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RESEARCH PAPER

Scenario of Solid Waste Management in Indian Cities: A Study of Pune, Visakhapatnam, and Tirupati

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Abstract: The quantum of solid waste generated by the world is growing with increasing development and changing lifestyles, making waste management a daunting challenge. The Solid Waste Management Rules, 2016, of India, along with initiatives by the Smart City Mission and Swachh Bharat Abhiyan, are pivotal in encouraging sustainable waste management. This paper establishes progress, gaps, and ground realities in solid waste management (SWM) in three of the best-performing cities in India. The paper first documents trends and practices in SWM in the three cities and then cross-checks the ground scenario through a primary survey of 322 citizens. The results show that all three cities have experienced improvements in SWM following government initiatives. Segregation of waste is the dominant protocol, and all three cities show a positive trend. The decentralization of wet waste treatment and sorting processes has facilitated material recovery. Centralized facilities, such as the waste-to-energy plant in Vishakhapatnam, the compressed biogas plant in Pune, and the biomethanation plant in Tirupati, are adding economic value to the system. Effective segregation and recovery have enabled scientific disposal, and advances have been made in the redemption of former dumpsites, with complete success in Tirupati.

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1. INTRODUCTION

Every year, the world generates two billion tonnes of municipal solid waste—a figure set to increase with the growing population, economic development, and the increased consumption of products (The World Bank 2022). Given its large population, India is one of the largest waste generators in the world. According to the Central Pollution Control Board's reply to a Right to Information request in 2020, India produces around 1.5 lakh tons of waste per day (2020). Although India's per capita waste generation is far less than that of developed nations, the cumulative amount is considerable and growing fast. However, the pressing concern regarding municipal solid waste in India is the lack of waste segregation and the consequent inability to scientifically treat, recover, and dispose of waste (Kumar and Agrawal 2020; Kumar *et al.* 2017).

Unlike rural areas, cities pose a challenge to decentralized waste treatment at source due to the concentration of economic activities, population density, and urban lifestyles. In cities, the burden of waste management falls on urban local bodies (ULBs). In India, municipal solid waste management (SWM) is a mandatory function of the city's municipality or municipal corporation under the 74th Constitution Amendment Act, 1992. However, due to a lack of streamlined procedures, capacity, financial mechanisms, and citizen participation, many SWM systems adopted by ULBs may be inefficient (Singh 2020). The Municipal Solid Waste Rules, 2000, and the Solid Waste Management (SWM) Rules, 2016, were enacted to guide ULBs through the process of adopting standards and techniques. They state the roles and duties of various allied authorities and stakeholders, including the different consumer classes (Ministry of Environment, Forest and Climate Change 2016), as well as establish a structure for the SWM logistical chain.

The existing literature has highlighted the need for regular monitoring and data collection to make sound decisions and take action (Goel 2008). The Swatch Bharat Mission 1 (2016) and 2 (2021) aim for scientific SWM, which is a step forward in complying with the requirements of the SWM Rules, 2016. The Swachh Survekshan ("survey") collects SWM information from ULBs, field observation, and citizens' experiences and ranks ULBs on their performance. This ranking promotes city competitiveness and emphasizes data-based management. Each year, the Swachh Survekshan has a unique agenda against which progress is measured using an extensive set of indicators. In contrast, the Service Level Benchmarking (SLB) initiative of

2010 is an urban governance reform that mandates that ULBs report data regarding urban services such as SWM under fixed, measurable, and comparable parameters (Ministry of Urban Development 2010). The achievements reported in the SLBs had served as the basis for sanctioning funds and tracking progress. While the SLBs served as a comprehensive means of assessing the performance of ULBs and identifying gaps in service delivery, reporting under Swachh Survekshan is elaborate and agenda-specific. Since the onset of Swachh Survekshan, reporting and data collection under the SLB initiative have been phased out, and instead, similar indicators are captured under the Service-Level Progress (SLP) reported by the ULBs in the Swachh Survekshan. As the indicators are the same, the performance of cities can be tracked since the SLB initiative was launched.

Despite efforts to improve SWM in Indian cities, municipal corporations face many challenges. Data from the Swachh Survekshan reveal stark variations in cities' performance across various parameters. For instance, Pune demonstrates excellent waste collection practices yet struggles with scientific disposal (NITI Aayog 2021). Cities continue to face challenges in several aspects of SWM, which calls for an assessment of on-ground realities and gaps in following SWM processes.

While several works of literature point out the challenges pertaining to SWM in Indian cities (Naveen and Sivapullaiah 2020; Kumar *et al.* 2017; Joshi and Ahmed 2016), there has been insufficient research on the reported benchmarks and the reasons for various successes and challenges. The primary objective of this study is to discover ground realities and the reasons underlying cities' reported SWM performances, including best practices, challenges, and compliance. By examining the status of SWM in three cities—Pune, Tirupati, and Visakhapatnam—this paper first briefly reports on the SWM practices followed and the reasons for improvement in recent years. Thereafter, through a citizen survey, it gauges the accuracy of SLB and SLP reporting to cross-check and identify critical issues.

These three cities were selected based on their SWM practices, locational importance, uniqueness, availability of documentation, and ease of conducting the survey. All three cities have some of the best SWM practices and ranked among the top 20 cities in the Swachh Survekshan in 2020 and 2021 (IITTM.ORG 2021). In 2022, in the above 10 lakh population category, Visakhapatnam was ranked fourth, and Pune was ranked ninth. In the below 10 lakh population category, Tirupati was ranked first (Singh 2023). Further, all three cities are a part of the Smart City Mission. This study also tracks the effects of the mission on SWM services in 2022.

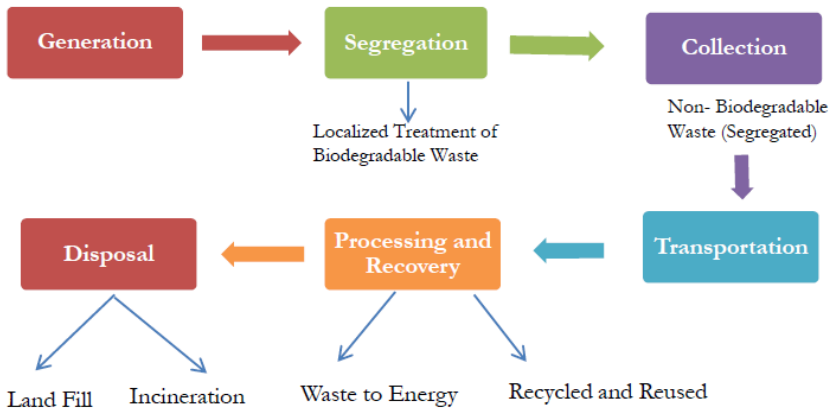
2. LITERATURE REVIEW

The processes associated with SWM, the provisions of the SWM Rules, 2016, and the challenges in meeting the requirements of the SWM Rules, 2016, need to be understood in order to compare and interpret the realities of SWM practices. This section elaborates on the same.

2.1 SWM Process

Solid waste refers to the "unwanted solid materials generated from human activities in residential, industrial or commercial areas commonly known as trash or garbage" (Awasthi, Chataut, and Khatri, 2023). Municipal solid waste is the solid waste generated within the jurisdiction of municipal authorities/ULBs, and it is to be collected, treated, and disposed of by the respective ULB (Stafford 2020). The municipal solid waste (MSW) management process is typically broken down into several steps as shown in Figure 1.

Figure 1: Functional Process of Municipal Solid Waste Management



Source: Author's compilation based on NITI Aayog (2021).

MSW is categorized into organic waste (biodegradable, commonly known as wet waste), recyclables (dry waste), inerts, sanitary and medical waste, construction waste, and hazardous waste (Miezah *et al.* 2015). The source of waste generation—such as households, commercial establishments, industries, or construction sites—determines the type and quantum of waste. Instead of a waste collection and disposal process, the integrated solid waste management concept suggests a sustainable waste reduction and reuse approach at every stage (Cobo *et al.* 2018). It emphasizes a conscious effort to generate less waste by promoting the following (Central Public Health and Environment Engineering Organisation 2016):

- reuse at source
- waste segregation
- use of organic waste in biogas plants or to generate compost
- collection of segregated waste for efficient recovery
- a focus on door-to-door collection rather than secondary bins
- recycle and reuse of waste
- incineration and waste-to-energy conversion of non-recyclable waste
- reduction of landfill demand.

This process deviates from the traditional unsustainable approach of collecting waste through secondary bins, transportation, and dumping.

2.2 SWM Rules, 2016, and Service-level Reporting

The SWM Rules, 2016, adopt an integrated SWM approach. This mandates waste segregation by various categories of generators and requires ULBs to perform door-to-door collection and treatment of segregated waste. Further, it is suggested that informal waste pickers, who recover reusable waste for a living, be roped into the formal waste management system as waste collectors. The rules also empower ULBs to charge waste generators, collect fines, generate revenue, and cover the service cost through these charges (Ministry of Environment, Forest and Climate Change 2016). The rules thus make waste generators responsible for waste management through charges and fees. Efforts towards making SWM financially sustainable through user charges are one of the fundamental policy reforms of the SWM Rules, 2016.

India's SLB initiative includes the urban services of SWM, water supply provision, and wastewater disposal. It is being expanded to include other sectors. The initiative requires ULBs to systematically and continuously measure, monitor, and report service levels. Performance parameters, procedures, and units of measurement are predetermined and comparable for uniformity in reporting across cities. The performance indicators for SWM include household coverage, efficiency of collection, extent of segregation, waste recovery and scientific disposal, collection of SWM charges, cost recovery, and complaints redressal (Ministry of Urban Development 2011). However, the enumeration of data per the SLB initiative has progressively become scant since the introduction of Swachh Survekshan.

The Swachh Survekshan ranking comprises three components: SLP (based on data provided by ULBs), certification (based on Garbage Free Cities rating, Open Defecation-Free rating, and so on) and citizen voice (based on

feedback, citizen engagement, and so on). The SLP indicators reported for 2023 were grouped into three criteria—segregated collection (7 indicators), processing and disposal (13 indicators), and sustainable sanitation (8 indicators) (Ministry of Housing and Urban Affairs 2023a). These SLP categories include all the SLB indicators and have additional ones even though the three criteria's indicators and weightings slightly change yearly. However, as the data compiled is extensive, the project's dashboard has only published information on source segregation; door-to-door collection; waste generation versus processing; and remediation of dumpsites and cleanliness thus far.

2.3 Challenges to SWM

While, in principle, the SWM Rules, 2016, promote sustainable SWM, their implementation faces several challenges. Waste segregation at source is a major challenge, as there is a lack of awareness among the citizenry in addition to an underdeveloped sense of responsibility (Kumar *et al.* 2017). In certain regions, segregating waste into multiple categories faces cultural resistance, as it may require certain waste to be stored at the source for several days due to infrequent collection, such as in the case of electronic waste. In many Indian cities, open dumping in fringe areas is rampant because the expansion of door-to-door collection services has not been able to catch up with rapid urban development (Naveen and Sivapullaiah 2020). Littering in public places calls for regular cleaning, which adds to service costs and effort.

ULBs incur high service costs to provide SWM services due to a lack of established and effective logistical infrastructure (Naveen and Sivapullaiah 2020). India does not subscribe to the culture of paying for SWM services, rendering the system financially inefficient (Krishna 2017). Several technical deficiencies exist, as many cities do not have mechanical/automatic waste-sorting machinery and continue to deploy manual sorting, which violates human dignity. Ragpickers and scrap dealers traditionally play critical roles in waste recovery, but the formalization of their roles in the mainstream SWM system is incomplete (Ahuja 2019).

Localized or decentralized treatment processes, such as vermicomposting organic waste, can be very effective. However, these practices are not widespread, and their application requires incentivization. Most local vermicompost plants are not well maintained or receive waste beyond their capacity, which causes problems for residents. Ultimately, they become defunct due to the not-in-my-backyard (NIMBY) syndrome (Joshi and Ahmed 2016). Research and policies necessitate that the responsibility of waste management be extended to waste producers by levying appropriate

charges and incentivising waste prevention. Dealing with legacy waste—that is, waste dumped over the past decades—and overfilled landfills are some of the other challenges faced by ULBs. Amidst residents' opposition to the establishment of landfills in their vicinity, there have been renewed efforts to reduce the existing stock through recovery processes such as bioremediation and scientific mining, which can also promote a circular economy (Singh 2021).

3. MATERIALS AND METHODS

The cities of Pune, Visakhapatnam, and Tirupati were selected for this study, as they follow SWM best practices and rank well in city cleanliness as per the Swachh Survekshan (IITTM.ORG 2021; Singh 2023). These cities are also part of national missions related to urban services, such as the Smart City Mission and Atal Mission for Rejuvenation and Urban Transformation (AMRUT). The three cities have different population sizes. This helped us deduce success factors and challenges in cities of different scales and with varying municipal capacities. The study of various population categories revealed the unique challenges facing the respective ULBs as well as their capacity to overcome these challenges. The ease of data collection was also considered during sample selection.

The first step was to review the best practices followed in the sample cities. The compendiums published by different government organisations and news reports were used to consolidate this information. Next, secondary data were gathered from the SWM plans, detailed project reports, SLBs, SLP, etc., provided by the concerned municipal corporations and internet sources such as the Swachh Survekshan dashboard. Information related to human resources deployed for SWM, transport vehicles and equipment, processing plant capacity, and other details were gathered as well.

A questionnaire survey was conducted among the residents of the sample cities to understand ground realities. The questions were based on the SWM Rules, 2016, and challenges pertaining to SLBs, SLP indicators, and SWM that have been reported in the literature. The questionnaire had three parts. The first part had questions on respondent type (household or institutional). The second part was about SWM services and practices. The third part provided space for collecting suggestions for improvement and the rationale for the same. The questions were close-ended; only the opinion-based questions used a Likert Scale. Responses were collected through door-to-door visits, online forms, and telephonic means to cover all segments of society. The data collection was performed in 2021–22. A total of 322 responses were used for the analysis, of which 103 were from

Pune, 108 from Visakhapatnam, and 111 from Tirupati. Lastly, the responses were compared using simple additive techniques. Thereafter, inferences were drawn and compliance was checked.

4. BEST PRACTICES IN THE SAMPLE CITIES

All three cities have adopted unique practices to tackle their municipal waste. The city background, quantum of waste handled, and SWM practices in the three cities are elaborated in this section.

4.1 Pune, Maharashtra

Pune is the second-largest city in Maharashtra and has a population of 3.1 million as per the 2011 Census (Pune Municipal Corporation, 2022). Its estimated current population of more than 4 million resides within 479 sq km, with a density of 6,522 persons per sq km (Pune Municipal Corporation, 2022). Pune generates 2,258 tons of waste every day (NITI Aayog 2021). Its SWM best practices include partnering with the waste pickers' association, SWaCH (or Solid Waste Collection and Handling), for door-to-door waste collection and recovery. This model has achieved high service coverage, including of slum settlements. The practice of segregating waste into dry and wet was introduced between 2006 and 2008 as a step towards easing waste handling when SWaCH became operational (Climate and Clean Air Coalition 2018). However, the challenge was the mixing of non-biodegradable waste, including sanitary, hazardous, medical, and recyclable waste. This proved to be a health hazard to workers and posed challenges for waste recovery, with a large amount ending up in landfills.

The municipal corporation initiated the Red Dot Campaign to promote segregation dry waste further into e-waste, plastic, sanitary, biomedical, garden, and construction waste at source for ease of handling and to increase efficiency in waste recovery (NITI Aayog 2021). The project helped mitigate the challenges associated with sorting mixed waste and enabled the operation of waste recycling plants at an industrial level. The city has adopted a zero-garbage policy, as part of which it aims to treat all types of waste in a decentralized manner. Under the policy, housing societies are incentivized to establish vermicomposting plants through discounts on property taxes (Thevar 2022). Biodegradable waste from hotels and eateries is collected and processed separately in a bio-methanation plant that receives funds from corporate social responsibility programmes (CSR) (Pune Municipal Corporation 2024). In this plant, the slurry is converted into compost and compressed biogas. Such initiatives

help convert waste into profit. These programmes have been strengthened further and expanded under the Smart Cities Mission.

Pune's biggest challenges are legacy waste, overwhelmed landfills, and defunct local treatment plants and recycling units. Efforts have been made to remediate dump-site land, and the ULB is working on reclaiming part of the land. One of the garbage depots of Pune—a 100-acre plot of land in Uruli Devachi—has been the source of significant complaints from local citizens over the past decade. In 2018, the municipal corporation converted part of this land into a scientific landfill site, and a few other similar sites have been established in different parts of the city. This has led to a reduction in untreated waste volumes. Further, the land holding the legacy waste is slowly being reclaimed through bioremediation and is being converted to urban forests—around 20 acres have already been transformed (Khairnar 2024).

4.2 Visakhapatnam, Andra Pradesh

Visakhapatnam is the second-largest city in Andra Pradesh. It has a population of 1.7 million per the 2011 Census and an estimated current population of 2 million, which resides within 681 sq km of the Greater Visakhapatnam Municipal Corporation. The city generates 1,150 tons of solid waste daily (Rao 2019). Its SWM best practices include the segregated collection of dry waste, wet waste, biomedical waste, and e-waste. Waste from commercial and market areas is collected separately, and a private agency has been employed to collect waste from hospitals (Hari Narayanan *et al.* 2018).

Much of the transformation in Visakhapatnam's SWM occurred after Cyclone Hudhud in 2014. The municipal corporation and the state government, with the aim to build back better and more resilient, introduced several initiatives. One such initiative is the regular collection of waste from a large part of the city. Earlier, waste was collected in two ways: via pushcarts for door-to-door collection or in dumper and compactor bins. Now, e-autorickshaws are deployed for waste collection. The municipal corporation is also focusing on eliminating secondary bins to improve cleanliness (Gilai 2020). Currently, it operates five compost yards where 200 tons of wet waste is converted into compost. The sale of this compost generates revenue for the system (Ahuja 2018). The city has also introduced recycling systems to tackle plastic waste management.

Further, Visakhapatnam is scaling up waste recovery through mechanized units and waste-to-energy plants, where 950 tons of dry waste is treated and about 9.9 MW of power is generated per day. This project is operated and managed by Jindal Urban Waste Management. A power purchase

agreement has been executed with a power distribution company, and the energy sales support cost recovery for the SWM system (The Hindu 2022). Procurement of garbage transport vehicles, the distribution of bins, and the setting up of processing plants is also supported by the Clean Andra Pradesh (CLAP) programme, which makes the system more centralized (Rao 2021).

4.3 Tirupati, Andra Pradesh

Tirupati has a population of 0.28 million as per the 2011 Census, and an estimated population of 0.5 million resides within 27.44 sq km of the Tirupati Municipal Corporation. Tirupati is a temple city and receives around 50,000 visitors every day. It produces 194 tons of waste daily (Venkiteela 2020). Tirupati ranked first in the below 10 lakh population category in Swachh Survekshan 2022 and secured 8th position overall in Swachh Survekshan 2023 (Ministry of Housing and Urban Affairs 2024). Waste is collected using pushcarts in congested and crowded areas, tricycles in other parts, and motorized vehicles in the outskirts, which typically have a lower population density. Colour-coded dustbins have been distributed to households for waste segregation into wet and dry waste, and a time slot is allotted for collection. Additionally, container bins are placed in chronic dumping spots.

The city has a centralized compost plant to treat wet waste. However, recently, a decentralized mechanism has been introduced, wherein households and societies are encouraged to oversee composting using simple techniques. A part of the city's composting is performed in open spaces such as gardens and parks, where dry leaves are composted using cost-effective, easy-to-use techniques and equipment (Swachh Bharat Urban 2018). Bulk generators have onsite box composting, and bio-chest machines have been established near the market and bazar areas for waste treatment (Mani *et al.* 2019; The Hans India 2018).

For centralized SWM, segregated waste is first moved to transfer stations. From here, dry waste is sent to a centralized processing unit, where it is further segregated into plastic, cloth, leather, etc., through mechanized and manual methods. Bales are created and sold to recycling industries for reuse. Tirupati has material-specific plants that process plastic and construction waste. Similarly, wet waste is centrally treated in compost and biomethanation plants (Arundhathi 2018). These processing plants have been constructed with Smart Cities funds (Municipal Corporation Tirupati 2022).

In 2017, there were several protests by the residents around the dumpsite. In 2022, Tirupati completed its dumpsite remediation project through

biomining and treatment of its legacy waste by partnering with a private company, Zigma (Swachh Bharat Mission Urban 2, 2022). The waste was segregated, sorted, and sold to recycling companies such as those that supply the cement and paper industries. These initiatives were undertaken jointly by the municipal and Smart City corporations, wherein they conducted extensive citizen campaigns to raise awareness. User charges have been introduced to meet the cost of waste management. The management of the enormous amount of waste generated by the pilgrims in and around the temple complexes is well supported by Tirumala Tirupati Devasthanams, which deploys waste collectors and oversees sorting and treatment plants (Raju and Sreenivasulu n.d.). Table 1 summaries SWM best practices in the sample cities.

Table 1: SWM Best Practices in the Sample Cities

City	Best Practices
Pune	• Partnership with the waste pickers' association for door-to-door waste collection and recovery • Red Dot Campaign for further segregation of dry waste • Decentralization of wet waste treatment through incentivization • Attempt to incrementally convert legacy waste dumpsites into scientific plants or urban forests
Visakhapatnam	• Segregated collection of waste • Elimination of secondary bins through door-to-door collection • Waste-to-energy plants and compost yards
Tirupati	• Segregated waste collection initiated with dustbin distribution • Streamlined, centralized scientific wet and dry waste treatment; recycling and reuse by industries • Decentralized process for bulk waste generators • Complete redemption of the dumpsite

Source: Author's compilation based on the literature review.

5. ANALYSIS AND RESULTS

The analysis and results are discussed in two parts, the first based on the data reported in the SLB and SLP and the second based on the household survey conducted.

5.1. Analysis of SLB and SLP data

Error! Reference source not found. shows the SLBs reported by the municipal corporations to the Ministry of Urban Affairs (formally known as the Ministry of Urban Development) in 2010. Since then, with the introduction of the SWM Rules, 2016, the Swachh Bharat Abhiyan launched in 2014, and AMRUT launched in 2015, much progress has been made, as indicated in **Error! Reference source not found.**, which shows the SLP documented by the Swachh Survekshan.

Table 2: Service-level Benchmarks Reported by the Sample Cities in 2010–11 (Baseline)

Service-level benchmarks	Benchmark	Pune	Visakhapatnam	Tirupati
Household-level coverage	100%	52.7%	61.7%	6.5%
Efficiency in the collection of solid waste	100%	100%	90%	87.5%
Extent of segregation of MSW	100%	27.9%	13%	0%
Extent of MSW recovered	80%	80%	11%	0%
Extent of scientific disposal of MSW	100%	100%	0%	0%
Extent of cost recovery	100%	60.9%	23%	0%
Efficiency in collection of SWM charges	90%	67%	30%	0%
Efficiency in redressal of customer complaints	80%	84.7%	60%	80%

Source*:* Ministry of Urban Development (2012)

It can be observed from the baseline SLBs and the recent SLP indicators that the sample cities have significantly improved household coverage for SWM services as well as enhanced collection efficiency. The SLP markers for Vishakhapatnam and Tirupati show remarkable advancements in waste collection. As evidenced by Table 3, Pune's waste segregation capacity has remained high and steady above 95%. Vishakhapatnam has also made tremendous progress in increasing segregation by 38% between 2020 and 2023. On the other hand, Tirupati trails behind in this regard.

Pune reported high efficiency in collecting service charges and cost recovery in the 2011 SLB itself. Visakhapatnam reported some progress in collecting user fees, while Tirupati did not collect any service charges in 2011 as per the reported SLBs; however, they were considering the possibility (Kummara, 2021). Cost recovery and user charges were not directly covered in the SLP but were part of a sub-parameter, for which recent data is unavailable. However, some observations regarding user

charges can be drawn based on SWM practices in the cities. In Pune, the SWM charges are built into property taxes, and, with advances in online

Table 3: Service-level Progress of the Sample Cities Reported in the Swachh Survekshan 2020 and 2021

	Segregation of waste	Door-to-door collection	Dumpsite remediation	Dry waste processed	Wet waste processed
Pune					
2020	100%	80%	67%	67%	83%
2021	100%	100%	72%	82%	95%
2022	96.50%	99%		100%	
2023	97%	99%	14%	100%	
Vishakhapatnam					
2020	60%	60%	33%	67%	83%
2021	88%	100%	80%	75%	100%
2022	98.38%	99.50%		100%	
2023	98%	100%	26%	100%	
Tirupati					
2020	100%	60%	50%	100%	100%
2021	88%	100%	100%	100%	100%
2022	75.75%	98.25%		91%	
2023	76%	98%	100%	91%	

Source: Ministry of Housing and Urban Affairs (2022; 2023b).

collection, the extent of SWM charges collection is also improving. Visakhapatnam has also enforced tax-based SWM fees (Rao 2022). The user charges for SWM in Tirupati were revised recently, which is expected to improve revenues (Indian Express 2021). All three cities generate revenue from waste recovery in dry as well as wet waste management plants. Moreover, the involvement of private parties in establishing treatment plants, operating them, and selling recycled products has transformed waste management into a financially sustainable sector. Lower cost recovery leads to greater demand for grants and budgetary allocations from central and state governments. These grants may be appropriate to meet capital requirements for construction or one-time purchase of machinery. However, at least a part of the cost associated with operating high-quality services needs to be recovered through user charges, or they will be rendered financially unsustainable. Currently, there is no precedent of any state charging cost-covering service charges to the public. Higher charges might result in people sidestepping the waste collection system and resorting to open dumping. The polluters pay principle holds polluters liable for environmental degradation caused by solid waste and makes the payment of charges for treating waste a responsibility of waste generators

(Gaur, Gurjar, & Chaudhary, 2022). Thus, steps need to be taken to increase the service charges paid by the people to recover SWM costs.

According to the baseline SLBs, waste recovery and scientific disposal were very high in Pune and negligible in Vishakhapatnam and Tirupati. The situation in Tirupati has improved with the installation of centralized and decentralized treatment plants and the remediation of legacy waste dumpsites. All three ULBs have reported improvements in wet waste processing, as on-site and centralized composting has been partially implemented in all three cities. It should be noted that the SLBs reported in 2011 on scientific disposal and waste recovery are supposedly inaccurate; there have been multiple agitations and allegations regarding waste, which have led to the identification of newer sites (Jadhav 2022; Banerjee 2020). Efforts have been made since then to increase waste recovery and scientific disposal, and the figures reported in SLP 2023 show an improving trend.

Pune has historically struggled with dry waste processing and has been forced to send waste to its dumpsite. Initiatives have been launched under various missions since to establish scientific waste-recovery plants, and the city reported satisfactory performance as per its SLP markers. Though Pune has begun bioremediation at the city's legacy waste dumpsite, it has not yet been able to remediate the complete dumpsite. The dumpsite remediation scenario in Vishakhapatnam is similar. Only Tirupati has managed to remediate the whole site. Lower scientific disposal indicates a higher chance of open dumping, which can lead to environmental degradation, health hazards, and soil and water pollution. If waste treatment, recovery, and disposal are not effective, then waste segregation becomes purposeless. Additional efforts and investment towards segregating waste would not then aid in bettering the environment.

Table 4: Results from the Household Survey

	Pune	**Visakhapatnam**	**Tirupati**
Household coverage	100%	94.5%	98%
Waste segregation	90%	70%	89%
Collection frequency (every day)	94%	64%	57%
Door-to-door waste collection	76%	45%	69%
Use of community bins	2%	24%	10%
Non-payment of service charges	45%	76%	57%
Willingness to pay	29%	10%	21%
Performance improvement rating (average out of 5)	3.3	3.4	3.4

Source: Author's compilation.

5.2. Results of the Household Survey

The results from the residents' survey, as shown in Table 4, revealed similar trends. As the survey was conducted in 2021–22, the results reflect the opinion of respondents regarding in-progress work vis-à-vis SWM in the three cities.

Several observations can be made when the results from

Table **4** are compared with It can be observed from the baseline SLBs and the recent SLP indicators that the sample cities have significantly improved household coverage for SWM services as well as enhanced collection efficiency. The SLP markers for Vishakhapatnam and Tirupati show remarkable advancements in waste collection. As evidenced by Table 3, Pune's waste segregation capacity has remained high and steady above 95%. Vishakhapatnam has also made tremendous progress in increasing segregation by 38% between 2020 and 2023. On the other hand, Tirupati trails behind in this regard.

Pune reported high efficiency in collecting service charges and cost recovery in the 2011 SLB itself. Visakhapatnam reported some progress in collecting user fees, while Tirupati did not collect any service charges in 2011 as per the reported SLBs; however, they were considering the possibility (Kummara, 2021). Cost recovery and user charges were not directly covered in the SLP but were part of a sub-parameter, for which recent data is unavailable. However, some observations regarding user charges can be drawn based on SWM practices in the cities. In Pune, the SWM charges are built into property taxes, and, with advances in online

Table 3. The following are the observations:

Household coverage: Coverage of SWM services is high in all three cities, and the respondents' opinions are in line with the SLP reported.

Waste segregation: Around 90% of Pune respondents reported that they segregate their waste into dry and wet waste, and most were aware of the localized treatment of organic waste. However, despite the city's acclaimed Red Dot Campaign, as described in the best practices section, none of the respondents reported segregating medical and sanitary waste. Approximately 70% of the respondents in Visakhapatnam and 89% of the respondents in Tirupati said that they segregate their waste into dry and wet waste. Nearly 6% of Tirupati respondents segregate medical and sanitary waste. An additional question was posed about the amount of waste generated by each household (in terms of the number of dustbins used). Only Tirupati respondents reported using more than two bins, which

indicates waste segregation. For Tirupati, the survey results show better compliance than the reported SLP in terms of segregation.

Collection frequency: Almost 94% of the Pune respondents said that waste is collected every day, 2% said it is collected every two days, and the remaining reported irregular collection. In Visakhapatnam, 64% of the respondents reported daily collection, 27% said the collection was scheduled on alternate days, and the remaining said it was infrequent. In Tirupati, 57% of the respondents said waste is collected daily, 33% said it is collected on alternate days, and the remaining said it was infrequent. Even though Visakhapatnam and Tirupati nearly fulfilled the SLP requirements, there is room for service improvement.

Waste collection method: Around 76% of the Pune respondents reported that waste is collected from home; 45% of the Visakhapatnam and 69% of the Tirupati respondents concurred. The remaining respondents—22% in Pune, 23% in Visakhapatnam, and 16% in Tirupati— said that their waste is collected from a fixed site along the route of the waste collection service. Only 2% of respondents from Pune use community bins, while 24% of respondents from Visakhapatnam and 10% from Tirupati use community bins. While none from Pune said they self-dispose their waste, 8% of Visakhapatnam and 5% of Tirupati respondents said they self-dispose their waste, indicating open dumping. Moreover, Pune respondents reported that they put out segregated garbage bins at their time of convenience outside their door. The waste then gets collected door-to-door by the SWaCH workers at designated times. In Tirupati, waste is collected at a fixed time by vehicles, and citizens should deposit their waste when the vehicle is near their place. Thus, the door-to-door collection system in Pune is more effective and user-friendly. The survey results are notably lower than the SLP reported for door-to-door services in all three cities.

Service charges: Approximately 45% of Pune respondents said that there are no charges for SWM services; 76% of the Visakhapatnam and 57% of the Tirupati respondents reported the same. In Pune, charges are collected in lump sum as a component of property tax. It should be noted that participants may be unaware of property tax components and, consequently, may have responded that the service is free. Further, in all three cities, residential societies can employ a private waste collection service for which charges are collected privately. Consequently, some participants may have responded that they are paying SWM charges, even though the user charges reaching the respective ULB may be low.

Willingness to pay: Around 57% of the Pune respondents, 83% of the Visakhapatnam respondents, and 66% of the Tirupati respondents said they

are unwilling to pay for SWM services, whereas around 10% of the respondents said they would pay only nominal charges. Nonetheless, 29% of the Pune, 10% of the Visakhapatnam, and 21% of the Tirupati respondents are willing to pay cost-covering charges. This indicates that citizens do not recognize the waste producer's responsibility and reversing the culture of providing free service will be a challenge.

Performance improvement: The respondents were asked to rate the improvement in SWM in the past five years on a scale of 1 to 5. This question was to gauge the development under the Smart City Mission and Swachh Bharat Abhiyan. The average score in all three cities was between 3.3 and 3.4, which indicates that citizens have noticed a significant improvement in SWM services. Thus, this study's observations regarding improvements in performance due to the implementation of various government initiatives and missions align with the observations made in the literature (Rao 2019).

6. DISCUSSION

Swachh Survekshan employs a holistic and integrated approach to monitor SWM services, including SLP reporting, certifications, and collection of public feedback. The SLP reported by the three cities is in tune with the ground realities found in this survey. However, the final scores do not portray the complete picture and miss out on ground-level details such as the frequency of waste collection and collection of SWM charges. Larger cities, such as Pune, and their ULBs have optimum SWM capacities, which is reflected in their performance. In a smaller city such as Tirupati, public action—such as proper waste segregation—may be prompt but is often short-lived. Installation of waste processing units in smaller cities should be accelerated and made more effective.

Several initiatives, such as the introducing RFID-tagged collection vehicles, distributing coloured-coded dustbins, increasing the involvement of NGOs and private-sector stakeholders, and promoting business opportunities in waste recovery, have strengthened SWM services in the three cities (Ministry of Housing and Urban Affairs 2024). Sustaining the capital-intensive treatment processes initiated under the Smart City Mission and Swachh Bharat Abhiyan is the next objective for ULBs. Another challenge is finding a market for recovered and recycled products such as compost, biofuel, scrap metals, papers, glass, and rubber. Various industries must be roped in to complete the reuse cycle.

This work will be useful in tracing the progress made in SWM in the sample cities, as it reveals the ground reality of SWM policy and programme implementation and highlights performance improvements and gaps. These findings are relevant to city governments, policy formulators, NGOs, researchers, other institutions in the sector, and citizens at large. Several other cities, such as Bengaluru, Navi Mumbai, Indore, and Surat, have unique, noteworthy initiatives that are helping them improve their SWM services (Pushkara 2022). A comprehensive study of best practices can add value to SWM practices in other Indian cities as well. Many new technologies, such as waste converters and shredders (Earth Care 2022), are emerging, and an understanding of these technologies can immensely streamline and enhance waste management processes.

7. CONCLUSION

This study agrees with the Swachh Bharat Abhiyan's Swachh Survekshan principle of implementing a data-driven SWM process. Reporting of the SLBs—and, now, the SLP—is crucial for tracking the performance of SWM services, comparing it with peers, and comprehending trends and patterns. The SLP indicators and the survey show that SWM services have improved in all three cities due to the Smart Cities Mission and Swachh Bharat Abhiyan initiatives. By studying best practices in Pune, Visakhapatnam, and Tirupati, this study indicates that several initiatives by all levels of government and citizens have led to improvements against most parameters by 40% to 50%.

The practice of waste segregation at source is taking root among the citizenry. Progressive efforts are being made to segregate dry waste further into sanitation, medical, garden, plastic, and other waste for a more efficient waste recovery process. Setting up waste processing plants and involving private-sector stakeholders in waste recovery and recycling has led to the development of innovative business models such as waste-to-energy plants in Visakhapatnam and compressed biogas in Pune. Centralization of these treatment processes and decentralization of certain processes, such as by establishing society-level vermicomposting and bio-chest machines near bulk generators, have added value to SWM services and reduced the burden on disposal services. Efforts towards establishing scientific waste disposal and dumpsite remediation have led to an incredible change in practices, wherein former dumpsites detested by citizens are being used for tree plantations and are being converted into urban forests attracting visitors.

Even though waste recovery and recycling are boosting cost recovery, the entire system is not financially independent. SWM is a societal necessity

created by human activities, and thus, SWM charges must be normalized on the polluters' pay principle to enable a mindset shift among citizens. The efficiency of segregated collection, treatment and recovery, scientific disposal, and the financial sustenance of the system are mutually dependent. Consistent and reliable waste collection will likely improve citizen satisfaction as well as reduce the environmental externalities.

Ethics Statement: We hereby confirm that this study complies with requirements of ethical approvals from the institutional ethics committee for the conduct of this research.

Data Availability statement: All data used is included in the paper.

Conflict of Interest Statement: No potential conflict of interest was reported by the author.

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