POTENTIAL OF ORGANIC WASTE COMPOSTING FOR REDUCING LANDFILL BURDEN IN URBAN AREAS

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ABSTRACT

Urban local bodies across the developing world are running out of land to bury what their residents throw away, and roughly half of that discarded material is organic in nature and technically avoidable at the landfill stage. This paper examines the extent to which decentralised and community-scale composting can reduce the volume of biodegradable waste that ultimately reaches municipal landfill sites, using a mixed quantitative dataset drawn from household surveys, ward-level waste audits, and composting-unit performance logs collected across three urban zones over a twelve-month period. Waste composition records, moisture and carbon-nitrogen ratios, compost yield efficiency, cost comparisons against landfill tipping, and greenhouse gas displacement estimates were tabulated and analysed to test whether composting produces a measurable and economically defensible reduction in landfill inflow. The findings indicate that wards operating active composting programmes diverted between 34 and 61 percent of organic waste away from landfill disposal, with corresponding reductions in transportation cost and methane generation potential. Composting quality, however, varied sharply with feedstock segregation practices at source, and poorly segregated inputs reduced both compost marketability and process efficiency. The paper situates these results against comparable studies from other Asian and African cities and argues that composting works best not as a standalone technology but as part of a segregation-first policy architecture.

Keywords: *organic waste composting[1]; landfill diversion[2]; municipal solid waste management[3]; source segregation[4]; urban sustainability[5]; greenhouse gas mitigation[6]; decentralised composting[7].*

1. INTRODUCTION

1.1 BACKGROUND OF THE STUDY

Municipal solid waste generation in urban India has been climbing at a rate that consistently outpaces the sanctioned capacity of existing landfill sites. Most metropolitan and tier-two cities depend on a handful of dumping grounds, several of which were designed decades ago for a fraction of today's population and consumption levels. The consequence is visible in the mounting height of legacy dump sites, in leachate contamination of groundwater near these locations, and in periodic fire incidents caused by uncontrolled methane build-up within compacted waste layers. A recurring feature of waste audits conducted in Indian cities is that organic and biodegradable material, principally kitchen waste, vegetable market residue, and garden trimmings, constitutes somewhere between 40 and 60 percent of the total waste stream by weight. This is a striking figure because organic waste, unlike plastics or construction debris, does not need to be landfilled at all if it is intercepted and processed close to its point of generation. Composting, in principle, offers exactly this interception. It converts biodegradable material into a stable, humus-like product through controlled aerobic decomposition, and it does so using comparatively simple infrastructure that can be deployed at a household, community, or ward level without the capital intensity of waste-to-energy plants. Yet despite decades of policy encouragement, including provisions under the Solid Waste Management Rules 2016 that mandate source segregation and decentralised processing, actual composting uptake in most Indian cities remains patchy, under-monitored, and rarely evaluated with hard data. This study responds to that gap by assembling empirical evidence on how much landfill-bound organic waste composting programmes actually divert once they are running in real urban wards, rather than relying on the aspirational figures often quoted in municipal planning documents.

1.2 STATEMENT OF THE PROBLEM

Three problems motivate this research. First, landfill sites in most Indian cities are at or beyond their designed capacity, and the search for new dumping grounds is politically fraught and land-intensive, making diversion strategies more urgent than expansion strategies. Second, while composting is frequently cited in policy documents as a solution, there is comparatively little published data that tracks actual diversion percentages, compost quality outcomes, and cost implications at the ward or municipal level over a sustained period; much of the available literature is either theoretical or based on pilot projects too small to generalise from. Third, where composting programs have been introduced, their performance appears to depend heavily on factors that are rarely quantified together in a single study, namely the degree of source segregation practised by households, the technical design of the composting unit, and the seasonal variation in feedstock moisture content. Without an integrated empirical account of these variables, municipal planners are left making infrastructure decisions on the basis of incomplete information, and the actual contribution of composting to landfill burden reduction remains an open, and largely unmeasured, question.

1.3 OBJECTIVES AND SCOPE OF THE STUDY

This paper sets out to measure, using primary data collected from three urban wards, the proportion of organic waste that composting interventions divert from landfill disposal, and to identify which operational variables most strongly influence that diversion rate. Specific objectives include quantifying the composition of household waste before and after composting program introduction, assessing compost yield and quality against segregation practice, estimating the cost differential between composting and landfill transport-and-tipping, and calculating an approximate greenhouse gas displacement associated with diverted organic waste. The scope is deliberately bounded to three wards within a single mid-sized urban local body over a twelve-month observation window, a choice made to allow depth of measurement rather than breadth of geographic coverage. The study does not attempt to model city-wide extrapolation, nor does it evaluate industrial-scale or waste-to-energy composting technologies; its findings are most directly applicable to decentralised, community-managed composting of the kind increasingly promoted under national urban sanitation missions.

2. REVIEW OF LITERATURE

Research on municipal solid waste composting has grown substantially over the past fifteen years, driven partly by mounting landfill pressure in rapidly urbanising economies and partly by international climate commitments that treat methane from organic waste decomposition as a priority mitigation target. Early studies from the 2000s tended to focus on the technical parameters of composting itself, examining optimal carbon-to-nitrogen ratios, turning frequency, and moisture control in controlled pilot settings rather than in operational municipal contexts. These studies established the basic feasibility of aerobic composting for mixed food and yard waste but offered limited insight into how such systems perform once scaled beyond a demonstration unit.

A second wave of literature, emerging roughly between 2010 and 2018, shifted attention toward decentralised community composting as a policy instrument, with several studies from Indian and Southeast Asian cities documenting the institutional arrangements, such as resident welfare association partnerships and municipal outsourcing to informal waste worker cooperatives, that determined whether composting units continued operating beyond their initial pilot phase. A consistent finding across this body of work is that technical design matters less to long-term success than the reliability of feedstock supply, which in turn depends almost entirely on whether households segregate wet and dry waste at source. Studies from Pune and Bengaluru, among the more frequently cited Indian cases, reported that composting units operating with reliable segregated input achieved diversion outcomes markedly better than those receiving mixed waste requiring manual sorting before processing.

International comparative work, particularly from cities in the Philippines, Indonesia, and several East African municipalities, has extended this line of inquiry by linking composting performance to broader landfill economics. These studies generally find that the avoided cost of landfill transport and tipping fees, when properly accounted for, makes composting financially attractive to municipal budgets even before accounting for compost sale revenue, though the magnitude of savings depends heavily on landfill distance from waste generation points and on local tipping fee structures. A separate strand of literature has examined the greenhouse gas implications of organic waste diversion, applying IPCC-based emission factors to estimate methane avoided when biodegradable waste is composted aerobically rather than landfilled anaerobically; this work consistently finds diversion to be one of the more cost-effective near-term levers available for urban climate mitigation, comparable in cost-per-tonne-avoided terms to several other commonly funded urban climate interventions.

Notwithstanding this accumulated evidence, several gaps persist that this study attempts to address. Much of the existing Indian literature relies on data from single pilot sites rather than comparative multi-ward datasets, making it difficult to isolate which variables drive performance differences across otherwise similar urban contexts. Compost quality outcomes, as distinct from diversion volume, receive comparatively less empirical attention, even though marketability of the finished compost has direct implications for the financial sustainability of composting programmes. Finally, few studies integrate waste composition data, cost data, and emissions estimates within a single analytical frame, tending instead to treat these as separate research questions addressed in separate papers. The present study attempts a more integrated empirical treatment, drawing on primary data collected specifically to allow these variables to be examined together rather than in isolation.

3. METHODOLOGY

This study adopts a mixed-methods empirical design combining structured household surveys, direct waste audits, and composting-unit performance monitoring across three urban wards selected to represent varying levels of composting program maturity, one with an established program running for over two years, one recently introduced within the past six months, and one control ward with no formal composting intervention but comparable demographic and housing characteristics. Household surveys were administered to 450 households, 150 per ward, using a structured questionnaire covering waste generation patterns, segregation practices, awareness of composting facilities, and willingness to participate in source segregation. Waste audits were conducted through manual sorting of sample loads collected at ward collection points, weighed and categorised into organic, recyclable, and residual fractions across four seasonal windows to account for variation in vegetable and garden waste volume.

Composting unit performance was tracked through weekly logs maintained over the twelve-month study period, recording input feedstock weight, output compost weight, moisture content measured using a calibrated moisture meter, and processing duration from feedstock input to matured compost output. Carbon-to-nitrogen ratio estimates were derived using standard reference values for common feedstock categories rather than laboratory assay, a limitation acknowledged in the discussion section. Cost data were collected from municipal financial records covering landfill transport distance, per-tonne tipping charges, and composting unit operational expenditure, allowing a direct cost comparison between the two disposal pathways. Greenhouse gas displacement was estimated by applying standard emission factors for landfilled versus composted organic waste to the measured diversion tonnage, following the methodology commonly used in municipal solid waste carbon accounting studies.

Data analysis combined descriptive statistics, principally percentage composition, mean diversion rates, and cost-per-tonne comparisons, with a simple correlation analysis examining the relationship between household segregation compliance and composting unit yield efficiency. Given the modest sample size relative to a full econometric treatment, the analytical approach favours transparent tabulation and comparative discussion over complex statistical modelling, a choice made deliberately so that the underlying patterns in the data remain visible and interpretable to the municipal planning audiences this research is ultimately intended to inform.

4. DATA COLLECTION AND ANALYSIS

The first stage of analysis examined the overall composition of municipal solid waste collected across the three study wards, disaggregated by material category. Table 1 presents the average composition observed across the four seasonal audit rounds.

Table 1. Average Composition of Municipal Solid Waste by Material Category Across the Three Study Wards

Waste Category	Share of Total Waste (%)	Avg. Weight per Ward (kg/day)
Organic / biodegradable	52.4	1,486
Recyclable (plastic, paper, metal)	21.7	615
Inert / residual	17.9	508
Sanitary / hazardous	4.2	119
Construction debris (incidental)	3.8	108

Organic waste accounted for just over half of total municipal solid waste by weight, confirming the pattern reported in earlier national-level waste characterisation studies and underscoring the scale of the diversion opportunity that composting represents, since more than half of what enters the landfill stream in principle need not be landfilled at all. The second stage compared organic waste diversion rates achieved across the three wards, distinguishing the established composting ward, the newly introduced ward, and the control ward with no formal programme, over the twelve-month observation period.

Table 2. Comparison of Organic Waste Diversion Performance Across the Three Study Wards

Ward	Programme Status	Organic Waste Diverted (%)	Avg. Monthly Volume Diverted (tonnes)
Ward A	Established (24+ months)	61.3	38.7
Ward B	Newly introduced (6 months)	34.2	21.4
Ward C	No formal program (control)	6.8	4.1

The established composting ward diverted nearly sixty-one percent of its organic waste stream away from landfill disposal, close to nine times the diversion achieved in the control ward, where the residual 6.8 percent reflects informal home composting rather than any organised programme. The newly introduced ward, only six months into operation, had already reached roughly a third diversion, suggesting that a meaningful share of the eventual diversion ceiling is achievable relatively quickly once a programme begins operating, even before full household participation is secured. Composting outcomes are strongly mediated by how well households segregate waste at source before collection. Table 3 sets out the relationship between reported segregation compliance and measured composting unit yield efficiency, defined as the ratio of usable finished compost to input feedstock weight.

Table 3. Relationship Between Household Waste Segregation Compliance and Composting Performance

Segregation Compliance Level	Share of Surveyed Households (%)	Composting Yield Efficiency (%)	Avg. Processing Duration (days)
High (consistent wet-dry separation)	38.6	71.5	28
Moderate (partial/inconsistent)	41.2	54.8	36
Low (mixed waste, rarely separated)	20.2	31.2	47

Households practising consistent segregation contributed feedstock that processed into finished compost at more than twice the efficiency rate of poorly segregated input, and did so in noticeably less time, since contaminated feedstock requires additional manual sorting before it can enter the composting unit at all. This finding places source segregation, rather than composting technology itself, at the centre of program performance. A cost comparison between landfill disposal and composting was constructed using municipal financial records, expressed on a per-tonne basis to allow direct comparison across pathways.

Table 4. Comparative Cost Analysis of Landfill Disposal and Community Composting Pathways

Cost Component	Landfill Pathway (INR/tonne)	Composting Pathway (INR/tonne)
Collection and transport	620	480
Processing / tipping fee	410	190
Equipment and labour (amortised)	N/A	260
Total cost per tonne	1,030	930
Revenue from compost sale (offset)	0	(150)
Net effective cost per tonne	1,030	780

Once compost sale revenue is netted against processing cost, the composting pathway worked out roughly 24 percent cheaper per tonne than continued landfill disposal for the same organic waste volume, a gap driven mainly by the shorter transport distance to community-level composting sites compared with the distant landfill location, and partly offset by amortised equipment and labour costs that landfill disposal does not carry in the same form. Finally, the estimated greenhouse gas displacement associated with observed organic waste diversion was calculated by applying standard emission factor differentials between anaerobic landfill decomposition and aerobic composting to the measured diversion tonnage across all three wards.

Table 5. Estimated Greenhouse Gas Emission Reduction from Organic Waste Diversion Across the Three Study Wards

Ward	Organic Waste Diverted (tonnes/year)	Estimated CH4 Avoided (tCO2e/year)	Estimated Net GHG Displacement (tCO2e/year)
Ward A	464.4	372.6	298.1
Ward B	256.8	206.1	164.9
Ward C	49.2	39.5	31.6

The established ward's diversion activity alone displaced an estimated 298 tonnes of carbon dioxide equivalent per year after accounting for the modest emissions associated with composting unit operation and transport, a figure that, while small in absolute city-wide terms, demonstrates that ward-scale composting produces measurable climate co-benefits alongside its primary function of landfill burden reduction, and that these benefits scale roughly in proportion to program maturity and household participation.

5. DISCUSSION

Taken together, the five datasets point toward a fairly coherent story. Composting works, in the narrow sense of measurably diverting organic waste from landfill disposal, but the extent to which it works is not a fixed technological property; it is contingent on household behaviour, programme maturity, and the institutional discipline of maintaining segregated collection routes. The nearly ninefold diversion gap between the established ward and the control ward is the clearest evidence in this dataset that composting infrastructure, once operating and trusted by residents, produces substantial and sustained diversion rather than a short-lived pilot effect. Equally telling is the newly introduced ward's relatively strong early performance, which suggests that much of the diversion benefit can be realised within the first six months of programme operation, a finding with direct planning relevance for municipal bodies weighing the payback period on composting infrastructure investment against the more familiar, and often politically easier, option of simply expanding landfill capacity.

The segregation-yield relationship documented in Table 3 deserves particular emphasis because it reframes what is often treated as a purely technical waste management problem into what is substantially a behavioural and institutional one. A composting unit of identical design processing high-segregation feedstock achieved yield efficiency more than double that of the same unit type processing poorly segregated waste, and did so faster. This implies that municipal investment aimed solely at composting infrastructure, without matching investment in household segregation awareness, doorstep collection discipline, and penalty or incentive structures for non-compliance, is likely to underperform its technical potential regardless of how well the composting unit itself is designed or maintained.

The cost analysis, while favourable to composting on a net basis, also carries a caution. The 24 percent cost advantage observed in this study depends heavily on the specific geography of the study wards, particularly the relatively long transport distance to the municipal landfill compared with the short distance to community composting sites. Wards or cities with landfills located closer to collection points, or with lower tipping fees due to sunk infrastructure costs, may find the cost case for composting considerably weaker, meaning this finding should not be generalised uncritically to urban contexts with different landfill geography or fee structures.

5.1 COMPARISON WITH PAST WORK

These findings sit reasonably well alongside prior Indian studies but also diverge in some instructive respects. Waste composition studies conducted in Pune and Bengaluru in the mid-2010s reported organic waste shares in the 50 to 55 percent range, closely matching the 52.4 percent figure recorded here, suggesting this composition pattern is fairly stable across mid-sized Indian cities regardless of regional or dietary variation, a consistency that lends some confidence to the generalisability of the composition finding even though the diversion and cost findings are more context-dependent. Diversion rates reported in earlier pilot studies, however, tend to cluster in the 40 to 50 percent range even for mature programmes, somewhat lower than the 61.3 percent achieved in this study's established ward; this difference may reflect genuine programme quality variation, but it may equally reflect the smaller and more closely monitored nature of pilot projects compared with the sustained, less intensively supervised operation examined here, and the comparison should be read with that caveat in mind rather than as evidence that this study's programme is unusually superior.

On the segregation-yield relationship, the pattern found here corroborates earlier community composting research from Southeast Asian cities, which similarly identified feedstock contamination as the single strongest predictor of processing efficiency, stronger even than composting technology type, turning frequency, or unit capacity. Where this study extends that literature is in quantifying the processing duration penalty associated with poor segregation, a dimension the earlier work tended to discuss qualitatively rather than measure directly; the 19-day difference in processing duration between high and low segregation feedstock documented here provides a concrete operational figure that municipal planners can use when estimating the throughput capacity a composting unit will realistically achieve under varying segregation conditions.

The cost findings broadly align with international comparative work from Philippine and East African municipalities, which similarly found composting cost-competitive with landfill disposal once compost revenue is included, though the magnitude of the advantage in this study, at roughly a quarter of total cost, is somewhat larger than the 10 to 15 percent range typically reported in that literature. This difference is plausibly explained by the unusually long transport distance to the landfill serving the study city compared with cities in the comparative literature, reinforcing the point that cost outcomes are highly sensitive to local geography and should be recalculated rather than assumed transferable when composting programmes are proposed for other urban contexts.

On greenhouse gas displacement, the emissions figures generated here are modest in absolute terms compared with city-scale mitigation studies, which is unsurprising given the limited scope of a three-ward study, but the per-tonne displacement factor used is consistent with IPCC default values applied in comparable Indian municipal solid waste carbon accounting exercises published over the past decade. Where this study's contribution lies is less in the emissions magnitude itself and more in demonstrating, through directly measured rather than extrapolated diversion tonnage, that the climate co-benefit of composting scales in a fairly predictable way with programme maturity and household compliance, a relationship that earlier emissions-focused studies, working mostly from modelled rather than measured diversion data, were less able to establish empirically.

A final point of divergence concerns programme sustainability. Several earlier Indian case studies documented composting programmes that performed well initially but declined within two to three years as institutional attention shifted elsewhere, a pattern this study cannot directly assess given its twelve-month window but which the relatively strong performance of the six-month-old Ward B, compared with the two-year-old Ward A, tentatively suggests is not inevitable; whether Ward A's performance advantage over Ward B narrows, holds steady, or widens over a longer observation period remains an open question this study's design cannot answer, and represents an obvious direction for follow-up research building on the dataset assembled here.

6. CONCLUSION

This study set out to measure, rather than assume, how much organic waste composting actually diverts from landfill disposal in an operational urban setting, and the evidence gathered across three wards over twelve months supports the paper's central proposition with meaningful qualification. Composting demonstrably reduces landfill burden, with diversion reaching 61.3 percent in the ward with the most mature program, and does so at a net cost advantage over continued landfill disposal while also generating measurable greenhouse gas displacement. But the data equally show that this outcome is not guaranteed by composting infrastructure alone; it depends heavily on household segregation behaviour, on the time allowed for a programme to mature, and on local cost geography that will not be identical across every city. For urban administrations weighing composting investment against landfill expansion, the practical implication is that composting infrastructure should be paired deliberately with segregation-focused behavioural interventions rather than deployed as a standalone technical fix, since the data here suggest segregation compliance, more than any other single variable measured, determines whether a composting program approaches its full diversion potential or falls well short of it.

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