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MUNICIPAL SOLID WASTE DYNAMICS AND SUSTAINABLE MANAGEMENT IN TAMIL NADU, INDIA

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ABSTRACT:
Municipal Solid Waste (MSW) management has become a major environmental and public health challenge in rapidly urbanizing cities due to increasing population, changing consumption patterns, and expanding urban activities. This study analyzed the long-term trends in MSW generation, population–waste relationship, waste composition, and current waste management challenges in Coimbatore City Municipal Corporation, Tamil Nadu, India, based on municipal records spanning the period 2000–2025. Waste generation dynamics and the relationship between population growth and waste generation were analyzed using trend analysis, compound annual growth rate (CAGR), per capita waste generation analysis, and linear regression. The results showed that MSW generation rose from 350 TPD in 2000 to 1237 TPD in 2025 with CAGR of 5.18% while the population growth was 3.71%. In addition, during the study period, per capita waste generation rose from 0.38 kg person-1 day-1 to 0.54 kg person-1 day-1, suggesting that the generation of waste is greater than the growth of population. The regression analysis showed a high positive correlation between population and waste generation (R^2 = 0.9185). Waste composition analysis revealed that 68.21% of the waste stream was made up of biodegradable waste, giving significant potential for composting and biomethanation. But, the underutilisation of treatment facilities, poor recovery of resources and the presence of legacy waste in the Vellalore dump site are still major problems. The study highlights the importance of strengthening source segregation, decentralised processing of organic waste, increasing recycling, and material recovery, and decreasing landfill dependency for sustainable MSW management in urban areas.

KEYWORDS: Biodegradable waste; Coimbatore; Municipal Solid Waste; Sustainable Waste Management; Waste generation trend

INTRODUCTION

Municipal Solid Waste management is one of the most critical environmental and sustainability challenges in the urban areas of the world, especially in fast-growing cities. About half of the world's population is already living in urban areas, and this number is expected to rise to 68% by 2050, with nearly 90% of the increase in urban populations in Asia and Africa [1]. In 2016, the estimated global MSW generation was 2.01 billion tonnes while it is projected to reach 3.40 billion tonnes in 2050 [2]. Lack of waste management is a cause of environmental degradation, greenhouse gas emissions, public health threats and a barrier to the achievement of Sustainable Development Goals (SDGs) 11 (Sustainable Cities and Communities) and 12 (Responsible Consumption and Production) (3). Hence, a plethora of research focused on circular economy the concept focusing on waste minimisation, recycling and resource recovery to foster environmental sustainability [4,5].

Global projections point that India, China and Nigeria will experience around 35% of global urban population growth between 2018 and 2050[1], a trend that is expected to substantially increase MSW generation and place additional pressure on urban environmental management systems. In India, MSW management has been a key challenge of producing over 160,000 MT of municipal waste per day with the treatment and resource recovery facilities being inadequate in many cities (6). Critical issues include lack of source segregation, inadequate recycling facilities and increased pressure on collection and disposal facilities [7,8]. Comparative assessments of waste management systems across cities have shown that governance quality, financial sustainability, and public participation are critical determinants of effective MSW management [9]. Recent reviews have highlighted limited processing capacity, and excessive dependence on landfill remains major challenges for sustainable MSW management in Indian cities [10,11]. To overcome these problems, the Solid Waste Management Rules, 2016 have been framed that include source segregation, door to door collection and scientific processing of municipal waste by Ministry of Environment, Forest and Climate Change (2016).The effective implementation of the standards set under SWM rules has led to successful exemplars like Indore, which demonstrates that through sustained source segregation, scientific processing, effective governance, and the active involvement of citizens, the outcomes of municipal solid waste management can be significantly enhanced — offering much to learn for other fast-growing cities.

In a nationwide assessment of urban cleanliness taking into account parameters including sanitation and solid waste management, Indore was recognized as the leading city in 2024-25, while Coimbatore ranked 28th among million plus populated cities [12]. Although Indore and Coimbatore generated a similar quantity of MSW approximately ranging from 1200 to 1300 TPD, Indore performs well in waste handling but Coimbatore still faces challenges in that.

Coimbatore City Municipal Corporation (CCMC) being one of the major industrial, commercial and educational centres in India has seen a significant demographic and economic growth over the last two decades. In 2025 population of the city is around 2.29 million and the amount of MSW produced daily is roughly 1,237 tonnes.The challenges in management of MSW in Coimbatore corporation are lack of proper source segregation, comparatively low scientific processing of waste and more legacy waste at Vellalore dumpsite. Comprehensive studies that combine trends in waste generation, waste growth dynamics, waste composition and challenges in current waste management are still limited. This lack of knowledge is limiting the capacity of policy makers to make informed predictions about future needs for infrastructure, recognize opportunities for resource recovery, and create sustainable waste management solutions.

The present study therefore aims to evaluate the trends of MSW generation, waste composition and challenges in current waste management in Coimbatore City Municipal Corporation (CCMC) based on waste data obtained from 2000 to 2025. The results are significant to develop an evidence base for sustainable management of MSW and resource recovery planning for informed policy making in CCMC, and also insights for other rapid urbanizing cities in developing countries.

CONCEPTUAL FRAMEWORK

The conceptual framework (Fig.1) depicts the systematic approach in this study to analyse the dynamics of MSW and facilitate sustainable management of MSW in Coimbatore City Municipal Corporation. It integrates the main factors that create waste (population growth, urbanisation, economic growth, consumption patterns) and municipal data (amounts of waste collected) with analysis tools of trend, per capita, linear regression to inform sustainable urban planning and sustainable waste management.

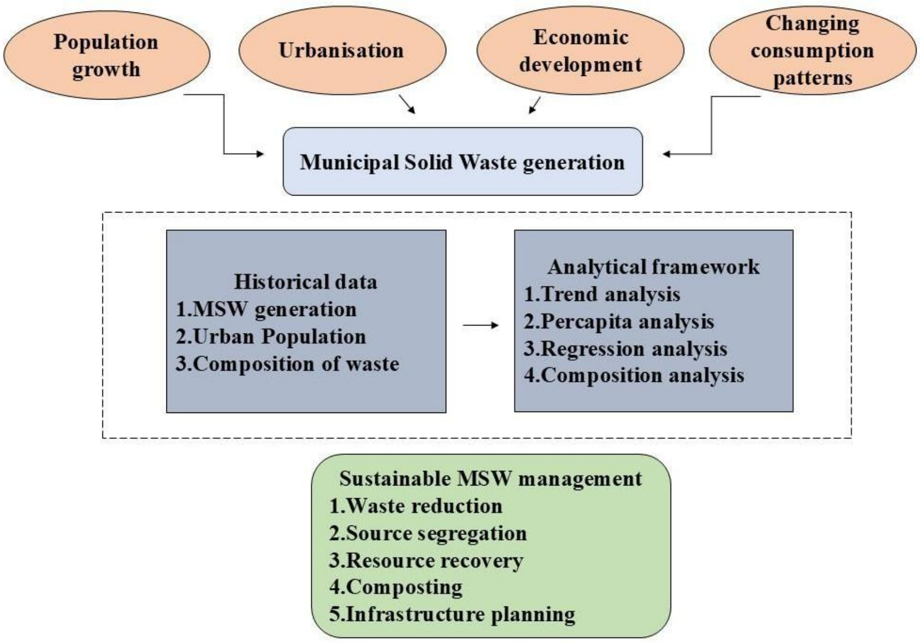


Fig 1. Conceptual framework for analysing MSW dynamics and sustainable management in CCMC

MATERIALS AND METHODS

Study Area

The study was conducted in Coimbatore City Municipal Corporation (CCMC) in the state of Tamil Nadu, India. The study area lies within the zone of 10°55′N to 11°05′N latitude and 76°55′E to 77°05′E longitude with an area of around 257 km². Coimbatore is the second largest urban agglomeration in Tamil Nadu after Chennai and it serves as major industrial and commercial centre in state. Figure 2 shows the geographical location of the study area.

Coimbatore has experienced a remarkable urbanisation, rapid industrialisation and population growth in the past 20 years, resulting in increased demand for its municipal services, including solid waste collection.The city's demographic and economic development and associated changes of consumption patterns provide an appropriate case study to examine the long-term changes in the generation of MSW and their implications for sustainable urban waste management.

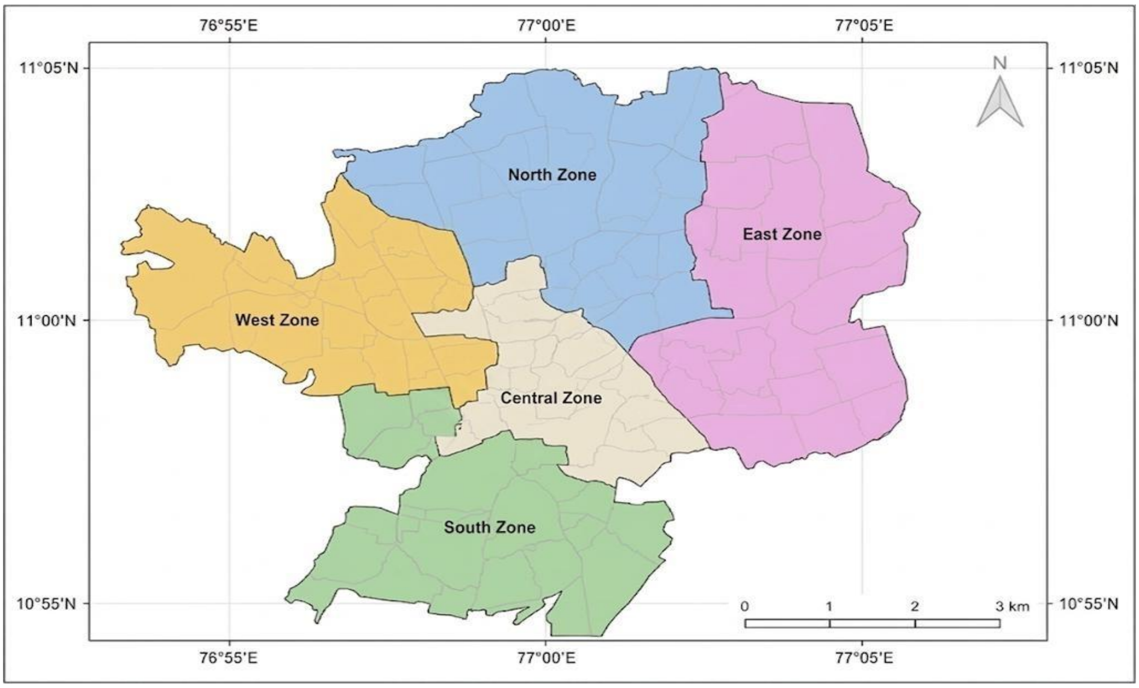


Fig 2. Location map of the study area showing Coimbatore City Municipal Corporation (CCMC), Tamil Nadu, India.

Data Source And Compilation

The study used secondary data collected from Solid Waste Management Department, CCMC. Records were collected, compiled and validated annually for consistency from 2000 to 2025 and analysed using Microsoft Excel 2021.

Data collected include population statistics, average daily municipal solid waste generation (tonnes per day, TPD) and material-wise waste composition data and processing facilities. Waste composition information comprised biodegradable waste, plastic, paper, metal, glass, textile and inert fractions. In the study, waste generation values are annual average daily MSW generated from municipal records.

ANALYTICAL METHODS

Trend in MSW Generation

Temporal changes in MSW generation and population in CCMC limit during 2000–2025 were evaluated using historical annual records. Trend analysis was used to examine direction and pattern of change over time, while Compound Annual Growth Rate (CAGR) was estimated to quantify average annual rate of growth over the study period. CAGR was calculated using:

$$CAGR = \left(\frac{V_n}{V_0}\right)^{1/n} - 1 \text{ …………………… (1)}$$

where V_n represents final value, V_0 represents initial value and n represents number of years.

Per Capita Waste Generation was estimated as

$$CWG_i = \frac{\textit{Total } MSW_i \textit{ generated}}{\textit{Urban Population}_i} \text{………………… (2)}$$

i=year (2000-2025)

where PCWGi represents Per Capita Waste Generation during ith year (kg $person^{-1}$ day^{-1}), MSWi represents Municipal Solid Waste generated per day during ith year (kg day^{-1}), and Urban Populationi represents total population under CCMC limits during ith year.

Regression Analysis Between Population and Waste Generation

Linear regression analysis was performed to evaluate the relationship between population growth and municipal solid waste generation [13]:

$Y = a + bX + \varepsilon$...(3)

where Y represents MSW generation (TPD), X represents population, a is the intercept, b is the regression coefficient and ε is the random error term. The coefficient of determination (R^2) was used to assess the strength of the relationship between population and MSW generation.

Waste Composition Analysis

Material-wise waste composition was analysed for biodegradable, plastic, paper, metal, glass, textile and inert fractions. The percentage contribution of each waste fraction was calculated following standard waste characterization procedures [6,14]:

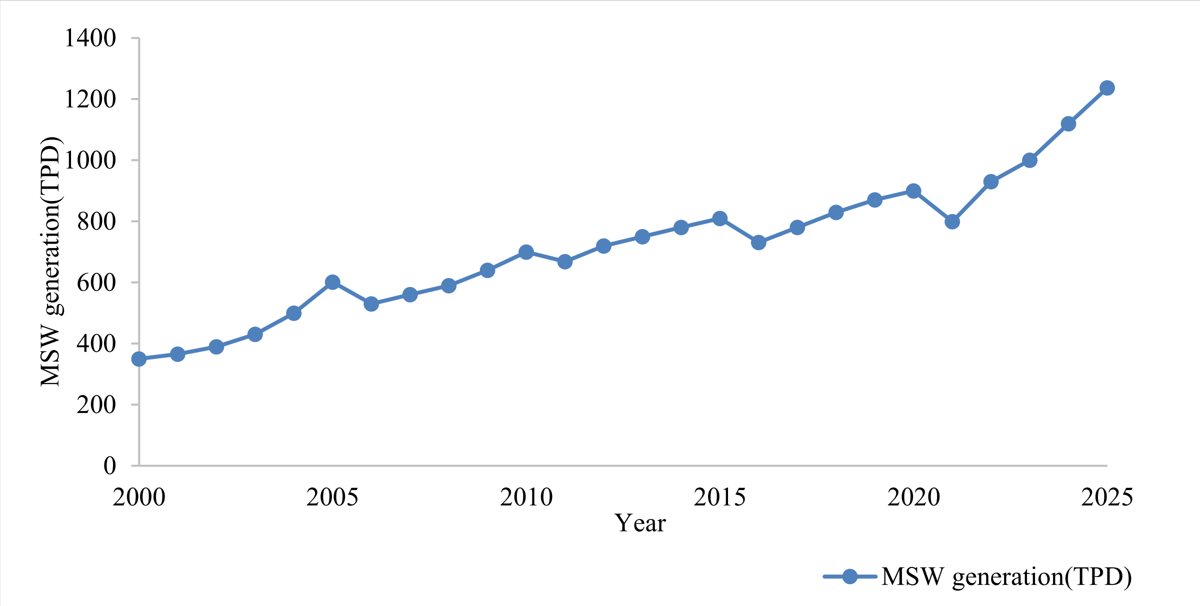
$$\text{Composition} = \frac{Wi}{Wt} \times 100 \text{ .... (4)}$$

where W_i represents the quantity of an individual waste generated (TPD) and W_t represents the total quantity of MSW generated (TPD).

RESULT AND DISCUSSION

Trend in MSW Generation

Generation of MSW shows a definite upward and consistent trend in CCMC (Fig. 3). The annual average daily waste generation has gone up from 350 TPD in 2000 to 1237 TPD in 2025, which is a total increase of around 253.4% over the 26-year period of study. There were some slight fluctuations from year-to-year, but the overall trend remains positive. This observed growth in waste production is similar to the results found in other fast growing urban areas of the world.
In 2021, there was a temporary reduction in the amount of MSW produced. This decline could be linked to the negative impacts of the COVID-19 pandemic, such as restrictive mobility, economic activity and disrupting economic operations. The drop was temporary, though, as generation of waste bounced back strong after 2021, following its historical pattern of rising every year. The overall graph indicates a steady rise in the generation of MSW in Coimbatore, even though there are some minor fluctuations.In the same timeframe, the population grew from 0.92 million to 2.29 million,



showing significant population growth certainly due to urbanisation. Notably, waste generation increase outpaced population growth rate makes a sensible view.

Fig 3. Temporal trend of average daily municipal solid waste generation in Coimbatore City Municipal Corporation (CCMC), 2000–2025 (Source: CCMC Solid Waste Management Department)

CAGR of the last 26 years (2000-2025) for both population and MSW of CCMC. Table 1 indicate that rate of MSW generation grew 5.18% per annum while population grew 3.71% per annum. The increase in municipal waste was not just due to population growth but also to a change in consumption patterns, lifestyle change and economic development within the city, as seen in the higher growth rate in municipal waste.

Table 1. CAGR analysis of MSW generation and population in Coimbatore City Municipal Corporation, 2000–2025

Indicator	Base Value (2000)	Final Value (2025)	CAGR (%)
Total MSW Generation	350 TPD	1,237 TPD	5.18
Population	9,20,000	22,88,042	3.71

Source: Computed from CCMC Solid Waste Management Department records (2000–2025). CAGR = Compound Annual Growth Rate; TPD = Tonnes per day.

The Per Capita MSW generation in CCMC has grown from 0.38 kg per person per day in 2000 to 0.54 kg per person per day in 2025 with an increase of about 42.1% during the study period (Fig. 4). This rise reflects the effect of population growth but also of changes in the consumption patterns and waste generation behaviour of individuals.

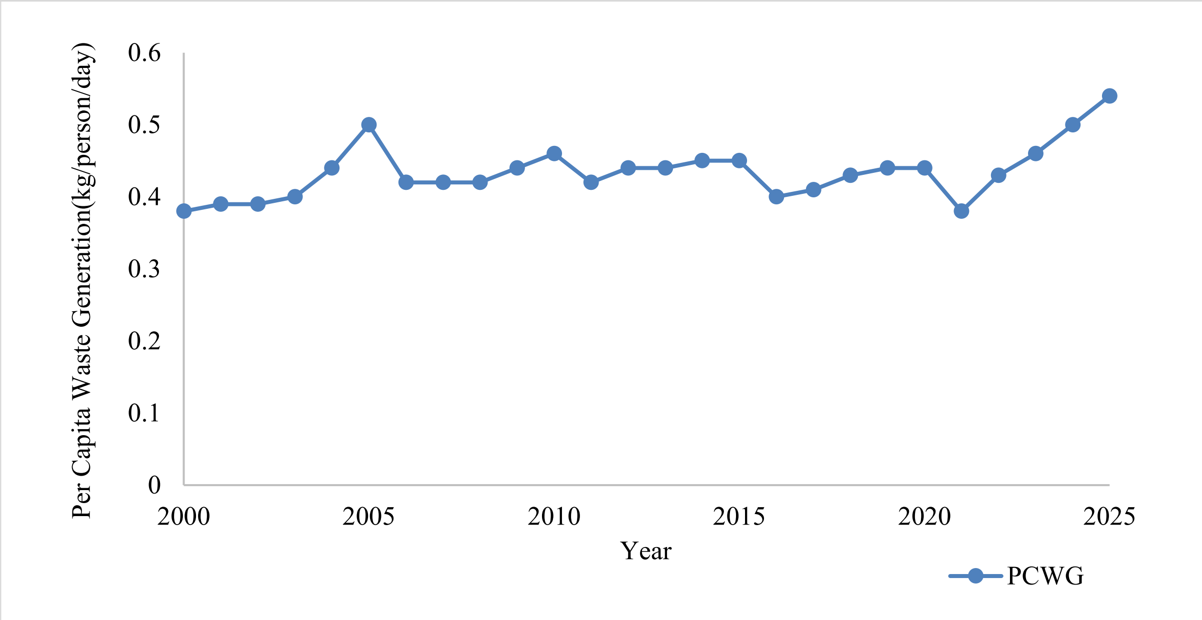


Fig 4. Per capita municipal solid waste generation trend in Coimbatore City Municipal Corporation (CCMC), 2000–2025 (Source: CCMC Solid Waste Management Department)

The increase in the growth rate of MSW as compared to population growth indicates that the increase in waste generation in Coimbatore is not solely due to population growth but also due to other factors such as urbanisation, economic development, lifestyle changes, and increased consumption of packaged products. The same trend has been observed in fast-growing urban areas across the globe, with increasing per capita waste production coinciding with socioeconomic development [2,4,15]. The results suggest waste generation has intensified over time and there is a need to implement integrated waste management systems focusing on waste minimisation, source segregation, recycling and resource recovery, to mitigate environmental impacts and enhance resource efficiency [16,17].

Relationship Between Population Growth And MSW Generation

The relationship between population growth and MSW generation in CCMC was analysed by simple linear regression analysis (Fig. 5). Results showed that there was a strong positive correlation between population and waste generation during the period of study.

The coefficient of determination (R^2) of the regression model was 0.9185, denoting that the model explains about 91.85% of the variation in MSW generation. The model was statistically significant ($F = 270.31$; $p < 0.001$), indicating that there was a strong relationship between the two variables. The regression equation that was fitted was:

$$\hat{Y} = -94.75 + 4.97 \times 10^{-4} X$$

where $\hat{Y}$ is the amount of MSW generated (TPD) and X is the urban population (number of persons). The regression co-efficient (4.97×10^{-4}) indicates that an increase of 1000 persons in the urban population is associated with an increase of approximately 0.497 tonnes of MSW per day, highlighting the positive influence of population growth on waste generation. Similar population–waste relationships have been reported in other rapidly urbanising cities, highlighting population growth as an important driver of municipal waste generation [2,4].

The high R2 shows that population growth was strongly related with increase in waste generation in Coimbatore. But the observed increase in quantity of waste is not solely attributed to population. Some of the other unexplained variation could be due to changes in consumption patterns, commercial activities, economic development and a few short-term disruptions, such as the temporary reduction in waste generation during 2021.

From a sustainable urban planning perspective, the strong relationship between population growth and waste generation highlights the importance of integrating waste management into broader urban development strategies. The increasing population will necessitate expansion of collection, processing and resource recovery system to maintain the sustainability of the MSW management system.

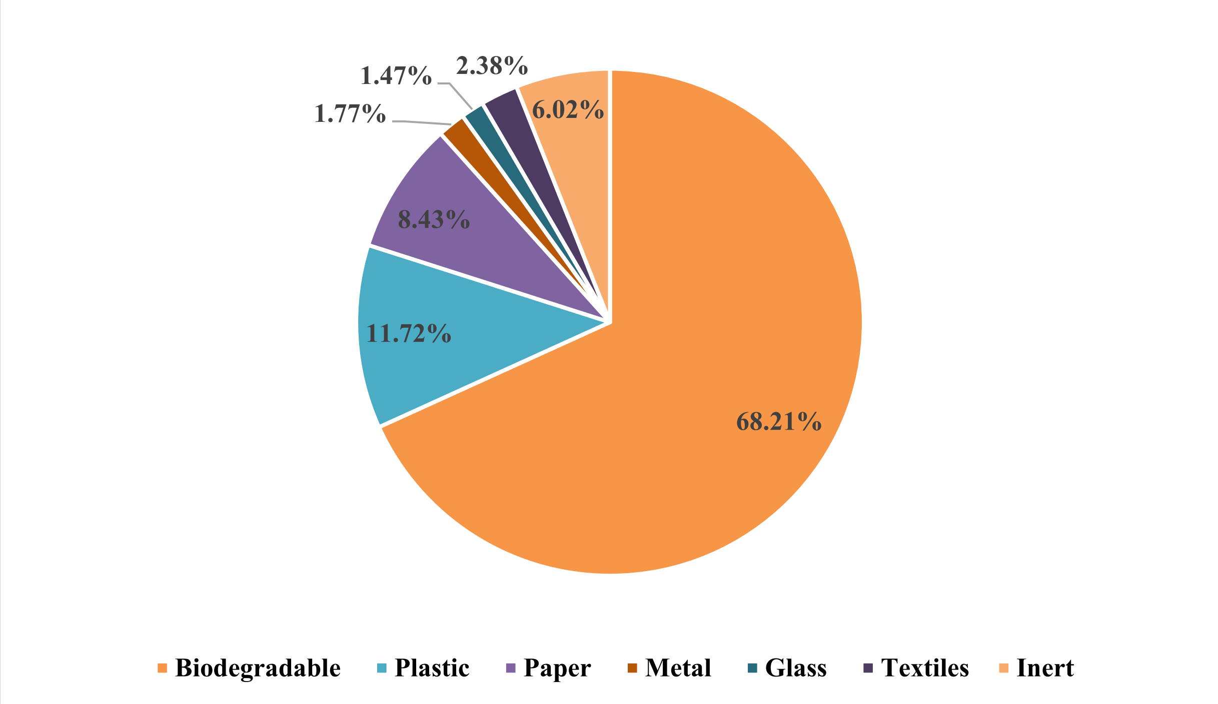


Fig 5. Regression between population and MSW generation in Coimbatore City Municipal Corporation (2000–2025). Each data point represents one calendar year from 2000 to 2025.

Material-Wise Composition Of MSW

The average material-wise composition of MSW generated in CCMC during 2021-2025 (Fig. 6) indicate that biodegradable waste occupies the highest percentage of the waste stream at 68.21% of total MSW followed by plastic (11.72%) and paper (8.43%). Comparatively small amounts of inert materials (6.02%), textiles (2.38%), metal (1.77%) and glass (1.47%) were also noticed.

Higher percentage of biodegradable waste is in alignment with the waste composition trend of many Indian cities where the major components of MSW are generally 50-70% organic [6,19,20]. The high rate of biodegradable waste shows that there is a high potential for recovering the resource through composting and biomethanation. The processing of biodegradable waste can lead to production of useful products like compost and biogas. In the municipal waste streams, which are dominated by organic wastes, similar studies have found that the technologies of biological treatment are important [5,14,21]. The results therefore

indicate the need to implement decentralized and centralized organic waste treatment systems in Coimbatore which serves as a great potential for sustainable urban development.

The average waste stream comprised 20.15% plastic and paper, presenting significant opportunities for material recovery and recycling. The increasing contribution of these fractions reflects changing urban consumption patterns and the growing use of packaged products [7]. There is scope for further improvement of recovery rates by strengthening source segregation practices and scaling up material recovery facilities, and by strengthening and improving the implementation of Extended Producer Responsibility (EPR) under the Solid Waste Management Rules, 2016.These measures will result in a reduction in the amount of recyclable materials entering the mixed waste stream [16,22,23].

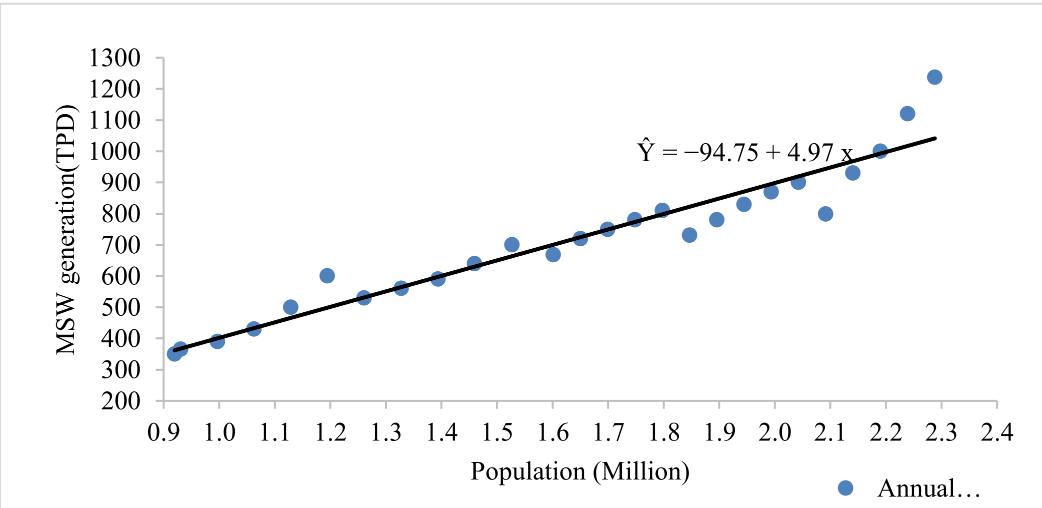


Fig 6. Average material-wise composition of MSW in Coimbatore City Municipal Corporation during 2021–2025. (Source: CCMC Solid Waste Management Department)

Challenges in Current MSW Management In CCMC

Although the corporation has implemented source segregation, door to door collection, and waste processing initiatives, certain gaps remain in achieving efficient resource recovery and sustainable waste management. One of the most significant issues in the current MSW management framework in Coimbatore is inadequate utilization of organic waste processing facilities. Although Micro Composting Centres (MCCs) are operational, their capacity utilisation remained low (15–22%) in recent years. This is especially important as waste composition analysis revealed that 68.21% of MSW is biodegradable, which implies high composting and biological treatment potential. Underuse of these facilities diminishes resource recovery and can lead to landfill disposal of biodegradable waste, which can cause greenhouse gas emissions and leachate.

The use of biomethanation technology is also underutilized. Biomethanation plants were not operating in 2024 and 2025, despite installed processing capacity, preventing the recovery of renewable energy and organic resources from biodegradable waste. This is an untapped opportunity to turn waste into renewable energy, biogas and minimize the negative environmental impact of disposal.

Landfill management remains a significant challenge in Coimbatore. Approximately 794,139 tonnes of legacy waste have accumulated at the Vellalore dumpsite. Despite the growth and development of Material Recovery Facilities (MRFs), amount of rejected wastes about 200 TPD going to landfill disposal demonstrates that source segregation and material recovery are not optimal. The lack of segregation lowers recycling efficiency and sends potentially recyclable material to disposal sites, adding to the strain on landfill systems. Furthermore, only 13% of incoming mixed waste is scientifically processed before disposal, limiting resource recovery and increasing reliance on landfill-based management.

Policy Implications For Sustainable MSW Management

Promoting Waste Reduction Through Economic And Regulatory Measures

The increasing waste generation in Coimbatore corporation indicates the need to shift policy attention from waste management to waste prevention. The Corporation should implement economic and regulatory instruments including pay-as-you-throw schemes for the bulk waste generators, support waste minimising businesses, green procurement in public institutions, waste audits in large commercial businesses etc. Waste at source can be further reduced by encouraging packaging reduction, the use of re-useable packaging and good product design for the environment. These measures would help de-couple waste production from urban expansion, reduce future waste management costs and decrease pressure on waste collection, processing and disposal infrastructure.

Strengthening Source Segregation And Decentralised Organic Waste Management

The city has made about 80% source segregation [24] and work needs to be done in terms of awareness programmes at ward level, incentive programmes for compliant households and commercial establishments and more stringent enforcement of source segregation rules for bulk waste generators. High percentage of biodegradable waste (68.21 Per cent) and low utilization of Micro Composting Centres (MCCs) highlight the need for mandatory source segregation and use of decentralised composting and biomethanation should be promoted in vegetable markets, hotels, institutions and residential communities to recover organic waste as much as possible and lower the amount of waste to be transported to disposal sites.

Improving Resource Recovery Through Circular Economy Approaches

The underutilisation of composting facilities and the continued generation of reject waste demonstrate that valuable resources are still being lost. Coimbatore needs to enhance the functioning of the Material Recovery Facilities, establish market linkages for recycled materials, and move towards better implementation of Extended Producer Responsibility for plastic packaging and other recyclable waste streams. The involvement of informal waste collectors in organised waste collection would further improve material recovery and contribute to the transition towards a circular economy [25].

Reducing Dependence On Landfills And Managing Legacy Waste

The presence of approximately 794,139 tonnes of legacy waste at the Vellalore dumpsite highlights the need to minimise future landfill disposal. Scientific remediation of legacy waste (eg. Biomining) should be prioritized, biodegradable waste diverted to composting and biomethanation facilities, and recycling of recoverable materials should be increased. These would help to minimise greenhouse gas emissions, reduce leachate production and reduce the environmental risks arising from long term waste storage.

Strengthening Community Participation And Sustainable Consumption

Increase in MSW production has outpaced population growth, so behavioral changes should be paired with infrastructure improvements. Public awareness campaigns, school and college outreach programmes, and resident welfare association collaborations can promote waste minimization, home composting, and conscious consumption. Incentive-based measures (e.g. recognition programmes for top-performing wards) could also encourage greater public involvement and sustained compliance.

The results show that source segregation, efficient use of existing treatment infrastructure, and enhancing recycling and decentralised organic waste management are essential to mitigate the growing volume of municipal solid waste in Coimbatore. Implementing these measures would enhance resource recovery, reduce reliance on landfills and minimise environmental impacts, thereby supporting more sustainable urban waste management in rapidly growing cities.

CONCLUSION

The study reveals that the generation of municipal solid waste has significantly increased in Coimbatore from 2000 to 2025, due to the synergetic impact of the simultaneous process of rapid urbanization, population growth and shifting consumption habits. The generation of MSW grew at a higher rate than the growth of the population, suggesting a trend of increasing per capita waste generation and strain on the waste management system. The waste composition analysis showed that biodegradable waste made up 68.21% of the municipal solid waste stream, presenting a high potential for composting and biological treatment. But the lack of full utilization of Micro Composting Centres, non-functional biomethanation plant and the piling of legacy waste at Vellalore dump site suggest that the existing infrastructure is not being used to its optimum capacity. While Coimbatore has made significant strides in source segregation and recycling programs, there is still room for enhanced processing efficiency and resource recovery to reduce the need for landfill disposal and its environmental costs. The overall findings of this study help to enhance the Sustainable Waste Management of CCMC and it gives practical tips for other cities which are facing environmental problems.

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CONFLICT OF INTEREST
The authors declare that there is no conflict of interest regarding the publication of this paper.

ETHICAL APPROVAL
This study was based exclusively on secondary data obtained from Coimbatore City Municipal Corporation (CCMC) and did not involve human participants, animals, clinical samples, or personal data. Therefore, ethical approval was not required.

CONSENT TO PUBLISH
All authors have read and approved the final version of the manuscript and consent to its publication.

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