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Waste Generation and Recovery in a Developing Country: A Case Study of Western Province, Sri Lanka

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ABSTRACT

The study's findings serve as a crucial foundation for policymakers, environmentalists, and stakeholders to take necessary actions and develop sustainable waste management strategies tailored to the specific challenges faced in the Western Province of Sri Lanka, contributing to broader global efforts to mitigate the growing waste crisis. It's a significant concern that the volume of waste is expected to triple by 2050, and the current waste management practices seem insufficient to handle this growth sustainably. The study indicates a per capita waste generation of 0.43 kg in Sri Lanka, with the Western Province at a higher rate of 0.53 kg. This data points to the urgency of addressing waste management practices in this region, especially considering its significance in the country's GDP. The results also show that the total municipal waste generation in the Western Province is 3248 kg per day whereas the recovery is only 25% (803 kg) in terms of recycling and composting. Burning, burying, and open dumping are highlighted as other prevailing practices for managing waste, which have adverse impacts on the environment and public health. Further research is recommended to identify and address these unaccounted waste streams, especially those at the household level.

INTRODUCTION

Rapid economic growth and urbanization frequently result in heightened resource consumption due to increased demand for goods and services. This surge in consumption generates a significant volume of waste, adversely impacting the environment. The predominant linear resource management model, starting from raw material extraction, through production and consumption, culminating in disposal, has inherent limitations. It prioritizes consumption and disposal over sustainable resource management practices. To mitigate the environmental consequences of resource consumption and waste production, a comprehensive approach is essential, encompassing the entire life cycle of products, from inception to disposal or recycling. This necessitates integrating sustainable practices at each stage of a product's life cycle. Embracing the principles of a circular economy is critical. This approach involves designing products for durability, facilitating reuse, repair, and recycling, thereby minimizing waste and prolonging material life cycles. Urgent policy reforms and systemic changes are imperative to encourage a transition towards a more sustainable and circular resource management approach. This might involve incentivizing eco-friendly product designs, promoting recycling and reuse initiatives, and enforcing regulations governing waste disposal methods.

Developing a holistic approach to managing resources and waste involves a collective effort from various stakeholders, including governments, industries, communities, and consumers. Transitioning to a more sustainable system will require innovative strategies, technological advancements, policy reforms, and behavioral changes to minimize environmental degradation and promote a more circular and responsible approach to resource use.

More than two billion metric tons (Mt) of waste are generated annually. This figure is anticipated to rise to 3.4 billion Mt by 2050, assuming current waste management practices persist (Kaza et al. 2018). By 2050, waste generation in developing nations is expected to triple (Kaza et al. 2018). Notably, the Asia-Pacific region is poised to significantly contribute to the world's waste output, accounting for roughly 23% of the total. In these developing countries, food and green waste collectively constitute over 50% of the overall waste generated. Recyclable materials like paper, cardboard, plastic, metal, and glass form a significant portion of waste streams, ranging from 16% in developing nations to approximately 50% in developed ones (Laurenti et al. 2014).

In Sri Lanka, about 62% of municipal solid waste is composed of biodegradable organic material, while the remaining portion comprises non-biodegradable materials

(Dharmasiri 2019). Reports indicate the absence of proper waste segregation at the household level before disposal (Warunasinghe & Yapa 2016). Bandara (2011) emphasizes the critical necessity of instituting an integrated solid waste management system in the country. Presently, the management of municipal solid waste falls under the jurisdiction of the local government network, comprising 24 Municipal Councils, 41 Urban Councils, and 276 Divisional Councils. However, disparate waste management approaches are adopted by various local government bodies based on their capacities, rather than implementing a unified waste management system nationwide. Hence, conducting a comprehensive assessment of material recovery potential is essential for establishing an integrated waste management system.

Given this context, the primary focus of this study centers on evaluating waste generation volumes, characterizing waste, analyzing waste management practices, and exploring the potential for material recovery in municipal solid waste within Sri Lanka's Western Province. The research endeavors to identify potential recyclable materials present in municipal solid waste. Furthermore, it aims to advocate for the advancement of material recovery options while also contributing to future research directed toward resolving issues associated with mismanaged waste within the household waste material chain.

MATERIALS AND METHODS

Study Area

The Western Province of Sri Lanka as shown in Fig. 1, with a population of 5.8 million, accounting for 27% of the nation's total population, was chosen as the focal area for this pilot study. Covering approximately 6% of Sri Lanka's land area, the Western Province accommodates the largest population among all provinces and contributes over 42.6% to the country's overall GDP, playing a vital role in the national economy (C & S 2021), (Dharmasiri 2019). The high population density, coupled with rapid urban development in this region, has significantly escalated the production of municipal solid waste.

The study area encompasses 25 open dumping sites as Fig. 2, where waste is disposed of, and the collected waste is managed through a channel regulated by local authorities. This institutional framework stands as the primary mechanism responsible for waste management in Sri Lanka.

Data Collection Procedure

The study defined its system boundary to cover the complete waste management process, commencing from household waste generation to its ultimate disposal. Obtaining the essential data for analysis involved identifying various facets such as municipal solid waste generation, waste management practices, different types and quantities of waste, and the methods used for disposal. The waste materials produced within the study area underwent characterization. Furthermore, gathering pertinent information about the waste composition and its management status involved utilizing published surveys, conducting questionnaires and interviews, and eliciting feedback from local authorities in the Western Province as stated in Fig. 3.

Calculation of Waste Recovery Percentage

This study employs the principles of a circular economy to evaluate the waste material recovery factor. A circular economy is an economic system that aims to eradicate waste while continuously regenerating resources (Tamine 2020). Advancing toward a circular economy necessitates not just responsible natural resource utilization but also facilitating reuse, repurposing, recycling, and reclaiming value from materials conventionally considered waste (Bouton 2016) Additionally, the study employs Material Flow Analysis to delineate the waste material chain from the household level to final disposal in the designated pilot area as shown in

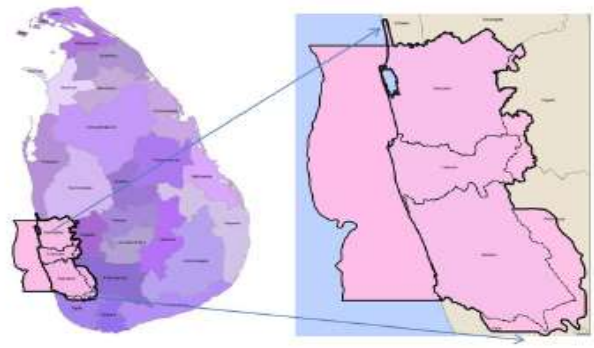
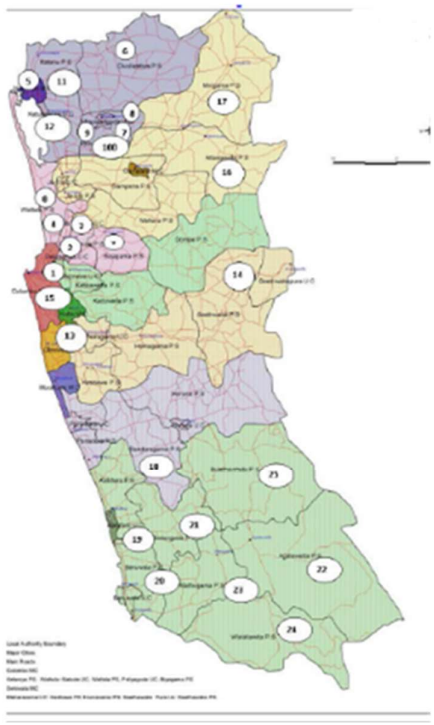


Fig. 1: The Western Province, Sri Lanka.



1. Sedewatha dumpsite
2. Manelgamuwa dumpsite
3. Eweriwatta personal land
4. Dikkowita dumpsite
5. Kochchikade dumpsite
6. Dumpsite of Hunumulla
7. Aluthepola coconut land
8. Yatiyana mahayaya coconut land (private land)
9. Walihena rubber cultivation (private land)
10. Niwala coconut cultivation (private land)
11. Low land of welihena and low land of Raddoliwa cemetery (private land)
12. Ambalanmulla dumpsite
13. Karadiyana waste management site
14. Seethawakapura composting plant
15. Maligawatta Government land
16. Dambuwatta dumpsite
17. Meerigama PS dumpsite
18. Bandaragama PS composting plant
19. Kaluthara Pohorawatha compost site
20. Darga town dumpsite
21. Dosat Estate
22. Agalawatta compost plant
23. St. John Estate
24. Walallawita compost plant
25. Bulathsinhala compost plant

Fig. 2: 25 Waste dump sites in the Western Province.

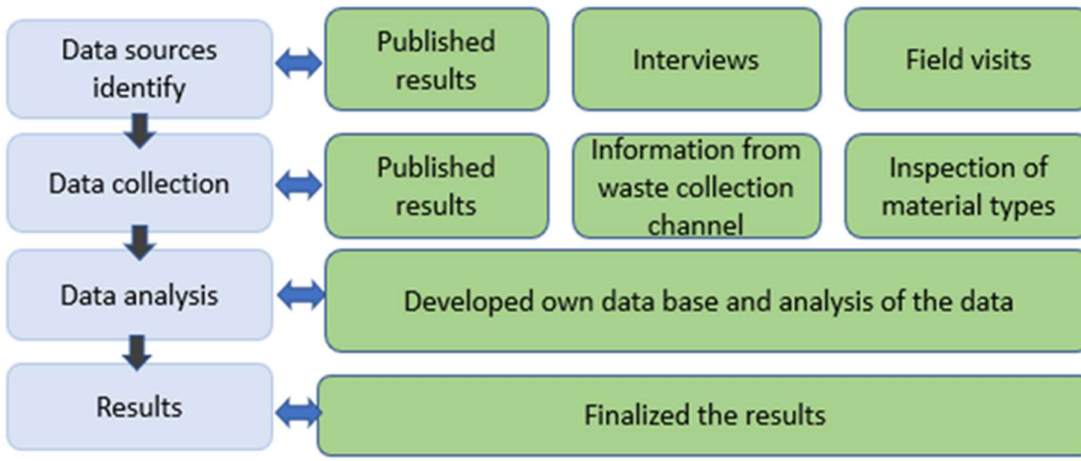


Fig. 3: Methodological framework.

Fig. 4. Material Flow Analysis is an analytical method utilized to quantify the movement and accumulation of materials or substances within a clearly defined system (Hunt et al. 2014). Rooted in the principle of mass conservation, this method finds extensive application in waste material flow analyses across various research fields (Gehrmann et al. 2017, Allesch & Brunner 2015).

Its widespread use in environmental education, particularly in waste management, underscores its significance as an analytical tool for informed decision-making concerning diverse issues related to waste analysis.

The waste recycling factor was developed using the following equation 3, supported by the material flow structure illustrated in Fig. 4.

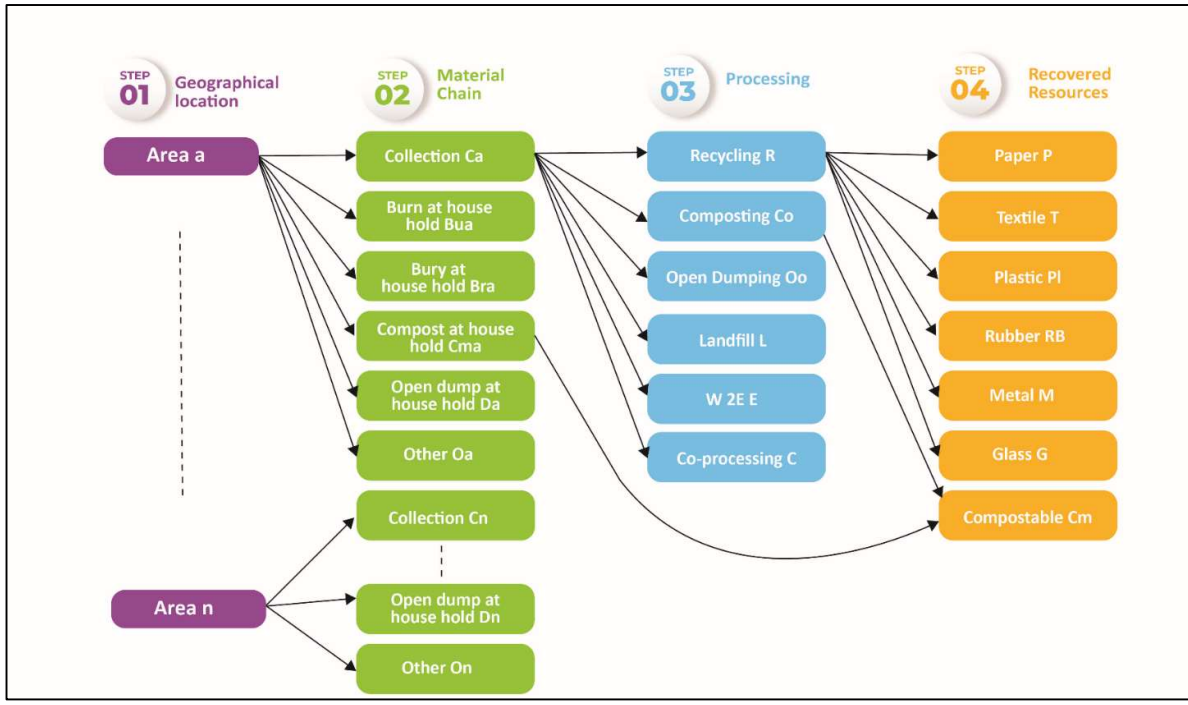


Fig. 4: Material flow structure.

Recycling material is represented in equation 1;

$$\sum_{a}^{n} a\left[\begin{matrix}\mathrm{CaR(P+T+Pl+RB+M+G)+CaCo+}\\ \mathrm{Cm-Bua-Bra-Da-\ Oo-L-E}\end{matrix}\right] \quad ...(1)$$

Where "a" is the MSW generation at area "a" (area can be a GN division etc.) in MT /d.

Ca- MSW collection percentage by local authorities (in GN divisions)

Bua, Bra, Da, Cma, represent the Burn, Bury, and Composting percentages at the household level respectively.

R- MSW recyclable volume percentage out of collection

Co- compostable material percentage out of collected volumes by GN division.

L, E, Oo, and C represent Landfill, Waste to Energy, Open dump, and Co-processing respectively.

P, T, Pl, RB, M, G, and Cm are the percentages of recyclable volumes of Paper, Textile, Plastic, Rubber, Metal, Glass, and compostable material (household and waste collection center point) respectively.

Where total MSW generation is represented in equation 2.

$$\sum_{A}^{n}[a+\cdots+n) \quad ...(2)$$

The total recyclable material percentage out of the whole MSW generation is illustrated by equation 3. equation (1)/ equation (2) …(3)

RESULTS AND DISCUSSION

Primary Waste Streams and Treatment Methods

In the results of the study presented in Fig. 5, the primary waste categorization at the household level on a percentage basis indicates the collection of waste by local authorities, burning material at the household level, burying material at the household level, composting waste at the household level, and other disposal mechanisms. Fig. 6 represents the Material Flow Analysis from the household doorstep to the final disposal point through three steps in the Western Province. Step 2 of Fig. 4 and Table 1 represent the basic treatment at the household level, while Table 2 represents the main waste categorization of the material at the collection point. Step 4 of Fig. 4 and Table 3 represent the final disposal solution for municipal solid waste in the Western Province. Previous study shows material flow movements of MSW from household to final disposal (Hemali & Alwis 2022), whereas the present study further elaborates on how MSW in Western Province behave in the context of the semi-urban environment.

Waste Recycling, Reusing and Repurposing

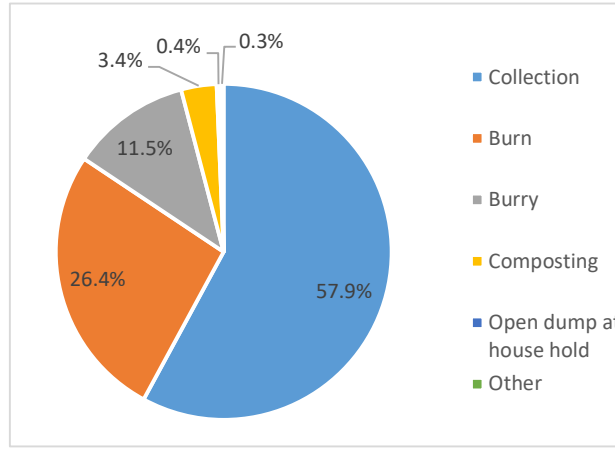


Fig. 5: Primary waste solution percentages at the household level, Western Province.

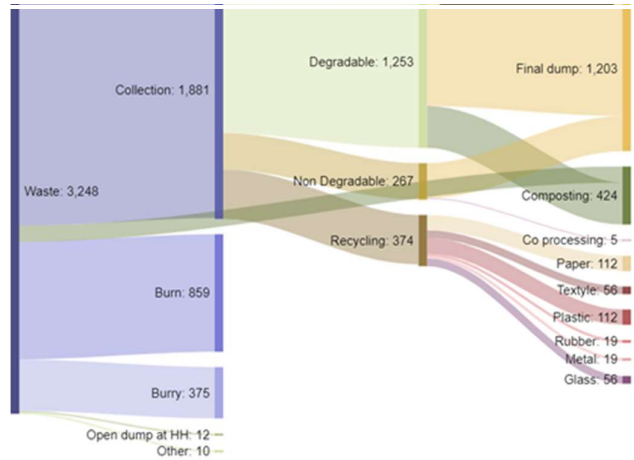


Fig. 6: Waste material flows in tonnes (Mts) from household level to disposal, Western Province, Sri Lanka (Hemal & Alwis 2022).

The study indicates that recycling and composting are the primary recovery methods adopted in the Western Province for proper waste management. However, most of the waste ends up in open dumps, while incineration and landfilling are not considered recovery options. In 2022, a Waste-to-Energy plant with a capacity to process 600 metric tons per day was established in the Western Province, but the plant is still not in full operation. However, waste-to-

Table 1: Types of waste treatment in the Western Province.

Waste treatment in Western Province step 2	Volume (tonnes per day)
Collection	1881
Burn	859
Bury	375
Composting	111
Open dump at household	12
Other	10

Table 2: Waste collection categorization based on primary material types.

Waste treatment in Western Province step 3	Volume (tonnes per day)
Degradable waste	1253
Non- degradable waste	267
Recycling waste	374

Table 3: Waste disposal categorization based on final treatment type.

Waste Treatment in Western Province Step 4	Volume (tonnes per day)
Open dumping	1203
Composting	424
Recycling paper	112
Recycling plastic	112
Recycling Textile	56
Recycling Glass	56
Recycling Rubber	19
Recycling Metal	19
Other	5

Table 4: Waste recycling/repurpose factor for individual waste type in the Western Province.

Waste Treatment in Western Province Step 4	Volume (tonnes per day)	Recycling/Repurpose factor for individual waste type
Composting	424	13.05%
Recycling paper	112	3.45%
Recycling plastic	112	3.45%
Recycling Textile	56	1.72%
Recycling Glass	56	1.72%
Recycling Rubber	19	0.58%
Recycling Metal	19	0.58%
Other	5	0.15%
Total	803	24.72%

energy is not considered a material recovery option in this study.

The overall results reveal that per capita waste generation in the Western Province is 0.53 kg, of which open dumping amounts to 0.21 kg while recycling and repurposing stand at 0.14 kg of the waste generated in the Western Province, the total volume of recycling and repurposing is 25%. Furthermore, the waste collection rate is 60% in Western Province, Sri Lanka as shown in Table 4. Further whole country represents the per capita waste generation of 0.43 kg.

Waste Dumping

As indicated in Table 3, the predominant waste volume is directed towards open dumping. To identify potential recyclable and reusable materials among the waste disposed of in this manner, there is a crucial need for further study on waste composition. Understanding the composition of waste deposited in open dumps is essential to pinpoint valuable materials that could be recycled or repurposed. Analyzing the waste composition allows for the identification of specific materials that could otherwise be salvaged, recycled, or reintroduced into production cycles, consequently reducing the amount of waste ending up in landfills or open dumping sites.

By conducting a detailed analysis of the waste composition in open dumps, the study aims to identify materials that could potentially be diverted from the waste stream for recycling or reusing purposes. This exploration can lead to more effective waste management strategies and contribute significantly to reducing environmental impacts while promoting a more sustainable approach to handling waste. Waste composting of the total waste generation in the Western Province, 13.05% of recovery is reported at waste composting in the Western Provinces as per Table 4. There is a potential to improve compostable volume in the Western Province.

Waste Burning and Burying at the Household Level

The study, as depicted in Table 1, underscores the necessity for additional research concerning unaccounted and unidentified material flows related to household-level burying and burning practices. These methods of waste disposal often result in significant environmental and human health hazards.

Burning or burying waste at the household level has significant adverse effects on both the environment and human health. These practices, often carried out as a means of waste disposal, contribute to pollution and pose serious risks due to the release of harmful substances into the air and soil. Understanding the materials commonly subjected to these disposal methods is crucial for addressing the associated environmental and health concerns.

There is an urgent need to promote sustainable waste management practices at the household level, such as recycling, composting, and responsible disposal at designated facilities.

Public awareness and education about the environmental and health consequences of improper waste disposal are crucial for encouraging responsible behaviors.

In conclusion, burning or burying waste at the household level has far-reaching and detrimental consequences for the environment and human health. Addressing these issues requires a comprehensive approach that includes proper waste management practices, education, and the development of sustainable alternatives to reduce the negative impact of waste disposal on our surroundings.

Further research in this area is crucial to identify the types of materials commonly disposed of through burning or burying, quantify their impact on environmental degradation, and assess the associated health risks. By shedding light on these unaccounted waste disposal practices, the study aims to provide insights that can drive policy changes, educational campaigns, and improved waste management strategies aimed at minimizing the harmful effects on the environment and human health.

CONCLUSION

Municipal Solid Waste stands as the primary source of waste generation in the country, constituting the largest volume. Despite being labeled as waste, this material holds immense potential for recycling and reuse. An extensive analysis of scientific literature reveals that a significant portion of municipal solid waste is often incinerated or buried without proper consideration for its recyclable value.

Hence, this study underscores the critical need for research focusing on unaccounted and unidentified material

flows linked to household-level burying and burning practices. Understanding and addressing these inadequately managed waste streams are pivotal, as these methods not only contribute to environmental degradation but also pose risks to human health.

Furthermore, a considerable portion of the collected waste is directed to open dumps. Exploring and evaluating the recycling potential of this particular segment of waste requires further investigation. Uncovering potential recyclable materials within waste deposited in open dumps can lead to the development of effective recycling strategies. This exploration is essential to reduce the burden on landfills, promote sustainable waste management practices, and harness the untapped potential for recycling and reuse within these waste streams.

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