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Sustainable Waste Management Strategies For Semi-Urban Areas: A Study On Pannimadai, Coimbatore

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Abstract
Semi-urban areas are often overlooked in mainstream policy discussions on waste management, despite facing growing challenges due to urban expansion, inadequate infrastructure and lack of public awareness. However, local communities in these regions are not passive recipients of these issues - they respond with their own forms of agency and initiative. This study focuses on Mullai Nagar in Pannimadai, Coimbatore, where residents, particularly women, engage in everyday acts of sustainable waste management, such as home composting and waste segregation. These practices, though modest, reflect a form of environmental consciousness and resistance to unsustainable waste disposal systems. Despite limited institutional support, local participation plays a crucial role in shaping effective grassroots solutions. Using an interventional model and empirical data from households, this study highlights how community-driven practices can challenge systemic gaps and pave the way for decentralized, sustainable waste governance in semi-urban India.

KeyWords*: Home Composting, Waste Segregation, Sustainable Waste Management, Semi-Urban Intervention, Community Participation.*

INTRODUCTION

India, the world's second-most populous country, is home to more than 1.21 billion people, accounting for 17.5% of the global population (Census of India, 2011). Over the decade from 2001 to 2011, the urban population in India grew by 31.16%, reflecting the nation's rapid urbanization. This urban shift has significantly altered the physical and demographic landscape of Indian cities, exerting immense pressure on existing infrastructure and essential services. Among the emerging challenges, Solid Waste Management (SWM) has become a critical concern. The unplanned and often inefficient handling of solid waste, compounded by large-scale migration and the development of megacities, has exposed gaps in India's waste infrastructure, including overreliance on landfilling, informal sector operations and minimal public accountability (Ministry of Housing and Urban Affairs, 2020).

The global context echoes similar concerns. According to the World Bank (2022), global waste production is expected to rise by approximately 70% by 2050 if sustainable measures are not adopted. Traditional disposal methods such as open dumping and landfilling have led to severe environmental consequences including groundwater contamination, soil degradation, and greenhouse gas emissions (United Nations Environment Programme, 2018). In response, sustainable waste management has emerged as a necessary strategy to mitigate environmental and public health impacts while promoting efficient use of resources. This approach emphasizes the principles of the circular economy - reduce, reuse, recycle and energy recovery, transforming waste from a liability into a resource (Ellen MacArthur Foundation, 2013). Countries like Sweden and Italy have demonstrated that with strong policies and community participation, sustainable systems are achievable. For instance, Sweden has successfully converted over 99% of its household waste into reusable energy (Swedish Waste Management Association, 2020). while Parma, Italy has surpassed 80% in recycling rates through strict waste segregation and public engagement (Zero Waste Europe, 2016).

Sustainable waste management addresses a range of environmental, economic and social challenges. It helps reduce pollution, conserve natural resources and mitigate climate change through methods like composting, anaerobic digestion and waste-to-energy conversion (Guerrero et al., 2013). Studies emphasize that adopting circular economy models not only reduces landfill dependence but also supports employment generation, economic efficiency and environmental resilience (European Environment Agency, 2019).

Globally, waste management strategies have evolved from mere disposal to integrated and sustainable approaches. The concept of a circular economy has gained momentum, focusing on designing waste out of the system and recirculating materials (Kirchherr et al., 2017). However, many developing nations, including India - still struggle with systemic issues - lack of infrastructure, low public awareness, weak policy enforcement and inadequate funding (Central Pollution Control Board, 2021). Semi-urban areas

are particularly vulnerable due to their transitional nature, limited access to resources and improper disposal practices. Nevertheless, these areas hold significant potential for grassroots innovations such as household-level composting and decentralized waste segregation. Composting organic waste not only reduces landfill burden but also produces nutrient-rich manure, thereby promoting agricultural sustainability and reducing dependence on chemical fertilizers (Sharholy et al., 2008).

This study focuses on Pannimadai, a semi-urban area in Coimbatore, Tamil Nadu, to analyse current waste management practices with an emphasis on sustainable strategies like home composting and source-level segregation. By identifying infrastructural gaps, assessing community engagement and evaluating existing policy frameworks, the research aims to propose viable, context-specific solutions. The findings are expected to contribute to developing practical, community-driven models for waste management that align with the environmental and socio-economic dynamics of semi-urban India.

MATERIAL AND METHODS

The study was limited to 30 households in Mullai Nagar, Pannimadai, Coimbatore, selected through convenience sampling. The researcher selected 10% of the total 300 households in the area, as a larger sample size might have made it difficult to manage follow-up procedures during the intervention. By selecting 30 households, the researcher ensured a manageable sample size while still capturing a representative portion of the community. The data collection was carried out during the year 2024, focusing on the awareness and practices of solid waste management at the household level. This study is interventional research focused on composting practices in households. A 5-point rating scale was employed for evaluating respondents' awareness and waste management practices, with categories ranging from always (1) to never (5).

The study followed a structured three-phase methodology - pre-intervention, during intervention, and post-intervention - to design, implement and evaluate a sustainable solid waste management strategy in the selected semi-urban community. In the pre-intervention phase, the awareness level and existing solid waste management practices among the sample population at the Panchayat level were assessed through a baseline survey. This initial evaluation provided crucial insights into the gaps in knowledge and practices, which informed the design of a context-specific intervention model.

During the intervention phase, the designed model was implemented using community-based awareness strategies. Pamphlets were developed in the local language to ensure accessibility and effective communication. The first pamphlet focused on educating the public about the importance of waste segregation at the source, while the second outlined a step-by-step process for preparing home compost. These pamphlets were distributed across the community and the implementation process was closely monitored to ensure clarity, reach and active participation.

In the post-intervention phase, a reassessment was conducted to evaluate changes in awareness levels and waste management behavior. Particular attention was given to improvements in waste segregation and composting practices, as these were key indicators of the intervention's effectiveness.

The model of intervention adopted in this study was an integrated and participatory approach, comprising four key components: (1) awareness creation, which aimed to influence community behavior through targeted informational tools; (2) waste segregation at source, which promoted sorting waste into biodegradable, non-biodegradable and sanitary categories to facilitate proper disposal and recycling; (3) pre-preparation of compost bins, which involved guiding households in selecting suitable bins, identifying appropriate locations and preparing the base with dry organic material to support decomposition; and (4) utilization of biodegradable waste, which encouraged the systematic addition of organic waste in layers, the use of microbial culture such as sour curd or buttermilk to accelerate composting, and regular turning of the compost for aeration. This model was implemented with the active involvement of the local Panchayat and the community, fostering long-term sustainability in household-level waste management.

A structured interview schedule, incorporating a carefully designed self-administered questionnaire, was utilized as the primary tool for data collection in this study. The questionnaire was developed to cover various dimensions, including socio-economic characteristics, existing waste management practices, levels of community awareness, and perspectives on sustainability in waste handling. The validity and reliability of the instrument were assessed, and the Cronbach's Alpha value was calculated to be 0.710, indicating that the tool was reliable and suitable for use in the study. Primary data was collected through face-to-face interviews, which enabled the researcher to capture not only quantitative responses but also qualitative insights into community participation and the challenges faced in managing household waste. In addition to primary data, secondary data was obtained from the Pannimadai Panchayat office and other relevant

reports to supplement the findings. The collected data was analysed using appropriate statistical tools, including frequency distributions, percentages, the Chi-Square test, the McNemar test and Binary Logistic Regression, to interpret the outcomes and evaluate the impact of the intervention on composting practices at the household level.

RESULTS AND DISCUSSION

1. Socio-economic Profile of the Respondents

The Socio-economic profile of respondents typically refers to the characteristics of the individuals participating in a study. These characteristics include age, education, income, occupation and so on.
Collecting and analyzing data on these socio-economic characteristics can provide valuable insights into the diversity and distribution of respondents, allowing researchers to better understand how different groups may perceive or be affected by certain issues, such as waste management challenges.
The Table 1 shows the Socio-economic profile of the respondents

Table 1: Socio-economic profile of the Respondents

Variable	Aspects	Frequency (n=30)	Percentage (%)
Age	21-30	9	30
	31-40	14	47
	41-50	6	20
	Above 50	1	3
Educational qualification	Primary	8	26
	Secondary	5	17
	Higher secondary	6	20
	Graduate	9	30
	Post graduate	2	7
Size of the family	2	2	7
	3	6	20
	4	13	43
	5	8	27
	7	1	3
Occupation	Home maker	23	77
	Others	7	23
Annual Income	80,000	4	13
	81,000-1,00,000	11	37
	1,01,000 -1,20,000	4	13
	Above 1,20,000	11	37

The above table 1 shows that most of the respondents belong to the age group of 31 to 40 years at 47%, closely followed by the age group of 21 to 30 years at 30%. The age group of 41 to 50 years accounts for 20%, while the least number of respondents are above 50 years at only 3%.
In terms of educational qualification, the majority of respondents are graduates at 30%, followed by those with primary education at 26% and higher secondary education at 20%. A relatively lower proportion of respondents completed secondary education at 17%, and only 7% have postgraduate qualifications, making it the least represented group.
With regard to the size of the family, most respondents have a family of 4 members (43%), followed by those with 5 members (27%). Families with 3 members make up 20%, while the smallest family size (2 members) and the largest (7 members) are the least common, both at 7% and 3% respectively.

As for occupation, the majority of respondents are homemakers (77%), while only 23% fall under other categories which includes retired persons and shop keeper.

When considering annual income, the highest percentage of respondents (37%) earn between ₹81,000–1,00,000, with an equal percentage (37%) earning above ₹1,20,000 annually. A smaller fraction (13%) earns up to ₹80,000, while another 13% earn between ₹1,01,000 and ₹1,20,000, showing a balanced distribution across income ranges.

2. Current Scenario of Waste Management

The current scenario of waste management involves a mix of traditional and modern disposal methods such as landfilling, incineration, composting, recycling and municipal collection. While efforts are being made to promote source segregation, recycling and sustainable practices, challenges like inadequate infrastructure, poor awareness and low regulatory compliance persist. Technological innovations, policy reforms and public participation are gradually shaping more efficient systems. However, open dumping and inefficient logistics continue in many areas. Assessing the current methods helps identify gaps, enhance efficiency and promote environmentally sound practices essential for achieving sustainable waste management and aligning with national and global environmental goals.

Table 2: Current Scenario of Waste Management

Variable	Aspects	Frequency (n=30)	Percentage (%)
Frequency of waste collection	Alternate days	26	87
	Irregular	4	13
Types of waste commonly generated in households	Kitchen waste	30	100
	Plastic waste	28	93
	Medical waste	3	10
	others	1	3
Disposal of plastic waste	Waste collection service	15	50
	Sell to scrap dealers	14	47
	Reuse	1	3
Waste accumulation in public areas	Frequently	8	27
	Occasionally	14	47
	Rarely	8	26
Face any health issues due to improper waste management	Yes, frequently	3	10
	Yes, sometimes	17	57
	No	10	33
Increase in stray animals	Yes, significantly	18	60
	Yes, slightly	12	40

The table 2 reveals that 87% of respondents receive waste collection services on alternate days, indicating a relatively regular collection system. However, 13% reported irregular collection, highlighting service gaps that need attention.

Regarding the types of waste generated, kitchen waste is universally produced (100%), followed closely by plastic waste (93%). Medical Waste (10%) and other types (3%) are less common, suggesting the need for focused strategies on biodegradable and recyclable waste.

In terms of plastic waste disposal, 50% depend on government collection services, while 47% sell it to scrap dealers, pointing to a strong role of the informal sector. Only 3% reported reusing plastic, indicating low levels of plastic reuse.

Concerning waste accumulation in public areas, 47% observe it occasionally, 27% frequently, and 26% rarely, indicating moderate to high instances of public space pollution.

Health impacts from improper waste management are also notable: 57% sometimes face health issues, and 10% frequently, while only 33% report no health issues, indicating a public health concern that must be addressed.

60% of respondents observed a significant increase in stray animals, and 40% reported a slight increase, suggesting that poor waste disposal may be contributing to animal-related disturbances and potential health risks.

Table 3: Cleanliness rating of the area

Variable	Aspects	Frequency (n=30)	Percentage (%)
Rate the cleanliness	Strongly Disagree	7	23
	Disagree	8	27
	Neutral	15	50

The table 3 indicates that 50% of the respondents reported neutral level of cleanliness standards in their area, A moderate 27% were disagree, suggesting an average level of cleanliness, while 23% strongly disagreed, indicating dissatisfaction and poor cleanliness conditions. This distribution reveals that while half of the respondents are content with cleanliness, a significant portion (50%) have either a neutral or negative view of the conditions.

This suggests uneven implementation of cleanliness and sanitation services possibly due to irregular waste collection or public negligence. Strengthening community awareness, improving waste infrastructure and ensuring consistent municipal services could help raise overall cleanliness satisfaction levels.

Table 4 Satisfaction with Current Waste Disposal Practices

Variable	Aspects	Frequency (n=30)	Percentage
Satisfaction with the current waste disposal practices	Neutral	17	56
	Dissatisfied	5	17
	Highly dissatisfied	8	27

The table 4 shows that a majority of respondents, 56% (17 out of 30) expressed a neutral opinion regarding current waste disposal practices. Meanwhile, 17% reported dissatisfaction and a notable 27% were highly dissatisfied with the existing system.

This indicates that while more than half of the respondents are neither fully satisfied nor entirely dissatisfied, a combined 44% expressed negative sentiments highlighting underlying concerns with the effectiveness, consistency and accessibility of current waste disposal services.

The high level of dissatisfaction suggests a need for improved waste management infrastructure, regular monitoring and greater community engagement to build public trust and satisfaction with waste disposal practices.

Table 5 Main Reason for Poor Waste Management

Variable	Aspects	Frequency (n=30)	Percentage (%)
Main reason for poor waste management	Lack of government action	11	37
	Lack of public awareness	5	17
	Insufficient waste collection infrastructure	9	30
	People's negligence	5	17
	Lack of government action	11	37

The data in table 5 shows that the most common reason for poor waste management as reported by 37% of respondents, is the lack of government action. This is followed by insufficient waste collection infrastructure at 30%. Additionally, 17% respondents reported lack of public awareness and people's negligence as key issues.

The findings suggests that both government inefficiency and weak infrastructure are seen as major problems. However, public behaviour and awareness also play an important role. Improving waste management will require stronger government efforts, better facilities and more public education and responsibility.

3. Ways to Make Waste Management More Effective and Sustainable

Ways to make waste management more effective and sustainable includes the strategies, interventions and best practices aimed at improving the efficiency, environmental soundness and long-term viability of waste handling systems. These approaches focus not only on proper disposal but also on reducing waste generation and promoting resource recovery.

Table 6 Ways to Make Waste Management More Effective and Sustainable

Variable	Aspects	Frequency (n=30)	Percentage (%)
Witness illegal dumping	Frequently	8	27
	Sometimes	16	53
	Rarely	6	20
Kind of waste commonly mismanaged	Plastic waste	29	97
	Food waste	1	3
Action taken for illegal dumping	Report it to authorities	3	10
	Ignore it	19	63
	Try to clean it	6	20
	Confront the person responsible	2	7

The data in table 6 reveals that illegal dumping is a frequent issue with more than half of respondents witnessing it occasionally or frequently. Plastic waste is overwhelmingly the most mismanaged waste, highlighting a significant problem with plastic disposal.

It is important to note that although many respondents notice illegal dumping, the majority do not take action. The fact that 63% of them overlook the issue suggests a lack of community involvement or awareness regarding the importance of addressing it. Additionally, the low percentage (10%) of respondents who report the issue to authorities points to either ineffective reporting systems or a general reluctance to engage in the matter.

To address this, there should be stronger enforcement of waste management policies, public awareness campaigns and more accessible reporting systems to encourage people to take action and reduce illegal dumping.

Table 7 Challenges faced by Panchayat in Waste Management

Variable	Aspects	Frequency (n=30)	Percentage
Challenges faced by panchayat	Overloaded waste bins	11	37
	Irregular waste disposal by residents	9	30
	Lack of cooperation from the community	10	33

The data in table 7 highlights that the panchayat faces multiple challenges in waste management with overloaded bins being the most common problem. The findings suggests that waste collection or bin capacity may be insufficient to meet the demand.

Additionally, lack of community cooperation and irregular waste disposal by residents are significant hurdles, reflecting a need for greater public involvement and better awareness of proper disposal practices. Addressing these issues will require improving infrastructure, increasing community engagement and ensuring more consistent waste collection services.

4. Community Participation and Awareness about Waste Segregation

Community participation and awareness about waste segregation refer to the involvement of local residents and their understanding of the importance of separating waste at the source into biodegradable and non-biodegradable components. This plays a critical role in the success of any waste management system, as segregation at the household and institutional level significantly enhances the efficiency of recycling and safe disposal.

Table 8 Community Participation and Awareness about Waste Segregation

Variable	Aspects	Frequency (n=30)	Percentage (%)
Currently practicing waste segregation at home	No	30	100
Main reason for not segregating waste	Lack of awareness	5	17
	Lack of separate bins	9	30

	No incentive to segregate	2	7
	It is inconvenient to handle	14	47
Waste segregation is important	Yes	16	53
	Somewhat	14	47
Willingness to take part in sustainable waste management	Yes	30	100

The table 8 shows that none of the respondents are currently practicing waste segregation, highlighting a major gap in waste management practices. The key barriers are inconvenience (47%), lack of separate bins (30%) and lack of awareness (17%), which indicate that infrastructure and education are critical in encouraging better waste management practices at the household level.

It is important to note that 53% of respondents recognize the importance of segregation and 100% are willing to participate in waste management. This suggests a strong public willingness to engage in waste management if the right infrastructure and incentives are provided. Efforts should focus on making waste segregation easier, more convenient and rewarding to encourage broader adoption.

5. Pre - Post Intervention Results

The pre-intervention and post-intervention analysis of sustainable waste management practices focuses on assessing changes in respondents' behaviors, knowledge, attitudes and challenges before and after an intervention. Pre-intervention data helps establish a baseline, capturing current Waste Management practices, awareness levels, attitudes toward sustainability and existing barriers, such as lack of knowledge or resources. Post-intervention data evaluates whether there have been improvements, such as an increase in waste segregation, better awareness of practices like composting, or a shift in attitudes towards sustainability. The analysis also looks at whether barriers to adoption have been reduced, such as overcoming lack of knowledge or access to resources. Comparing these data points helps gauge the effectiveness of the intervention, providing insights into how different socio-economic groups responded and whether the program successfully promoted sustainable waste management behaviors.

Table 9 Disposal of Household Waste

Variable	**Aspects**	**Pre Intervention**		**Post Intervention**	
		(n=30)	%	**(n=30)**	%
Disposal of household waste	Waste collection services	28	93	30	100
	Composting	0	0	19	63

Before the intervention, 93% of respondents (28 out of 30) relied on waste collection services for the disposal of household waste, while no 1% practiced composting. This indicates that waste disposal was largely dependent on external services with little to no involvement of households in waste reduction and sustainable practices like composting.

After the intervention, there was a significant improvement. Majority (100%) of respondents started utilising waste collection services, showing that the intervention has successfully ensured comprehensive access to waste disposal services. Additionally, 63% (19 out of 30) have started practicing composting, highlighting a shift towards more sustainable waste management practices at the household level.

This change suggests that the intervention successfully raised awareness and encouraged participation in composting, contributing to a more sustainable approach to waste disposal. The overall results reflect a positive shift in waste management practices, with greater involvement of the community in sustainable actions.

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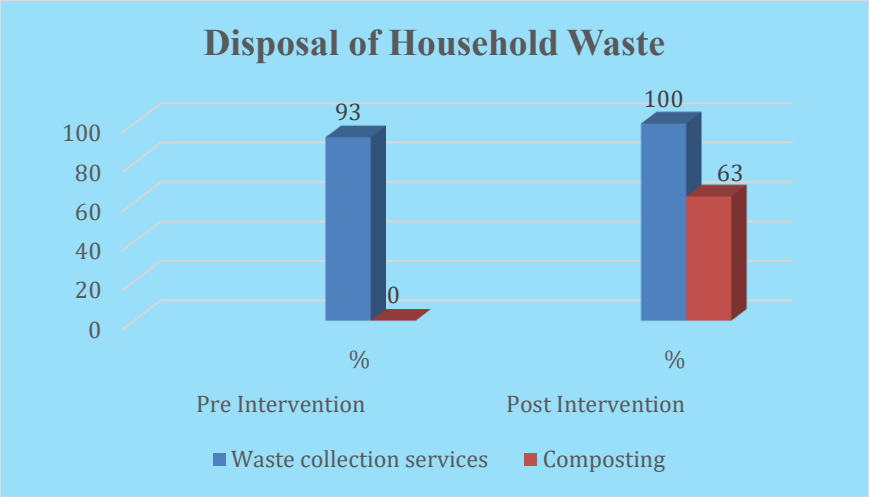

Figure 1 Disposal of Household Waste

Table 10 Aware of the Concept of Waste Segregation

Variable	Aspects	Pre Intervention		Post Intervention	
		(n=30)	%	(n=30)	%
Aware of the concept of waste segregation	Yes	5	17	30	100
	Somewhat	25	83	0	0

Before the intervention, only 17% of respondents (5 out of 30) were fully aware of the concept of waste segregation, while the remaining 83% (25 out of 30) had only partial understanding. This indicates that although some level of awareness existed, it was largely incomplete and likely insufficient to drive effective waste management practices.

After the intervention, majority (100%) reported being fully aware of the concept of waste segregation. This demonstrates a significant improvement in knowledge and understanding, suggesting that the intervention effectively bridged the awareness gap.

The results show that the intervention successfully enhanced participants' comprehension of waste segregation which is a critical first step toward encouraging responsible behavior and sustainable waste practices. Indicating, the households are better equipped to adopt and maintain proper waste segregation habits.

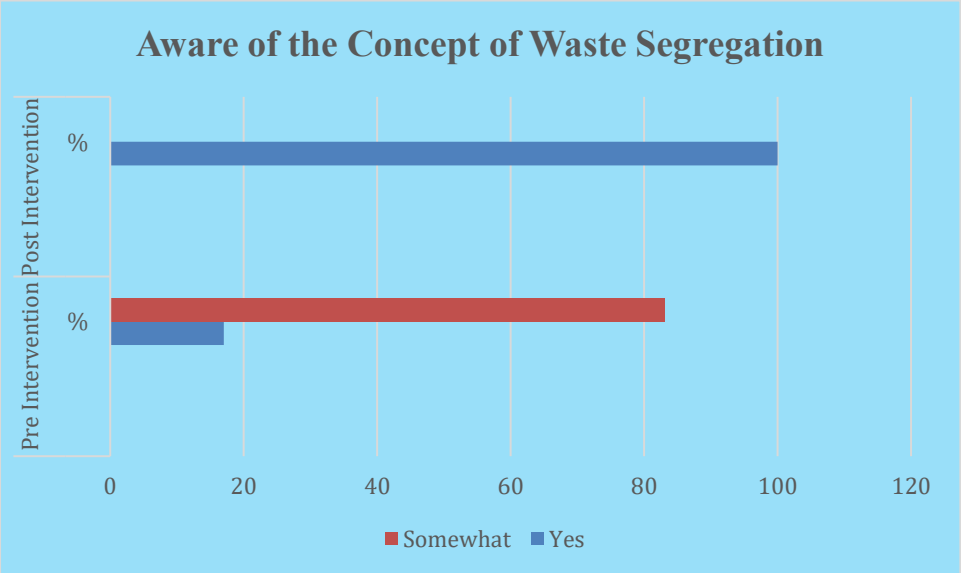

Figure 2 Aware of the Concept of Waste Segregation

Table 11 Adaption of Waste Segregation Practices

Variable	Aspects	Pre Intervention		Post Intervention	
		(n=30)	%	(n=30)	%
Currently practicing waste segregation	Yes, always	0	0	19	63

	Sometimes	0	0	5	17
	No	30	100	6	20

Before the intervention, none of the respondents (0 out of 30) reported always or sometimes practicing waste segregation. Majority (100%) indicated that they did not engage in any form of waste segregation, reflecting a complete lack of awareness or adoption of waste segregation practice at the household level.
After the intervention, 63% of respondents (19 out of 30) started practicing waste segregation, by knowing its significance. while 17% of respondents (5 out of 30) practice waste segregation occasionally only when monitored. Only 20% (6 out of 30) continued not to practice segregation, stating the inadequate infrastructure is one of the major reasons. This marks a substantial improvement in adopting waste segregation practices.

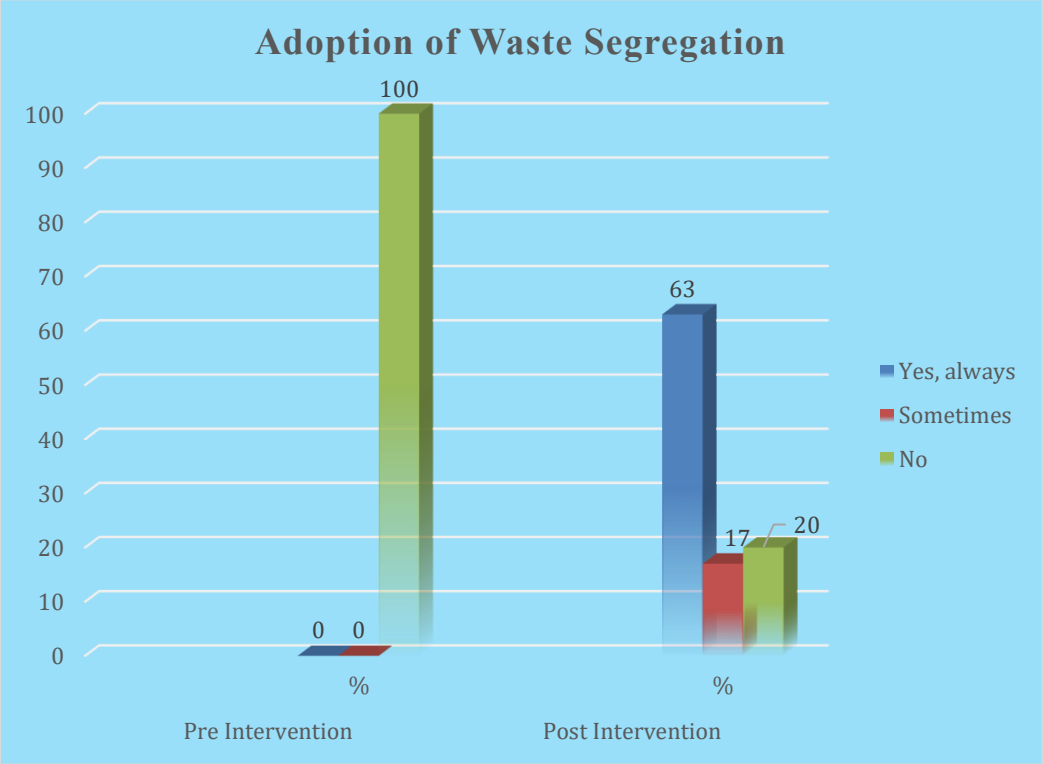

Figure 3 Adoption of Waste Segregation

Table 12 Separate bins for Waste Disposal

Variable	Aspects	Pre Intervention		Post Intervention	
		(n=30)	%	(n=30)	%
Separate bins	Yes	1	3	19	63
	No	29	97	11	37

Before the intervention, only 3% of respondents (1 out of 30) reported using separate bins for waste segregation at home, while the vast majority 97% (29 out of 30) did not have separate bins. This indicates a lack of basic infrastructure or awareness necessary for effective waste segregation at the household level.
After the intervention, there was a notable improvement, with 63% of respondents (19 out of 30) reporting the use of separate bins. However, 37% (11 out of 30) still did not adopt the practice. This shows a positive shift toward enabling proper waste segregation, though a portion of households may still face barriers such as lack of resources.
The results suggest that the intervention was effective in promoting the use of separate bins as a foundational step toward better waste management. The increase in adoption reflects growing awareness and practical action among households. However, the remaining gap also indicates the need for continued education, support or provision of resources to encourage full participation in waste segregation.

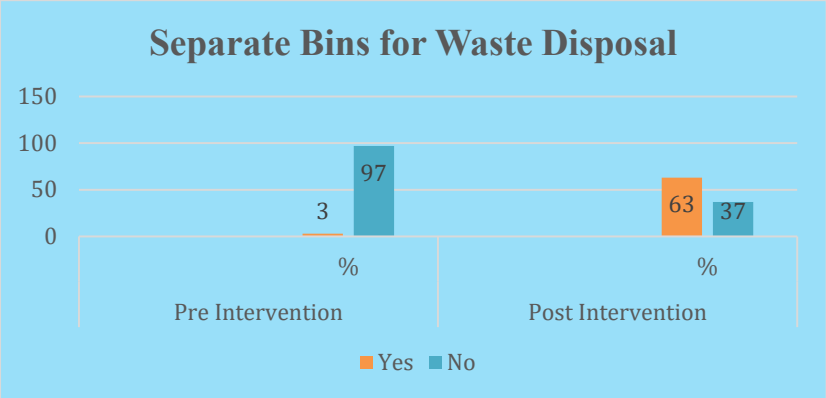

Figure 4 Separate bins for Waste Management

Table 13 Role of Government in Improving Waste Management

Variable	Aspects	Pre Intervention		Post Intervention	
		(n=30)	%	(n=30)	%
Role of government in improving waste management	Strict enforcement of waste management laws	25	83	20	67
	Providing more infrastructure	10	33	13	43
	Conducting awareness programs	22	73	24	80
	Incentivizing waste segregation and recycling	2	7	1	3

Before the intervention, 83% of respondents (25 out of 30) believed that strict enforcement of waste management laws was the key role of the government in improving waste management. Additionally, 73% (22 out of 30) highlighted the importance of conducting awareness programs, while 33% (10 out of 30) felt that providing more infrastructure was necessary, and 7% of respondents (2 out of 30) reported government can provide incentive for sustainable waste segregation.

After the intervention, there was a slight shift in the respondent's perception towards government action. Support for conducting awareness programs increased to 80% (24 out of 30), indicating that the intervention may have underscored the value of education and information dissemination. The percentage of respondents emphasizing strict enforcement dropped to 67% (20 out of 30), suggesting a possible shift toward recognizing the importance of proactive engagement rather than punitive measures. Similarly, the view that the government should provide more infrastructure rose to 43% (13 out of 30), while support for incentives decreased slightly to 3% (1 out of 30).

These changes suggest that the intervention not only improved individual awareness and practices but also influenced perceptions of how systemic improvements should be approached. The growing emphasis on awareness and infrastructure indicates a broader understanding among participants that sustainable waste management requires both education and supportive systems, not just enforcement.

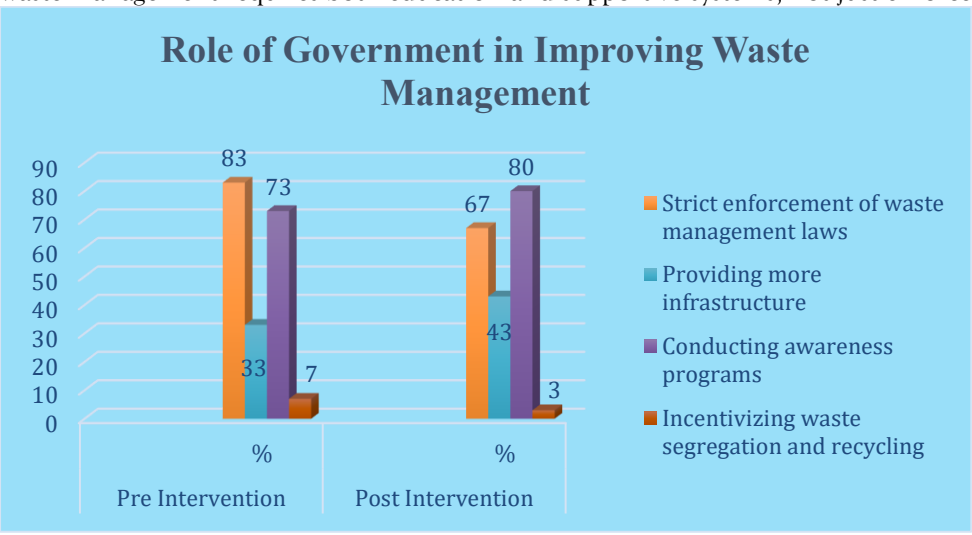

Figure 5 Role of Government in Improving Waste Management

Table 14 Role of Community in Waste Management

Variable	Aspects	Pre Intervention		Post Intervention	
		(n=30)	%	(n=30)	%
Role of community in waste management	Participation in cleanliness drives	2	7	0	0
	Proper waste segregation	11	37	22	73
	Reporting illegal dumping	14	47	20	67
	Educating proper waste management	3	10	6	20

Before the intervention, perceptions of the community's role in waste management were varied. Only 7% of respondents (2 out of 30) identified participation in cleanliness drives as a community responsibility. A larger portion, 37% (11 out of 30), acknowledged the importance of proper waste segregation, while 47% (14 out of 30) believed that reporting illegal dumping was part of the community's role, and 10% (3 out of 30) felt that educating others on proper waste management was a community responsibility.

After the intervention, there was a notable shift in perceptions. The importance of proper waste segregation rose significantly to 73% (22 out of 30), and reporting illegal dumping increased to 67% (20 out of 30). Awareness about the community's role in educating others also improved, with 20% (6 out of 30) recognizing it as important. Interestingly, none of the respondents identified participation in cleanliness drives, reflecting a shift in focus toward more sustainable, ongoing practices rather than one-time clean-up programmes.

These changes suggest that the intervention was effective in broadening participants' understanding of meaningful and sustainable community roles in waste management. The increased recognition of segregation, reporting and education highlights a more active and informed attitude toward environmental responsibility at the community level.

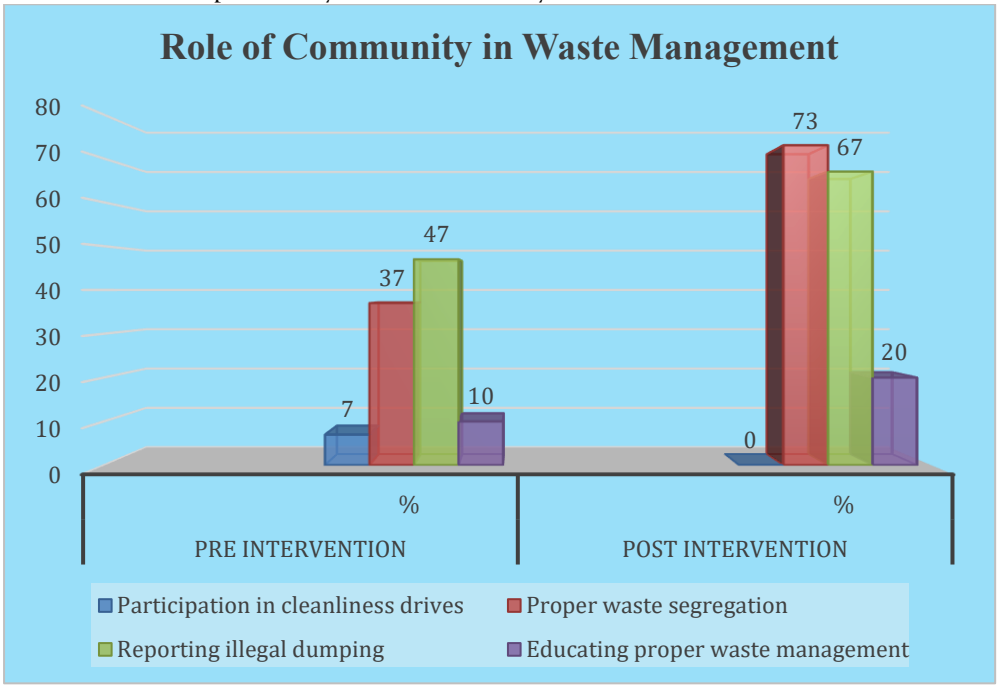

Figure 6 Role of Community in Waste Management

Table 15 Awareness Programme on Waste Management

Variable	Aspects	Pre Intervention		Post Intervention	
		(n=30)	%	(n=30)	%
Received any awareness Programme on waste management	Yes	2	93	30	100
	No	28	7	0	0

Before the intervention, 93% of respondents (28 out of 30) reported that they had not received any awareness programme on waste management, while only 7% (2 out of 30) had received some form of awareness programme.

After the intervention, there was a complete turnaround, with all respondents (100%) indicating that they had received awareness programme on waste management. This reflects the success of the intervention in providing essential knowledge and information to all participants.

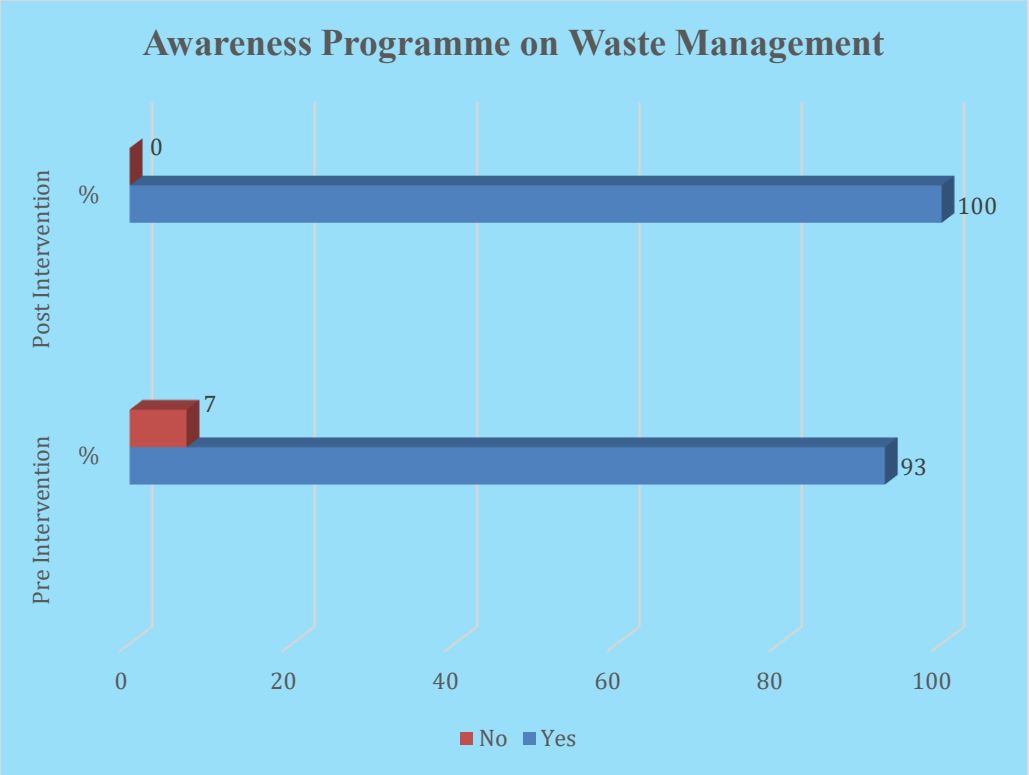

Figure 7 Awareness Programme on Waste Management

Table 16 Waste Segregation should be Enforced by Law

Variable	Aspects	Pre Intervention		Post Intervention	
		(n=30)	%	(n=30)	%
Waste segregation should be enforced by law	Yes	30	100	30	100
	No	0	0	0	0

Before and after the intervention, majority (100%) agreed that waste segregation should be enforced by law, with no participants opposing this view. This consistent response indicates that the belief in the importance of legally enforced waste segregation was already strongly held within the community and remained unchanged.

The result highlights the unified opinion on the need for legal enforcement to ensure proper waste segregation, which could be valuable for supporting future policies aimed at improving waste management.

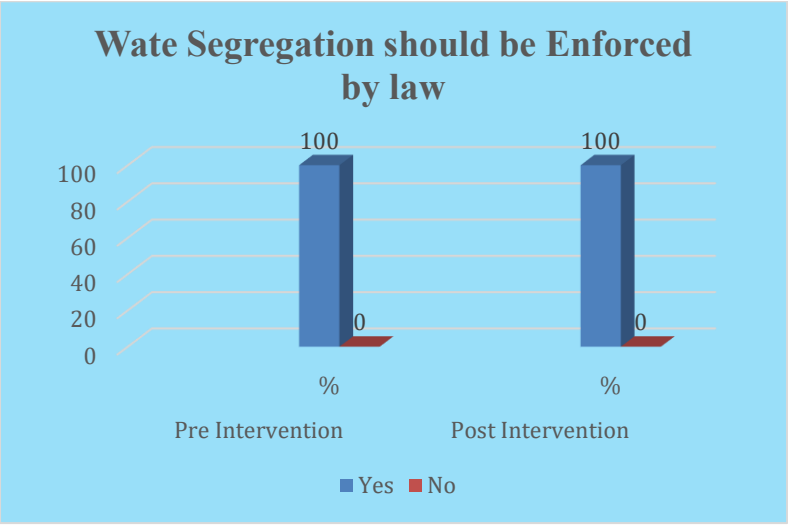

Figure 8 Waste Segregation should be Enforced by Law

6. Hypothesis Testing

Hypothesis testing is a statistical method used to make inferences or draw conclusions about a population based on data. It involves formulating and testing an assumption (hypothesis) about a population parameter. Using software tools like SPSS (Statistical Package for the Social Sciences), researchers can perform hypothesis testing efficiently by inputting data, selecting appropriate statistical tests and interpreting the output to determine whether to accept or reject the hypothesis. SPSS simplifies the analysis process by providing user-friendly interfaces, built-in test options and detailed result interpretations, making it a powerful tool for hypothesis testing in research.

The Hypothesis of this study,

✓ H01 - There is no significant influence of education level on awareness of waste segregation among respondents.

✓ H02 - There is no significant difference in the level of awareness regarding the concept of waste segregation in pre and post intervention.

✓ H03 - There is no significant increase in home composting practices at post intervention.

✓ H04 - There is no significant relationship between education and the likelihood of practicing composting in post-intervention.

Association between Education and Awareness on Waste Segregation
(Pre Intervention)

H01 - There is no significant influence of education level on awareness of waste segregation among respondents.

Table 17: Chi-Square Test between Education and Awareness on Waste Segregation

Test Statistic	Value	df	Asymp. Sig. (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)
Pearson Chi-Square	10.364[a]	1	.001	—	—
Continuity Correction[b]	7.349	1	.007	—	—
Likelihood Ratio	11.875	1	.001	—	—
Fisher's Exact Test	—	—	—	.003	.003
Linear-by-Linear Association	10.018	1	.002	—	—
Number of Valid Cases	30	—	—	—	—

The Chi-Square test was conducted to examine the association between the educational level of respondents and their awareness regarding waste segregation. The results are summarized as follows:

● The Pearson Chi-Square value is 10.364 with 1 degree of freedom and a p-value of 0.001, which is highly significant ($p < 0.05$).

● The Continuity Correction (Yates' correction) value is 7.349 with a p-value of 0.007, also indicating a significant relationship.

● The Likelihood Ratio value is 11.875 with a p-value of 0.001, supporting the Pearson Chi-Square result.

● The Fisher's Exact Test also yielded a significant two-sided p-value of 0.003, which is appropriate when expected cell counts are low.

● The Linear-by-Linear Association value of 10.018 ($p = 0.002$) suggests a statistically significant trend or linear relationship.

These results indicate a statistically significant association between education level and awareness about waste segregation. In other words, respondents with higher levels of education were more likely to be aware of waste segregation practices.

Since the sample size is small ($n = 30$), the significance of Fisher's Exact Test further strengthens the validity of this association.

Therefore, Hypothesis H01 - stating that there is no significant influence of education level on awareness of waste segregation is rejected.

Changes in the Awareness on Waste Segregation Pre-Post Intervention

H02 - There is no significant difference in the level of awareness regarding the concept of waste segregation in pre and post intervention.

Table 18 McNemar test for Awareness level
(Pre-Post Intervention)

Test Statistics	Value
Test Type	McNemar Test

Sample Size (N)	30
Degrees of Freedom (df)	1
Test Statistic (χ^2)	Binomial Test (used due to small sample size)
Exact Significance (2-tailed)	p = 0.000
Distribution Used	Binomial Distribution

The exact binomial test was used for accuracy due to the small sample size ($n < 30$). A p-value of 0.000 indicates a statistically significant change in awareness levels pre-post intervention.

The McNemar Test was used to analyse the change in awareness about waste segregation before and after the intervention among 30 participants. This test is appropriate for paired nominal data, especially when examining the effectiveness of an intervention over time.

The test statistic was computed using the binomial distribution which is more accurate for small sample sizes. The exact two-tailed p-value is 0.000 indicating a highly significant change ($p < 0.05$).

This result implies that there was a statistically significant improvement in awareness on waste segregation following the intervention. In other words, the intervention had a positive and meaningful impact on enhancing the participants' awareness levels.

Therefore, the Hypothesis H02 - There is no significant difference in the level of awareness regarding the concept of waste segregation in pre and post intervention is rejected.

Adoption of Composting Practices Pre-Post Intervention

H03 - There is no significant increase in home composting practices at post intervention.

Table 19: McNemar Test for Adoption of Composting Practices (Post Intervention)

Test Statistic	**Value**
Test Name	McNemar Test (non-parametric)
Sample Size (N)	30
Degrees of Freedom (df)	1
Test Statistic (χ^2)	Binomial Test (used due to small sample size)
Exact Significance (2-tailed)	p = 0.000
Distribution Used	Binomial Distribution

The McNemar test was employed to evaluate the change in home composting practices after the intervention among 30 participants. This non-parametric test is suitable for analyzing paired nominal data, particularly for assessing changes in responses over time.

The test statistic was calculated using the binomial distribution, which is more reliable for small sample sizes. The exact two-tailed p-value was found to be 0.000.

Since the p-value is less than the commonly accepted significance level of 0.05, the result is statistically significant. This indicates that there was a meaningful change in home composting practices at post intervention.

Therefore, Hypothesis H03 – There is no significant increase in home composting practices at post intervention is rejected.

Relationship Between Education and Composting Behaviour Post-Intervention

H04 - There is no significant relationship between education and the likelihood of practicing composting in post-intervention.

Table 20 Binary Logistic Regression for Education Vs Composting (Post Intervention)

Aspect	**Result**
Model Fit	
Nagelkerke R^2	0.497
Omnibus Tests of Model Coefficients	
Chi-square	13.566
Degrees of Freedom (df)	1
p-value	0.000 (statistically significant)

The binary logistic regression analysis showed that educational qualification significantly influences composting behaviour among the respondents ($\chi^2 = 13.566$, $df = 1$, $p = 0.000$). The model accounted for approximately 49.7% of the variation in composting practices (Nagelkerke $R^2 = 0.497$) and accurately

classified 73.3% of the cases. Participants with higher educational qualifications were more likely to engage in composting, highlighting the positive impact of education on sustainable waste management practices.

Hence, the Hypothesis H04 - There is no significant relationship between education and the likelihood of practicing composting in post-intervention is rejected.

RECOMMENDATIONS

1. **Strengthening Waste Collection Infrastructure**

- **Regular and Reliable Collection**: Given that 13% of respondents reported irregular waste collection, it is crucial to enhance waste collection frequency and ensure it is consistent. Introducing a more frequent and predictable schedule, especially in high-density areas, will address concerns and prevent waste accumulation.
- **Expanded Infrastructure**: Increasing the number of bins and ensuring they are well-maintained, accessible and appropriately sized will address the issue of overloaded bins. This infrastructure should include separate bins for dry and wet waste supporting segregation efforts.

In India, the Government of India (GoI) has allocated ₹5,000 crore under the Swachh Bharat Mission – Urban 2.0 (SBM-U 2.0), a national program aimed at improving urban sanitation and cleanliness. Out of this, ₹1,200 crore is specifically earmarked for improving door-to-door waste collection, providing segregated bins and enhancing composting facilities.

Funds should be used to provide three-bin systems for households typically colored green for wet waste, blue for dry waste and red for sanitary waste. Waste collection vehicles should be modernized with Global Positioning System (GPS) and Radio Frequency Identification (RFID) technology to track routes and monitor collection efficiency. Globally, countries like Japan and Sweden have achieved efficiency by synchronizing collection with decentralized Waste sorting hubs. India can adopt similar strategies by establishing ward-level decentralized Waste collection centres ensuring faster and more localized waste processing.

2. **Community Engagement and Awareness Campaigns**

- **Increase Public Awareness**: The significant rise in awareness post intervention (from 17% to 100%) indicates the effectiveness of educational initiatives. More awareness programs should be launched regularly, utilizing multiple channels like social media, local events and community outreach to promote segregation, recycling and composting.
- **Sustainability Education**: Emphasize the long-term benefits of waste segregation and composting through schools, local events and workshops. Local leaders and influential figures should be involved in these programs to inspire and motivate the community.

Community awareness is the cornerstone of effective waste management. Under Swachh Bharat Mission – Urban 2.0 (SBM-U 2.0) a dedicated component is Information, Education, and Communication (IEC) which promotes public understanding of sanitation and hygiene. Information, Education, and Communication (IEC) activities may include wall paintings, street plays, local awareness drives, school programs and media campaigns in regional languages.

Internationally, Parma, Italy has achieved over 80% recycling rates through sustained public engagement, citizen education and compliance monitoring. India can build similar engagement by appointing Swachhata Ambassadors (cleanliness champions) at ward or village levels and forming Resident Welfare Associations (RWAs) to coordinate with municipal bodies and conduct local cleanliness audits.

3. **Government Action and Policy Support**

- **Enforce Segregation Laws**: With 100% of respondents supporting the idea of mandatory waste segregation, it's crucial to push for stronger legislation that makes waste segregation compulsory. The government should establish penalties for non-compliance.
- **Incentivize Participation**: Motivate people by providing incentives for households that actively engage in waste segregation and composting.

Government policies and enforcement play a vital role in successful Waste management. The Solid Waste Management Rules, 2016, notified by the Ministry of Environment, Forest and Climate Change (MoEFCC), mandate source segregation, door-to-door collection and scientific disposal. However, implementation gaps persist due to weak enforcement.

India can utilize funds from Swachh Bharat Mission – Urban 2.0 (SBM-U 2.0) and the Atal Mission for Rejuvenation and Urban Transformation (AMRUT 2.0) to build institutional capacities of Urban Local Bodies (ULBs) and Gram Panchayats (GPs). Policies must be enforced through user charges, spot fines and incentives for compliance. Drawing inspiration from Colombia, where informal waste workers have

been formally integrated and supported financially, Indian cities can replicate similar models for improved equity and system efficiency.

4. **Promotion of Composting and Recycling**

- **Local Composting Facilities**: Given the rise in composting practices from 0% to 63%, there should be more support for local composting initiatives. Establishing community composting sites where residents can drop off organic waste or providing composting bins to households can be a valuable step in reducing landfill waste.
- **Enhance Recycling Systems**: Strengthening the recycling infrastructure by collaborating with local recycling facilities or scrap dealers can reduce plastic waste. Partnerships can be formed with private recyclers to ensure proper handling of recyclable materials and create a more sustainable waste management system.

For dry Waste such as plastic and paper, Material Recovery Facilities (MRFs) must be expanded. Swachh Bharat Mission – Urban (SBM-U) has also set aside ₹900 crore for Material Recovery Facilities (MRFs) and Waste-to-Energy (WTE) infrastructure. In New York City, Composting has been made mandatory, and in Pune, India, decentralized composting and ward-level sorting centres have improved overall waste management efficiency. These models offer replicable frameworks for India to scale up recycling and composting .

CONCLUSION

The present study, **"Sustainable Waste Management Strategies for Semi-Urban Areas: A Study on Pannimadai, Coimbatore,"** demonstrates that strategic, community-focused interventions can substantially improve waste management practices in semi-urban areas. Before the intervention, the waste management practices are poor with significant challenges such as poor awareness, lack of infrastructure and minimal public participation with none of the households practicing waste segregation and composting. Post-intervention results showed a dramatic shift: 100% of respondents became aware of waste segregation, 80% adopted segregation practices, 63% began composting and the usage of separate bins increased from 3% to 63%. These outcomes validate the effectiveness of a simple, structured intervention model that focused on awareness creation, source segregation, composting practices and utilization of biodegradable waste.

The study also revealed that socio-economic factors, particularly education strongly influenced the adoption of sustainable practices, as confirmed through hypothesis testing. While the intervention achieved notable success, challenges such as composting-related inconvenience, space constraints and maintenance needs persist indicating the necessity for enhanced infrastructure and ongoing community support.

Importantly, the findings align directly with the United Nations Sustainable Development Goals, particularly SDG 6 (Clean Water and Sanitation), SDG 11 (Sustainable Cities and Communities), SDG 12 (Responsible Consumption and Production), SDG 13 (Climate Action), and SDG 15 (Preserving Land). By promoting waste reduction, composting and community participation the intervention supports the creation of more inclusive, safe, resilient and sustainable living environments.

Overall, the intervention not only bridged critical knowledge and practice gaps but also empowered residents to take ownership of environmental sustainability. This model offers a scalable and replicable framework for other semi-urban areas, reinforcing the idea that institutional support combined with grassroots participation is vital for long-term environmental health and global sustainable development. With continued efforts such localized initiatives can significantly contribute to achieving national and international sustainability goals.

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