

Recycling of Waste Materials Generated in the streets of Puducherry (Pondicherry), India

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ABSTRACT

Rapid urbanisation, tourism growth, and changing consumption patterns have made municipal solid waste (MSW) management a critical civic challenge in Puducherry (formerly Pondicherry), a Union Territory on India's south-eastern coast. This paper presents a systematic review of published research, government reports, and grey literature on the generation, composition, collection, and recycling of waste found on Puducherry's streets, situating local findings against national and global statistics. Sixty-one records were initially identified through structured searches of academic databases and institutional repositories; after removing duplicates and screening for relevance, 19 studies and reports met the inclusion criteria and were synthesised narratively following a PRISMA-informed protocol. Results show that Puducherry Urban Agglomeration generates approximately 350-530 tonnes of municipal solid waste per day, with a per-capita generation rate historically around 0.59 kg/capita/day, dominated by biodegradable material (about 65%) followed by paper, plastics, and other dry recyclables. Formal door-to-door collection and composting programmes coexist with a substantial informal recycling economy of waste pickers and scrap dealers who intercept dry recyclables before they reach dumpsites. Compared with global recycling rates below 20% and India's national processing rate of roughly 50-79%, Puducherry's performance is mixed: source segregation and NGO-led awareness programmes have improved outcomes in some wards, yet open dumping, leachate contamination near disposal sites, and incomplete segregation persist. The discussion identifies infrastructure, behavioural, and governance gaps and situates Puducherry within India's Swachh Bharat Mission trajectory. The review concludes that a scaled-up, decentralised, and formally integrated recycling model – combining source segregation, material recovery facilities, and legal recognition of informal waste workers – offers the most viable path to a circular waste economy for the city.

KEYWORDS

- Municipal Solid Waste • Recycling • Street Waste • Puducherry • Pondicherry
- Systematic Review • Circular Economy • Informal Waste Sector • India
- Swachh Bharat Mission

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INTRODUCTION

Solid waste management is one of the most persistent challenges facing rapidly urbanising cities in the developing world. As populations grow, incomes rise, and consumption patterns shift toward packaged and disposable goods, the volume and complexity of waste generated in public spaces — streets, markets, beaches, and commercial corridors — increases faster than the infrastructure required to manage it. Puducherry (colonially known as Pondicherry), the capital of the Union Territory of Puducherry, is a compact coastal city of historical, cultural, and touristic importance on India's Coromandel Coast. Its French colonial heritage, active tourism sector, growing resident population, and status as a relatively high per-capita-income Union Territory have combined to produce a waste stream that is both substantial in volume and demanding in composition.

Streets are a particularly visible and policy-relevant site of waste accumulation. Street waste in Puducherry originates from multiple overlapping sources: household spillover and illegal dumping, market and vendor debris, sweeping waste, construction and demolition debris, plastic litter from tourism and food vending, and organic matter from roadside trees and gardens. Unlike waste collected directly from households, street waste is frequently mixed, contaminated, and exposed to weather, which complicates downstream sorting and recycling. At the same time, streets are where much of India's informal recycling economy operates: waste pickers, itinerant buyers, and scrap dealers who recover paper, plastic, metal, and glass before it is landfilled.

This paper undertakes a systematic review of the available literature and institutional documentation on waste recycling in Puducherry's streets, with three objectives: (i) to synthesise what is empirically known about the generation, composition, and disposal of street-level municipal solid waste in the city; (ii) to characterise the formal and informal recycling systems operating in Puducherry and assess their effectiveness; and (iii) to benchmark Puducherry's performance against national (Indian) and global recycling and waste-management statistics, in order to identify the scale of the gap between local practice and international good practice.

MATERIALS AND METHODS

1. Review Design

This review followed a systematic, PRISMA-informed narrative synthesis approach, appropriate given the heterogeneity of study designs (quantitative waste-audit studies, qualitative stakeholder assessments, and administrative/government reports) found in the municipal solid waste literature on Puducherry, which precluded formal meta-analysis.

2. Search Strategy and Sources

Structured searches were carried out across academic and grey-literature sources, including Science Direct, Pub Med, Research Gate, Google Scholar, and institutional repositories, supplemented by government and multilateral sources: the Puducherry Local Administration Department, the Central Pollution Control Board (CPCB), the Ministry of Housing and Urban Affairs, the World Bank's "What a Waste" database, and the UNEP Global Waste Management Outlook 2024. Search terms combined "Puducherry" OR "Pondicherry" with "solid waste," "municipal waste," "recycling," "street waste," "waste segregation," and "informal waste sector." World and India-level statistics were drawn from the UNEP Global Waste Management Outlook (2024), World Bank "What a Waste 2.0," CPCB annual reports, and the Centre for Science and Environment's State of India's Environment in Figures (2024).

3. Eligibility Criteria

- **Inclusion:** peer-reviewed studies, theses, and institutional/government reports addressing MSW generation, composition, collection, or recycling in Puducherry/Pondicherry; comparative India- or world-level waste statistics used for benchmarking.
- **Exclusion:** studies focused solely on liquid/sewage waste, biomedical waste unrelated to street waste, or duplicate/overlapping datasets already captured in a more recent source.

4. Study Selection and Synthesis

An initial pool of 61 records was identified. After removing 14 duplicates, 47 records were screened by title and abstract, of which 24 were excluded as not specific to Puducherry or not addressing solid waste. Twenty-three

full texts were assessed for eligibility; 4 were excluded for insufficient methodological detail or lack of accessible data, leaving 19 sources retained for qualitative synthesis (12 peer-reviewed studies/theses on Puducherry MSW, 4 government/institutional reports, and

3 India/world-level statistical reports used for benchmarking). Data were extracted on waste quantity, composition, collection coverage, recycling/composting practices, informal-sector involvement, and reported challenges, then synthesised thematically.

5. Study Selection Summary

Table 1: Summary of the systematic screening process (PRISMA-informed)

Screening Stage	Records	Excluded	Reason for Exclusion
Records identified through database/registry search	61	—	—
After duplicate removal	47	14	Duplicate records across databases
Title/abstract screening	23	24	Not specific to Puducherry or not MSW-focused
Full-text assessment	19	4	Insufficient data / methodological detail
Studies included in synthesis	19	—	—

GLOBAL AND NATIONAL CONTEXT: WORLD STATISTICS ON WASTE AND RECYCLING

Understanding Puducherry's street-waste recycling performance requires benchmarking against global and national trends, since municipal recycling infrastructure, informal-sector integration, and policy stringency vary enormously by income level and region.

1. Global Waste Generation and Recycling Trends

- The world generates more than 2.01-2.3 billion tonnes of municipal solid waste annually (World Bank, UNEP GWMO 2024), a figure projected to rise to 3.8-4.0 billion tonnes by 2050 under a business-as-usual scenario.
- At least 33% of global MSW is not managed in an environmentally safe manner — openly dumped or burned rather than collected and treated.
- Global recycling performance remains low: less than 20% of the world's waste is recycled annually, with the majority still landfilled or openly dumped.
- Nearly three billion people worldwide lacked access to basic waste collection services as of 2020, with collection rates below 40% in Central/South Asia and Sub-Saharan Africa.
- Global plastic waste generation was approximately 360 million tonnes in 2020, projected to reach roughly 500 million tonnes by 2030; global e-waste reached about 62 million tonnes in 2022, projected to exceed 80 million tonnes by 2030.

- The annual cost of waste mismanagement is projected to nearly triple, from about US\$252 billion in 2020 to US\$640 billion by 2050, if current trends continue unaddressed.

2. India's National Waste Profile

- India generates an estimated 160,000+ tonnes of municipal solid waste per day (CPCB), with per-capita generation historically around 0.34 kg/person/day, projected to rise toward 0.7 kg/person/day by 2025 — a trajectory that would move India past Germany, Japan, and Brazil in total waste generation.
- Roughly 21% of India's MSW (over 30,000 tonnes/day) remains unprocessed and ends up in landfills or open dumpsites; national processing/treatment shares have nonetheless risen substantially since 2016 under the Swachh Bharat Mission.
- Only about 17% of India's identified legacy-waste dumpsites have been remediated, with plans in motion for a further 26% and no action yet on 56%; states such as West Bengal, Mizoram, and Ladakh process less than half of their generated MSW.
- India's informal recycling sector — waste pickers and scrap dealers — is estimated to intercept and recycle the majority of high-value dry recyclables (plastics, metals, paper) that would otherwise be landfilled, effectively substituting for missing formal material-recovery infrastructure in most cities.

- Best-performing Indian cities (e.g., Indore, Surat) demonstrate that 100% source segregation and door-to-door collection are achievable, processing close to

100% of daily waste through multi-bin segregation (up to six categories) and decentralised treatment.

3. Comparative Snapshot

Table 2: Comparative snapshot of waste generation and recycling indicators – global, national, and local (Puducherry) scales

Indicator	Global	India (National)	Puducherry (Local)
Annual MSW generation	~2.01-2.3 billion tonnes	~58-60 million tonnes (160,000+ t/day)	~530 t/day (Puducherry Urban Agglomeration)
Per-capita generation	~0.74 kg/person/day (avg.)	~0.34 kg/person/day (rising toward 0.7 by 2025)	~0.59 kg/capita/day (2008 estimate)
Share recycled (formal + informal)	<20%	Majority of dry recyclables via informal sector; ~50-79% overall processed	Partial – composting + informal recycling; no comprehensive city-wide rate published
Waste mismanaged / unprocessed	~33%	~21% (30,000+ t/day landfilled untreated)	Open dumping persists at Karuvadikuppam and other sites
Collection coverage	~70% (below 40% in South Asia average)	Improving under Swachh Bharat Mission	Door-to-door collection instituted since 2015 via private contractor

RESULTS

1. Waste Generation and Composition in Puducherry

Longitudinal data collated from municipal assessments show that MSW generation in Puducherry city rose from approximately 265 tonnes/day in 2003 to 370 tonnes/day in 2008, corresponding to a per-capita generation factor of about 0.59 kg/capita/day. More recent administrative figures from the Local Administration Department of Puducherry indicate that the wider Puducherry Urban Agglomeration Area (PUAA) – comprising the Pondicherry and Oulgaret Municipalities together with parts of the Ariyankuppam and Villianur Communes, with a population of approximately 6.54 lakh per the 2011 Census – now generates around 350 tonnes/day within the PUAA and roughly 530 tonnes/day across all five municipalities and ten commune panchayats of the Union Territory.

Composition analysis of samples drawn from the main dumping yard at Karuvadikuppam found that biodegradable material accounted for approximately 65% of MSW by weight, with the remaining 35% classified as non-biodegradable. Within this profile, yard/garden waste was the single largest category (38.4%), followed by paper (30%) and plastics (10.4%), with the remaining 21.2% comprising glass, metals, textiles, and miscellaneous debris. Street-level waste –

sweepings, market debris, and litter – draws disproportionately from the paper, plastic, and yard-waste fractions, since these are the materials most visibly discarded or blown into public rights-of-way.

2. Collection, Segregation, and Formal Recycling Systems

Puducherry's municipalities have adopted door-to-door collection with source segregation as their principal collection model. Since September 2015, collection and transportation across the Puducherry Urban Agglomeration Area has been contracted to a private operator (Swachatha Corporation) for a ten-year term following a competitive e-tender process. Organic waste is directed toward aerobic composting and vermi-composting facilities, while non-biodegradable dry waste is intended to be picked up separately and channelled into recycling streams. A waste-characterisation study commissioned by the Local Administration Department found a gross calorific value of MSW ranging from approximately 3,830 to 6,342 kcal/kg depending on waste type, informing a proposed waste-to-energy component with an expected generation capacity of around 6 MW.

Nonetheless, multiple assessments identify persistent shortcomings in the existing system: incomplete segregation at source, insufficient processing capacity relative to generation, and continued reliance on open dumping at legacy sites. A siting study for a sanitary landfill

evaluated 17 candidate locations against criteria including area, bedrock depth, slope, and groundwater depth, and found that only 3 met the suitability threshold; the same study documented elevated concentrations of heavy metals (iron, chromium, copper, zinc), high total hardness, and elevated coliform counts in leachate and groundwater near existing dumpsites, indicating ongoing environmental contamination from inadequately engineered disposal.

3. Informal Recycling and Civil-Society Involvement

A substantial share of dry-recyclable recovery in Puducherry, as in most Indian cities, occurs through the informal sector — itinerant waste pickers, scrap collectors, and small buy-back dealers who intercept paper, plastic, metal, and glass either directly from streets and dumps or through door-to-door purchase, before these materials would otherwise reach a landfill. This mirrors the national pattern in which informal workers are widely credited with recovering the majority of India's high-value dry recyclables in the absence of comprehensive formal material-recovery infrastructure.

Non-governmental organisations have also played a documented role in strengthening residential and street-level waste segregation in Puducherry. A case study of the NGO Shuddham, operating within Puducherry town, found that its awareness and education programmes promoted source separation, strengthened door-to-door collection, converted recovered waste into raw material for reuse, and created additional livelihood opportunities — illustrating a public-NGO partnership model for improving segregation rates ahead of downstream recycling.

4. Environmental and Public-Health Pressures

Rapid urbanisation combined with a growing tourism sector has strained Puducherry's waste infrastructure. Reported consequences include overflowing collection points, persistent open dumping in and around the city, and degraded environmental quality near disposal sites, consistent with contamination findings from the landfill-siting assessment described above. These pressures are compounded by the city's coastal setting, where mismanaged street waste has a comparatively short pathway to marine and estuarine environments.

DISCUSSION

1. Puducherry in Comparative Perspective

Set against global and national benchmarks, Puducherry's waste-management trajectory is neither an outlier of crisis nor a model of excellence — it occupies a middle position typical of mid-sized Indian Union Territory capitals. Its historical per-capita generation rate (~0.59 kg/capita/day) already exceeds India's national average (~0.34 kg/person/day, rising toward 0.7 by 2025), plausibly reflecting the city's above-average per-capita income, tourism-driven consumption, and urban density. Its reliance on a hybrid model — municipal door-to-door collection paired with an uncoordinated but functionally significant informal recycling sector — mirrors the pattern documented nationally, where informal waste pickers are frequently described as the reason India's effective recycling rate is not considerably lower than the formal system alone would achieve.

2. Strengths of the Current System

- Institutionalised door-to-door collection with a decade-long private-sector contract provides continuity that many Indian municipalities lack.
- Composting (aerobic and vermi-composting) offers a low-technology, locally appropriate route for the ~65% biodegradable fraction of the waste stream.
- NGO partnerships (e.g., Shuddham) demonstrate that community-level awareness campaigns can durably shift segregation behaviour and create recycling-linked livelihoods.
- A waste-characterisation study with calorific-value data lays groundwork for a complementary waste-to-energy pathway for non-recyclable residual waste.

3. Persistent Gaps

- Incomplete source segregation remains the binding constraint, consistent with the experience of lower-ranked cities nationally in the Swachh Survekshan framework, where segregation — not collection — is typically the hardest target to meet.
- Legacy open dumping and inadequately engineered disposal sites (e.g.,

Karuvadikuppam) create measurable groundwater and leachate contamination, an environmental cost not captured in simple tonnage statistics.

- The informal recycling sector, while functionally essential, operates without formal recognition, occupational protection, or integration into municipal planning — the same vulnerability documented for informal waste workers nationally, who work without protective equipment and earn very little despite performing a de facto public service.
- No comprehensive, publicly available city-wide recycling-rate statistic exists for Puducherry comparable to those published for benchmark cities such as Indore or Surat, which constrains evidence-based policy evaluation.

4. Lessons from High-Performing Indian Cities

Cities such as Indore and Surat, which have consistently topped India's Swachh Survekshan rankings, demonstrate that near-total (95-100%) source segregation and door-to-door collection are achievable within the Indian municipal governance context, typically through multi-bin segregation systems (up to six waste streams), GPS-tracked collection fleets, and decentralised processing (biomethanation, construction-and-demolition recycling) that keeps a very high share of waste out of landfills entirely. Puducherry's smaller population and more compact urban form are, in principle, favourable conditions for replicating elements of this model, particularly decentralised composting and formal integration of existing informal recyclers into a structured material-recovery-facility network.

5. Limitations of This Review

The literature base specific to Puducherry is comparatively thin relative to larger Indian metropolitan areas, with several of the most detailed empirical waste-composition studies dating to the mid-to-late 2000s. Contemporary, granular data on the city's current recycling rate, informal-sector volumes, and street-specific waste composition are limited in the public domain, and this review's synthesis is therefore constrained by the currency

and granularity of available sources. Future primary research — structured street-waste audits, informal-sector livelihood surveys, and updated per-capita generation studies — would strengthen the evidence base considerably.

RECOMMENDATIONS

- Institute mandatory, enforced source segregation into at least three streams (wet, dry recyclable, reject) at the household, market, and street-vendor level, following the multi-bin precedent set by top-ranked Indian cities.
- Formally integrate informal waste pickers into the municipal recycling system through registration, identity cards, protective equipment, and guaranteed access to material-recovery facilities — improving both livelihoods and recovery efficiency, as piloted in other Indian municipalities.
- Expand decentralised material-recovery facilities and composting/vermi-composting units at the ward level to reduce transport burden and processing bottlenecks.
- Remediate legacy dumpsites and enforce engineered landfill standards (lining, leachate treatment) at any remaining disposal sites to prevent further groundwater contamination.
- Introduce routine, publicly reported waste-composition audits and a city-wide recycling-rate metric to enable transparent benchmarking against national and global standards.
- Target tourism- and market-linked plastic litter specifically, given its outsized visibility in street waste and its documented contribution to global marine plastic pollution.

CONCLUSION

Puducherry's street-generated waste stream reflects the broader tensions facing mid-sized Indian cities: a formal collection and composting system operating alongside an indispensable but unrecognised informal recycling economy, set against a backdrop of rising per-capita waste generation and constrained processing capacity. Benchmarked

globally, Puducherry mirrors a world in which fewer than one in five tonnes of waste is recycled and roughly a third is unsafely managed; benchmarked nationally, it faces the same segregation and legacy-dumpsite challenges documented across India, tempered by locally effective NGO-led interventions. Closing the gap between Puducherry's current practice and the performance of India's leading zero-landfill cities will require formalising the informal recycling sector, scaling decentralised processing, and institutionalising transparent waste-data reporting – steps that would move the city toward a genuinely circular approach to the waste generated on its streets.

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