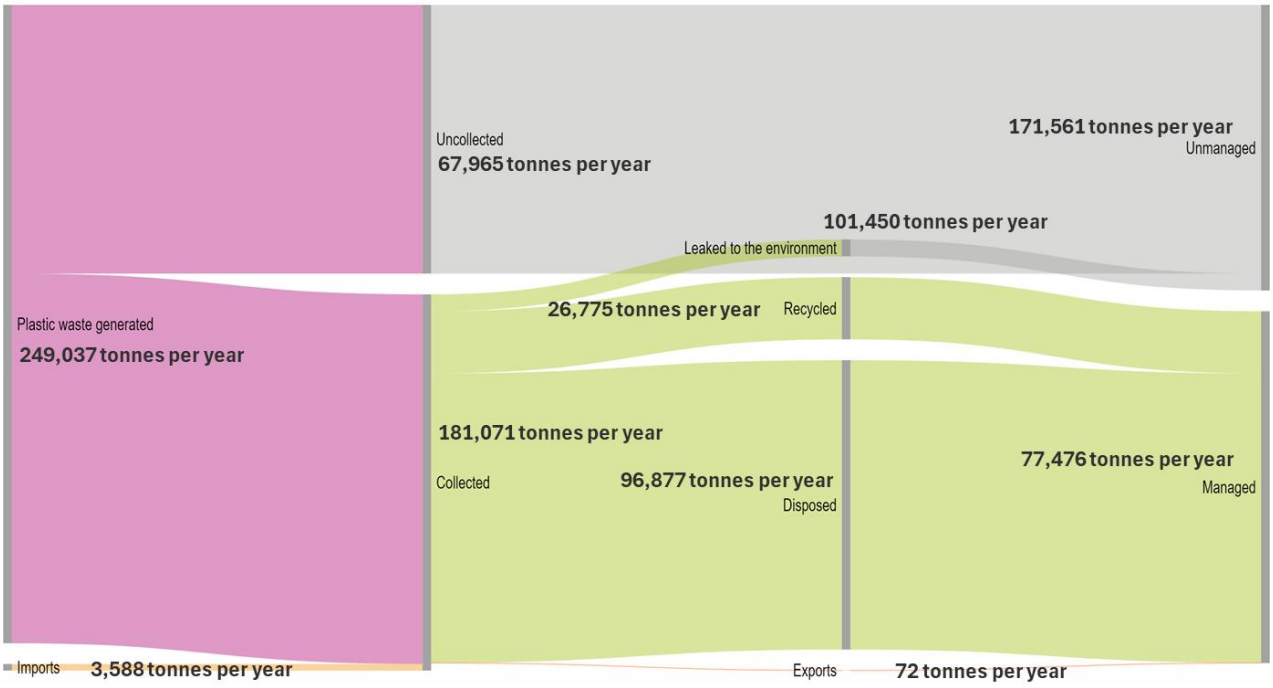

Figure 1: Sankey diagram of plastic waste flows, Sri Lanka

A key limitation of this preliminary inventory activity is the unavailability of reliable waste statistics with the critical actors in the waste management sector, Local Authorities (LAs), and the informal sector. Waste quantitative and qualitative (e.g., composition, sorting quantities) data keeping is available only in very few LAs; thus, generalizing available statistics to the entire country increases the uncertainty. Therefore, it is imperative that there should be a mechanism for data gathering related not only to waste collection or service coverage but also to quantitative figures in the whole waste stream from generation to final disposal for improving the national inventory.

It was also observed that key value chain actors in privately owned resource recovery and recycling enterprises have limited cooperation with regulatory and administrative organization which affect the governance of recycling businesses and efficient collection of data and information. Gradual conversion of the informal sector to the formal sector through local government intervention will enable regular data and information gathering. The process can streamline by establishing a centralized data collection and processing centre at NSWMSC or CEA. In this, the advantage of IT infrastructure in personal and institutional levels can be used to shift the conventional book record keeping practices to digital data recording, sharing and analysis.

The data keeping in the waste sector is not uniform among local authorities (lateral) and different actors in the value chain (vertical). Therefore, there should be a mechanism to identify, classify, and standardize all waste management actors based on internationally recognized norms enabling data validation and comparison for international agreements and treaties.

Finally, it is worth noting that the primary waste collection duty is an obligatory function of Local Authorities that act in a discrete physical boundary. However, informal sector recyclable collectors always cross the physical boundaries of LAs; consequently, recognizing and allocating informal resource recovery actors for a LA is challenging. Therefore, the informal sector resource recovery and recycling should be evaluated as a regional or national activity and merge with the "national inventory" at downstream of the waste stream.

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List of Abbreviations

BRS	Secretariat of the Basel, Rotterdam and Stockholm Conventions
CEA	Central Environmental Authority
DB	Database
GIZ	German Corporation for International Cooperation
HDPE	High-density Polyethylene
IGES-CCET	IGES Centre Collaborating with UNEP on Environmental Technologies
JICA	Japan International Cooperation Agency
LAs	Local Authorities
LDPE	Low-density Polyethylene
ME&NR	Ministry of Environment and Natural Resources
MOE	Ministry of Environment
MFA	Material Flow Analysis
MC	Municipal Council
MSW	Municipal Solid Waste
NAPPWM	National Action Plan on Plastic Waste Management
NGOs	Non-governmental Organisations
NORAD	Norwegian Development Agency
NSWMSC	National Solid Waste Management Support Centre
NPCPRP	National Post Consumer Plastic Recycling Project
PS	Pradeshiya Sabaha
PET	Polyethylene Terephthalate
PVC	Polyvinyl Chloride
PP	Polypropylene
PS	Polystyrene
SDG	Sustainable Development Goals
SD	Standard Deviation
TBM	Transboundary Movement
UNEP	United Nations Environment Programme
UC	Urban Council
WMA-WP	Waste Management Authority – Western Province
WaCT	Waste Wise Cities Tool

1. INTRODUCTION

1.1 Background

In Sri Lanka, the manufacturing industry of plastic products, packaging and polymers has been growing over the last 45 years, especially since the easing of restrictions in related economic policies in the early 80s to promote import and export-oriented economies. Currently, about 400 companies are engaged in the plastic industry in Sri Lanka (Ministry of Environment, 2021) (Central Environmental Authority, 2023). In addition, considerable amounts of plastic products are imported to the country as consumer products and capital goods.

Some earlier research estimated plastic consumption per capita at about 6 kg per annum (Basnayake., et al., 2020) including both hard and soft plastics (films); however, the percentage of plastic waste in the MSW composition varies greatly between urban and rural settings. For example, a nationwide study conducted in 2016 (Japan International Cooperation Agency & Kokusai Kogyo Co. Ltd 2016) revealed that the rural waste stream mainly comprises biodegradable waste, and that plastic waste accounts for only 5% considerably lower than urban cities (Ministry of Environment, 2021).

The plastic waste recycling industry in Sri Lanka is mainly driven by private entrepreneurs with the collaboration of informal sector recyclable collectors and their junkshop networks. Informal collectors collect source-separated plastic waste from households and institutions for reselling to junk shops (agglomerates) where they are cleaned, stored, treated, and later sold to local recycling industries to use within the country or for export, mainly to China and India in the forms of granules, chips, and flakes. Small recycling businesses and door-to-door collectors often purchase high-value plastic waste (e.g., broken furniture, household items etc.) from households and other establishments, thus the residual waste is mainly composed of low-value and problematic plastic waste such as contaminated packaging film, degraded plastics, multi-layered/heavily printed packaging, and shopping (grocery) bags which eventually end up in open dumpsites and the natural environment.

Since 2006, the government of Sri Lanka has introduced policies and regulations aiming to achieve sustainable waste management with a particular focus on plastic waste pollution prevention as a key intention. In 2006, the Central Environmental Authority (CEA) banned the manufacture and distribution of all polythene products with a thickness of less than twenty (20) microns to promote reuse and increase the recycling potential. In the following year, the Ministry of Environment and Natural Resources (ME&NR) launched another project, the National Post Consumer Plastic Recycling Project (NPCPRP), focused on achieving three main objectives; 1) to address the behaviour change necessary among Sri Lankan consumers to ensure the proper disposal of plastic waste in such a manner causing no harm to the environment or natural resources, 2) to establish the necessary logistics to enable the collection and recycling of post-consumer plastic waste, and 3) to reduce the foreign exchange overhead by enhancing recycling of post-consumer plastic waste. By 2018, the NPCPRP had established 12 recyclable collection and plastic recycling facilities in 12 Local Authorities (LAs) of Sri Lanka.

In 2011, Waste Management Authority of Western Province introduced a new concept for waste resource recovery – *Sampath Piyasa* – or Resource Centres where recyclables are sold and purchased

according to the type of material, weight, and market value. *Sampath Piyasa* were recognized by many other LAs outside the Western Province as an effective way of collecting recyclables from citizens as well as raising awareness as they demonstrate that recyclable wastes have a market value. A national programme called *PILISARU* financially supported the LAs wishing to establish *Sampath Piyasa* from 2008 to 2015.

Further, the National Action Plan on Plastic Waste Management 2021-2030 (Ministry of Environment, 2021) was developed by the Ministry of Environment (MoE) to reinforce the enactment of 3R throughout the entire lifecycle of plastic waste management – from importation, processing, final use, collection to disposal. This effort is believed to assist in Sri Lanka's role as a global partner to achieve the goals of the 2030 Agenda for Sustainable Development, particularly Goal 12 on responsible consumption and production, and Goal 14 on life below water.

The LAs are also equipped to collect plastic waste with collection vehicles either dedicated to non-degradable (recyclable) waste collection or partitioned tractor trailers for source-segregated waste collection. The implementation of mandatory source separation policy and regulations by LAs after Meethotumulla dumpsite disaster in 2017 compelled citizens to discharge source separated waste as degradable and non-degradable wastes. In addition, several non-governmental organisations (NGOs) and international donor agencies work in the plastic waste management sector in Sri Lanka at different scales. Plastic waste is typically recycled into household items such as buckets and basins, horticultural utensils such as flowerpots, and packaging materials such as shopping bags, plastic films, and containers. In addition, some entrepreneurs upcycle waste plastics to value-added products such as yarn, containers, and packages. However, significant quantities of plastic waste are still not collected at all, particularly in inaccessible communities in urban and rural areas, where it is either burned or buried onsite, or indiscriminately disposed of in the environment (Basnayake et al., 2020).

1.2 Purpose

Quantifying plastic waste generation and flows is challenging, and data on the nature of plastic waste and its generation and management is often limited. Many countries lack the necessary data collection and management systems in place to provide detailed information on waste management systems, specifically plastic waste management. Under such circumstances, it is necessary to develop a first-generation inventory by drawing on a range of data sources to estimate plastic waste quantities and flows. However, such data sources are very scant in Sri Lanka, a fact recognized by the National Action Plan on Plastic Waste Management (NAPPWM) (2021-2030), highlighting the need to develop a national inventory and monitoring mechanism as a first goal to address the plastic waste issue.

A first-generation inventory successfully balances accuracy in representing a complex flow of materials against the availability of data and the resources needed to collect more accurate data. It is a tool that enables better tracking of waste plastics and their environmentally sound management. The inventory should track the generation of plastic wastes and describe the types and quantities that are managed through the established formal and informal system, as well as leakage into the natural environment. Data generated through a regular inventory process will help countries establish a national reporting framework which in turn will enable them to fulfil reporting obligations to the Basel Convention and develop appropriate strategies for ensuring the environmentally sound management of plastic waste.

This report therefore presents the national plastic waste inventory for Sri Lanka, which was jointly developed by the MoE, Sri Lanka, the Secretariat of the Basel, Rotterdam and Stockholm Conventions (BRS Secretariat), IGES Centre Collaborating with UNEP on Environmental Technologies (CCET) and the University of Peradeniya (UoP) with the collaboration of Central Environmental Authority (CEA), National Solid Waste Management Support Center (NSWMSC), Waste management Authority-Western Province (WMA-WP), Local Authorities, and several private and non-governmental organizations. This project is being implemented as part of an umbrella project entitled "Marine litter and microplastics: promoting the environmentally sound management of plastic waste and achieving the prevention and minimization of the generation of plastic waste" (BRS-Norad-1), which is being implemented in Sri Lanka and Ghana, and also features global activities. The BRS-Norad-1 project is financed by the Norwegian Agency for Development Cooperation (Norad) with additional funding by the Government of the Netherlands.

1.3 Key Outputs

Forming a national plastic waste inventory based on material flow analysis enables estimation of plastic waste quantities that are managed within the waste management system and those that escape into the environment. Key outputs generated using this inventory include:

Regional and national estimations of plastic waste quantities:

- Collected by formal and informal services.
- Present in mixed waste fractions sent to disposal and incineration and co-generation facilities
- Recycled
- Left uncollected at source

Regional and national estimations of plastic waste leakage:

- During collection
- During sorting
- During transportation
- From final disposal sites

A qualitative understanding of the key actors, their roles, and the interdependencies of flows within the plastic waste management landscape.

These outputs help local and national stakeholders understand the extent of mismanagement of plastic waste and thereby, design strategies, objectives, and interventions to address them in a sustainable manner. An evidence-based understanding of the waste management system enables effective use of limited resources – including financial and human – at national and local levels through targeted action. For instance, leakage of plastic waste due to improper waste handling can be addressed through training and capacity-building activities aimed at specific parts of the waste management system. Similarly, data on the proportion of plastic waste disposed and recycled can inform decisions around technology and infrastructure needs, and thereby help direct investments to the right points of the system.

1.4 Structure of the Report

The report includes five key sections.

- *Section 1* gives an introduction to the report, including background, purposes, outputs, structures, scope, and key concepts used.
- *Section 2* presents the methodology and scope of the inventory toolkit. It describes the material flow analysis (MFA) and sources of plastic waste considered in the methodology.
- *Section 3* describes the data and information gathering using the flow diagram and the spreadsheet structure used in the methodology. This section includes several steps: Step 1 – Baseline data collection, Step 2 – Leakage factors estimation, and Step 3 – Inventory calculation.
- *Section 4* presents the key results summarizing the national estimations of plastic waste management based on the MFA.
- *Section 5* describes steps to be taken in future iterations of the inventory to improve the accuracy and repeatability of the methodology used.

1.5 Scope of the Report

The scope of the national plastic waste inventory is considered in terms of:

- *Product lifecycle* **-** The stage of the product lifecycle during which plastic waste is generated (i.e., production, consumption, waste generation, and waste disposal).
- *Sector* - The sector which generates the waste (e.g., municipal, commercial, industrial, or agricultural plastic waste).
- *Type of plastic* - There are various types of plastic polymers (and additives), and these are used in different products. As such, it is important to categorize plastics waste in terms of the main types concerned. Common approaches used to categorize different types of plastic include:
    - Primary polymer (e.g., PET, PP, HDPE, LDPE, PS)
    - Product type (e.g., packaging, consumer products, e-Waste, automotive products, construction products)
    - Physical property (e.g., macro (>5 mm) or micro plastics (<5 mm), flexible or rigid packaging, durable or nondurable products, high or low recyclable value, multilayer or monolayer packaging)

This study focuses on the macro-scale plastic waste (i.e., plastic items and fragments over 5 mm in size) generated by municipal waste management (municipal sources means any Local Authority area of the country as a legitimate government entity for management of municipal solid waste). This plastic type was chosen as it is mainly generated from post-consumer sources, as opposed to industrial waste, and because the largest fraction of post-consumer plastic waste is packaging, which is typically disposed as part of municipal waste. It is also widely accepted that municipal plastic waste is the waste fraction most commonly mismanaged and, as a result, often ends up in

the wider terrestrial and marine environment as a pollutant. As such, it is the typical starting point for assessing plastic waste issues.

However, it is important to recognize that other sources and types of plastics are also potentially important, besides municipal plastic waste. Whilst the automotive and construction sectors use large quantities of plastic, these plastic items are typically in use for much longer periods. The agricultural sector can be a major generator of plastic waste in contexts where films are used as crop cover and mulch. Microplastic generation is also important, although less well understood than macro plastics. A recent study indicates that microplastics account for approximately 13 million tonnes of plastic leakage into the world's oceans annually, and about 11% of total plastic leakage (Pew and SYSTEMIC, 2020). Microplastics can be in primary (manufactured beads, pellets, etc.) or secondary form (derived from the degradation of larger plastic items), according to their source, and such distinction is important as it influences their final state in the environment, i.e., the physical changes they undergo due to physical and chemical weathering[1].

Clearly it is important in any specific context to consider whether a focus on municipal waste is appropriate or whether other sectors that generate significant quantities of plastic waste and pose a high risk of plastic pollution warrant assessment.

1.6 Scope of the Report

The scoping review guided the concepts and definitions used in this methodology, which are described in further detail below.

- *Municipal Solid Waste (MSW)* refers to the mixed solid waste generated by households or waste that is similar in composition to household waste generated by commercial and institutional sources (including schools, hospitals, and government buildings). This excludes industrial (manufacturing, construction, and demolition), agricultural, healthcare, and hazardous waste.
- *Recovery processes* involve the recovery of material or energy from waste through recycling, composting, incineration with energy recovery, mechanical or biological processes for waste treatment, etc.
- *Recycling* is a recovery process involving the mechanical or biological conversion of waste into products that can be used for the original or other purposes. It excludes energy recovery.
- *Disposal* involves the transfer or placement of waste in disposal sites such as landfills.
- *Incineration* refers to the controlled combustion of waste with or without energy recovery. Also, here in this report, the combustible plastic waste that is treated in co-generation (ex. Cement kilns) are considered as incineration.

[1] ACS Publications 2020, Microplastic Research Should Embrace the Complexity of Secondary Particles https://bit.ly/2QxjVuq

- *Controlled landfills* are sites which are officially designated as disposal sites and have basic, improved or advanced control features to manage the waste received on site. These can range from advanced features, such as proper containment of the waste and its leachate or collection of landfill gas, to limited features, such as dedicated staffing on site, defined site boundary (with or without fencing), basic covering for waste and varying levels of record keeping.
- *Uncontrolled landfills* are sites which may or may not be officially designated for disposal and have limited or no controls for containment, management or recording of the waste received on site.
- *Formal mixed waste collection* refers to the collection of mixed waste by formal services comprising institutions (e.g., LAs) and organisations that are registered businesses and hold official licenses to undertake waste management activities such as collection, sorting, disposal, and treatment.
- *Informal mixed waste collection* refers to the collection of mixed waste undertaken by informal services comprising individuals and/or family or community-run enterprises that are usually unregistered and unregulated and carry out value-adding waste management activities typically using low capital input and labour-intensive techniques. Their operations may often be in violation of or in competition with the operations of formal authorities[2].
- *Formal recyclables collection* refers to the collection of source-segregated recyclables including plastic waste by formal services (e.g., LAs).
- *Informal recyclables collection* refers to the collection of source-segregated recyclables by informal services (e.g., door-to-door collectors, street collectors, rag-pickers, recyclable collecting entrepreneurs).
- *Sorting* refers to the separation of plastic waste from mixed waste and the segregation of various plastic types within the source-segregated plastics collected as part of recyclables collections.
- *Sorting ecosystem* refers to all the actors and activities associated with the sorting of plastic waste, which may be undertaken by formal and informal actors. Sorting activities can take place in waste transfer stations, aggregators, or bulking sites or at formal and informal sorting facilities.
- *Flows* are the pathways and quantities representing plastic waste generated, managed, and leaked into the environment.

[2] UN-Habitat. (2021). Waste Wise Cities Tool. Step by Step Guide to Assess a City's Municipal Solid Waste Management Performance through SDG indicator 11.6.1 Monitoring. UN-Habitat

The following types of flows are assessed in this methodology:

Generation – Plastic waste fraction of municipal waste generated at source, which is considered the starting point of the inventory.

Collection – Plastic waste fraction that is collected through the various collection pathways, including mixed and source segregated waste collections by formal and informal services.

Transportation – Final stage transportation of plastic waste within the country to both disposal and energy recovery facilities as part of mixed waste collections or to recycling and other recovery facilities after sorting. Interim transportation during collection and sorting is not included in these flows.

Sorting – Sorting flows represent activities occurring within the sorting ecosystem.

Recycling – Conversion of plastic waste outputs from sorting in to flakes or pellets which can be used to substitute for primary (i.e., non-recycled) materials in manufacturing activities.

Incineration – Plastic waste fractions that are sent for incineration (including co-generation energy recovery) facilities as part of mixed waste disposal.

Uncollected waste – Plastic waste that is never captured by the management system and is lost to the environment from the point of generation through activities such as dumping in water bodies, burning or burial.

Leakage – Plastic waste fractions that are lost from the different stages of the management system into the environment, including collection, sorting, transportation, and disposal. Uncollected waste is treated as a separate flow to leakage as this fraction does not enter the waste management system in any way.

2. METHODOLOGY

2.1 Material Flow Analysis (MFA)

As shown in Table 2, approaches for developing a first-generation inventory of plastic wastes, set out in the Practical guidance for the development inventories of plastic waste (UNEP 2022)[3], can be grouped into two main types: (i) the 'product lifetime' approach, which focuses on using production and trade data from sources such as national production statistics (e.g., Prodcom[4]) and international trade datasets (e.g., UN Comtrade[5]), and combining this with product lifetimes to estimate likely plastic waste generation in broad-based categories (UNEP, 2022), and (ii) the 'material flow analysis' (MFA) approach, which estimates the generation of plastics waste and pathways by drawing on field studies of waste generation and its management and/or proxy data from similar contexts.

Table 2: Comparison between product lifetime and MFA approach[6]

Product lifetime approach	MFA approach
• Uses existing production and trade data sets and thus typically requires less time and resources • Tends to be skewed towards those sectors for which accurate data on plastics is available, but can miss plastic items and products that are not reported in these datasets or are included under different categories because they only comprise one part of the material • Does not consider how wastes are managed, so does not provide any insight into what happens to the plastic waste after it is generated	• Typically, more resource-intensive as it requires information from various points in the waste management system • Relies on primary data collection and/or estimation based on proxy data from other, similar contexts • Describes how plastic waste flows from the point of generation and into the waste management system, and thus provides an insight into its mismanagement and potential leakage into the environment

The methodology used to develop a national plastic inventory for Sri Lanka is based on MFA method and toolkit developed under the Basel Convention (UNEP, 2022), with due consideration of the importance of understanding the inputs, outputs, and calculations. MFA allows the mapping of flows of plastic waste arising from sources of generation (e.g., householders and businesses), through the formal and informal waste management systems, to its recovery and final disposal, or leakage into the environment, as well as assessment of the degree of 'leakage' of waste plastics from the waste management system. Understanding the points at which leakage occurs is critical to enabling targeted interventions to tackle plastic pollution. Several methodologies for assessing the generation and flow of plastic waste have been developed over recent years, driven

[3] https://www.basel.int/Guidanceoninventoryofhazardouswastes/tabid/8755/Default.aspx
[4] https://ec.europa.eu/eurostat/web/prodcom
[5] https://comtrade.un.org/
[6] Pisharody & Lerpiniere, 2021

by the increased level of interest and urgency associated with tackling the significant scale of plastic pollution occurring globally. Some of the better-known works are:

- Plastic waste inputs from the land into the ocean (Jambeck et al., 2015)
- River plastic emissions to the world's oceans (Lebreton et al., 2017)
- Production, use, and fate of all plastics ever made (Geyer et al., 2017)
- Primary Microplastics in the Oceans: A Global Evaluation of Sources, (Boucher et al. , 2017)
- The Waste Flow Diagram (GIZ, 2020)
- National Guidance for Marine Plastic Hot Spotting and Shaping Action (UNEP and IUCN, 2020)
- Global Plastic Action Partnership Pilot in Indonesia (PEW and SYSTEMIQ, 2019)
- Breaking the Plastics Wave (Pew and SYSTEMIC, 2020)
- Plastic Waste Material Flow Analysis for Thailand (World Bank, 2022)

Among them, the methodology for this plastic waste inventory specifically draws upon two existing waste flow assessment (WFA) methodologies, which are described below.

UN-Habitat - Waste Wise Cities Tool:

The Waste Wise Cities Tool (WaCT), developed by UN-Habitat, is based on the United Nations Sustainable Development Goals (SDG) indicator 11.6.1 monitoring methodology. It is useful for conducting city-level assessments of an MSW management system (UN-Habitat, 2021), and provides a framework for collecting data on waste generation, collection, and management. The methodology can be used for monitoring performance in relation to SDG 11.6.1.

GIZ - Waste Flow Diagram:

The Waste Flow Diagram (WFD) developed by GIZ, University of Leeds, Eawag and Wasteaware is a tool enabling city-level assessment of plastic waste fractions of MSW. The mapping of plastic waste flows by the tool uses observational assessments, which enables rapid assessment with reduced data requirements, but at the expense of accuracy. It provides a framework for quantifying leakages of plastic waste from the MSW management system and is also closely linked to and uses the UN SDG indicator 11.6.1 monitoring methodology for primary data collection.

The MFA framework providing the basis for the methodology is illustrated in Figure 2. The flows of waste and recyclable materials are typically very complex, involving many steps and numerous different actors. Representing this flow is highly challenging, and to provide a detailed, actor-by-actor level of granularity would require disproportionately large data collection and highly burdensome assessment. The MF diagram developed for this methodology was therefore a simplified version of the flows and was intended to identify the key parts of the flow whilst being simple enough to be practicable to populate with data as part of the inventory development process.

The different parts of the MF diagram are described below:

- *Grey boxes* represent the different stages of the MSW system such as collection, sorting and disposal.
- *Purple arrows* represent flows of plastic waste between the various stages.
- *Blue arrows* represent the leakage of plastic waste at each stage.

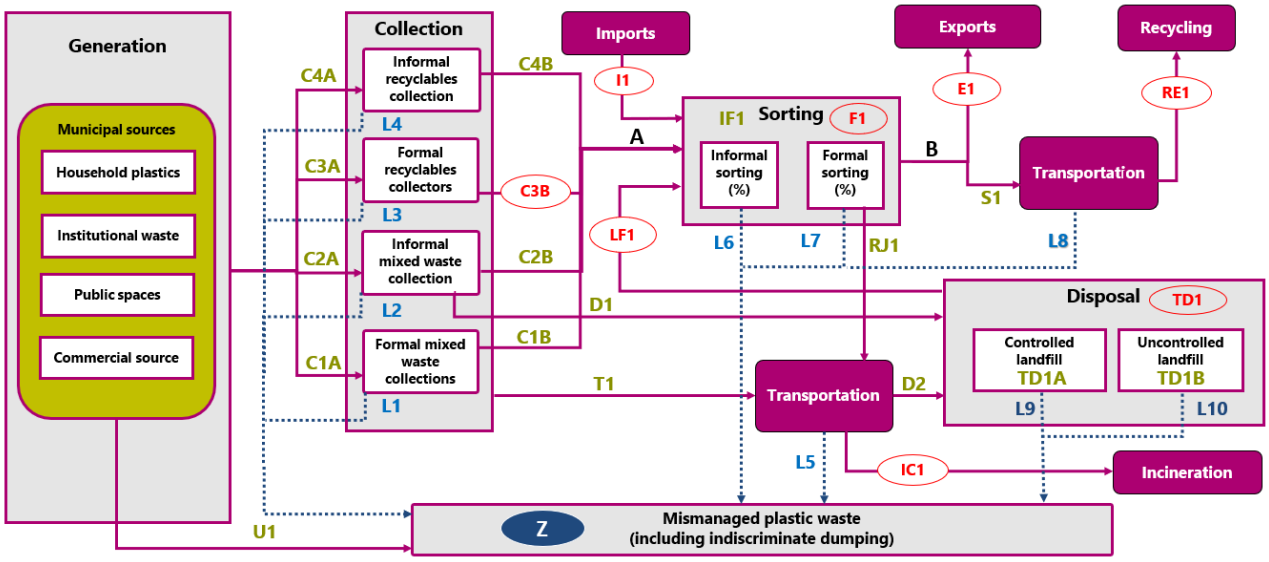


Figure 2: Material Flow Analysis Framework for plastic waste inventory development[7]

The methodology required various key data points to be completed to construct the MFA, which are highlighted in red in Figure 2. Other data points (labelled in green) were calculated using a combination of these key values and other supporting data points (the full data collection and calculation process is described below). The leakage rates at each point of the MFA were then estimated based on a qualitative assessment (see below for more information). The flow also includes the import and export of plastic, which were estimated using a methodology developed to calculate the Transboundary Movement (TBM) of plastic waste. The MF diagram is comprised of the following parts:

- *Generation*. This is the quantity of plastic waste generated at the municipal level, and by sources that typically form part of the municipal waste management system: residents, businesses, institutions, and public spaces (e.g., streets and parks).
- *Collection*. This describes the different collection methods of plastic waste from their points of generation and comprises formal and informal collection flows. It also differentiates between i) plastic waste that is collected separately as part of source-segregated collection systems, and ii) waste plastic collected as part of mixed waste. The informal collection system can be particularly complex, comprising a wide range of actors, such as door-to-door collectors who buy recyclables from residents, informal recyclers collecting materials from containers in the street as well as workers collecting plastic waste from landfills (see flow LF1).

[7] Pisharody & Lerpiniere, 2021

- *Sorting.* This refers to the sorting of plastic waste for mechanical and chemical (where applicable) recycling. Mixed waste without recyclable plastic fractions may be sent to further recovery (energy) or disposal facilities. Sorting typically involves removing unwanted materials and items and separating plastics into different polymers and grades so that they can be sold for reprocessing into new materials. In many contexts, sorting is undertaken by formal and informal actors often within complex ecosystems of different actors conducting different types of interlinked sorting operations at various scales. As well as sorting of source-segregated plastic, some mixed wastes may also be sorted to remove valuable plastic components. For the purposes of this model, it is assumed that the removal of plastic for recycling at the sorting stage is undertaken by the formal sector (i.e., at formal material recovery facilities). Removal of plastics by the informal sector is considered to account for the inflow of LF1 as part of the informal mixed waste collection flow.
- *Landfill disposal.* This is the disposal of waste plastics at designated landfill disposal sites, which are divided into two types following the WaCT approach with SGD 11.6.1 methodology: controlled disposal sites and uncontrolled disposal sites (UN-Habitat, 2019).
- *Recycling:* These are materials that have been sorted and are sent for recycling into new materials and new products.
- *Incineration.* This element represents the volume of plastic waste disposed of through formally operated incineration plants and does not differentiate between incineration with or without energy recovery.
- *Imports and exports.* This captures the flows into and out of the waste management system in the form of imported and exported plastic waste.
- *Transportation.* This step captures the transport of mixed waste to disposal sites and the transport of sorted waste plastics to recycling and recovery facilities and includes consideration of the potential leakage from the relatively long-distance formal transport of plastic wastes.
- *Mismanaged plastic waste.* This is the aggregate quantity of waste that escapes into the environment as the sum of all estimated leakages from different elements of the system and uncollected plastic waste.

2.2 Use of Archetypes

One of the key considerations for developing plastics waste inventories, especially for compiling estimates for national, regional, or global studies, is the use of archetypes. An archetype stratifies an area of interest (e.g., a country) into representative regions linked by similar factors, such as population density, level of economic activity and waste management systems and practices.

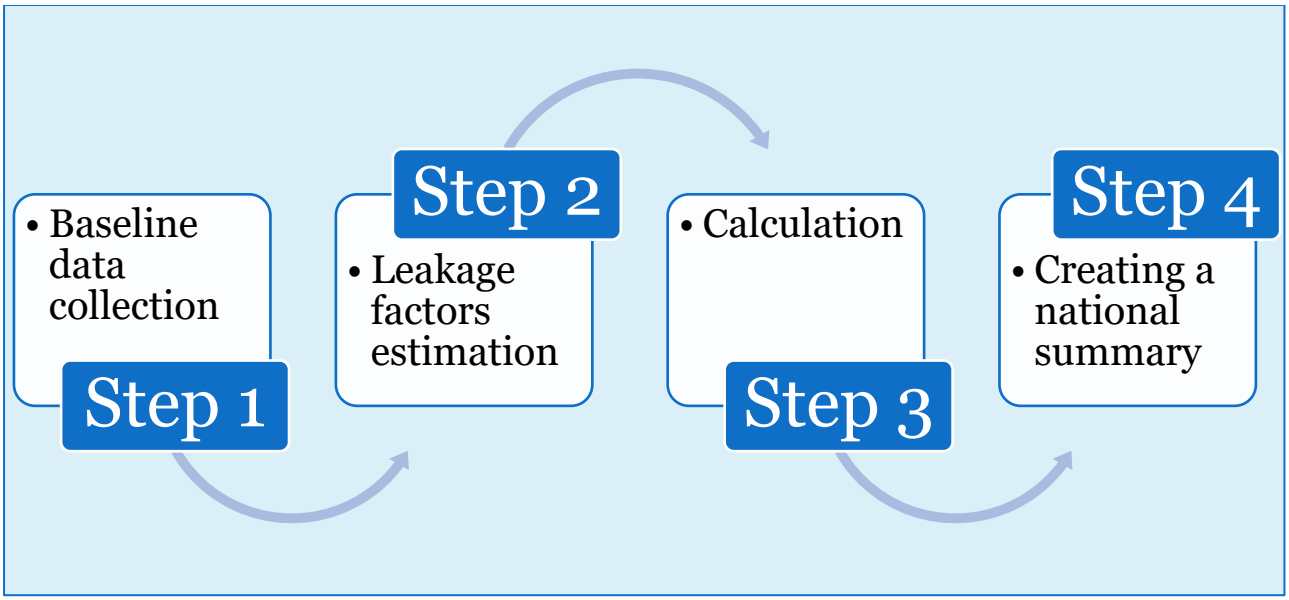
The simplest and most common archetype classification used by existing studies is geographical units, such as 'urban' and 'rural' (normally using World Bank definitions and datasets) (Pew and SYSTEMIC, 2020), which is considered appropriate as waste generation and management tend to vary most significantly based on these two geographical signifiers while also linking them in terms of the two defining aspects (waste generation and management). Moreover, plastic waste flow estimations for a typical urban area can be scaled up to a combination of urban areas, using a factor such as population, and the same can be done for rural areas, thus enabling regional or national estimates of plastic waste flows. Some studies use finer granularities, such as remote, rural, medium, and mega (PEW and SYSTEMIQ, 2019). Defining archetypes in terms of a unit's proximity to a watercourse and/or a coast is another common approach (e.g., Jambeck et al., 2015; Lebreton et al., 2017; Pew and SYSTEMIC, 2020).

Usually, data collected on a per capita basis in individual archetypes is extrapolated by population to obtain archetype-level estimations. Regional estimations from all archetypes can therefore be summed up to derive national estimates. However, such scaling up can introduce an element of error, according to the quality and accuracy of the baseline data used. Nonetheless, archetypes are a useful tool for providing an initial understanding of the plastic waste management landscape in the absence of other reliable estimations. Iterations of the inventory over time will help in the identification of gaps in data availability. This, in turn, will feed into developing regional and national data collection and monitoring systems.

2.3 Spreadsheet structure

The methodology comprises four steps, each of which forms a separate worksheet in the attached MS Excel model:

Step 1 – Baseline data collection
Step 2 – Leakage factors estimation
Step 3 – Calculation
Step 4 – Creating a national summary



The spreadsheet consists of three copies of the worksheets describing Steps 1 to 3, one for each archetype. This allows for separate handling of variations in waste management for each archetype. After flows in the MF diagram were calculated for individual archetypes, the outputs were combined to form a national summary of flows in a separate group of worksheets named 'National summary'. This will be explained in detail in Step 4. In summary, this methodology was intended as an entry point for assessing plastic waste leakage as a starting point for assessing and investigating plastic management and potential interventions for improvements. It thus serves as a basis for assessing the scale of plastic waste generation and the potential environmental leakage, as well as more detailed analysis in the future. The key steps of the methodology and data application are detailed in the following sections.

3. DATA AND INFORMATION GATHERING

3.1 Baseline data

Defining archetypes

The first step of data collection involved defining the archetype for this study via a scoping meeting, following the suggestions provided by Ministry of Environment and local government administrative divisions of the Ministry of Provincial Councils and Local Government Affairs. In Sri Lanka, local government is the lowest level of administrative unit and comprises three units – Municipal Councils (MCs), Urban Councils (UCs) and Pradeshiya Sabha (PSs) – which provide local public services including MSW management. As of April 2023, Sri Lanka had 24 MCs (Mega category), 41 UCs (Medium category) and 276 PSs (Small category).

Data sources and approaches

The next step was to collect the necessary data points for each archetype, which involved an intense review of existing studies and information sources for appropriate data and, where resources permitted, collection of primary data via site visits, surveys, and interviews with key stakeholders. The MFA framework developed for this methodology has been created to minimize the number of necessary data points whilst providing sufficient detail, which are summarised in Table 3. First, the MFA for the three archetypes was developed. The steps of the inventory methodology were repeated for each archetype to derive separate output flows. For each data point of the archetypes, per capita estimates were synthesised using sample data collected from the selected 11 Municipal Councils, nine Urban Councils, and 16 Pradeshiya Sabhas representing the whole country based on the data availability in 2022 (recorded during 2015–2022 period). This is first extrapolated using the population of the archetype to generate a data point to be entered in the baseline data proforma for the archetype. The output flows derived for each archetype from the three MFAs were then combined to create a national-scale inventory of plastic waste, to which was added plastic waste imports and exports.

To allow for variation in data points due to different contexts, calculations were adjusted or overwritten to replace data points with actual data. For example, the MFA process allows quantities of plastic waste sorted by informal activities to be calculated based on other key data points; however, if *primary* data was available on the level of informal sorting that takes place, that data was used for the MFA calculation. Where data points themselves were not available, other studies or proxy values were used. In the case of absence of waste composition data at the LA level for example, proxy data on composition from similar contexts was used, and in the absence of this, values were estimated based on expert judgement.

The study also focused on the data points most likely to be available from recorded sources and studies, such as the formally managed systems of waste collection, recycling, and disposal. Data from the informal system was less likely to be recorded so these data points were either calculated or estimated and replaced with primary data if available for these factors for incorporation into the model. Much of the primary data collection needed for applying this methodology was undertaken using the

methodology and principles of WaCT (UN-Habitat, 2021). It must be noted that the reliability of data varies depending on whether it is derived from primary sources, current records, and studies or from older studies, outdated records or estimations.

Table 3: Baseline data required

No	MFA ref.	Data point	Unit	Description	Data Source
1	-	Population	No.	Total population of archetype	From Department of Census and Statistics Sri Lanka (2022)
2	-	Rate of MSW generation	Kg/person/day	Rate of generation of municipal solid waste per person per day	1. Primary data collection (see Step 2 of WaCT) from LAs 2. Recent waste characterisation studies (Japan International Cooperation Agency & Kokusai Kogyo Co. Ltd, 2016) 3. Triangulation of values from representative regions obtained through a literature review (Sato et al., 2020) (Basnayake et al., 2020) (Basnayake B.F.A., 2020) (Karunarathna et al., 2020) (Alahakoon and Karunarathna, 2020) (Samarasinghe et al., 2014) (Karunarathna et al., 2018a) (Karunarathna et al., 2018b) (Karunarathna et al., 2018 c)
3	-	Proportion of plastic waste in MSW	%	Proportion of MSW that comprises plastic waste	
4	TD1	Quantity of plastic waste disposed at designated disposal sites[8]	Tonnes/day	Quantity of plastic waste received at designated landfill sites (controlled and uncontrolled)	1. Primary data collection (see Step 5 of WaCT). Estimated as the proportion or quantity of plastic in the waste

[8] Designated Disposal – Sites recognized and used by public and private authorities for waste disposal

No	MFA ref.	Data point	Unit	Description	Data Source
5	-	Proportion of total plastic waste disposed to designated disposal sites, which ends up in controlled landfills	%		received at the respective sites. 2. Triangulation of values from representative regions obtained through a literature review (Sato et al., 2020) (Basnayake et al.,2020) (Basnayake B.F.A., 2020) (Karunarathna et al., 2020)
6	-	Proportion of total plastic waste disposed to designated disposal sites, which ends up in uncontrolled landfills	%		(Alahakoon and Karunarathna, 2020) (Samarasinghe et al., 2014)
7	-	Proportion of total plastic waste received at designated disposal sites that comes from formal mixed waste collection services	%		
8	-	Proportion of total plastic waste received at landfills that comes from informal mixed waste collection services.	%		
9	IC1	Quantity of plastic waste received at incineration facilities	Tonnes/day	Includes incineration both with and without energy recovery	

No	MFA ref.	Data point	Unit	Description	Data Source
10	RE1	Quantity of plastic waste received at recycling facilities	Tonnes/day	The quantity of waste received by recycling facilities (after sorting). Includes both mechanical and chemical recycling.	1. Obtained through interviews and waste characterisation studies (see Step 4 of WaCT) at recovery facilities receiving sorted waste. Estimated as the proportion or quantity of plastic in the waste received at the respective sites. 2. From literature sources.
11	I1	Quantity of plastic waste imported	Tonnes/year	Based on assessment of transboundary movement data	1. Use of TBM methodology 2. Other official sources such as inventories at CEA
12	E1	Quantity of plastic waste exported	Tonnes/year	Based on assessment of transboundary movement data	
13	RJ1	Proportion of plastic waste that is rejected during formal sorting processes	%	It is assumed that this material is sent for disposal.	1. Obtained through interviews and waste characterisation studies (see Step 2 of WaCT) at sorting facilities receiving sorted waste. Estimated as the proportion or quantity of plastic in the waste received at the respective sites. 2. From literature sources
14	-	Proportion of plastic waste that is rejected during informal sorting processes	%	It is assumed that this material is not sent for formal disposal. This data point is used to calculate the	Derived from data point 13

No	MFA ref.	Data point	Unit	Description	Data Source
				leakage rate from informal sorting activities.	
15	F1	Quantity of plastic waste sorted for recycling by formal sorting facilities	Tonnes/day	Quantity of plastic waste sorted by formal sorting facilities (before leakage and rejects)	Obtained through surveys of the sorting system to identify number of facilities and capacities. Key players can be interviewed to obtain estimates of daily throughput of plastic waste.
16	C3B	Quantity of plastic waste collected by formal services	Tonnes/day	Quantities of source segregate plastic waste collected by formal collection services for sorting	Obtain through official records of transfer stations or sorting facilities receiving waste from formal services or through interviews of key stakeholders in the service.
17		Quantity of mixed waste received at formal sorting facilities	Tonnes/day	From formal and informal mixed waste collections	
18	-	Proportion of mixed waste received at formal sorting facilities that comes from formal sources	%	Proportional split of formal and informal mixed waste collections received at formal sorting facilities	
	-	Proportion of mixed waste received at formal sorting facilities that comes from informal sources	%		Derived from data point 18
19	-	Proportion of plastic in mixed waste received at formal sorting facilities that comes from formal mixed waste collections	%	Plastic fraction of mixed waste received by formal sorting facilities from formal and informal sources	Obtained through surveys of the sorting system to identify number of facilities and capacities. Key players can be interviewed to obtain estimates of daily throughput of plastic waste.

No	MFA ref.	Data point	Unit	Description	Data Source
20	-	Proportion of plastic in mixed waste received at formal sorting facilities that comes from informal mixed waste collections	%		
21	LF1	Quantities of plastic waste collected by informal services through waste picking at landfills	Tonnes/day		Obtained through waste characterisation studies and interviews of the informal sectors and key disposal sites.

A thorough literature review was conducted to identify the data needed to populate the MFA for each archetype, with additional data obtained via interviews and requests to key stakeholders. Where suitable data could not be identified, estimates were developed based on expert opinion and comparison with data from similar contexts in other countries. The population statistics were obtained from the national census, which is reliable and verified, and all other waste generation-related data and information were either sourced from published reports or scientific publications. It should be noted that the number of observations obtained for each data point varied depending on the data availability and reliability. The toolkit calculation used the average values of each archetype; however, the obtained standard deviation (SD) is also shown in the data table to illustrate the possible deviations. The key data sources are summarised in Table 4, and the key data points used are individually discussed in the sections below.

Table 4: Key data sources used for plastic waste data in Sri Lanka

No.	Source	Baseline data point
1	Department of Census and Statistics (2012) Census of population and Housing Final Report, Statistics Ministry of Policy Planning Economic Affairs, Child Youth and Cultural Affairs. ISBN: 978-955-577-940-1.	1 Leakage factors
2	Japan International Cooperation Agency and (JICA) Kokusai Kogyo Co., Ltd. (2016). Data Collection Survey on Solid Waste Management in Democratic Socialist Republic of Sri Lanka. Report No. JR-16-029.	2-10 Leakage factors

No.	Source	Baseline data point
3	Japan International Cooperation Agency (2017). Survey on Method of Solid Waste Management Annual Budget Making and Utilizing Waste Collection and Disposal data in Local Authorities of Sri Lanka - Final report, Kokusai Kogyo Co., Ltd.	2, 3
4	Japan International Cooperation Agency (2019). Democratic Socialist Republic of Sri Lanka Pollution Control and Reduction of Environmental Burden in Solid Waste Management (ReEB Waste), EX Research Institute Ltd., Kokusai Kogyo Co., Ltd., JR-19-012.	2, 3, 4 Leakage factors
5	Central Environmental Authority (CEA) (2016). Proposed waste to energy project at Sri Lanka Board of Investment Land, Dompe - Report, Available at: http://cea.nsf.ac.lk/handle/1/19808.	2, 3 Leakage factors
6	Central Environmental Authority (CEA) (2014). Construction of Solid Waste Disposal Facilities Project in Sri Lanka - Report, Kunhwa Co., Ltd.	2, 3
7	Sato, S., Chiharu, I., Chiaki, N. and Karunarathna A.K. (2020). Evaluation of organic and recyclable waste separation at generation source in Ratnapura and Kataragama local authorities in Sri Lanka, Detritus, Vol 12/2020, pp 176-196. DOI 10.31025/2611-4135/2020.14006.	2-10 Leakage factors
8	B.F.A. Basnayake, R.T.K. Ariyawansha, A.K. Karunarathna, S.M. Werahera, N. Mannapperuma. (2020). A. Pariatamby and M. S. Bhatti Ed. Sustainable Waste Management Challenges in Sri Lanka. Sustainable Waste Management Challenges in Developing Countries. IGI Global. https://www.igi-global.com/chapter/sustainable-waste-management-challenges-in-sri-lanka/240084.	2, 3, 4, 5, 6 Leakage factors
9	Japan International Cooperation Agency (2019). Democratic Socialist Republic of Sri Lanka Pollution Control and Reduction of Environmental Burden in Solid Waste Management (ReEB Waste), EX Research Institute Ltd., Kokusai Kogyo Co., Ltd., JR-19-012.	2, 3, 4 Leakage factors
10	Central Environmental Authority (CEA) (2016). Proposed waste to energy project at Sri Lanka Board of Investment Land, Dompe - Report, Available at: http://cea.nsf.ac.lk/handle/1/19808.	2, 3 Leakage factors
11	Central Environmental Authority (CEA) (2014). Construction of Solid Waste Disposal Facilities Project in Sri Lanka - Report, Kunhwa Co., Ltd.	2, 3
12	Ilesinghe, A. M. (2017). Post-Consumer Plastic Waste Generation and Resin Types for Recycling: A Case Study in Kandy Municipal Council. BSc dissertation, Department of Natural Resources, Faculty of Applied Science, Sabaragamuwa University of Sri Lanka, Sri Lanka.	2, 3, 4, 5, 6 Leakage factors

No.	Source	Baseline data point
13	Danthurebandara, M.; Van Passel, S.; Machiels, L.; Van Acker, K. (2015). Valorization of thermal treatment residues in Enhanced Landfill Mining: environmental and economic evaluation. J. Cleaner Prod. 99, 275–285.	4–8
14	Stakeholder interviews (Local Authorities) by local project team	2, 3, 4, 5, 6 Leakage factors
15	Records from sorting facilities of Local Authorities	13, 14, 18 Leakage factors

3.2 Key Data Points

Data point 1 - Population

Population by archetype

- Mega (Municipal Councils): 2,369,075
- Medium (Urban Councils): 1,382,060
- Small (Pradeshiya Sabha): 17,091,992

As highlighted above, archetypes for the inventory were based on the local administrative divisions currently in place in Sri Lanka. Therefore, Municipal Councils, Urban Councils and Pradeshiya Sabhas respectively represent the Mega, Medium, and Small archetypes, which are comprised of 24 Municipal Councils, 41 Urban Councils and 276 Pradeshiya Sabhas, respectively. Population data for each archetype was obtained using the 2012 clarified data for the national population provided by the Department of Census and Statistics.

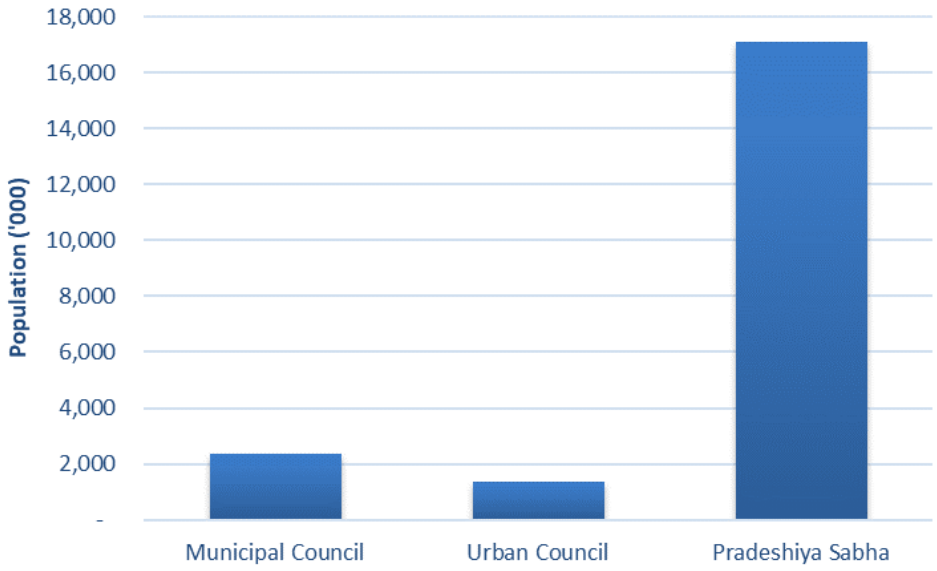


Figure 3: Population by archetype

Data point 2 – Rate of MSW generation

Criteria/ Data point	Mega (Municipal Council) *n=11*	Medium (Urban Councils) *n=9*	Small (Pradeshiya Sabha) *n=16*
Per capita waste generation rate (kg/person/day)	1.14 ± 0.37	0.80 ± 0.29	0.46 ± 0.18

The key data source for the waste generation was from a series of primary data collection surveys such as the survey conducted by Japan International Cooperation Agency & Kokusai Kogyo Co. Ltd. in 2016, Data Collection Survey on Solid Waste Management in Democratic Socialist Republic of Sri Lanka, Japan International Cooperation Agency in 2017, Survey on Method of Solid Waste Management Annual Budget Making and Utilizing Waste Collection and Disposal data in Local Authorities of Sri Lanka and in 2019, Pollution Control and Reduction of Environmental Burden in Solid Waste Management (ReEB Waste) in 2019. Several other reliable reports and publications (e.g., Basnayake et al., (2020), Central Environmental Authority (2014), and Sato, et al., (2020)) were also used to obtain waste generation rates, which were then verified through stakeholder consultation with Local Authorities.

Data point 3 – Proportion of plastic in MSW

Criteria/ Data point	Mega (Municipal Council) *n=9*	Medium (Urban Councils) *n=9*	Small (Pradeshiya Sabha) *n=15*
Proportion of plastic in MSW (%)	6.89 ± 2.08	6.45 ± 2.98	5.47 ± 2.42

Plastic waste compositions for various LAs of Sri Lanka have been reported in multiple studies. Plastic was found to be the second most abundant inorganic waste fraction in the waste stream after paper waste, with an average composition of 16% (Basnayake et al., 2020). Having considered regional variations and estimated average composition in past years, the same author estimated (2020) that plastics made up 6% of Sri Lanka's waste, on average. The data points for inventory calculated average plastic waste percentages for each archetype and the values are presented in the table above.

Data point 4 – Total plastic waste disposed to landfills

The national MSW waste statistics revealed that the amount of waste disposed of in the Dompe sanitary landfill was not significant (<0.1%); thus the material flow calculation assumes all the final disposal sites are uncontrolled landfills or open dumpsites (Karunarathna et al., 2021). The amount of plastic waste disposed to landfill was calculated from two data sources: total waste received at uncontrolled landfills and plastic waste composition of disposed waste. Data synthesis for this data point is demonstrated in table below.

Criteria/ Data point	Mega (Municipal Council) *n*=2	Medium (Urban Councils) *n*=2	Small (Pradeshiya Sabha) *n*=5
Total amount of waste disposed in uncontrolled landfill (Tonnes/day)	2,207.71	815.58	4,009.16
Plastic Percentage (%)	6.89	6.45	5.47
Per capita plastic waste disposal in landfill (g/person/day)	45.75	21.20	7.48
Total population of each architype (Persons)	2,369,075	1,382,060	17,091,992
Total plastic waste disposed in uncontrolled landfill (Tonnes/day)	108.39	29.27	127.76

Daily tonnages brought to the uncontrolled landfill from MC, UC, and PS were referenced from available reports (Japan International Cooperation Agency (2019); Japan International Cooperation Agency (2017); Japan International Cooperation Agency & Kokusai Kogyo Co. Ltd., (2016); Karunarathna, et al., (2021); National Solid Waste Management Support Centre, (2015)). Then the volume of disposed plastics waste of each LA in the three architypes was calculated using the waste composition data. Thereafter, a per capita plastic waste disposal figure was calculated for each LA, which was then used to calculate average per capita plastic waste disposal amounts for each architype. The average per capita plastic waste disposal value was then multiplied by the total population of each architype to estimate the plastic waste tonnage disposed of in uncontrolled landfills.

Data points 5 and 6 – proportion of waste disposed to controlled and uncontrolled landfills

Criteria/ Data point	Mega (Municipal Council) *n*=2	Medium (Urban Councils) *n*=2	Small (Pradeshiya Sabha) *n*=5
Plastic waste disposed in controlled landfills (%)	0.0 ± 0.0	0.0 ± 0.0	20.0 ± 0.0
Plastic waste disposed in uncontrolled landfills (%)	100.0 ± 0.0	100.0 ± 0.0	80.0 ± 0.0

A small portion of the waste collected within a few Pradeshiya Sabha areas (Small architype) is disposed of in sanitary landfills. The sanitary landfill in Dompe (Dompe PS) and a semi-engineered landfill in Kataragama (Kataragama PS) are the two key controlled landfill facilities, while a few LAs in Eastern Province maintain landfills as controlled landfills (Japan International Cooperation Agency (JICA), 2019). Consequently, it was estimated that only 20% of waste collected by Pradeshiya Sabhas is disposed of in controlled landfills.

All other types of MSW final disposal sites used by LAs in Sri Lanka are uncontrolled landfills (Karunarathna et al., 2021). Therefore 100% of waste collected has been assumed to be disposed of in uncontrolled landfills.

Data points 7 and 8 – proportion of total plastic waste at landfills that comes from formal and informal waste collection

Criteria/ Data point	**Mega (Municipal Council)** ***n=6***	**Medium (Urban Councils)** ***n=5***	**Small (Pradeshiya Sabha)** ***n=5***
Proportion of total plastic waste received at landfills that comes from formal mixed waste collection services (%)	83.25	99.44	93.33
Proportion of total plastic waste received at landfills that comes from informal mixed collection services (%)	16.75	0.56	6.67

For waste arriving at landfills, no data was identified providing insight into its collection method (formal or informal); however, most plastic waste is assumed to come from formal collection. Informal waste collectors, especially certain religious institutes, hotels, and recyclable collectors bring mix and residual waste to dumpsites. JICA (2016, 2019) developed MSW stream flows for 13 LAs in Sri Lanka and found that the major portion of plastic waste delivered to landfill sites comes from the formal collection system, while a small fraction was delivered by the informal sector (Japan International Cooperation Agency & Kokusai Kogyo Co. Ltd., 2016).

In addition, most of the Mega (Municipal councils) and a considerable number of Medium (Urban Council) architypes have source segregated waste collection involving two categories, organic and inorganic, collected separately. The organic waste is usually sent to composting facilities while a fraction of the inorganic portion is delivered to sorting facilities to recover recyclable resources. However, all types of residual waste from composting and sorting facilities are disposed of in uncontrolled landfills. Moreover, source segregated waste collected by LAs lacking resource recovery facilities directly dispose of organic and inorganic waste in uncontrolled dumpsites. The Small architype units (Pradeshiya Sabha) in rural areas generally collect mix waste or partially sorted waste and dispose of it in uncontrolled landfills.

Data point 9 – Quantity of plastic waste received at incineration facilities

Criteria/ Data point	Mega (Municipal Council) *n=6*	Medium (Urban Councils) *n=5*	Small (Pradeshiya Sabha) *n=4*
Quantity of plastic waste received at incineration and co-generation facilities (Tonnes/day)	21.29 ± 1.21	10.35 ± 0.06	8.84 ± 0.00

Sri Lanka has only one MSW incineration facility, and this was used to obtain waste statistics to reveal the sources and quantity of plastic waste in the received waste. It was found that the waste collected within Colombo MC and a few suburbs contribute to the throughput of the incinerator facility. The quantities received at the facility and populations of the LAs were used to derive the per capita incineration rate for each architype, then the total quantity for each architype was estimated using the total population of the architype.

Discussions with LAs revealed that a portion of collected inorganic waste is openly burned at disposal sites; however, such sites were not recognized as standard incineration facilities. A small portion of plastic waste from LAs is ultimately delivered to a cement manufacturing plant in Puttalam, although precise quantitative information was not available to source the origin.

Data point 10 – quantity of plastic waste received at formal recycling facilities

Criteria/ Data point	Mega (Municipal Council) *N=6*	Medium (Urban Councils) *N=5*	Small (Pradeshiya Sabha) *N=5*
Quantity of plastic waste received at formal recycling facilities (Tonnes/day)	34.25 ± 1.21	16.18 ± 0.40	22.93 ± 0.12

Estimation of this data point was based on partial data availability and was conducted as a three-step process:

- Gathering available data on the capacity of all recognized formal recycling facilities operated by LAs and private businesses
- Making informed assumptions about the actual quantities recycled based on available in-house inventories and assumed efficiency of the facilities
- Using expert judgment to estimate the proportions of plastic waste received at the facilities, as originating from individual archetype

The Local Authorities in Sri Lanka operate approximately 80 recyclable collection facilities, of which eight perform mechanical recycling. In addition to the LAs' own recyclable collection facilities, there is a considerable number of plastic collection facilities owned and operate by private sector entrepreneurs. As per data collected from the Recyclers Association of Sri Lanka, Central Environmental Authority of Sri Lanka, national Action Plan on Plastic Waste Management 2021-

2030 and research studies by Alahakoon and Karunarathna (2020); Gunarathne, et al. (2019); Illesinghe (2017); Karunarathna, et al. (2020); and Samarasinghe, et al. (2021), there are more than 2,000 individual plastic waste collectors.

Based on the available information, it is assumed that all plastic waste recycling from the three archetypes in Sri Lanka takes place in these facilities; however, information on actual quantities of plastic waste recycled in these facilities was not available. Therefore, an assumption was made that such plants function at 75% capacity, thus approximately 73 tonnes per day of plastic waste is recycled in formal recycling facilities of Sri Lanka. In terms of collection amounts, the estimate using the available data showed that the total recyclable material collection may vary from 16.18 TPD in Urban Councils to 34.25 TPD in Municipal Councils. In the absence of other data sources, this estimation has been used as the total tonnage received for recycling from both formal and informal sources.

It is important to note that recycling levels for different archetypes are assigned based on the quantity of plastic generated in that archetype, not the specific location where recycling takes place. For example, a significant quantity of plastic waste generated in a Medium archetype is thought to be recycled in recycling plants located in Mega archetype areas. In such cases, the recycling level is allocated to the Medium archetype, i.e., the archetype within which the plastic waste is generated.

Data points 11 and 12 – Quantities of plastic waste imported into and exported from Sri Lanka

Criteria/ Data point	National statistics (metric tonnes/day) in year 2022
Import	9.83
Export	0.20

Quantities of plastic waste imported into and exported from Sri Lanka were obtained from the Sri Lanka Customs. The import/export statistics (HS codes 39151000, 39153000, 39159000) from 2012-2022 were used in the analysis. It was found that the export quantities gradually decreased while the import quantities increased.

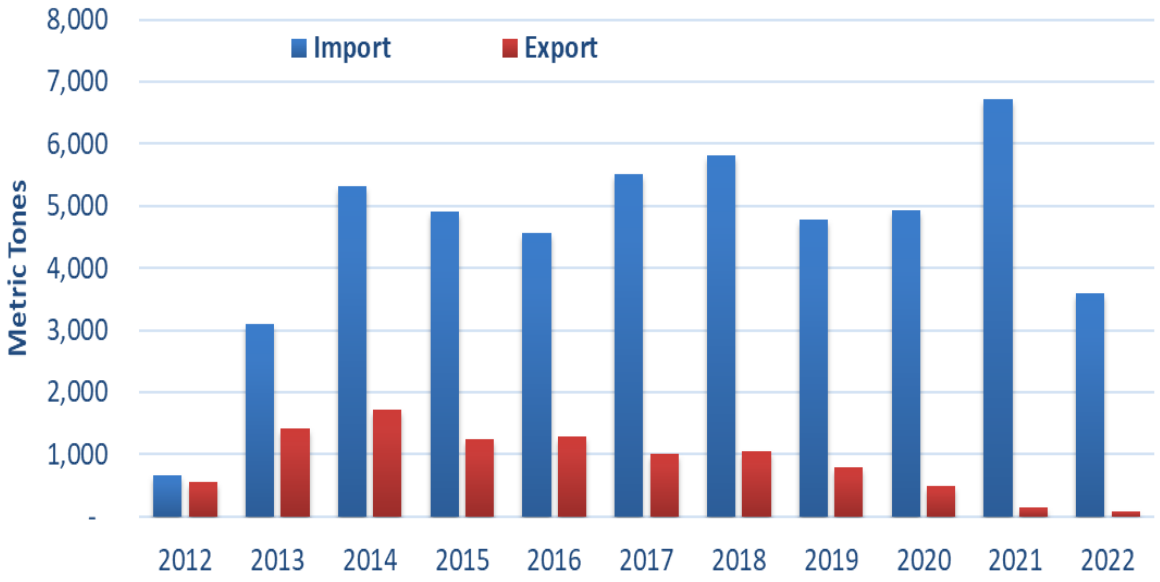


Figure 4 Amount of plastic waste imported to and exported from Sri Lanka

However, waste import and export partitioning for archetypes was complicated since the import/export material flow was unclear. Therefore, the plastic import to and export from the country was used only in the final material flow calculations. The values recorded in the year 2022 were used as the most appropriate waste plastic import/export data.

Data points 13 and 14 – Reject rates of formally and informally sorted plastic waste

Criteria/ Data point	Mega (Municipal Council) *n=6*	Medium (Urban Councils) *n=5*	Small (Pradeshiya Sabha) *n=5*
Reject rate of formally sorted plastic (%)	13.3 ± 8.16	20.0 ± 28.06	39.0± 37.82
Reject rate of informally sorted plastic (%)	10.0± 0.00	7.0 ± 2.74	39.0 ± 53.10

Reliable data on sorting rejects is limited. Some data records were obtained through stakeholder data requests from 15 LAs and 10 major recycling facilities. In addition, the waste material flow balance described in published reports was used as a secondary data sources (Japan International Cooperation Agency & Kokusai Kogyo Co. Ltd. (2016); Karunarathna, et al., (2020); Karunarathna, et al., (2018b); and Sato, et al., (2020)).

Data point 15 – Quantity of plastic waste sorted for recycling by formal sorting facilities

Criteria/ Data point	Mega (Municipal Council) *n=6*	Medium (Urban Councils) *n=5*	Small (Pradeshiya Sabha) *n=5*
Quantity of plastic waste sorted for recycling by formal sorting facilities (tonnes/day)	19.37 ± 8.16	20.16 ± 28.06	52.23± 37.82

Data requests from local authorities and literature sources have indicated that plastic waste sorting is done in different stages of the value chain. Most of these sorting activities are thought to process source segregated plastic collected by formal and informal collection services. However, there are also facilities in LAs (e.g., Sampath Piyasa, Recycling centre) that process mixed waste and separate plastic and other recyclable materials.

Comprehensive data on the scale and type of this sorting infrastructure was not available at the time of this study. Information on small and medium-scale private sector is particularly limited. Therefore, the following estimation was done based on available data:

- It was found that almost all the feedstock received at the sorting facility undergoes some degree of sorting. That means approximately 45.32 tonnes of plastic waste received at formal recycling facilities are sorted.
- The distribution of sorting throughput among different archetype was complicated because the recyclables collected by the private sector flows across geographical boundaries (i.e. LAs), meaning that private sector recycling businesses are borderless entities.

Data point 16 - Quantity of source segregated plastic waste collected by formal collection services

Criteria/ Data point	Mega (Municipal Council) *n=6*	Medium (Urban Councils) *n=5*	Small (Pradeshiya Sabha) *n=5*
Quantity of source segregated plastic waste collected by formal services (tonnes/day)	9.01 ± 0.98	4.29 ± 0.61	2.52 ± 0.16

This data point refers to the quantities of source segregated plastic waste collected by formal sector in Sri Lanka. Stakeholder consultations have indicated that only a small number of private sector stakeholders collect source segregated plastic waste as opposed to the collection of recyclables and mixed plastic waste. However, data regarding actually collected tonnages was limited; thus, the most appropriate estimation was taken based on expert judgment.

Data point 17 – Quantity of mixed waste received by formal sorting facilities

Criteria/ Data point	Mega (Municipal Council) *n=6*	Medium (Urban Councils) *n=5*	Small (Pradeshiya Sabha) *n=5*
Quantity of mixed waste received at formal sorting facilities (tonnes/day)	0.00 ± 0.00	0.025 ± 0.06	0.014 ± 0.031

Data records from the stakeholders indicate that these facilities accept and sort mixed waste collections from both formal and informal sources. These formal sorting facilities sort the mixed waste into the various recoverable fractions. Data from these facilities was used to estimate the total tonnage of mixed waste accepted by formal sorting facilities. The records indicate that the recycling facilities in LAs accept only a small amount of mix waste in which acceptance by facilities in municipal councils was negligible.

Data point 18 – Proportion of mixed waste received by formal sorting facilities from formal and informal sources

Criteria/ Data point	Mega (Municipal Council) *n=6*	Medium (Urban Councils) *n=5*	Small (Pradeshiya Sabha) *n=5*
The proportion of mixed waste received at formal sorting facilities that come from formal sources (%)	20.00 ± 40.82	0.00 ± 0.00	0.00 ± 0.00

Based on stakeholder conversations, it is also assumed that mixed waste is not sorted for recyclables in the medium and small archetypes. Therefore, these are considered zero. For the Mega archetype, by getting the average value, it is assumed as 16.67% as the proportion of mixed waste received by formal sorting facilities.

Data points 19 and 20 – Proportion of plastic in mixed waste received from formal and informal services by formal sorting facilities

Criteria/ Data point	Mega (Municipal Council) *n=6*	Medium (Urban Councils) *n=5*	Small (Pradeshiya Sabha) *n=5*
The proportion of plastic in mixed waste received at formal sorting facilities that come from formal mixed waste collections (%)	7.7 ± 3.81	6.52 ± 3.32	5.58 ± 3.87
The proportion of plastic in mixed waste received at formal sorting facilities that come from informal mixed waste collections (%)	7.7 ± 3.81	6.52 ± 3.32	5.58 ± 3.87

Local Authority feedback and literature records suggest an average plastic composition of the mixed waste from formal and informal sources of 5.58–7.7%, which was based on a qualitative understanding of the waste handling practices as per reports from stakeholders. Expert judgement was used to apply a value for informal mixed waste collections based on waste discharge practices of generators.

Data point 21 – Quantities of plastic waste collected by informal services through waste picking at landfills

Criteria/ Data point	Mega (Municipal Council) *n=6*	Medium (Urban Councils) *n=5*	Small (Pradeshiya Sabha) *n=5*
Quantities of plastic waste collected by informal services through waste picking at landfills (tonnes/day)	9.69 ± 0.52	1.41 ± 0.09	1.44 ± 0.02

The records from LAs and literature were used to estimate the quantity of plastic waste recovered from the final disposal site. Municipal Councils have the highest concentration of MSW and serve a comparatively high-income population and a greater number of commercials and services. Therefore, it was found that the amount of plastic waste recovered from dumpsites located in municipalities subjected to a greater amount of plastic resource recovery.

3.3 Leakage factors

Once the baseline data points have been populated, the next step was to estimate the extent of plastic waste leakage from the waste management system. This leakage can be due to a range of factors, including the rejection of non-recyclable plastics during sorting or poor handling practices during waste collection that causes plastics to escape during storage, transportation or from disposal sites.

Table 5: Summary of plastic waste leakage factors and associated leakage flows

Leakage factors for each stage of the MSW management system	Associated leakage flow (see MF diagram)
Leakage during formal mixed waste collection	L1
Leakage during informal mixed waste collection	L2
Leakage during formal recycling collections	L3
Leakage during informal recycling collections	L4
Leakage during transportation to disposal and incineration	L5
Leakage during informal sorting	L6
Leakage during formal sorting	L7
Leakage during transportation to recycling	L8
Leakage at controlled disposal sites	L9
Leakage at uncontrolled disposal sites	L10

A leakage factor describing the percentage of plastic waste leakage was estimated for each stage of potential leakage (see Table 5). These leakage factors were estimated using an approach developed within the Waste Flow Diagram (GIZ, 2020) methodology. the rationale for this approach is described in detailed in Step C: Quantifying plastic leakage in the WFD user manual. For ease of use, the WFD leakage calculation methodology has been aligned with the terminologies used in this methodology and reproduced in this section.

A qualitative approach was used based on a number of 'leakage influencers' describing each stage of the MSW. Each leakage influencer is associated with a numerical 'leakage potential.' Then we assigned leakage potentials based on observational data (for example, the nature of waste storage or types of transport operations). These potentials were then used to estimate the percentage leakage or leakage factor of plastic waste for the associated plastic waste leakage flows (L1 to L10). The calculations used to derive leakage factors are described in Table 6.

Table 6: Calculation of leakage factors (Source- GIZ, Waste Flow Diagram)

MSW stage	Leakage influencer	Description	Calculation
During collection	Collection containers	Likelihood of leakage based on how waste is stored at the point of collection	(L1 to L3) Leakage from collection services = Collection containers + Method of loading + Primary transportation + Handling
	Method of loading	Likelihood of leakage based on method of loading collected waste onto transportation	
	Primary transportation	Likelihood of leakage based on type and control of primary transportation used to collect waste	
	Handling	Likelihood of leakage due to multiple handling of waste	
During sorting	Storage	Likelihood of non-rejects being dumped or mismanaged during storage	First, establish % rejects in sorting facilities. (see baseline data points 22) (L6 and L7) Leakage from formal sorting = (Reject rate/100 × Disposal of rejects) + (Non-rejects/100 × (Storage + Sorting))
	Sorting	Likelihood of non-rejects being dumped or mismanaged during storage	
During informal recycling collections or waste picking from landfills	Extraction of recyclables	Likelihood of leakage occurring during door-to-door collection or scavenging and waste-picking stages	(L4) Leakage from the informal value chain = Extraction of recyclables + Transportation
	Transportation	Likelihood of leakage during transportation from collection to aggregation or sale point	
During transportation	Vehicle capacity	Likelihood of leakage due to insufficient capacity in the vehicle compared to the load	(L5 and L8) Leakage from transportation = Vehicle capacity × Containment of waste × Cover for vehicles
	Containment of waste (at the point of loading)	Likelihood of leakage if waste is not contained during transportation	

MSW stage	Leakage influencer	Description	Calculation
	Cover for vehicle	Likelihood of leakage if the vehicle is not covered	
During disposal	Environment hazards		(L9 and L10) Leakage from disposal = Environmental hazards + (Weather exposure × Waste handling × Coverage × Burning × Fencing)
	Weather exposure		
	Waste handling		

[a] These calculations are applied to formal and informal mixed waste collection as well as formal recycling collections (or source segregated collections). [b]These calculations are applied to formal and informal sorting facilities. [c] These calculations are applied when plastic waste is transported to disposal, recycling and energy recovery facilities

Leakage factors were estimated based on discussions with the local project team, consultant team and qualitative assessment of literature sources. Qualitative information on Survey on Method of Solid Waste Management Annual Budget Making & Utilizing Waste Collection and Disposal Data in Local Authorities in Sri Lanka and Data Collection Survey on Solid Waste Management in Democratic Socialist Republic of Sri Lanka was used to assign leakage factors. The choices of the various scores are made based on the above sources and assumptions.

Table 7: Rationale for selecting leakage factors and resultant leakage percentages in the three archetypes

Flow ref.	Leakage flow	Mega (%) Municipal Councils	Medium (%) Urban Councils	Small (%) Pradeshiya Sabha
L1	Leakage during formal mixed waste collection	3.5 Formal collection services with access to resources like door-to-door collection, curb-side collection and frequent collection are available for MCs. Compared to the Pradeshiya Sabha, handling and loading procedures assure substantially less leakage.	5.00 Leakage in medium archetype is more than mega archetype and two times lesser than the small archetype. Access to like door-to-door collection, curb-side collection and frequent collection is comparatively lower than the mega archetype.	10.80 Small archetypes are thought to provide formal collection services at a significantly reduced rate. Where facilities are available, these places do not have access to them, therefore waste is held for extended periods of time in open dumps and is more likely to leak during handling and transportation.

Flow ref.	Leakage flow	Mega (%) Municipal Councils	Medium (%) Urban Councils	Small (%) Pradeshiya Sabha
L3	Leakage during formal recycling collections	2.00 There are more facilities available for formal recycling collection than other archetypes. But on some occasions, it can be seen that there are shortages in stocking spaces for recycling collections.	3.50 An insufficient budget and lack of knowledge of proper operation methods and the insufficient number of waste collection workers and the malfunction of collection vehicles result in more leakage than the mega archetype.	10.80 Small archetypes are equipped with lesser facilities and there are no proper management activities compared to other archetypes. There are no specific containers or vehicles for separated waste collection. In some LAs, containers/ bags are distributed to the residents, therefore it is inefficient for collection workers to open the plastic bags to check whether it is organic waste or other waste each time they load waste.
L2	Leakage during informal mixed waste collection	3.50 Data availability in informal mixed waste collection services are very low and it is assumed that leakage is lower in bigger archetypes due to the proper infrastructure facilities and selective picking of valuable recyclables.	5.00 Leakage is more occurring than mega archetype and less occurring than smaller archetypes based on the availability of facilities. It is also assumed low leakage potential due to the proper infrastructure facilities and selective picking of valuable recyclables.	10.80 The amenities that the waste collection groups have access to in small archetypes are thought to be of lower quality than those in considerably bigger archetypes. It is also assumed high leakage potential due to the insufficient infrastructure facilities and selective discharge of invaluable recyclables.

Flow ref.	Leakage flow	Mega (%) Municipal Councils	Medium (%) Urban Councils	Small (%) Pradeshiya Sabha
L4	Leakage during informal recycling collections	0.20 The informal recycling collection workers are anticipated to have better quality transportation and storage facilities for the collection and shorter travel distances compared to the small archetype to deposit their waste at aggregator or sorting facilities due to the presence of several SMEs and more population in most of the Mega and some parts of the medium archetype.	0.20 The informal recycling collection workers are anticipated to have better quality transportation and storage facilities for the collection and shorter travel distances compared to the small archetype to deposit their waste at aggregator or sorting facilities due to the presence of several SMEs and more population in most of the Mega and some parts of the medium archetype.	2.50 Workers have to travel more distances with limited transportation and infrastructure facilities available causing more leakage.
L7	Leakage during formal sorting	5.94 Mega archetype and medium archetype have more developed facilities for sorting and more trained workers than small archetype. According to the Data Collection Survey on Solid Waste Management in Democratic Socialist Republic of Sri Lanka (2026), MCs and UCs spend considerable budget to improve facilities at resource recovery facilities.	4.63 Mega archetype and medium archetype have more developed facilities for sorting and more trained workers than small archetype. According to the Data Collection Survey on Solid Waste Management in Democratic Socialist Republic of Sri Lanka (2026), MCs and UCs spend considerable budget to improve facilities at resource recovery facilities.	43.45 There are less facilities and trained staff for the sorting activities. Less spaces for sorting and storing results higher leakage than other archetypes.

Flow ref.	Leakage flow	Mega (%) Municipal Councils	Medium (%) Urban Councils	Small (%) Pradeshiya Sabha
L6	Leakage during informal sorting	9.48 Informal sector active in Mega archetype and medium archetype have sufficient facilities for sorting. Most of the large-scale recycling facilities (including mechanized facilities) are located in Municipal Councils.	7.30 Informal sector active in Mega archetype and medium archetype have sufficient facilities for sorting. A few large-scale and several medium scale recycling facilities (including mechanized facilities) are in Urban Councils.	43.45 There are less facilities and trained staff for the sorting activities. Less spaces for sorting and storing results higher leakage than other archetypes.
L5	Leakage during transportation to disposal	0.08 Mega archetype has an appropriate fleet of collection and transport vehicles, and use of open vehicles is comparatively lower. Compared to the Urban Councils or Pradeshiya Sabha, handling and loading procedures assure substantially less leakage.	0.50 Medium archetype has a considerable fleet of collection and transport vehicles, and the use of open vehicles is comparatively lower. Compared to the Pradeshiya Sabha, handling and loading procedures assure substantially less leakage.	0.50 Small archetypes often use open-collection vehicles (Tractors) for waste collection and transport, leading to increased leakage potential. However, the facilities are comparable to Urban Councils.
L8	Leakage during transportation to recycling	0.2 Mega archetype has an appropriate fleet of collection and transport vehicles, and use of open vehicles are comparatively lower. Compared to the Urban Councils or Pradeshiya Sabha, handling and loading procedures assure substantially less leakage.	0.3 Medium archetype has a considerable fleet of collection and transport vehicles, and use of open vehicles are comparatively lower. Compared to the Pradeshiya Sabha, handling and loading procedures assure substantially less leakage.	0.50 Small archetypes often use open-collection vehicles (Tractors) for waste collection and transport, increasing the leakage potential. Moreover, the PS areas are much greater than other archetypes that increase the leakage potential during long-distance travelling of open vehicles.

Flow ref.	Leakage flow	Mega (%) Municipal Councils	Medium (%) Urban Councils	Small (%) Pradeshiya Sabha
L5	Leakage during transportation to incineration	0.02 Mega archetype has an appropriate fleet of collection and transport vehicles, and the use of open vehicles are comparatively lower. Compared to the Urban Councils or Pradeshiya Sabha, handling and loading procedures assure substantially less leakage.	0.15 Medium archetype has a considerable fleet of collection and transport vehicles, and the use of open vehicles are comparatively lower. Compared to the Pradeshiya Sabha, handling and loading procedures assure substantially less leakage. However, the distance to be travel to incineration facilities is greater than MCs.	0.50 Small archetypes often use open-collection vehicles (Tractors) for waste collection and transport, increasing the leakage potential. Moreover, the PS areas are much greater than other archetypes that increase the leakage potential during long-distance travelling of open vehicles. Also, poor waste transfer station management and longer distance to incineration facilities.
L9	Leakage at uncontrolled disposal sites	80.70 Uncontrolled disposal sites do not have dedicated areas for informal waste picking. Waste handling practices are expected to poor. Waste is not kept covered. In disposal sites, waste may be burnt on site in some instances. These disposal sites may have some fencing.	80.53 Uncontrolled disposal sites do not have dedicated areas for informal waste picking. Waste handling practices are expected to poor. Waste is not kept covered. In disposal sites, waste may be burnt on site in some instances. These disposal sites may have some fencing.	80.50 Uncontrolled disposal sites do not have dedicated areas for informal waste picking. Waste handling practices are expected to poor. Waste is not kept covered. In disposal sites, waste may be burnt on site in some instances. These disposal sites may have some fencing.
L10	Leakage at controlled disposal sites	80.70 None of the MCs has access to controlled landfill sites. Thus, the same leakage factor for the uncontrolled dumpsites was assigned	80.12 None of the UCs has access to controlled landfill sites. Thus, the same leakage factor for the uncontrolled dumpsites was assigned	80.50 Only a few PSs has access to controlled landfill sites. More than 99% of the LAs dispose waste in open dumpsites; thus, the same leakage factor for

Flow ref.	Leakage flow	Mega (%) Municipal Councils	Medium (%) Urban Councils	Small (%) Pradeshiya Sabha
		for the controlled landfills.	for the controlled landfills.	the uncontrolled dumpsites was assigned for the controlled landfills.

3.4 Material flow calculations

The baseline data and leakage factors enabled the calculation of the flows shown in the MF diagram, which is described in Table 8. This methodology was based on existing approaches that enable the quantification of plastic waste at a city level and that have been adapted to allow the quantification process to be scaled up to the country level. The reliability and accuracy of results obtained are, therefore, dependent on the quality of baseline data used. The methodology has been developed for countries to begin the process of quantifying the generation, management, treatment, and disposal of plastic waste in the absence of other national estimations. If other national-level estimations are available, data points used, and results obtained in both methodologies can be compared to assess the accuracy of the results. If resources allow it, other available methodologies (e.g., the national analysis model developed by the Global Plastic Action Partnership) may be used simultaneously or subsequently to check the results of the methodology described in this document (PEW and SYSTEMIQ, 2019). Common outputs such as quantities of plastic waste collected, recycled, disposed and leaked can be compared directly to check for the extent of variability in the values obtained through both methodologies.

Table 8: Summary of flow calculations

Flow ref	Description	Type	Calculation
Generation			
X	Total plastic waste generation	Key data point	= Population × Rate of MSW generation per capita × % Proportion of plastic waste in MSW
U1	Uncollected waste	Calculated	= X - (C1A+C2A+C3A+C4A)
Treatment			
RE1	Tonnes plastic received for recycling	Key data point	Data point 10
IC1	Tonnes plastic waste received for incineration	Key data point	Data point 9
S1	Tonnes of plastic waste sorted for recycling	Calculated	= RE1/(1-%leakage during transportation to recycling/100)
F1	Tonnes of plastic waste received for sorting at formal facilities (pre-sorting)	Key data point	Data point 15
IF1	Tonnes of plastic waste received for sorting at informal facilities (pre-sorting)	Calculated	= (B-F1+RJ1+L7)/(1-%leakage during informal sorting/100)
B	Sum of all plastic waste sorting outputs	Calculated	= RE1+S1
Disposal			
TD1	Tonnes of plastics waste disposed in landfills	Key data point	Data point 4
TD1A	Plastic waste disposed in controlled landfills	Calculated	= TD1*Proportion of disposed plastic ending up in controlled landfills (data collection ref 5)
TD1B	Plastic waste disposed in uncontrolled landfills	Calculated	= TD1*Proportion of disposed plastic ending up in uncontrolled landfills (data collection ref 6)
D1	Plastic waste in informal mixed waste collections delivered to landfill	Calculated	= TD1*Proportion of total plastic waste received at landfills that comes from informal mixed waste collection services (data collection ref 7)
D2	Plastic waste in formal mixed waste collections delivered to landfills	Calculated	= TD1*Proportion of total plastic waste received at landfills that comes from formal mixed waste collection services (data collection ref 8)

Flow ref	Description	Type	Calculation
T1	Plastic waste from formal mixed waste collections for transportation to disposal	Calculated	= (IC1+D2)/ (1-%leakage during transportation to disposal/100) - RJ1
RJ1	Plastic waste rejects from sorting dispatched to landfills	Calculated	= F1*Reject rate at formal sorting facilities
Collection			
C1B	Tonnes of plastic waste received from formal mixed waste collections	Calculated	= Qty of mixed waste received in formal sorting facility × Proportion of formal mixed waste collection × Proportion of plastic in formal mixed waste collection (data ref 17, 18 and 19)
C2B	Tonnes of plastic waste received from informal mixed waste collections for sorting	Calculated	= Qty of mixed waste received in formal sorting facility × Proportion of informal mixed waste collection × Proportion of plastic in informal mixed waste collection (data ref 17, 18 and 20)
C3B	Tonnes of plastic waste received from formal recycling collection for sorting (pre-sorting)	Key data point	Data point 16
C4B	Tonnes of plastic waste received from informal recycling collections for sorting	Calculated	= C4B=A-I1-C3B-C2B-C1B-LF1
C1A	Tonnes plastic waste collected by formal mixed waste collection	Calculated	= (C1B+T1)/(1-%leakage during formal mixed waste collection)
C2A	Tonnes plastic waste collected by informal mixed waste collection	Calculated	= (C2B+D1)/(1-%leakage during informal mixed waste collection)
C3A	Tonnes plastic waste collected by formal recycling collections	Calculated	= C3B/(1-%leakage during formal recycling collections)
C4A	Tonnes plastic waste collected by informal recycling collections	Calculated	= (C4B)/(1-%leakage during informal recycling collections)
LF1	Informal recyclables taken from landfill	Key data point	Data point 20

Flow ref	Description	Type	Calculation
A	Sum of all plastic waste received for sorting	Calculated	=IF1+F1+L6+L7+RJ1
Imports and Exports			
I1	Plastic waste received through imports	Key data point	Data point 11
E1	Plastic waste sent for exports	Key data point	Data point 12
Leakages and Mismanaged waste			
L1	Leakage during formal mixed waste collections	Calculated	= C1A*%Leakage factor for formal mixed waste collection
L2	Leakage during informal mixed waste collections	Calculated	= C2A*%Leakage factor for informal mixed waste collection
L3	Leakage during formal recycling collections	Calculated	= C3A*%Leakage factor for formal recycling collections
L4	Leakage during informal recycling collections	Calculated	= C4A*%Leakage factor for informal recycling collections
L5	Leakage during long distance transportation of mixed waste to disposal	Calculated	= (RJ1+T1)*% Leakage factor for transportation to disposal
L6	Leakage during informal sorting	Calculated	= IF1*%Leakage factor for informal sorting
L7	Leakage during formal sorting	Calculated	= F1*%Leakage factor for formal sorting
L8	Leakage during long distance transportation of plastic waste to recycling	Calculated	= S1*%Leakage factor for transportation to recycling
L9	Leakage from controlled landfill sites	Calculated	= TD1A*%Leakage factor for controlled disposal
L10	Leakage from uncontrolled landfill sites	Calculated	= TD1B*%Leakage factor for uncontrolled disposal
Z	Mismanaged waste leaking into the environment	Calculated	= All Leakages + U1

4. RESULTS

Once the MFA has been populated for each archetype, the key values from each MFA were summed to provide an overall estimate of plastic waste flows at a national level. The inventory provides insights into the following aspects of plastic waste management and is discussed in details below.

- National summary of plastic waste management
- Proportion of generated plastic waste captured by collection services
- Proportion of collected plastic recycled and disposed.
- Leakages from the waste management system
- The level of unmanaged plastic waste

4.1 National Summary of Plastic Waste Management

Key outputs from the inventory as shown in the summary:

- The total estimated municipal plastic waste generation in Sri Lanka is 249,037 tonnes annually (see Figure 5). This show that the total plastic waste generation occurs in 276 rural areas (Pradeshiya Sabha) because 82% of the population in the country is resided rural areas. However, when looking at the per capita plastic waste generation, the highest plastic waste generation can be found in urban areas (28.6 kg/year/person), and this is significantly higher than in rural areas (9.1 kg/year/person).
- Approximately 181,000 tonnes per year (73%) of plastic waste is collected by a combination of formal and informal collection systems. The highest plastic waste collection rate can be found in MCs (91%), followed by UCs (90%). On the other hand, the lowest plastic waste collection rate is noticed in Pradeshiya Sabha areas (62%).
- An estimated 67,965 tonnes per year (27%) of plastic waste is not collected at all. These materials are typically either burnt, illegally dumped, or buried on site.
- The informal recycling sector is active in Sri Lanka and is estimated to collect 65,383 tonnes of source segregated plastic waste (92% of source segregated plastic waste collection), as well as an estimated 10,416 tonnes of plastic waste as part of mixed waste collections (although only a small part of plastic in mixed waste is separated for recycling). However, formal source segregated recycling services by LAs are thought to account for a much lower proportion of waste plastic recycling (22.5%).
- Annually, approximately 27,000 tonnes of all plastic waste are estimated to be sent for recycling. This is equivalent to 11% of the estimated total plastic waste generation. Levels of recycling are thought to be highest in the urban areas and relatively low in rural areas.
- Approximately 97,000 tonnes of plastic waste are sent to designated disposal sites each year. There are a small number of controlled disposal sites in Sri Lanka, located in the Pradeshiya Sabha areas. The majority of disposed waste is sent to uncontrolled dumpsites with limited controls.
- A further 101,450 tonnes (41%) are estimated to leak from the waste management system during collection, transporting, sorting, and landfilling.

- Approximately 3,588 tonnes/year of plastic waste were imported to the country while only 72 tonnes/year of plastic waste were exported from Sri Lanka during the 2012-2022 period.
- In total, approximately 169,415 tonnes which is about 68% of plastic waste generated in Sri Lanka each year is unmanaged plastic. This includes uncollected plastic waste that may be buried and burnt and fractions that escape into the broader environment before entering or from within the waste management system.

Table 9 The plastic waste inventory outputs

Description	Tonnes per year			
	MC	UC	PS	National
Generation				
Total plastic waste generation	67,663	26,143	155,231	249,037
Uncollected waste	6,358	2,605	59,003	67,965
Proportion of plastic that is uncollected	9%	10%	38%	27%
Treatment				
Tonnes plastic received for recycling	12,499	5,906	8,370	26,775
Tonnes plastic waste received for incineration & co-generation	7,771	3,776	3,228	14,775
Tonnes of plastic waste sorted for recycling or recovery	12,501	5,923	8,412	26,837
Tonnes of plastic waste received for sorting at formal facilities	7,071	7,359	19,062	33,493
Tonnes of plastic waste received for sorting at informal facilities	7,504	719	8,961	17,183
Sum of all plastic waste sorting outputs	12,501	5,923	8,412	26,837
Disposal				
Tonnes of plastics waste disposed in landfills	39,563	10,682	46,632	96,877
Plastic waste disposed in controlled landfills	0	0	9,326	9,326
Plastic waste disposed in uncontrolled landfills	39,563	10,682	37,306	87,550
Plastic waste in informal mixed waste collections delivered to landfill	6,627	60	3,109	9,795
Plastic waste in formal mixed waste collections delivered to landfills	32,936	10,622	43,523	87,081
Plastic waste from formal mixed waste collections for transportation to disposal	39,795	12,999	39,552	92,345
Plastic waste rejects from sorting dispatched to landfills	943	1,472	7,434	9,849
Collection				
Tonnes of plastic waste received from formal mixed waste collections	0	0	0	0
Tonnes of plastic waste received from informal mixed waste collections for sorting	0	1	0	1
Tonnes of plastic waste received from formal recycling collection for sorting	3,288	1,567	920	5,775
Tonnes of plastic waste received from informal recycling collections for sorting	9,825	8,151	46,186	64,162
Tonnes plastic waste collected by formal mixed waste collection	41,238	13,683	44,341	99,262
Tonnes plastic waste collected by informal mixed waste collection	6,867	64	3,486	10,416
Tonnes plastic waste collected by formal recycling collections	3,355	1,624	1,031	6,011
Tonnes plastic waste collected by informal recycling collections	9,845	8,167	47,371	65,383
Informal recyclables taken from landfill	3,537	513	527	4,577

Description	Tonnes per year			
	MC	UC	PS	National
Sum of all plastic waste received for sorting	16,650	10,232	47,634	74,515
Imports and Exports				
Plastic waste received through imports				3,588
Plastic waste received through exports				72
Leakages and Mismanaged waste				
Leakage during formal mixed waste collections	1,443	684	4,789	6,916
Leakage during informal mixed waste collections	240	3	376	620
Leakage during formal recycling collections	67	57	111	235
Leakage during informal recycling collections	20	16	1,184	1,220
Leakage during long distance transportation of mixed waste to disposal	31	72	235	338
Leakage during informal sorting	711	52	3,894	4,657
Leakage during formal sorting	420	630	8,283	9,333
Leakage during long distance transportation of plastic waste to recycling and recovery	2	18	42	62
Leakage from controlled landfill sites	0	0	7,508	7,508
Leakage from uncontrolled landfill sites	31,927	8,602	30,031	70,560
Mismanaged waste leaking into the environment	41,219	12,740	115,456	169,415
MC: Municipal Councils (n = 24), UC: Urban councils (n= 41), PS: Pradeshiya Sabha (n= 276)				

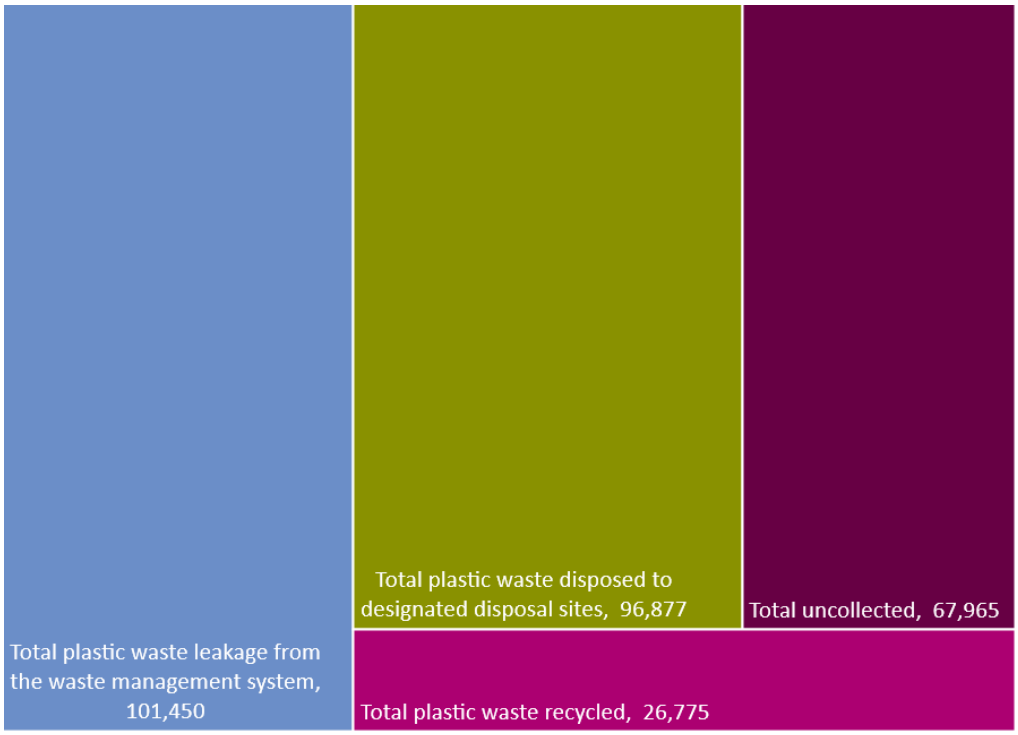


Figure 5: Summary of plastic waste quantities and main fates (tonnes per year)

4.2 Collection systems

It is estimated that at the national level, 73% of the generated plastic waste is captured by waste collection services (Figure 6). Collection coverage in municipal council areas (Mega areas) are the highest, estimated at 91%. In urban council areas, plastic waste collection coverage is 90%, albeit there is considered to be considerable variation in this coverage between LAs. It is estimated that roughly 62% of the plastic waste in small archetype (Pradeshiya Sabhas) is collected by LA.

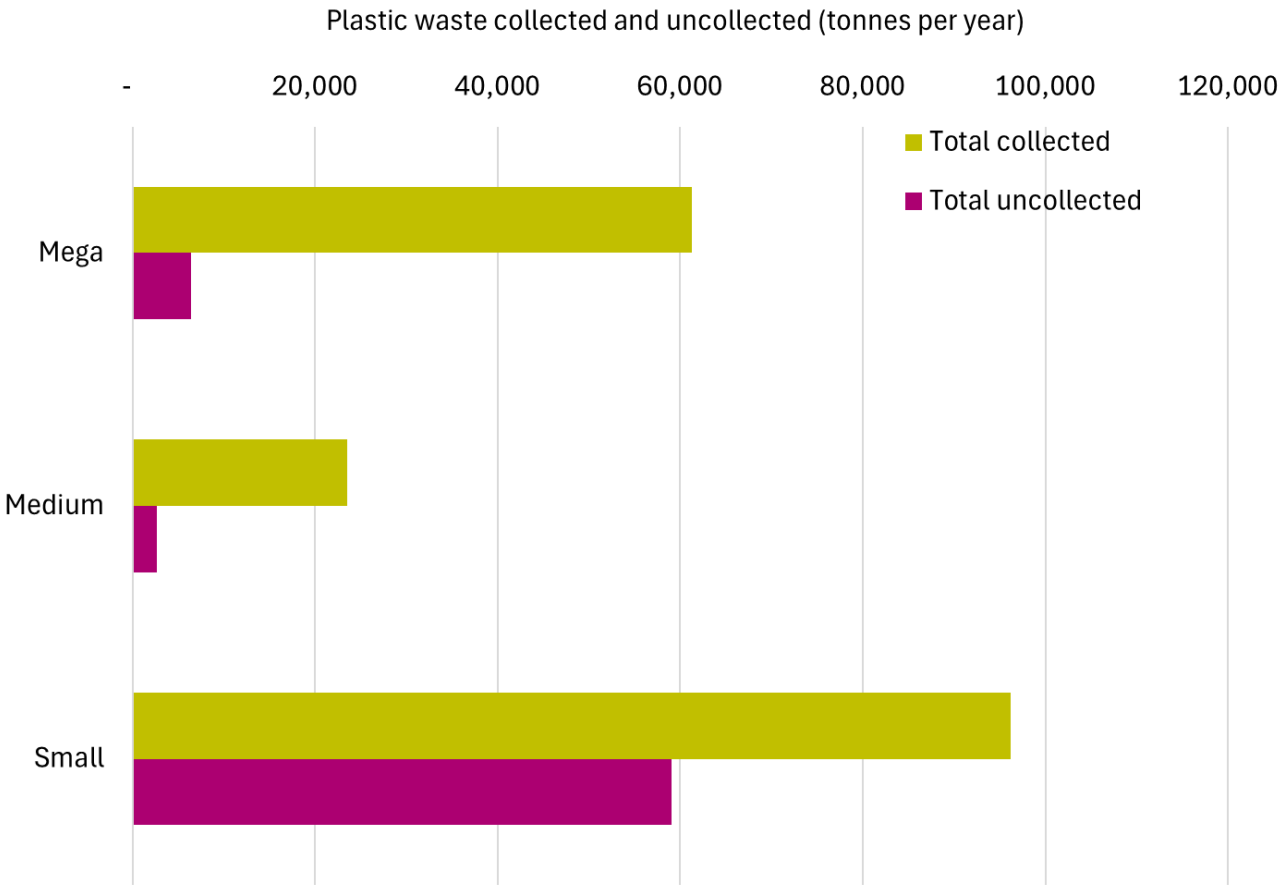


Figure 6: Proportion of plastic collected and uncollected

The formal sector collects the majority of plastic waste (see Table 10) which is in the form of mixed waste and predominantly transferred for landfill disposal, albeit with small quantities transferred for sorting at formal mixed waste treatment facilities. In contrast, the informal sector collects the majority of source segregated plastic waste, illustrating this sector's key role in collecting waste plastic for recycling. An estimated 4,577 tonnes of plastic waste are also collected from landfill sites by informal sector waste-pickers. Thus, the role of informal sector is important in any future efforts to increase the plastic waste recycling in the country. Despite this, a significant proportion of plastic waste remains unrecovered as part of the mixed waste (approximately 96,877 tonnes) deposited in disposal sites (see Table 9).

Table 10: Quantity of plastic waste collected by formal and informal collection services

Archetypes	Formal Source segregated (tonnes/year)	Formal Mixed waste (tonnes/year)	Informal Source segregated (tonnes/year)	Informal Mixed waste (tonnes/year)
Mega (Municipal Council)	3,355	41,238	9,845	6,867
Medium (Urban Council)	1,624	13,683	8,167	64
Small (Pradeshiya Sabha)	1,031	44,341	47,371	3,486
National	6,011	99,262	65,383	10,416

Uncollected plastic waste is typically openly dumped, burned, or buried. This is particularly prevalent in rural regions where collection coverage is low. Table 11 summarises relevant data on the disposal of waste.

Table 11: Means of MSW disposal by archetype (Source: JICA, 2016; Basnayake et al., 2020)

MSW (ton/day)	Mega Cities (Municipal Councils)	Medium Cities* (Urban Councils)	Small Cities* (Pradeshiya Sabhas)
	%	%	%
Total	100	100	100
Collected	80	54	52
Burned by household	6.5	7.8	11.5
Public dump (container)	45.8	57.5	53.41
Public dump (open space)	14.4	24.7	22.89
Dumped indiscriminately	3.2	4.4	3.5
Buried by household	1.4	4.1	4.7
Other	1.2	0.3	0.4
Uncollected	20	46	48

4.3 Plastic waste recycling and disposal

Of the estimated 225,102 tonnes of plastic waste collected in Sri Lanka: 26,775 tonnes are estimated to be sent for recycling; 96,877 tonnes are sent to designated disposal facilities. Although the waste management system annually collects 181,071 tonnes are collected by formal and informal sectors, 96,877 tonnes of plastic waste leaked from disposal sites to environment due to inappropriate management of final disposal facilities while 23,382 tonnes of plastic waste leaked to environment via the collection, transportation, and sorting operations (see Figure 7).

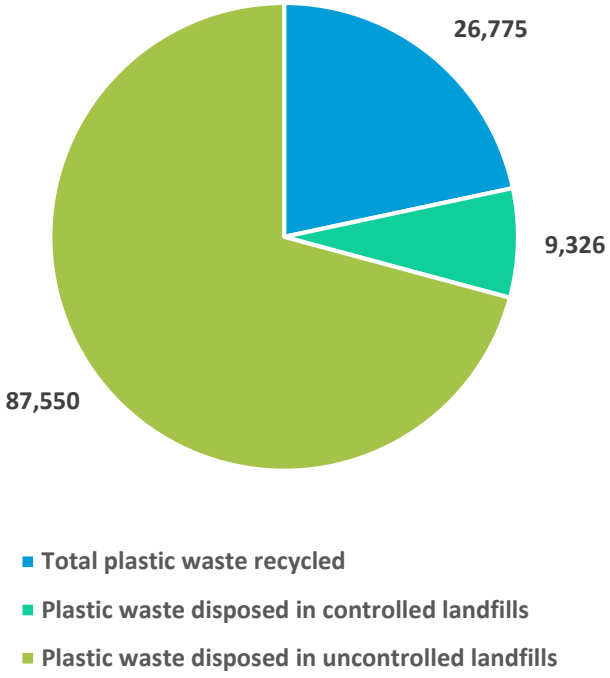


Figure 7: Proportion of plastics recycled, disposed in landfills and leaking from waste management system (tonnes per year)

The 26,775 tonnes of plastic waste sorted and sent for recycling represents 11% of total plastic waste generation nationally, indicating that there is significant potential to increase recycling levels. The majority of recycled plastics is sorted in the informal system (Japan International Cooperation Agency & Kokusai Kogyo Co. Ltd. (2016); Gunarathne et al., (2019); Samarasinghe et al. (2021)).

Sri Lanka's optimum plastic recycling capacity is estimated to be of the order of 200,000 tonnes per year (Samarasinghe et al., 2021). Clearly, not all plastics can be recycled economically but if we assume that it is feasible to recycle 50% of plastic wastes, then this indicates that an additional 173,000 tonnes of recycling capacity are needed.

4.4 Leakage from the waste management system

The 12.9% of total plastic waste collected is estimated to leak from the waste management system via handling, sorting and transport operations (excluding estimated leakage from landfill sites). This is an order of magnitude lower than the total estimated quantity of uncollected waste. However, is still amounts to over 23,383 tonnes per year.

Figure 8 illustrates the quantities that are estimated to leak from different parts of the waste management system and illustrates the differences between archetypes.

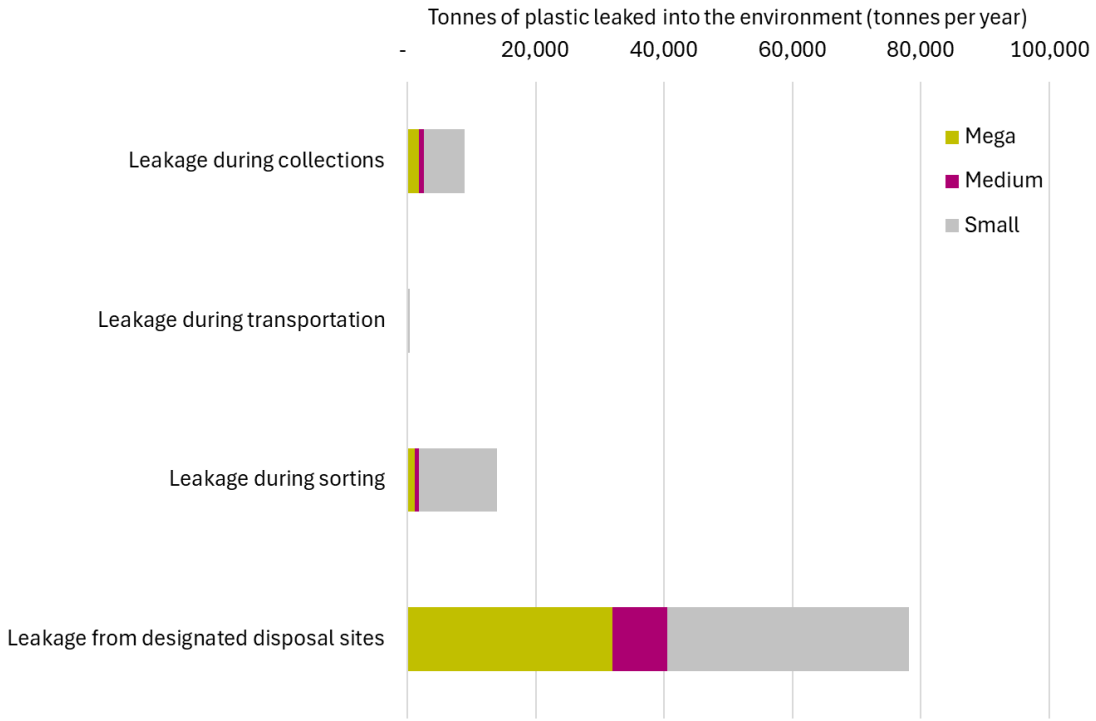


Figure 8: Summary of plastic waste leaked into the environment from the waste management system (tonnes per year)

4.5 Unmanaged plastic waste

Unmanaged plastic waste comprises uncollected plastic waste and plastic leaking from the waste management system. Approximately 175,000 tonnes per year of unmanaged plastic waste is estimated to be generated in Sri Lanka each year (Table 12). This represents a significant environmental and public health burden and is also a missed economic opportunity.

Table 12 Un-managed plastic waste by archetypes

	Mega (Municipal Council)	Archetype Medium (Urban Council)	Small (Pradeshiya Sabha)	National
Total plastic waste generation	67,663	26,143	155,231	249,037
Total plastic waste leakage from the waste management system	34,862	10,135	56,453	101,450
Total uncollected	6,358	2,605	59,003	67,965
Proportion of plastic waste uncollected	9%	10%	38%	27%
Total unmanaged	41,219	12,740	115,456	171,561
Proportion of plastic waste unmanaged	61%	49%	74%	69%

4.6 Data Availability and Limitations

There are limitations in this exercise due to the lack of reliable data on waste generation, collection, recycling value chain, waste treatment, and waste disposal. However, the brief plastic waste inventory presented in the National Action Plan (Ministry of Environment, 2021) is reinstated by the comprehensive estimate presented in this report. The data points used in this first-generation inventory provide a framework for establishing data recording and collection systems. For example, data collection processes and studies can be established for data points where it was necessary to use proxy data, or where the data used was considered to be of low accuracy. In addition, creating a centralised data recording and storage system for common waste data from regional and local authorities will ensure comparability of data between archetypes and ensure the robustness of the results.

The various processes and systems that may be established for regularly collecting and updating data points are listed below.

Table 13: Steps to update unknown or inaccurate data points

Data point	Source of data	First generation inventory limitations	Next steps
4 to 8 and 21	Data obtained from landfill/dumping sites	– Likely to be based on proxy values or estimations from other studies	– Commission composition studies at landfill sites to be conducted as a one-off study or periodically (e.g., 2–5-year frequency). – Establish a data recording regime as part of the landfill site administration system
9, 10, 13, 15, 17, 18 to 20	Data obtained from formal facilities (incineration, co-generation, sorting and recycling)	– Likely to be based on proxy values or expert judgment of facility stakeholders. – Available inventory data is not descriptive enough to extract precise information	– Commission a one-off composition study at the facilities. – Establish a data-recording regime as part of the facility-licensing requirement.
8, 14, 20, 21	Data obtained from informal services or facilities	– Likely to be based on proxy values, estimations or expert judgment of informal and formal services	– Collaborate with the informal sector to conduct composition studies at various sites periodically.

In the longer term, these data collection processes can be integrated into a 'second generation' inventory whereby data on the quantities of plastic waste generated. Its management are systematically reported as part the regulatory framework (for example, waste generators report the quantities of plastic waste they dispose of; waste management operators report the quantities

of materials collected and reprocessed, etc). They are closely linked to the establishment of detailed waste legislation and enforcement systems, which will produce real-time and reliable data from recognised actors and licensed facilities. Second generation inventories are, therefore, developed using data generated through reporting obligations and ongoing data records, unlike first generation inventories, which are based on targeted data collection and estimation processes in the absence of any existing data records.

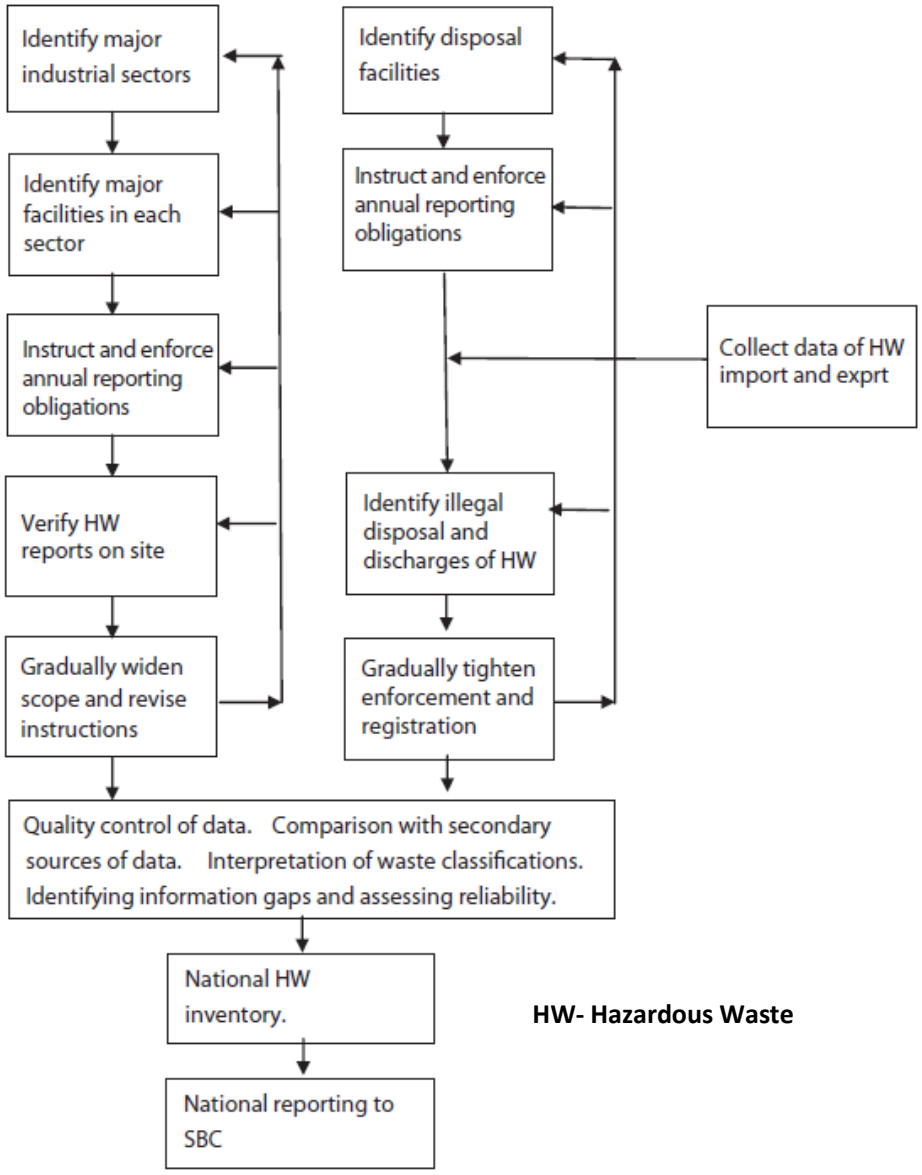


Figure 9: Roadmap for second-generation inventories (Source: UNEP, 2016)

The roadmap (Figure 9) for second-generation inventories described in the Basel Convention Methodological Guide for Hazardous Waste Inventories is a suitable example of a transition pathway from a first to second generation inventory and may be adapted for the national plastic waste inventory[9].

Once this type of system has been developed, it replaces the need to conduct a detailed inventory process as a separate study, albeit there may still be a need to conduct focused studies on issues such as composition to supplement the data contained in the second-generation inventory.

It was also observed that key value chain actors in privately owned resource recovery and recycling enterprises have limited cooperation with regulatory and administrative organizations, which affect the governance of recycling businesses as well as the efficient collection of data and information. Gradual conversion of the informal sector to the formal sector through local government intervention will enable the regular gathering of data and information. It was also observed that recyclables are often exchanged between formal and informal collectors, which leads to double counting the resource recovery statistics. For instance, the recyclable waste collected by LAs are often purchased by informal sector merchants and re-traded to recyclers; however, inventory identifies such quantitates as independent waste resource recovery activities. Therefore, the exchange of plastic waste between formal and informal sectors should be recognized and integrated to the inventory.

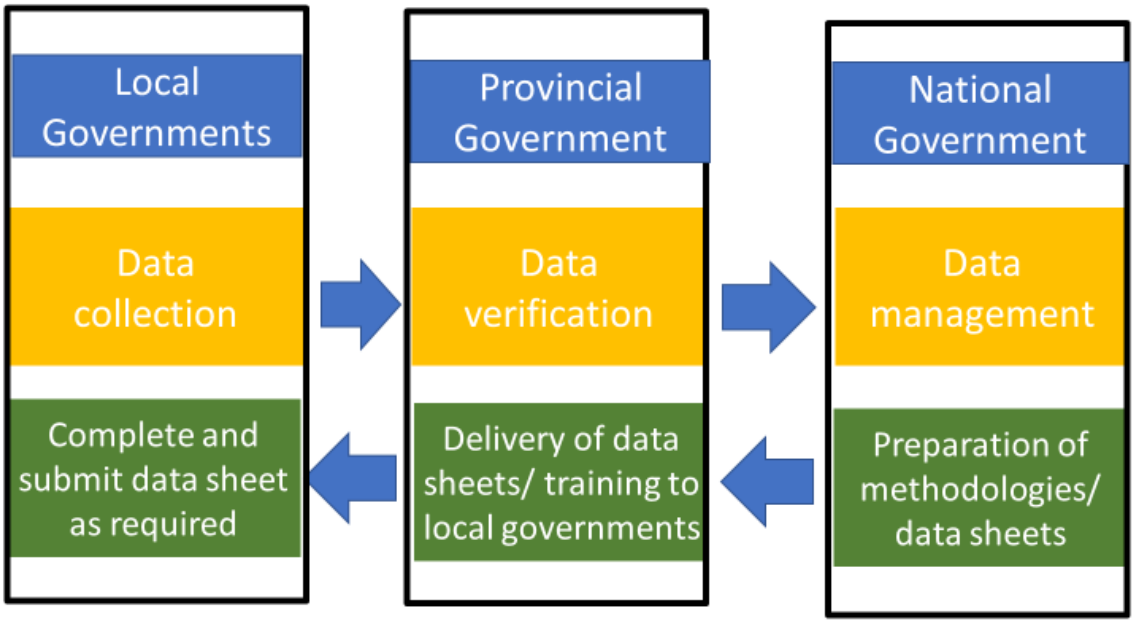
[9] UNEP 2016, Methodological Guide for the Development of Inventories of Hazardous Wastes and Other Wastes Under the Basel Convention
https://www.basel.int/Implementation/Publications/GuidanceManuals/tabid/2364/Default.aspx

5. CONCLUSION AND RECOMMENDATIONS

The National Plastic Waste Inventory stands as an indispensable tool for informed decision-making. It empowers both national and local governments to monitor evolving trends in plastic waste management, make well-informed decisions, and track the progress of implementing national and local policies, strategies, and action plans. Furthermore, it provides accurate and up-to-date information to the public and stakeholders, enhancing their understanding of the effectiveness of efforts to improve plastic waste management and its associated benefits. However, to maintain its effectiveness, it is crucial to regularly collect and update inventory data from here on. While there is currently no existing national-level system, it is highly recommended to establish a simple database (DB) system for collecting interconnected data.

Establishment of Regular Data Collection and Reporting System

The objective is to process, analyse, interpret, create projections, generate reports, and manage statistical data related to plastic waste management in the country. This DB system's development should be based on a flow of information with a multilevel governance structure in Sri Lanka, involving national, provincial, and local governments.



Local Governments

Local governments, including Municipal Councils (MCs), Urban Councils (UCs), and Pradeshiya Sabahas (PSs), hold significant responsibility for managing municipal solid waste in Sri Lanka. They play a pivotal role in collecting relevant information within their geographical boundaries using standardized formats provided by national and provincial authorities.

Local governments require daily or weekly data records for annual results. Data organization and storage can be digital or physical, depending on equipment availability. The following steps should be taken to collect the data: Designate a responsible person within the local government for data collection and recording. Maintain a record gathering public and private data. Send this data to the Provincial Authority on a monthly basis. This individual will receive proper training from the Provincial and National Authorities to gather raw data (e.g., trip and equipment tables) directly from those responsible for waste management and municipal operations and performing necessary calculations, measurements, and estimations related to plastic waste management.

Provincial Governments

Relevant Provincial Institutions, including provincial officials from the Ministry of Environment (MOE), Central Environmental Authority (CEA), and district departments, can serve as intermediaries between national and local governments. Their roles encompass receiving data from local governments within their jurisdictions and conducting analysis and validation exercises before forwarding it to the national Ministry. They will distribute questionnaires and data sheets, collect information, oversee verification, and digitize data. Their primary roles also include building capacity within local governments, coordinating regularly, and ensuring the quality, accuracy, and authenticity of data before transmission to the Ministry. The Provincial Authorities need to collect data from Local Authorities by monthly or quarterly basis, and keep continuous communication with local governments and staff responsible for data collection to ensure a smooth information flow.

National Government

The Ministry of Environment (MOE), Central Environmental Authority (CEA), and the National Solid Waste Management Support Centre (NSWMSC) act as coordinating agencies direct responsible for creating and managing the inventory/database. They need to collaborate with other relevant ministries, departments, and institutions as necessary to verify the data provided by the Local Authorities. Their responsibilities encompass: Creating and distributing questionnaires, forms, and solid waste collection trip tables for use by municipalities. These materials should be readily accessible within the institution or supplied and distributed by Provincial Directions. Managing data and publishing periodic reports, statistics, and publications on plastic waste management and its inventory. At national level, information could be updated annually, with Provincial Authorities responsible for completing and updating the data. Based on this information, the national authority is responsible for publishing national data reports.

Structure of the Database

The current National Plastic Waste Inventory provides a comprehensive overview of plastic waste management in the country, covering various aspects such as plastic waste generation, collection, recycling, treatment, final disposal, mismanagement, and environmental leakage, based on Material Flow Analysis (MFA). While all these parameters are essential for understanding overall plastic waste management, it is advisable to initially focus on fundamental plastic waste management data when developing the database to maintain it as simple and practical. These data can be collected by local governments with limited trial and error and guide the assessment of national plastic waste management performance based on Sustainable Development Goals (SDG) indicators for municipal solid waste management (11.6.1) and resource recovery (12.5.1). The key data points to focus on include:

- Total plastic waste generation
- Per capita plastic waste generation
- Total plastic waste collected
    - Tonnes of plastic waste collected by formal mixed waste collection
    - Tonnes of plastic waste collected by informal mixed waste collection
    - Tonnes of plastic waste collected by formal recycling collections
    - Tonnes of plastic waste collected by informal recycling collections
- Total plastic waste recycled
    - Tonnes of plastic waste recycle from formal treatment facilities
    - Tonnes of plastic waste recycle from informal recycling facilities
    - Tonnes of plastic waste recovered from landfills
- Total plastic waste disposed of in designated disposal sites
    - Plastic waste disposed of in controlled landfills
    - Plastic waste disposed of in uncontrolled landfills

To ensure the sustainability and effectiveness of the national plastic inventory database, several recommendations are essential:

- Establish clear agreements or collaborations among key stakeholders, including the MOE, CEA, NSWMSC, Provincial Directorates, and Local Authorities, to define responsibilities and roles for project success.
- The key actor in the waste management sector, Local Authorities, generally keep only waste sector service records (e.g., vehicle fleet, workforce, financial transactions etc.) but give a low priority for recording quantitative and qualitative characteristics of waste. Therefore, each LAs should establish a mechanism for collecting and reporting not only collection or service coverage but also quantitative figures in the whole waste stream, from generation to final

disposal. Promote and ensure training opportunities for Local Governments tailored to the needs of each municipality, involving technicians in decision-making processes for municipal planning is required.

- Encourage national agencies to analyse the collected data, publish annual plastic waste inventory report and use it as a basis for formulating new policies, ordinances, and strategies or monitoring the performance of existing ones.
- Strengthen the role of Provincial Directorates as intermediaries between the national and local authorities, ensuring timely information transmission. In this, the advantage of IT infrastructure at the personal and institutional level can be used to shift the conventional book record-keeping practices to digital data-keeping at the national level.
- Designate a responsible individual within each local government to ensure timely and accurate data collection and submission to Provincial Directorates. Moreover, creating linkages with research and technology centres, testing facilities and other specialized institutions is essential for capacity building, and knowledge transfer on national inventorying.

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FURTHER INFORMATION

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