VOLUME 01 ISSUE 02 (2026)

Journal of Waste to Value System

Assessment of Municipal Solid Waste Generation, Composition, and Resource Recovery Potential: A Data-Driven Circular Economy Perspective

K Vidhvan Kumar

Dr NTR University of health sciences, Vijayawada, 520008, Email- vidhvankumar007@gmail.com

*Corresponding author: K Vidhvan Kumar, vidhvankumar007@gmail.com

Abstract

The management of municipal solid waste (MSW) still presents a significant problem of environmental and resource efficiency, caused by the growing amount of waste produced, the unequal level of waste treatment and continued reliance on waste disposal practices. Variations in waste generation were analysed using descriptive statistics, income group comparisons, correlation analysis and multiple regression to determine factors associated with the recovery performance. Total annual municipal solid waste production is 8.58 million tonnes, and the median per-capita per-day production rose from 0.44 kg in low-income countries to 1.43 kg in high-income countries. Organic wastes accounted for the highest share of 41.73%, followed by paper, plastic, glass and metals. An estimated potentially recoverable fraction of 78.91%, and a combined mean recycling and composting rate of 28.62%, equate to a recovery gap of 49.92 percentage points. Gross domestic product was significantly positively associated with the total waste generation, but none of the waste composition variables was significant predictors in the regression model. The results revealed that a significant number of recoverable materials are yet to be used and that source segregation, appropriate recovery technologies, and policies for the circular economy in context are needed.

Keywords- *municipal solid waste; waste composition; resource recovery; circular economy; recycling; waste management*

https://doi.org/

1. INTRODUCTION

Urban waste has emerged as one of the biggest environmental and resource management issues arising from the increasing urbanisation, population growth, evolving consumption patterns and economic growth. An ever-growing volume of domestic, commercial, institutional and market waste has been putting significant strain on waste collection systems, treatment plants, landfill space and municipal finances (Chen et al., 2020). The impacts are uncontrolled dumping, uncontrolled burning, clogging of drainage systems, contamination of soil and water, public health risks and the loss of potentially valuable materials that can be recovered and returned to productive use (Abubakar et al., 2022).

Municipal solid waste management encompasses a chain of activities that are interrelated and include waste generation, storage, collection, transport, sorting, treatment, recovery and disposal. Anyplace where there is a weakness can decrease the overall efficiency of the system and lead to higher environmental costs. However, developing countries can be plagued by a lack of collection coverage, poor source segregation, insufficient treatment facilities, reliance on open dumps and a lack of participation of the informal sector in formal recycling (Alam & Qiao, 2020). The same obstacles have been identified in other developing economies where institutional fragmentation and financial limitations are combined with the limited technical capacity and weak institutions' enforcement to hinder the application of integrated approaches in waste-management (Fernando & Zutshi 2023). Planning, data reliability, the availability of suitable infrastructures, engagement of stakeholders and local treatment possibilities are thus essential for sustainable collection and management (Pires et al., 2019).

It is the composition of waste that is critical to the design of effective waste management and recovery strategies. Organic materials can be composted or anaerobically digested, and paper, plastic, glass and/or metals can be recycled. Under suitable technical and environmental conditions, there can also be benefits from energy recovery of the residual combustible fractions. The efficiency of these options will be influenced by the type of waste, source separation, level of contamination, demand, institutional capacity and choice of technology (Khan et al., 2022).

Waste management systems largely remain conventional in many countries. Under controlled conditions with engineering measures, leachate management, and landfill-gas recovery systems, landfilling can be a solution that offers controlled containment, but poorly managed landfills can have long-term environmental and climatic impacts (Nanda & Berruti, 2021). The waste sector is a source of GHG emissions because of the release of methane from the decomposition of organic waste, the use of fossil fuels during the collection and transportation of waste, and uncontrolled combustion of waste (Küfeoğlu, 2024). In recent years, waste-management systems have been exposed to shock and stress from global disruption, highlighting the vulnerability of municipal waste-management systems to sudden changes in waste quantity, waste composition, labour availability and demand for services (Neumeyer et al., 2020). Recent global evaluations, therefore, highlight the need to shift from waste disposal to waste prevention and recovery of materials, biological treatment and creation of value from waste (International Solid Waste Association, 2024).

The circular economy is an alternative approach to the linear, take-make-dispose model of waste management, seeking to shift it towards preventing, reusing, recycling, recovering and regenerating waste. Circular economy policy aims to keep the value of materials, avoid reliance on virgin materials and minimise environmental leakage during production and consumption processes (Ellen MacArthur Foundation, 2021). To make this concept measurable, there needs to be clear targets and indicators that will provide waste-management outcomes such as recycling rate, recovery efficiency, landfill reduction, resource productivity, etc. (Morseletto, 2020). The promotion of product durability, waste prevention, secondary-material markets and better recovery systems is increasingly highlighted in policy frameworks as key pillars of a cleaner and more competitive economy (Plan, 2020). Circular practices can also be used to create jobs, inclusion in the informal sector, recovery of energy and local economic development in the context of development (Priyadarshini & Abhilash, 2020). Evidence of the performance of the existing circular economy approach in the MSW sector, and the potential for further recovery, is needed. A high proportion of recyclable or biodegradable does not necessarily indicate a high recovery as technical, financial, behavioural and institutional challenges may make it difficult to divert away from waste (Mandpe et al., 2023). Another result of the LCA is that a waste-management decision must take into account not only the performance level of the system, or a single performance indicator, as was done in the past, but rather its environmental, economic, and social impacts from the collection to the disposal of the waste (Ceraso & Cesaro, 2024). Waste generation, material composition, current treatment practices and circular economy opportunities, thus, require to be linked based on a common analytical framework, which demands data-driven evaluation. It is even more important in the context of evidence that exists globally, where there are still income group and geographical disparities in waste-generating potential, treatment capacity, and resource recovery.

Although international interest in the circular economy and the management of waste has been increasing, there is still a lack of knowledge on how the different levels of waste generation, the composition of waste, treatment methods and socio-economic factors affect the opportunities for resource recovery in different countries

OBJECTIVES

1. To evaluate the trend in the generation of municipal solid waste at the country, geographical region and income level per capita.
2. To quantify and understand the composition of municipal solid waste and the percentage of organic and dry recyclable waste that can be recovered.
3. Assess current recycling and composting and disposal stream, quantify the resource recovery gap and determine the potential for further development of circular economy municipal solid waste management.

2. METHODOLOGY

2.1 Research Design

The present study has adopted a quantitative, cross-sectional and data-driven research design to evaluate the solid waste generation, composition, treatment pattern and resource recovery potential in a circular economy perspective from the municipal solid waste. The What A Waste Global Dataset was used for secondary data analysis and was used to obtain information at the country and city levels on municipal solid waste management. The country-level dataset was the principal analysis source, with the city-level dataset used to make comparisons.

2.2 Data Source

The dataset used in the study is the What A Waste Global Dataset, which is available on Kaggle (Arman, 2020). The downloaded archive contained country-level data, city-level data, and codebooks for both. Information about waste generation, population, Gross Domestic Product (GDP), income categories, region, waste composition, collection coverage, and treatment methods was provided in the country-level file. Similar information was provided in the city-level file for urban areas. The codebooks were used to confirm the coding of variables, the units of measurement, the years reported and the sources of data.

2.3 Study Variables

Total generation of MSW, in tonnes per year, was the primary outcome variable. The population was used to calculate per-capita waste generation. The following percentages of waste were considered for waste composition: Food and Organic Waste, Paper and Cardboard, Plastic, Glass, Metal, Rubber and leather, Wood, Yard Waste, and Other Waste. Waste management practices were assessed with percentages of waste that is recycled, composted, anaerobically digested, incinerated, dumped in landfills, dumped in the open, dumped in the sea and waste that is not accounted for. Explanatory variables were region, income group, gross domestic product and coverage of collections.

2.4 Data Cleaning and Preparation

The data sets were checked for the presence of duplicate records, missing values, irregular formats and improbable observations. The numeric variables were standardized and percentage values were verified to be in the range of 0-100. The data were not statistically imputed, since they were a mixture of data from multiple sources and years. For each analysis, however, an available-case approach was used. The totals for waste composition were also checked for consistency, and incomplete waste composition records were not included in analyses that required a complete waste composition profile.

2.5 Derived Indicators

Total waste produced by all the municipalities was divided by population and tonnes converted to kg to work out annual per-capita waste generation. The annual value has been divided by 365 to calculate per-capita generation. The potentially recoverable fraction was assumed to be a combination of organic waste, paper/cardboard, plastic, glass and metal. A recycling, composting and anaerobic digestion percentage was summed to determine the current resource-recovery rate. The difference between the current recovery rate and the potentially recoverable fraction was calculated to estimate the resource-recovery gap. The data set used these indicators as theoretical recovery, which did not contain any contamination rates, market conditions, processing efficiencies, or technical recovery losses.

2.6 Statistical Analysis

Data was summarized using descriptive statistics such as mean, median, standard deviation, minimum, maximum, frequencies and percentages of waste generation, composition and treatment pattern. Regional and income group comparisons were made, looking at differences in per-capita waste generation, per-capita recyclables content, per-capita share of organic waste, and per-capita recovery. Appropriate correlation analysis (Pearson or Spearman) was used according to the distribution of the data. Multiple regression analysis was performed to study how gross domestic product, income category, population, collection coverage and waste composition affect per-capita waste generation rate, and current resource recovery rate.

2.7 Circular Economy Assessment

The circular economy assessment involved three aspects: material availability for potential recovery, actual recovery performance and reliance on waste disposal. Resource availability is represented by the share of organic and recyclable material, while the share of recovered by recycling, composting, and anaerobic digestion represents the existing recovery performance. Disposal dependence was manifested in landfilling, open dumping, marine disposal and unaccounted waste.

2.8 Ethical Considerations and Limitations

The study was based on secondary data that was publicly available and did not involve human subjects or personal information and thus did not require formal ethical approval and informed consent. The conclusions were, however, drawn with caution due to the varied scale of geographical and years of observation in the What A Waste Global Dataset and institutions and reporting systems.

3. RESULTS

3.1 Dataset Coverage and Municipal Solid Waste Generation

The country-level data consisted of 217 countries and territories. There were 215 observations where the municipal solid waste generation and population data were available. On average, the countries produced 8.58 million tonnes of MSW per year, but the amount of waste generated was very unevenly distributed, with a median of 1.77 million tonnes per year. The average per-capita waste generated was 1.04 kg per day per person, ranging from 0.10 to 4.35 kg per day per person is shown in Table 1. In all income groups, daily waste generation was continuously rising. The median production per capita per day was 0.44 kg/person/day in low-income countries, 0.47 kg/person/day in lower-middle-income countries, 0.83 kg/person/day in upper-middle-income countries and 1.43 kg/person/day in high-income countries, as shown in Figure 1.

Table 1. Descriptive statistics of municipal solid waste generation and recovery indicators

Indicator	Valid n	Mean	SD	Median	Minimum	Maximum
Total MSW generation (million tonnes/year)	215	8.58	27.14	1.77	0.004	258.00
Annual per-capita MSW (kg/person/year)	215	377.87	276.75	316.04	37.37	1,586.99
Daily per-capita MSW (kg/person/day)	215	1.04	0.76	0.87	0.10	4.35
Potentially recoverable fraction (%)	163	78.91	14.78	83.70	27.50	100.40
Recycling and composting rate (%)	55	28.62	18.10	29.00	0.28	66.06
Resource-recovery gap (percentage points)	51	49.92	25.56	54.20	−8.23	90.75

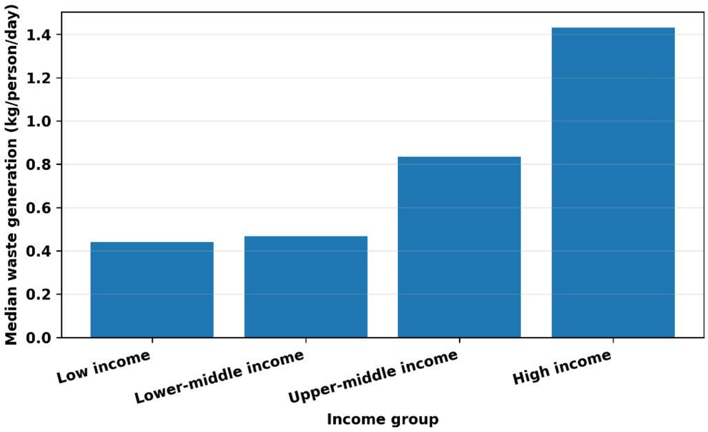

Figure 1. Median daily municipal solid waste generation by income group

3.2 Municipal Solid Waste Composition

The food and organic waste accounted for the highest percentage of the municipal solid waste stream (41.73% on average). Paper and cardboard had the largest share at 15.28%, and plastic the second largest at 11.69%. The mean shares of glass and metal were relatively low at 4.76% and 4.28%, respectively. The remaining or other waste category was an average of 18.42%, as shown in Table 2. As is evident in Figure 2, biodegradable organic waste was the main waste stream. The overall potentially recoverable fraction of organic waste, paper, plastic, glass and metal was 78.91%, suggesting a significant percentage of municipal waste could be diverted from final disposal.

Table 2. Composition of municipal solid waste

Waste component	Valid n	Mean (%)	SD	Median (%)	Minimum	Maximum
Food and organic waste	176	41.73	17.90	43.20	3.10	87.60
Paper and cardboard	176	15.28	9.48	13.16	2.00	58.70
Plastic	175	11.69	5.59	11.50	1.00	32.00
Glass	171	4.76	3.40	4.00	0.00	21.40
Metal	170	4.28	3.52	3.00	0.10	19.38
Other waste	175	18.42	16.02	14.00	0.80	92.70

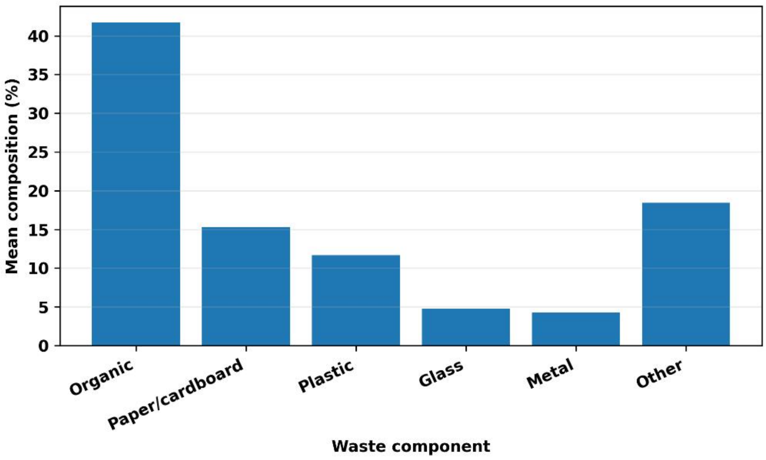

Figure 2. Average composition of municipal solid waste

3.3 Existing Waste-Treatment Practices

There was a lot of variation among waste treatment pathways. An average of 17.37% of reported municipal waste was recycled, and 8.14% was composted. Only two observations were reported for anaerobic digestion, with an average of 0.20%. Among the countries reporting controlled landfills, the average was 42.21%, while the average for countries reporting open dumping was 54.79%, as shown in Table 3. Figure 3 shows that more people were using disposal-based practices than material-recovery pathways. Shares reported for open dumping and controlled landfilling were much higher than shares reported for recycling and composting.

Table 3. Reported municipal solid waste-treatment practices

Treatment pathway	Valid n	Mean (%)	SD	Median (%)	Minimum	Maximum
Recycling	124	17.37	15.23	13.66	0.001	67.00
Composting	68	8.14	7.59	5.74	0.08	31.24
Anaerobic digestion	2	0.20	0.14	0.20	0.10	0.30
Incineration	48	28.43	23.54	22.84	0.14	85.00
Controlled landfill	43	42.21	34.14	33.00	0.01	100.00
Open dumping	68	54.79	30.86	57.70	4.00	100.00

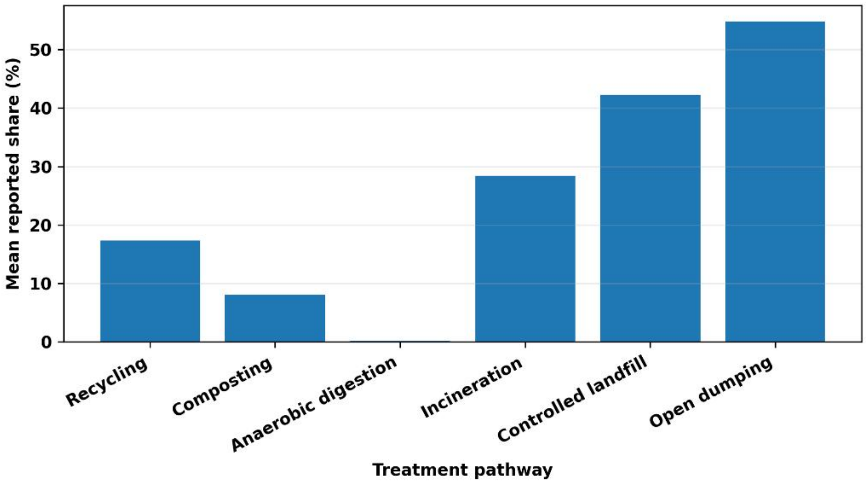

Figure 3. Average reported shares of municipal solid waste-treatment pathways

3.4 Resource-Recovery Potential and Recovery Gap

For 163 countries, complete information was available for the five categories of potentially recoverable waste. The mean potentially recoverable fraction was 78.91% with a median of 83.70%. When considering countries with complete composition and recycling–composting data, however, the mean current recovery rate was only 28.62%. The mean estimated recovery gap was 49.92 percentage points, with the median gap at 54.20 percentage points. Most observations have been made below the equality line in Figure 4, and, as a result, the reported recycling and composting rates are generally significantly lower than the potentially recoverable material fraction. The recoverability was moderately negatively correlated with current recycling and composting performance (Spearman's $\rho = -0.344$, $n = 51$), and strongly positively correlated with the recovery gap (Spearman's $\rho = 0.747$, $n = 51$).

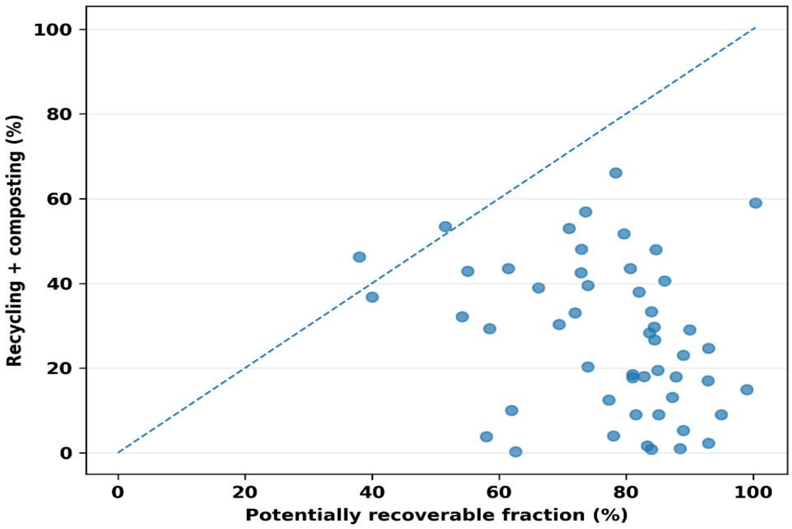

Figure 4. Relationship between potentially recoverable waste and current recycling and composting rates

3.5 Regional Differences In Circular Economy Performance

There were significant variations in waste generation and recovery performance by region. The highest median daily waste generation was in North America (2.22 kg/person/day), followed by Europe and Central Asia (1.22 kg/person/day). Lower median values were observed in South Asia, Sub-Saharan Africa, East Asia and the Pacific, as shown in Table 4. Among regions for which there were enough observations, Europe and Central Asia had the highest mean recycling and composting rate and the lowest median recovery gap. On the other hand, Latin America and the Caribbean and the Middle East and North Africa showed high potentially recoverable fractions, but relatively low current recovery rates. These differences are presented in Figure 5.

Table 4. Selected waste and recovery indicators by region

Region	Median daily MSW (kg/person/day)	Mean recoverable fraction (%)	Mean recycling and composting (%)	Median recovery gap (percentage points)
East Asia and the Pacific	0.94	79.43	31.52	44.01
Europe and Central Asia	1.22	74.30	38.04	35.58
Latin America and the Caribbean	0.90	83.92	4.97	81.70
Middle East and North Africa	0.95	88.06	13.39	74.00
North America	2.22	78.27	22.49	61.02
South Asia	0.43	83.45	13.26	63.21
Sub-Saharan Africa	0.45	70.83	3.80	54.20

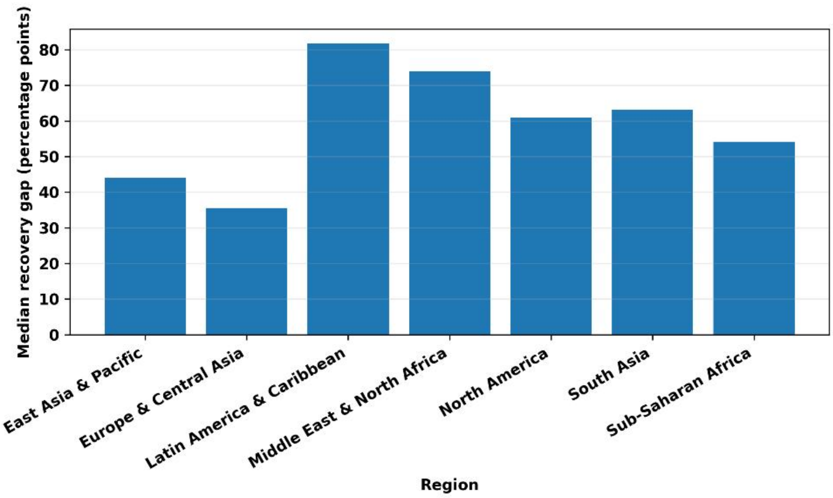

Figure 5. Median resource-recovery gap across geographical regions

3.6 Association Between Economic Scale And Waste Generation

Total municipal solid waste generation was found to be positively ranked with GDP (Spearman's $\rho = 0.886$, $n = 192$), and the relationship was strong. Its correlation with per-capita waste generation per day was not as strong, however ($\rho = 0.272$, $n = 192$). The results show that total waste production was significantly different in larger economies, whereas more per capita waste was produced in more populous and waste-managing economies with higher consumption levels.

3.7 Summary Of Results

By analysing the 215 countries, it was found that the amount of municipal solid waste generated per day is heterogeneous, with the average amount being 8.58 million tonnes and per capita generation increasing in richer countries. The major component was organic waste (41.73 %), followed by paper, plastic, glass and metallic components in significant quantities, with an estimated 78.91 % recoverable. Overall, however, the recycling and composting rate was just 28.62% with a recovery gap of 49.92 percentage points. There was no significant change in the primary disposal methods, open dumping and controlled landfilling. There was a strong linkage between GDP and overall waste generation, and the regression model accounted for 62.8% of the variation of overall waste generation, with GDP being the significant predictor.

4. DISCUSSION

The results illustrate significant differences in the amount, composition and treatment of municipal solid waste across the world, as well as in the recovery of resources from waste. The mean country waste generation of 8.58 million tonnes/year was much higher than the median value of 1.77 million tonnes/year, reflecting a significant skewness in the distribution profile with a relatively small number of countries with high population size and economic size generating disproportionately large amounts of municipal waste.

This income-gap pattern is further evidence of socio-economic disparities in waste production. The amount of waste per person per day rose from 0.44 kg in low-income countries to 1.43 kg in high-income countries. This is a characteristic of more prosperous economies and involves an increase in purchasing power, use of packaged products, shorter product lifecycles and more disposable consumption patterns. However, most developed nations have better collection and treatment facilities, while developing nations may have more rapid waste growth than the development of waste collection and treatment facilities. Despite a rise in policy interest, the institutional and technical barriers can still delay the uptake of the circular economy (Ezeudu et al., 2021).

Food and other organic material were the highest proportion, making up an average of 41.73% in waste composition analysis. This discovery shows great potential for composting and anaerobic digestion, especially in nations where organic waste is being dumped in landfills or open dumps. Biological treatment may lead to methane reduction, yield soil amendments and produce renewable energy. In cases where digestate can be recycled and utilized as valuable products, additional value may be achieved by anaerobic digestion. In addition to digestate composting, biological processes can be used to recover nutrients and produce valuable biomass, as evidenced by research on the nutrient-rich digestate (Fuentes-Grünewald et al., 2021).

The other significant portion of municipal waste consisted of dry recyclables such as paper, plastic, glass and metals. The presence of these helped to achieve an estimated potential recoverable fraction (PRF) of 78.91%, but the mean combined recycling and composting rate was just 28.62%. Due to the persistence, value and leakage of plastic, recovery of plastics is particularly important. Regional studies of circular plastic systems indicate that policy fragmentation, weak collection, limited sorting facilities and unstable markets for plastics as secondary materials are still significant obstacles to plastics recovery (Rodríguez-Meza et al., 2026). Public participation is also crucial, as consumer choice, segregation at source and acceptance of recycled products have an impact on the effectiveness of the circular waste policies. In terms of behavioral change, digital evidence suggests that public attention and environmental attitudes can help change behavior as long as they are backed by reliable information and infrastructure.In the field of behavioral change, digital evidence shows that if public attention and environmental attitudes are backed by reliable information and infrastructure, then they can help change behavior (Huang et al., 2022).

The treatment results indicate persistence of reliance on controlled landfilling and open dumping and comparatively low use of recycling, composting and anaerobic digestion. The high mean open-dumping value is of particular concern since it means the uncontrolled disposal increases the risks of air pollution, water contamination, proliferation of diseases vectors and greenhouse gas emissions. The volume of residual waste to be disposed of could be reduced, but the type of technology should be based on the characteristics of the waste, the moisture content, calorific value, emission-control capacity, financing and institutional conditions in the area (Farooq et al., 2021). Incineration should, therefore, not be seen as a panacea for all waste management problems, particularly in regions where wet organic waste is the primary waste stream and source separation is not extensive. The results were also helpful in informing diversification of recovery pathways. The biohydrometallurgical technology can be used for the recovery of metals from specialised waste streams, but in the case of electronic waste, it is not possible to collect it as part of a mixed municipal waste stream, but rather as a separate stream and treated under technically controlled conditions (Magoda & Mekuto, 2022). Other wastes can be turned into value-added products, as is the case with waste cooking oil used in modified bituminous (Uz & Gökalp, 2020). The broader models of circular resources, such as reusing treated wastewater in constructed wetlands, also demonstrate how waste products can be converted to useful resources in environmental sectors (Lekshmi et al., 2020).

These examples illustrate that circularity is not limited to traditional recycling processes and involves multi-sectoral material use strategies. The study is not about harmful effects to human health directly, but from molecular research, we know that certain environmental exposures that are hazardous may result in serious biological effects. Examples include the involvement of cellular signalling and metabolic changes in arsenic-related pulmonary fibrosis, but these biomedical data are not comparable with the data obtained from the management of municipal waste (Wang et al., 2021).

CONCLUSION

This study shows that there are significant differences in the amount of MSW generated, composition of MSW, treatment and recovery performance of MSW between countries, regions and income groups. The results indicate that in general, the countries with a higher economic development produce more waste per capita, and many developing economies are experiencing a sharp rise in waste production without a corresponding expansion in waste collection, segregation, treatment and recovery facilities. The greatest amount of municipal solid waste was organic waste, and significant amounts of paper, plastic, glass, and metals were identified. The material streams signify considerable potential for composting, anaerobic digestion, recycling and special resource recovery systems. Although the high potential PFR, the recovery rate of recycling and composting was still relatively low, resulting in a large PFR gap. The reliance on landfills and open burning in the dumpster also shows the lack of waste-to-secondary resource conversion. Enhancing the source segregation, expanding the use of biological treatment, building recycling markets, engaging informal workers, selecting proper WtE technologies and engaging more citizens are crucial to progress towards circular municipal waste management. The policy should also consider the local composition of waste, income situation, and institutional capacity, instead of using any universal solutions. In general, a data-driven circular economy can aid in better planning, decrease environmental stress, increase material efficiency and convert municipal waste into an economic resource.

REFERENCES

1. Abubakar, I. R., Maniruzzaman, K. M., Dano, U. L., AlShihri, F. S., AlShammari, M. S., Ahmed, S. M. S., ... & Alrawaf, T. I. (2022). Environmental sustainability impacts of solid waste management practices in the global South. International journal of environmental research and public health, 19(19), 12717.
2. Alam, O., & Qiao, X. (2020). An in-depth review on municipal solid waste management, treatment and disposal in Bangladesh. Sustainable Cities and Society, 52, 101775.
3. Arman. (2020). What a waste global dataset: Solid waste management statistics from 330 cities [Data set]. Kaggle. https://www.kaggle.com/datasets/mannmann2/what-a-waste-global-dataset
4. Ceraso, A., & Cesaro, A. (2024). Life Cycle Sustainability Assessment of municipal solid waste management systems: A review. Journal of Environmental Management, 368, 122143.
5. Chen, D. M. C., Bodirsky, B. L., Krueger, T., Mishra, A., & Popp, A. (2020). The world's growing municipal solid waste: trends and impacts. Environmental research letters, 15(7), 074021.
6. Ezeudu, O. B., Agunwamba, J. C., Ugochukwu, U. C., & Ezeudu, T. S. (2021). Temporal assessment of municipal solid waste management in Nigeria: prospects for circular economy adoption. Reviews on environmental health, 36(3), 327-344.
7. Farooq, A., Haputta, P., Silalertruksa, T., & Gheewala, S. H. (2021). A framework for the selection of suitable waste to energy technologies for a sustainable municipal solid waste management system. Frontiers in Sustainability, 2, 681690.
8. Fernando, S. J., & Zutshi, A. (2023). Municipal solid waste management in developing economies: A way forward. Cleaner Waste Systems, 5, 100103.
9. Fuentes-Grünewald, C., Gayo-Peláez, J. I., Ndovela, V., Wood, E., Kapoore, R. V., & Llewellyn, C. A. (2021). Towards a circular economy: a novel microalgal two-step growth approach to treat excess nutrients from digestate and to produce biomass for animal feed. Bioresource technology, 320, 124349.
10. Huang, H., Long, R., Chen, H., Sun, K., & Li, Q. (2022). Exploring public attention about green consumption on Sina Weibo: Using text mining and deep learning. Sustainable Production and Consumption, 30, 674-685.
11. International Solid Waste Association. (2024). Global waste management outlook 2024: beyond an age of waste, turning rubbish into a resource.
12. Khan, S., Anjum, R., Raza, S. T., Bazai, N. A., & Ihtisham, M. (2022). Technologies for municipal solid waste management: Current status, challenges, and future perspectives. Chemosphere, 288, 132403.
13. Küfeoğlu, S. (2024). Waste management emissions. In Net zero: Decarbonizing the global economies (pp. 555-611). Cham: Springer Nature Switzerland.
14. Lekshmi, B., Sharma, S., Sutar, R. S., Parikh, Y. J., Ranade, D. R., & Asolekar, S. R. (2020). Circular economy approach to women empowerment through reusing treated rural wastewater using constructed wetlands. In Waste Management as Economic Industry Towards Circular Economy (pp. 1-10). Singapore: Springer Singapore.
15. MacArthur, E. (2021). Universal circular economy policy goals. Ellen MacArthur Foundation.
16. Magoda, K., & Mekuto, L. (2022). Biohydrometallurgical recovery of metals from waste electronic equipment: current status and proposed process. Recycling, 7(5), 67.

17. Mandpe, A., Paliya, S., Gedam, V. V., Patel, S., Tyagi, L., & Kumar, S. (2023). Circular economy approach for sustainable solid waste management: A developing economy perspective. Waste Management & Research, 41(3), 499-511.
18. Morseletto, P. (2020). Targets for a circular economy. Resources, conservation and recycling, 153, 104553.
19. Nanda, S., & Berruti, F. (2021). Municipal solid waste management and landfilling technologies: a review. Environmental chemistry letters, 19(2), 1433-1456.
20. Neumeyer, X., Ashton, W. S., & Dentchev, N. (2020). Addressing resource and waste management challenges imposed by COVID-19: An entrepreneurship perspective. Resources, Conservation and Recycling, 162, 105058.
21. Pires, A., Martinho, G., Rodrigues, S., & Gomes, M. I. (2019). Sustainable solid waste collection and management.
22. Plan, C. E. A. (2020). For a cleaner and more competitive Europe. European Commission (EC): Brussels, Belgium, 28.
23. Priyadarshini, P., & Abhilash, P. C. (2020). Circular economy practices within energy and waste management sectors of India: A meta-analysis. Bioresource Technology, 304, 123018.
24. Rodríguez-Meza, L. R., Romero-Perdomo, F., & González-Curbelo, M. Á. (2026). Examining Latin America's Transition to a Circular Economy for Plastics. Environmental Management, 76(2), 65.
25. Uz, V. E., & Gökalp, İ. (2020). Sustainable recovery of waste vegetable cooking oil and aged bitumen: Optimized modification for short and long term aging cases. Waste Management, 110, 1-9.
26. Wang, P., Xiao, T., Li, J., Wang, D., Sun, J., Cheng, C., ... & Liu, Q. (2021). miR-21 in EVs from pulmonary epithelial cells promotes myofibroblast differentiation via glycolysis in arsenic-induced pulmonary fibrosis. Environmental Pollution, 286, 117259.